A Report on
The Twenty-second International
TOVS Study Conference

Saint-Sauveur, Québec, Canada
31 October – 6 November 2019

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FOREWORD

The International TOVS Working Group (ITWG) brings together operational and research users and providers of infrared and microwave satellite sounding data. It is convened as a sub-group of the International Radiation Commission (IRC) of the International Association of Meteorology and Atmospheric Physics (IAMAP) and the Coordination Group for Meteorological Satellites (CGMS). The ITWG organises International TOVS Study Conferences (ITSCs) which have met approximately every 18 to 24 months since 1983. Through this forum, relevant experts exchange information on all aspects of the data processing and use, with a focus on inferring information on atmospheric temperature, moisture, and cloud fields. This includes evaluation of new data, processing algorithms, derived products, impacts in numerical weather prediction (NWP) and climate studies. The group considers data from all sounding instruments that build on the heritage of the TIROS Operational Vertical Sounder (TOVS), including hyperspectral infrared instruments.

This Working Group Report summarises the outcomes of the Twenty-second International TOVS Study Conference (ITSC-XXII) hosted by Environment and Climate Change Canada in Saint-Sauveur, Québec, Canada between 31 October and 6 November 2019. The ITWG Web site contains electronic versions of the conference presentations, posters and publications which can be downloaded (http://cimss.ssec.wisc.edu/itwg/). Together, these documents and web pages reflect a highly successful meeting in Saint-Sauveur.

We wish to thank Environment and Climate Change Canada for their excellent hosting of the conference, and in particular the local organizing committee, including Louis Garand, Milly Cayo, and Farrah Mullings who ensured a very smooth running of the meeting. The Manoir Saint-Sauveur provided a brilliant venue for the occasion.

ITSC-XXII was sponsored by industry and government agencies, including ABB, CNES, CPI/Orbital Systems, EUMETSAT, L3Harris, Météo France, NOAA/JPSS Program Office, NOAA/GOES-R Program Office, and the World Meteorological Organization (WMO).

The following report encompasses an executive summary highlighting the main developments and conclusions, followed by the detailed working group reports, the conference program, and abstracts of all presentations and posters.

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ITSC-XXII Sponsors

TOVS STUDY CONFERENCE (ITSC-XXII)
Saint-Sauveur, Québec, Canada: 31 October – 6 November 2019

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ITSC-XXII Group Photo at the Manoir St Sauveur
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1. EXECUTIVE SUMMARY

1.1 INTRODUCTION

The Twenty-Second International TOVS Study Conference, ITSC-22, was hosted by Environment and Climate Change Canada at the Manoir Saint-Sauveur in Saint-Sauveur, Québec, Canada, between 31 October and 6 November 2019. The conference was attended by 152 participants from 45 organizations, providing a wide range of scientific and technical contributions. Seventeen countries and three international organizations were represented: Argentina, Australia, Brazil, Canada, China, France, Germany, India, Japan, Norway, Russia, South Korea, Spain, Sweden, Switzerland, United Kingdom, United States, ECMWF, EUMETSAT, and the WMO. Working Groups were formed for key topic areas, leading to very productive discussions.

Apart from excellent support by the local hosts, Environment and Climate Change Canada, ITSC-22 was sponsored by industry and government agencies. The industry and government agencies included: ABB, CNES, CPI/Orbital Systems, EUMETSAT, L3Harris, Météo France, NOAA/JPSS Program Office, NOAA/GOES-R Program Office, and the World Meteorological Organization (WMO). The success of ITSC-22 was largely due to the excellent work of the local organizing committee from Environment and Climate Change Canada including Louis Garand, Milly Cayo, and Farrah Mullings, as well as the invaluable administrative and logistical support provided by Leanne Avila and Maria Vasys of SSEC and Leah Leighty of the University of Wisconsin–Madison CALS Conference Services.

The technical program was organized in sixteen sessions containing 80 oral presentations and 125 posters. The range of issues covered in oral presentations and posters included the following:

- Current, new and future observing systems and calibration/validation;
- Operational reports from space agencies and NWP centres;
- Data assimilation applications;
- Climate applications;
- Processing software systems;
- Advanced Sounder science;
- Radiative transfer developments;
- Cloud and precipitation applications; and
- Retrieval science.

Working Groups met to consider six key areas of interest to the ITWG, including:

1. Radiative Transfer and Surface Property Modelling,
2. Climate,
3. Data Assimilation and Numerical Weather Prediction,
4. Advanced Sounders,
5. International Issues and Future Systems,
6. Products and Software.

The Working Groups reviewed recent progress in the above areas, made recommendations on key areas of concern and identified items for action. These were further reviewed in a plenary

session at the end of the conference. Activities that had taken place since ITSC-21 in Darmstadt, Germany were presented in a dedicated session of Working Group status reports. Technical sub-groups also met during ITSC-22 to discuss developments and plans concerning specific software packages, shared and in common use.

Two sessions were dedicated to the assimilation of infrared and microwave radiances in cloudy or rainy conditions. Many NWP centers are working to achieve a mature assimilation system that can ingest all-sky microwave radiances for a wide range of frequencies. Clouds are still an area of active research for the infrared community. Advances in the all-sky assimilation of geostationary infrared sensors have been made, mostly in advanced assimilation systems at mesoscale (e.g. 3/4D-EnVar). Several presentations have focused on the new hyperspectral infrared sensor GIIRS onboard the CMA FY-4A geostationary satellite. Recent progress has been made by CMA to collaborate with other centers (e.g. ECMWF) in data evaluation and in preliminary assimilation trials made in the CMA GRAPES system. EUMETSAT and CMA also reported on characterization of sounder data from their latest polar-orbiting operational satellites Metop-C and FY-3D. As progress has been made in the last two decades in the assimilation of microwave and infrared sensors in NWP models, processes at the interface with the "meteorological" atmosphere now have to be better accounted for. Several talks highlighted the importance of using consistent information between the models used to describe the Earth system (Surface, NWP, Chemistry, etc.). Indeed, there is a trend among NWP centers to increase the level of complexity and coupling between those various models, with possibly different strategies for the forecast and for the assimilation. This is particularly crucial for hyperspectral infrared sensors which are able to bring unique information to the various models.

As recommended by CGMS, a dedicated session was set up to exchange information with other CGMS working groups (ICWG, IPWG) and one ITWG sub-group that is preparing to become a CMWG working group (ISWG).

The conference agenda and PDF versions of the oral presentations and posters can be viewed at the ITSC-22 website at http://cimss.ssec.wisc.edu/itwg/itsc/itsc22/program/.

1.2 SUMMARY OF MAJOR CONCLUSIONS AND RECOMMENDATIONS

The ITSC-22 presentations, posters, Working Group meetings and discussions documented significant issues in many areas and identified areas for future activity. The full list of action items and recommendations can be found in the detailed reports from each working group. The main conclusions and recommendations are summarised below.

Radiative Transfer Modelling

1. **To sensor manufacturers and science teams:** Provide SRFs with higher quality, consistent format, and with rapid availability. Commercial providers need to provide SRFs, APCs, and calibration information in support of RT. Maintain and update Spectral Response Function databases for all available sensors, focusing on operational sensors. Recommend calibration information from sensor to be applied to RTM / SRF.

Climate

2. **To Satellite data providers**: Allow access to level-0 data for all data after commissioning, and during the commissioning phase ensure some negotiated access regardless of the vendor.
3. **To Satellite agencies**: Plan ahead in designing sounding instruments to cover atmospheric layers from 1hPa to 0.1hPa when SSMIS is no longer available.
4. **To Space agencies**: When designing, characterizing and calibrating new sensors satellite agencies and instrument vendors should ensure that metrological traceability is achieved for all pre-flight measurements influencing the accuracy of level-1 products. This information should be comprehensively documented and be made available to end users.
5. **To Space agencies**: The group recommends that satellite agencies support targeted studies aimed at translating GCOS ECV requirements into radiometric, spectral and sampling specifications for new sensors, particularly addressing requirements that are specific and additional beyond those generated from other applications such as NWP, etc.
6. **To Space Agencies**: The group recommends satellite agencies to keep and/or establish a 2-satellite configuration for the same sensor in the same orbit (same equator crossing time) to improve the confidence in derived CDRs and to also provide a measure to assess the stability and health of the instruments on the two satellites.
7. **To Satellite data providers**: Distribute a set of selected channels and PC scores for (upcoming) hyperspectral sensors. This way, users could reconstruct the radiances, compare the reconstructed channels with the distributed channels and check if PCs are done correctly and get a feeling about the potential information loss. The archiving and open availability of full L1C data for climate studies should be preserved and re-processed data should be publicized whenever available.

Data Assimilation and Numerical Weather Prediction

8. **To Space Agencies**: The constellation of at least three orbits (early morning, morning, and afternoon), each with full sounding capabilities (IR and MW), should be maintained. The overpass times of operational satellites with sounding capability (IR and MW) should be coordinated between agencies to maximize coverage and include a satellite in early morning orbit.
9. **To Space Agencies**: In support of maintaining a robust global satellite observing system, instrumentation to allow continued sounding of the temperature of the upper stratosphere and mesosphere (as for the SSMIS UAS channels) should be explored.
10. **To Satellite Operators**: New operational data dissemination infrastructure should be tested at an early stage (well before launch) with simulated data.
11. **To Satellite Operators**: There should be open and early access to new satellite data for all NWP centers to help with calibration and validation.
12. **To Satellite Operators**: Satellite agencies should work with their primary user communities to assess the limitations in the exploitation of satellite data, and also engage with users less closely connected to their agencies.
13. **To Satellite Operators**: Consider, as part of the cost of satellite programmes, providing computational and personnel resources targeted at operational NWP centers to optimize the public's return on investment from these expensive measurement systems.

14. **To Satellite Operators**: When using PC compression (for hyperspectral infrared sounder data), noise normalisation should be performed using the full noise covariance matrix.
15. **To Satellite Operators**: Proceed with work on the use of Hybrid PC compression and investigate practical application of this method, including the incorporation of granule-based vectors in BUFR.
16. **To Satellite Operators**: If a change to data processing results in a change in brightness temperature of 0.1K or 20% of NEdT (whichever is smaller), this should be made clear in notifications to users. These notifications should be made no later than 8 weeks before the change and test data should be provided if possible.
17. **To Satellite Operators**: The overlap period where one satellite resource is replacing another should be chosen after consultation with the user community and should follow WMO guidelines.
18. **To Satellite Operators**: In order to facilitate evaluation of new satellite data by NWP centers, aim for distribution in near-real time.
19. **To NASA and NOAA**: Continue to provide AIRS Aqua data in real-time to NWP centers for as long as calibration of the instrument is possible.

Advanced Sounders

20. **To CMA**: Disseminate the HIRAS and GIIRS data six months after launch if possible, and not only via EUMETCAST but also to the Global User Community.
21. **To CMA**: Consider to make available as soon as possible the HIRAS spectra at full spectral resolution for all bands. This also applies to all future hyperspectral sounders.
22. **To CMA**: Investigate and consider extending the output range of FY-3D GIIRS spectra to ~680 1/cm.
23. **To Roshydromet and Roscosmos**: Recommend establishing a Direct Broadcast capability for the data on the Meteor-M satellite, in particular for the hyperspectral IKFS-2 data.
24. **To Space Agencies:** Consistent with numerous previous ITWG and ASWG recommendations, and consistent with the WMO Integrated Global Observing System (WIGOS) Vision for the Global Observing System in 2025 and 2040, the ASWG strongly recommends that space agencies develop and implement plans to fill the gaps in IR hyper-spectral sounding within the Geostationary constellation.
25. **To Space Agencies**: The constellation of at least three polar orbits (early morning, morning, and afternoon), each with full sounding capabilities (IR and MW), should be maintained. The overpass times of operational satellites with sounding capability (IR and MW) should be coordinated between agencies to maximize their value.
26. **To Space Agencies**: Implement high spatial resolution and contiguous sampling detector arrays in future hyperspectral infrared sounding instruments.
27. **To Space Agencies:** To develop, test, and implement an SI-traceable radiometric standard in space as soon as feasible.

International Issues and Future Systems

28. **To Space Agencies**: Consider building in as much RFI screening and mitigation into their ground segment processing as possible, noting efforts already starting at ESA and in research groups in the US, Japan and China.
29. **To Space Agencies**: Consider DBNet requirements when designing core ground segment software, and then to make software available to DBNet operators.

30. **To Space Agencies**: Note that the strong requirement for traceable calibration comes from NWP as well as the climate application area.
31. **To Space agencies**: Note that the benefits of satellite missions to the ITWG community are increased when early evaluation is undertaken by many independent centers. Facilitating early access to new data is therefore highly recommended.
32. **To satellite operators**: Consider if the SAF concept would be beneficial for them (other satellite operators), as it has been for EUMETSAT.

Products And Software

33. **To satellite operators:** Implement subscription-based notification of anomalies or events that impact users.
34. **To EUMETSAT**: Provide a schedule for release of different types of test data for both EPS-SG and MTG.
35. **To JAXA:** Consider providing AMSR-2 L1 software for release to the DB community. The CSPP team could host it.
36. **To international telecommunication agencies:** The frequencies used in DB reception (L band and X band) should be preserved, to ensure continued fidelity of downlink reception.

1.3 FUTURE PLANS

The next ITSC is expected in 2021. In the meantime, ITWG will continue to inform the infrared and microwave sounding community of the latest news and developments through its Web site (maintained by the University of Wisconsin-Madison/CIMSS) and via the email list (also maintained by CIMSS).

1.4 ACKNOWLEDGEMENTS

This report relied on the active participation of all ITSC attendees and those working group chairs. We acknowledge that writing of this report is possible only through the collective work of ITWG members.

SUMMARY OF ACTIONS AND RECOMMENDATIONS

RADIATIVE TRANSFER AND SURFACE PROPERTY MODELLING

Recommendation RTSP-1 to fast model developers

Fast non-LTE models should include a representation of ozone variability in the mesosphere in support of shortwave radiance simulations.

Recommendation RTSP-2 to CGMS

To encourage sensor manufacturers and instrument engineering and science teams to provide SRFs with higher quality, consistent format, and with rapid availability. Commercial providers need to provide SRFs, APCs, and calibration information in support of RT.

Recommendation RTSP-3 to GSICS and CGMS/WMO/SATURN

Maintain and update Spectral Response Function databases for all available sensors, focusing on operational sensors. Recommend calibration information from sensor to be applied to RTM / SRF.

Action RTSP-1 on Benjamin Johnson

Create Community SRF repository and coordinate inputs from RTWG and other contributors. Continue to support previous recommendations of creating a spectral response function (SRF) repository, to be shared publicly with the RT community.

Recommendation RTSP-4 to the RT and LBL community

The RTSP-WG strongly supports continuous line-by-line model development as a fundamental basis for accurate radiative transfer calculations in fast RT models. The RT community also encourages and supports the development of competing line-by-line codes (encourage innovation and diversity).

Recommendation RTSP-5 to LBL developers

Encourage line-by-line model developers to include a better formulation of the Voigt line shape (e.g., include velocity dependence).

Action RTSP-2 on Raymond Armante

To communicate results obtained using a speed dependent formulation of the Voigt line shape providing an assessment of the impact in the infrared region of the spectrum, especially in the long-wave.

Recommendation RTSP-6 to Fast RT and LBL community

Look at the current continuum absorption models at higher MW frequencies (< 1000 GHz) and investigate the use of the MTK_CKD model in line-by-line microwave codes. Including Far-IR in support of new missions.

Recommendation RTSP-7 to LBL developers

Characterization of LBL model biases and uncertainties, especially focusing on warm and moist air masses. Attempt to map uncertainties in spectroscopy into radiance uncertainties, starting from major lines of a given region.

Action RTSP-3 on Marco Matricardi

To communicate to the working group on the CO2 perturbation impact on LBL radiances, and to provide a report on the perturbation of the line mixing model.

Recommendation RTSP-8 to spectroscopic model developers

A strong emphasis should be put on the continuous support of theoretical and laboratory spectroscopic studies. Continuous efforts should be maintained in the generation and improvement of basic line parameters.

Recommendation RTSP-9 to spectroscopic model developers

The RTSP-WG recommends promoting research into spectroscopy of higher frequency microwave channels up to 1000 GHz.

Recommendation RTSP-10 to the physical modeling community, ICWG, ISWG, IPWG, IWWG

To develop accurate physical models to support emissivity modeling requirements in RT models.

Recommendation RTSP-11 to reference-quality model developers

The RTSP-WG strongly recommends support of developing reference-quality ocean-surface emissivity modeling, specifically Infrared, Microwave, for both active and passive simulations. And support the development of a reference surface emissivity model (English, et al.).

Recommendation RTSP-12 to vegetation modeling community

Spectral library developers to include broader and more diverse vegetation sampling (e.g., new types), and include the effects of senescence. Also include the impact of the diurnal cycle.

Action RTSP-4 on ISWG

Identify group that can provide broadened vegetation parameters in support of the spectral databases.

Recommendation RTSP-13 to snow modeling community

Determine the classification methodology for emissivity modeling over snow-free land surfaces, statistical vs. physical or some mixture thereof.

Recommendation RTSP-14 to surface modeling community

Improve the interface between land surface model parameters and RT models, and specifically incorporate angular dependence impact on polarized emissivity and reflectivity over all surface types. Include, specifically, the temperature dependence of the index of refraction of water, land, snow/ice, and vegetated surfaces.

Action RTSP-5 on Nick Nalli, Stu Newman, and Steve English

Identify up-to-date and develop new laboratory measurements across spectral ranges [UV-MW] and resolution of interest for various surface properties (land, water/ocean, snow cover, sea-ice), and anything that's missing, specifically include Far-IR.

Recommendation RTSP-15 to aerosol/materials modeling laboratories

The RTSP working group recommends encouraging research into laboratory measurements of aerosol refractive indices, with an initial focus on common dust and sea-salt modes. Characterization of the indices of refraction of hygroscopic aerosols at different moisture levels is also highly encouraged.

Recommendation RTSP-16 to fast RT model developers

Explore the necessity of using non-spherical aerosol particle scattering properties in fast RT models in support of detailed scattering calculations (e.g., LIDAR).

Recommendation RTSP-17 to RT and physical model developers

With regard to the computation of cloud and aerosol optical properties and formation of parametric schemes in fast models: we recommend that there be an intercomparison of the parameterized schemes in order to assess the validity and continuity of the schemes across various size parameter ranges. This should assess against particle physical and optical properties from ultraviolet to microwave.

Action RTSP-6 on Benjamin Johnson

To continue to report on current developments of physical and scattering properties of aerosols, clouds, and precipitation to the RTSP working group. These links will be hosted on the RTSP WG webpage.

Recommendation RTSP-18 to ice/precipitation model developers

For all scattering/absorbing particles, extend the frequency range to cover the ranges of current and upcoming sensors, from visible to microwave (i.e., ICI channels). Extend the range of particulate sizes to be consistent with observed parameters for each particle type.

Recommendation RTSP-19 to laboratory property modelers

Far-IR studies of temperature dependent index of refraction.

Recommendation RTSP-20 to RT developers

Encourage the comparison / validation of full scattering solvers. This should include the computational efficiency, specifically including the adjoint model.

Recommendation RTSP-21 to RT developers

For aerosol scattering computations, more research is needed to characterize the regimes where fast RT approximations are effective.

Recommendation RTSP-22 to RT developers

To look at the importance of simulating radiances in turbulent layers in coordination with model developers.

Action RTSP-7 on Benjamin Johnson and Marco Matricardi

To maintain and update list of “golden” field experiments (variety of observations, high data quality, good sensor overlap/coverage), need input from instrument scientists and other key users/developers.

Action RTSP-8 on Marco Matricardi

To provide link on MAGIC campaign calibrated datasets.

Action RTSP-9 James Hocking and Benjamin Johnson

To coordinate the CRTM/RTTOV/ARMS model intercomparison effort. JEDI/UFO is a possible framework. Aim toward developing a standardized intercomparison framework for testing new coefficient files / scattering tables, etc. And to reach out to ARMs developers to include them in the effort.

Action RTSP-10 to the RTSP-WG Co-Chairs and members

Share RTSP recommendations with other relevant working groups (e.g., ITSC, IPWG, ICWG, IWWG, ISWG, ISDA, and other groups where reference radiative transfer will be of interest). Individuals from RTSP-WG should volunteer to present recommendations at their respective meetings.

Recommendation RTSP-23 to the RT model development community

Promote the extension of RT models to the simulation of active/passive data (e.g., Radar/LIDAR/Scatterometers), and to UV, Visible, and Far-Infrared portions of the spectrum. An accurate treatment of atmospheric and surface polarization (linear and circular) should also be considered in support of these bands.

Recommendation RTSP-24 to the RT modeling community and partners

Support the development of a set of community models for building a reference standard radiative transfer model, but using existing reference models where available (e.g., LBL, Spectroscopic databases).

Action RTSP-11 on the "IRRTM" team

Deliver whitepaper and present on the International Reference Radiative Transfer Model ("IRRTM") status and planning to ITSC, IPWG, ICWG, IWWG, ISWG, ISDA, and other groups where reference radiative transfer will be of interest.

CLIMATE

Action Climate-1 on Heikki Pohjola

Provide information on the status of information about FCDRs in OSCAR to the Climate WG. This information will also be added to the Climate WG webpage.

Action Climate-2 on Climate Co-Chairs

Provide information on the CEOS/CGMS Joint Working Group on Climate on the Climate WG webpage (e.g. link to report, etc.).

Action Climate-3 on Climate Co-Chairs

Provide information on the GCOPS and AOPC gap analysis report to the Climate WG webpage (e.g. link to report, etc.).

Recommendation Climate-1 to satellite agencies

Satellite data providers should allow access to level-0 data for all data after commissioning, and during the commissioning phase ensure some negotiated access regardless of the vendor.

Recommendation Climate-2 on satellite agencies

Upper stratosphere and lower mesosphere are an important component in the climate system. Satellite agencies should plan ahead in designing sounding instruments to cover atmospheric layers from 1hPa to 0.1hPa when SSMIS is no longer available.

Recommendation Climate-3 to satellite agencies

When designing, characterizing and calibrating new sensors satellite agencies and instrument vendors should ensure that metrological traceability is achieved for all pre-flight measurements influencing the accuracy of level-1 products. This information should be comprehensively documented and be made available to end users.

Recommendation Climate-4 to GSICS

GSICS should ensure that traceability is part of their best practices for calibration/inter-calibration.

Recommendation Climate-4 to satellite agencies

The group recommends that satellite agencies support targeted studies aimed at translating GCOS ECV requirements into radiometric, spectral and sampling specifications for new sensors, particularly addressing requirements that are specific and additional beyond those generated from other applications such as NWP, etc.

Recommendation Climate-6 to satellite agencies

The group recommends satellite agencies to keep and/or establish a 2-satellite configuration for the same sensor in the same orbit (same equator crossing time) to improve the confidence in derived CDRs and to also provide a measure to assess the stability and health of the instruments on the two satellites.

Action Climate-4 on WG Co-chairs

Co-chairs to ask GSICS for guidance on stewardship of data, documentation and metadata related to the recovery and assessment of early satellite data sets.

Action Climate-5 on Climate WG members

To determine the requirements for uncertainty information from all operational hyperspectral IR instruments and document.

Action Climate-6 on Climate WG co-chairs

To ask GSICS to forward the request to the instrument teams at agencies to provide the uncertainty information from all operational hyperspectral IR instruments

Recommendation Climate-7 to satellite providers

Satellite data providers should distribute a set of selected channels and PC scores for (upcoming) hyperspectral sensors. This way, users could reconstruct the radiances, compare the reconstructed channels with the distributed channels and check if PCs are done correctly and get a feeling about the potential information loss. The archiving and open availability of full L1C data for climate studies should be preserved and re-processed data should be publicized whenever available.

Recommendation Climate-8 to GRUAN

GRUAN should be encouraged to provide subsets of satellite targeted observations (NOAA and MetOp satellites) and EUMETSAT encouraged to support MetOp targeted

radiosondes at selected GRUAN sites similar to ongoing JPSS targeted radiosonde programs with NOAA satellites. These are most valuable in the context of climate (and weather) oriented validation.

DATA ASSIMILATION AND NUMERICAL WEATHER PREDICTION

Action DA/NWP-1 on ITWG Co-Chairs

To bring relevant recommendations to the attention of CGMS.

Recommendation DA/NWP-1 to all relevant space agencies

The constellation of at least three orbits (early morning, morning, and afternoon), each with full sounding capabilities (IR and MW), should be maintained. The overpass times of operational satellites with sounding capability (IR and MW) should be coordinated between agencies to maximize coverage and include a satellite in early morning orbit.

Recommendation DA/NWP-2 to the satellite agencies

In support of maintaining a robust global satellite observing system, instrumentation to allow continued sounding of the temperature of the upper stratosphere and mesosphere (as for the SSMIS UAS channels) should be explored.

Recommendation DA/NWP-3 to the NWP centres

Work to assess the impact of the upper atmospheric sounding channels of SSMIS in NWP and determine the information content unique to those channels, e.g. via data denial experiments.

Recommendation DA/NWP-4 to space agencies

New operational data dissemination infrastructure should be tested at an early stage (well before launch) with simulated data.

Recommendation DA/NWP-5 to space agencies

There should be open and early access to new satellite data for all NWP centres to help with calibration and validation.

Recommendation DA/NWP-6 space agencies

Satellite agencies should work with their primary user communities to assess the limitations in the exploitation of satellite data, and also engage with users less closely connected to their agencies.

Recommendation DA/NWP-7 to funding bodies of NWP centres and space agencies

Consider, as part of the cost of satellite programmes, providing computational and personnel resources targeted at operational NWP centres to optimise the public's return on investment from these expensive measurement systems.

Action DA/NWP-2 on NWP WG members

Send any evidence of RFI in the observations to Stephen English (stephen.english@ecmwf.int) and Richard Kelley (barometer@verizon.net) and also the results of experiments investigating the effects of RFI on forecast skill.

Action DA/NWP-3 on NWP WG Co-Chairs

Discuss with Stephen English (stephen.english@ecmwf.int) and Richard Kelley (barometer@verizon.net) where to collate information on RFI in NWP (e.g. DA/NWP-WG web page).

Action DA/NWP-4 on NWP WG members

If you have estimates of revised channel characteristics resulting from post-launch diagnostics, please email these to the Radiative Transfer Working Group Co-Chairs (Benjamin.T.Johnson@noaa.gov & Marco.Matricardi@ecmwf.int).

Action DA/NWP-5 on NWP centres

Continue to provide information on instrument channels assimilated and their observation errors for inclusion on the NWP Working Group pages in advance of each conference.

Action DA/NWP-6 on Working Group Members

Look at the working group website and make suggestions and corrections.

Action DA/NWP-7 on Working Group Co-Chairs

Review the current mailing list membership and migrate to a new platform (google groups).

Recommendation DA/NWP-8 to data providers

Agree on a standardized procedure for calculation of NEdT estimates for inclusion within BUFR for microwave data.

Action DA/NWP-8 on Working Group Co-Chairs

Clarify with Banghua Yan regarding the status of the provision of NEdT estimates in BUFR files for microwave data from NOAA/NESDIS.

Recommendation DA/NWP-9 to data providers

Include azimuthal viewing and solar angles as appropriate in BUFR for present and future instruments.

Recommendation DA/NWP-10 to space agencies and data providers

When designing new or modified BUFR formats, please circulate drafts to the NWP community via the NWP Working Group for feedback, prior to submission to WMO.

Recommendation DA/NWP-11 to EUMETSAT

Communicate when NSR for S-NPP CrIS will be switched off and provide a parallel stream for a short time (a few weeks) to allow users to transition to the new dataset.

Action DA/NWP-9 on Working Group Co-Chairs

Ensure the April 1st 2020 date for the end of NESDIS distribution of S-NPP NSR CrIS data is communicated to the group.

Recommendation DA/NWP-12 to data providers

When using PC compression, noise normalisation should be performed using the full noise covariance matrix.

Recommendation DA/NWP-13 to EUMETSAT

Proceed with work on the use of Hybrid PC compression and investigate practical application of this method, including the incorporation of granule-based vectors in BUFR.

Recommendation DA/NWP-14 to NWP centres

All centres should use the IASI Hybrid PC-compressed dataset to ensure they are prepared for MTG-IRS. Users are requested to provide feedback to EUMETSAT on the use of these data.

Recommendation DA/NWP-15 to data providers

If a change to data processing results in a change in brightness temperature of 0.1K or 20% of NEdT (whichever is smaller), this should be made clear in notifications to users. These notifications should be made no later than 8 weeks before the change and test data should be provided if possible.

Action DA/NWP-10 on WG Co-Chairs

Provide feedback to CGMS that significant changes to operational datastreams continue to be inadequately communicated to users.

Recommendation DA/NWP-16 to data providers

The overlap period where one satellite resource is replacing another should be chosen after consultation with the user community and should follow WMO guidelines.

Recommendation DA/NWP-17 to DBNet providers

Switch on the production of VIIRS cluster information for DBNet for IASI and CrIS.

Action DA/NWP-11 on Andrew Collard

Check with NESDIS-STAR on plans to implement the VIIRS cluster algorithm for global CrIS data dissemination.

Action DA/NWP-12 on Chris Burrows and Qifeng Lu

Seek expressions of interest on coordinating evaluation of GIIRS and HIRAS data.

Action DA/NWP-13 on WG members

Share impact assessment results for FY-3E with the group and CMA as soon as possible after data becomes available, in particular to provide evidence to support the early morning orbit.

Recommendation DA/NWP-18 to NWP centres

Evaluate IKFS-2 data.

Recommendation DA/NWP-19 to data providers

In order to facilitate evaluation of new data by NWP centres, aim for distribution in near-real time.

Action DA/NWP-14 on Working Group Co-Chairs

Coordinate collation of information on impact of Metop-C instruments in operational NWP, along with information regarding thinning algorithms and error correlations used and share the collated information with working group members.

Recommendation DA/NWP-20 to NWP centres

Produce impact studies for DBNet and low latency data and present results at the Seventh WMO Workshop on the Impact of Various Observing Systems on NWP in Seoul in May 2020.

Action DA/NWP-15 on Mitch Goldberg

Forward existing studies on the impact of DBNet data to the Working Group.

Action DA/NWP-16 on Working Group Co-Chairs

Circulate the NWP-SAF survey on user requirements for monitoring activities.

Action DA/NWP-17 on Working Group members

Complete NWP-SAF survey on user requirements for monitoring activities

Action DA/NWP-18 on Thomas Auligné

Contact Samantha Pullen (samantha.pullen@metoffice.gov.uk) to discuss circulation of FSOI intercomparison study.

Recommendation DA/NWP-21 to NWP-SAF

Share ECMWF instrument event records with the community, together with illustrative monitoring plots where appropriate.

Action DA/NWP-19 on Working Group Co-Chairs

Add a link to ECMWF instrument event records to the Working Group web page when such a link is provided by the NWP-SAF.

Action DA/NWP-20 on users of the NWPSAF Cloud and Aerosol Detection Software

Provide feedback to Reima Eresmaa (Reima.Eresmaa@ecmwf.int) on requirements for future upgrades.

Action DA/NWP-21 on Thomas August and Fiona Smith

Determine whether the IASI-NG End Users Requirements Document can be shared. If any questions remain, discuss at ISSWG how to help NOAA formulate a requirement on maximum inter-detector calibration differences.

Recommendation DA/NWP-22 to NASA and NESDIS

Continue to provide AIRS Aqua data in real-time to NWP centres for as long as calibration of the instrument is possible.

Action DA/NWP-22 on Karen St. Germain

Send to WG co-chairs the target performance and reference architecture for the Broad Area Announcement to industry for next-gen instrument proposals, including identified areas for potential trade-offs.

Action DA/NWP-23 on Working Group Co-Chairs

Send out an email to the DA/NWP WG members containing supporting documentation from Karen St. Germain inviting participation in a working group to make recommendations to NOAA on the proposals for next-generation satellites.

Action DA/NWP-24 on NWP Working Group members

Respond to the request from Karen St. Germain and DA/NWP WG co-chairs to join a working group to provide feedback to NOAA on proposals for next-generation satellites.

ADVANCED SOUNDERS

Recommendation AS-1 to space agencies (CMA)

Disseminate the HIRAS and GIIRS data six months after launch if possible, and not only via EUMETCAST but also to the Global User Community.

Recommendation AS-2 to space agencies (CMA)

Consider to make available as soon as possible the HIRAS spectra at full spectral resolution for all bands. This also applies to all future hyperspectral sounders.

Recommendation AS-3 to space agencies (CMA)

FY-3D GIIRS data has good noise performance below the current longwave cutoff of 700 1/cm; CMA to investigate and consider extending the output range of FY-3D GIIRS spectra to ~680 1/cm.

Action AS-1 on ITWG Co-chairs

Bring these recommendations to the attention of space agencies at CGMS.

Recommendation AS-4 to space agencies (Roshydromet and Roscosmos)

ASWG recommends establishing a Direct Broadcast capability for the data on the Meteor-M satellite, in particular for the hyperspectral IKFS-2 data.

Action AS-2 on ITWG Co-chairs

Bring this recommendation to the attention of space agencies at CGMS.

Action AS-3 on ASWG co-chairs

To follow the data release date and circulate the information to the ASWG.

Action AS-4 on ASWG co-chairs

To circulate to ASWG members the information on the bandwidth for the MTG IRS L1 PC dissemination as soon as it is available.

Action AS-5 on Karen St. Germain

To provide information on the new NOAA trade study mission.

Action AS-6 on ASWG Co-chairs

To organize ASWG members and provide feedback to NOAA on all aspects of the proposed mission(s).

Recommendation AS-5 to space agencies

To keep IR and MW sounders together on the same platform.

Recommendation AS-6 to space agencies

To study whether or not to have the imager on the same platform.

Recommendation AS-7 to space agencies

To keep good inter-satellite calibration and consistency for both IR and MW.

Action AS-7 on ITWG Co-chairs

Bring these recommendations to the attention of Space Agencies at CGMS.

Action AS-8 on Louis Garand

To send documentation on those studies to ASWG.

Recommendation AS-8 to ASWG

To look at available PC and give feedbacks to ASWG co-chairs.

Recommendation AS-9

The hybrid method of EUMETSAT should be taken as the best practice to establish PC for IRS on MTG.

Recommendation AS-10 to NWP centers

To investigate the use of theoretical PC reconstructed radiances, for a representative set of spectral channels, to be used in the radiance assimilation process.

Recommendation AS-11 to satellite agencies (NOAA, JAXA)

Consistent with numerous previous ITWG and ASWG recommendations, and consistent with the WMO Integrated Global Observing System (WIGOS) Vision for the Global Observing System in 2025 and 2040, the ASWG strongly recommends that space agencies develop and implement plans to fill the gaps in IR hyper-spectral sounding within the Geostationary constellation.

Recommendation AS-12 to satellite agencies

The constellation of at least three polar orbits (early morning, morning, and afternoon), each with full sounding capabilities (IR and MW), should be maintained. The overpass times of operational satellites with sounding capability (IR and MW) should be coordinated between agencies to maximize their value.

Recommendation AS-13 to satellite agencies

Implement high spatial resolution and contiguous sampling detector arrays in future hyperspectral infrared sounding instruments.

Recommendation AS-14 to satellite agencies

To develop, test, and implement an SI-traceable radiometric standard in space as soon as feasible.

Action AS-9 on ITWG Co-chairs

To re-iterate these recommendations to space agencies via CGMS.

INTERNATIONAL ISSUES AND FUTURE SYSTEMS

Action IIFS-1

Stephen English to obtain copy of the White Paper from the NPL meeting on traceable calibration and circulate for comment, then feed back comments to White Paper authors.

Action IIFS-2

Peng Zhang to discuss with Ken Holmlund if further action or comment is needed from ITWG on this topic (Link to Recommendation IIFS21-9).

Recommendation IIFS-1 to CGMS WG I

Space Agencies to consider building in as much RFI screening and mitigation into their ground segment processing as possible, noting efforts already starting at ESA and in research groups in the US, Japan and China.

Action IIFS-3 on IIFS members

To provide a summary of known activities, such as the ESA initiative (Link to Recommendation IIFS-1).

Action IIFS-4 on Rich Kelley

To contact Chris Kummerow about efforts in his team and report to ITWG (Link to Recommendation IIFS-1).

Action IIFS-5 on Stephen English

To bring ECMWF RFI workshop report to the attention of all space agencies and CGMS.

Recommendation IIFS-2 to ITWG members

ITWG members to plan to participate as actively as possible in consecutive RFI-related workshops at ECMWF in 2021.

Action IIFS-6 on Stephen English

To send information to the ITWG mailing list about RFI Workshops once dates are known (Link to Recommendation IIFS-2).

Recommendation IIFS-3 to ITWG members

ITWG to begin to assemble evidence of the value to society of bands above 95 GHz through their use in meteorology.

Action IIFS-7 on Stephen English

To ensure specific requests are made for studies of the value of bands above 95 GHz in preparation for workshops in 2021 (Link to Recommendation IIFS-3).

Action IIFS-8 on Stephen English and Philippe Chambon (Co-Chair, IPWG)

To discuss joint ITWG-IPWG efforts on DBNet and science issues with respect to the Meteor-M programme.

Action IIFS-9 on Stephen English

To thank EUMETSAT for their efforts regarding Russian data and to confirm ITWG's on-going requirement for observations with good timeliness.

Recommendation IIFS-4 to WMO

To continue to work with Permanent Representatives (PRs) in countries with DBNet ground stations to encourage provision of sufficient bandwidth to redistribute the hyperspectral IR sounder observations in addition to the MW sounder observations.

Action IIFS-10 on Heikki Pohjola

To raise Recommendation IIFS-4 with the WMO.

Recommendation IIFS-5 to WMO

To note increasing importance of timely observations and, with CGMS and Space Agencies, to continue to explore innovative methods, such as used by GPM, to provide global data with excellent timeliness for next generation satellite programmes.

Action IIFS-11 on Heikki Pohjola

To raise Recommendation IIFS-5 at WMO Space Secretariat.

Recommendation IIFS-6 to CGMS

Space Agencies to consider DBNet requirements when designing core ground segment software, and then to make software available to DBNet operators.

Action IIFS-12 on Peng Zhang

To ensure Recommendation IIFS-6 is communicated to Space Agencies via CGMS.

Action IIFS-13 on Philippe Chambon and Niels Bormann

To inform TROPICS team of continued ITWG interest in TROPICS but stressing that to ensure engagement from the ITWG community delivery of a large proportion of TROPICS data in NRT is necessary.

Recommendation IIFS-7 to ITWG Co-Chairs

To actively invite contributions from users and providers on experiences with Cubesats and small satellites to ITSC-23.

Action IIFS-14 on IIFS Co-Chairs

To assist ITWG Co-Chairs with Recommendation IIFS-7.

Recommendation IIFS-8 to CGMS

If a mission needs engagement from application areas with a NRT data requirement, budget should be allocated to provide this.

Action IIFS-15 on ITWG Co-Chairs

To report Recommendation IIFS-8 to CGMS.

Action IIFS-16 on Stephen English and Heikki Pojhola

To circulate Critical Satellite Data Paper and papers on CGMS and WMO best practise to IIFS members, who will provide feedback to what extent these are being adhered to by small satellite operators.

Recommendation IIFS-9 to CGMS

Space Agencies to note that the strong requirement for traceable calibration comes from NWP as well as the climate application area.

Action IIFS-17 on ITWG Co-Chairs

To ensure Recommendation IIFS-9 is communicated to CGMS.

Action IIFS-18 on ITWG Co-Chairs

To ensure Recommendation IIFS21-8 is again communicated to CGMS.

Action IIFS-19 on Peng Zhang

To report to GSICS the appreciation of the IIFS WG for the GSICS effort and the presentations at ITSC-22.

Action IIFS22-20 on Stephen English

To circulate HLPP to IIFS members, then pass all comments received within one month to CGMS via Mitch Goldberg.

Recommendation IIFS-10 to WMO

Link SATURN pages from relevant OSCAR pages to encourage uptake of SATURN as OSCAR is an indispensable tool and is therefore widely used. If uptake remains low, carry out a survey to establish if there is a requirement for SATURN, and if so what is preventing uptake. If there is no requirement for SATURN, to discontinue and concentrate resources on OSCAR.

Action IIFS-21 on Heikki Pohjola

To bring Recommendation IIFS-10 to attention of WMO Space Secretariat.

Recommendation IIFS-11 to space agencies (and agencies involved in re-transmission of satellite data) via CGMS

Space agencies to note that the benefits of satellite missions to the ITWG community are increased when early evaluation is undertaken by many independent centres. Facilitating early access to new data is therefore highly recommended.

Action IIFS-22 on ITWG Co-Chairs

To ensure Recommendation IIFS-11 is brought to the attention of CGMS.

Action IIFS-23 on Stephen English and Peng Zhang

To ask for feedback from CGMS on CGMS response to this recommendation (link to Recommendation IIFS21-3).

Recommendation IIFS-12 to ITWG Co-Chairs

ITWG co-chairs to share actions and recommendations from ITWG with co-chairs of other groups, and to consider the actions and recommendations from all groups prior to CGMS and identify actions and recommendations that are common to more than one group. These could be presented to CGMS as joint recommendations, given them stronger visibility.

Recommendation IIFS-13 to ITWG Co-Chairs

To continue to pursue very actively the IRC/IAMAS relationship, to gain more support for ITWG initiatives regarding Radiative Transfer.

Action IIFS-24 on IIFS Co-Chairs
To assist ITWG Co-Chairs with Recommendations IIFS-12 and IIFS-13.

Recommendation IIFS-14 to space agencies
To consider if the SAF concept would be beneficial for them, as it has been for EUMETSAT.

Action IIFS-25 on ITWG Co-Chairs
To ensure Recommendation IIFS-14 brought to attention of CGMS and to pass on ITWG congratulations on 20 years of the NWP and Climate SAFs to EUMETSAT.

PRODUCTS AND SOFTWARE

Action PSWG-1 on Nigel Atkinson
To provide Lihang Zhou with information on the VIIRS to CrIS clustering in AAPP.

Action PSWG-2 on SSEC (Scott Mindock)
To work with NOAA to obtain and make available LUTs for VIIRS, ATMS, CrIS.

Action PSWG-3 on Lihang Zhou
To discuss with the CLASS team whether a scripted retrieval from CLASS can be supported to allow easier access to larger/historic data amounts

Action PSWG-4 on Lihang Zhou
To circulate a link to the NOAA 90-day rolling archive.

Recommendation PSWG-1 to agencies
To implement subscription-based notification of anomalies or events that impact users.

Recommendation PSWG-2 to software providers
To give advance notice of plans for moving to new operating systems. One year is considered reasonable notice.

Recommendation PSWG-3 to software providers
We encourage software providers to explore the use of containers for packaging their software.

Recommendation PSWG-4 to software providers
To avoid frequent package updates. As a guide, not more than twice per year is recommended, excluding patches.

Recommendation PSWG-5 to EUMETSAT
To provide a schedule for release of different types of test data for both EPS-SG and MTG.

Recommendation PSWG-6 to Agencies

When designing software, keep DB users in mind from the outset in order to minimise costs at the user end.

Action PSWG-5 on PSWG co-chairs

To ask EUMETSAT for an update on the feasibility of providing ASCAT processing software to DB users.

Recommendation PSWG-7 to CSPP team

To look into reducing the latency and improving the coverage of CrIS products.

Recommendation PSWG-8 to JAXA

To consider providing AMSR-2 L1 software for release to the DB community. The CSPP team could host it.

Recommendation PSWG-9 to Agencies

Where a sounder and imager are on the same platform, a means should be provided to map the imager data to the sounder fields of view, so that the users have ready access to this information.

Recommendation PSWG-10

The frequencies used in DB reception (L band and X band) should be preserved, to ensure continued fidelity of downlink reception.

Action PSWG-6 on PSWG co-chairs

To update the group web page by next ITSC, assuming Wordpress is implemented by CIMSS as planned.

2. WORKING GROUP REPORTS

2.1 RADIATIVE TRANSFER AND SURFACE PROPERTY MODELLING

Web site: https://groups.ssec.wisc.edu/groups/itwg/rtsp

Working Group Members: Marco Matricardi (Co-Chair, ECMWF), Benjamin Johnson (Co-Chair, JCSDA), Raymond Armante (LMD/CNRS), Maziar Bani Shahabadi (ECCC), Bruna Barbosa Silveira (CNRM/Météo-France), Chris Barnet (Science and Tech. Corp.), Eva Borbas (SSEC/UW-Madison), Pascal Brunel (Météo-France), Laurent C.-Labonnote (University of Lille - LOA), Ming Chen (CICS-ESSIC, University of Maryland), Adrien Deschamps (CNES), Robin Faulwetter (DWD), Michelle Feltz (SSEC/UW-Madison), Victoria Galligani (CIMA-CONICET), Sylvain Heilliette (ECCC), James Hocking (Met Office), Buddhi Prakash Jangid (NCMRWF), Masahiro Kazumori (JMA), Robert Knuteson (SSEC/UW-Madison), Eunhee Lee (KMA), Zhenglong Li (SSEC/UW-Madison), Haixia Liu (IMSG, NOAA/NCEP/EMC), Cristina Lupu (ECMWF), Silke May (DWD), Stefano Migliorini (Met Office), Hidehiko Murata (JMA), Nicholas Nalli (IMSG, NOAA/NESDIS/STAR), Stu Newman (Met Office), Kozo Okamoto (JMA/MRI), Pascale Roquet (Météo-France), Benjamin Ruston (NRL), Nadia Smith (Science and Tech. Corp.), Patrick Stegmann (UCAR/JCSDA), Christoforos Tsamalis (Met Office), Jerome Vidot (Météo-France), Daniel Zhou (NASA)

2.1.1 Fast RT model coefficient generation

The RTSP-WG seeks to improve the availability and quality of spectral response functions needed to generate accurate coefficients required by fast RT models.

Recommendation RTSP-1 to fast model developers

Fast non-LTE models should include a representation of ozone variability in the mesosphere in support of shortwave radiance simulations.

Recommendation RTSP-2 to CGMS

To encourage sensor manufacturers and instrument engineering and science teams to provide SRFs with higher quality, consistent format, and with rapid availability. Commercial providers need to provide SRFs, APCs, and calibration information in support of RT.

Recommendation RTSP-3 to GSICS and CGMS/WMO/SATURN

Maintain and update Spectral Response Function databases for all available sensors, focusing on operational sensors. Recommend calibration information from sensor to be applied to RTM / SRF.

Action RTSP-1 on Benjamin Johnson

Create Community SRF repository and coordinate inputs from RTWG and other contributors. Continue to support previous recommendations of creating a spectral response function (SRF) repository, to be shared publicly with the RT community.

2.1.2 Line-By-Line models

RTSP-WG seeks to improve the quality of LBL models, and support diversity and continued development and funding for LBL modelling efforts.

Recommendation RTSP-4 to the RT and LBL community

The RTSP-WG strongly supports continuous line-by-line model development as a fundamental basis for accurate radiative transfer calculations in fast RT models. The RT community also encourages and supports the development of competing line-by-line codes (encourage innovation and diversity).

Recommendation RTSP-5 to LBL developers

Encourage line-by-line model developers to include a better formulation of the Voigt line shape (e.g., include velocity dependence).

Action RTSP-2 on Raymond Armante

To communicate results obtained using a speed dependent formulation of the Voigt line shape providing an assessment of the impact in the infrared region of the spectrum, especially in the long-wave.

Recommendation RTSP-6 to Fast RT and LBL community

Look at the current continuum absorption models at higher MW frequencies (< 1000 GHz) and investigate the use of the MTK_CKD model in line-by-line microwave codes. Including Far-IR in support of new missions.

Recommendation RTSP-7 to LBL developers

Characterization of LBL model biases and uncertainties, especially focusing on warm and moist air masses. Attempt to map uncertainties in spectroscopy into radiance uncertainties, starting from major lines of a given region.

Action RTSP-3 on Marco Matricardi

To communicate to the working group on the CO2 perturbation impact on LBL radiances, and to provide a report on the perturbation of the line mixing model.

2.1.3 Spectroscopic parameters

Similar to our support for line-by-line modeling improvements, we also seek to encourage the development and the improvement of spectroscopic databases, particularly with respect to those databases that support LBL models. We address a specific need for extending research into higher microwave frequencies that will be used on future sensors.

Recommendation RTSP-8 to spectroscopic model developers

A strong emphasis should be put on the continuous support of theoretical and laboratory spectroscopic studies. Continuous efforts should be maintained in the generation and improvement of basic line parameters.

Recommendation RTSP-9 to spectroscopic model developers

The RTSP-WG recommends promoting research into spectroscopy of higher frequency microwave channels up to 1000 GHz.

2.1.4 Surface properties

The following recommendations are aimed at strengthening the research aspects of surface modeling and associated RT simulations, and encourages communication and collaboration between and within the physical modeling and RT modeling communities.

Recommendation RTSP-10 to the physical modeling community, ICWG, ISWG, IPWG, IWWG

To develop accurate physical models to support emissivity modeling requirements in RT models.

Recommendation RTSP-11 to reference-quality model developers

The RTSP-WG strongly recommends support of developing reference-quality ocean-surface emissivity modeling, specifically Infrared, Microwave, for both active and passive simulations. And support the development of a reference surface emissivity model (English, et al.).

Recommendation RTSP-12 to vegetation modeling community

Spectral library developers to include broader and more diverse vegetation sampling (e.g., new types), and include the effects of senescence. Also include the impact of the diurnal cycle.

Action RTSP-4 on ISWG

Identify group that can provide broadened vegetation parameters in support of the spectral databases.

Recommendation RTSP-13 to snow modeling community

Determine the classification methodology for emissivity modeling over snow-free land surfaces, statistical vs. physical or some mixture thereof.

Recommendation RTSP-14 to surface modeling community

Improve the interface between land surface model parameters and RT models, and specifically incorporate angular dependence impact on polarized emissivity and reflectivity over all surface types. Include, specifically, the temperature dependence of the index of refraction of water, land, snow/ice, and vegetated surfaces.

Action RTSP-5 on Nick Nalli, Stu Newman, and Steve English

Identify up-to-date and develop new laboratory measurements across spectral ranges [UV-MW] and resolution of interest for various surface properties (land, water/ocean, snow cover, sea-ice), and anything that's missing, specifically include Far-IR.

2.1.5 Optical and physical properties: Aerosols, clouds, and precipitation

The optical properties of aerosol, clouds, and precipitation particles require continued support to improve physical and radiometric accuracy. The accuracy of scattering computations can be significantly affected by errors and uncertainties of the parameterization of optical properties of the scattering particles.

Recommendation RTSP-15 to aerosol/materials modeling laboratories

The RTSP working group recommends encouraging research into laboratory measurements of aerosol refractive indices, with an initial focus on common dust and sea-salt modes. Characterization of the indices of refraction of hygroscopic aerosols at different moisture levels is also highly encouraged.

Recommendation RTSP-16 to fast RT model developers

Explore the necessity of using non-spherical aerosol particle scattering properties in fast RT models in support of detailed scattering calculations (e.g., LIDAR).

Recommendation RTSP-17 to RT and physical model developers

With regard to the computation of cloud and aerosol optical properties and formation of parametric schemes in fast models: we recommend that there be an intercomparison of the parameterized schemes in order to assess the validity and continuity of the schemes across various size parameter ranges. This should assess against particle physical and optical properties from ultraviolet to microwave.

Action RTSP-6 on Benjamin Johnson

To continue to report on current developments of physical and scattering properties of aerosols, clouds, and precipitation to the RTSP working group. These links will be hosted on the RTSP WG webpage.

Recommendation RTSP-18 to ice/precipitation model developers

For all scattering/absorbing particles, extend the frequency range to cover the ranges of current and upcoming sensors, from visible to microwave (i.e., ICI channels). Extend the range of particulate sizes to be consistent with observed parameters for each particle type.

Recommendation RTSP-19 to laboratory property modelers

Far-IR studies of temperature dependent index of refraction.

2.1.6 Model solvers and approximations

Scattering approximations used in fast RT models are essential for operational use within simulations involving scattering atmospheres. The RT community should compare results from scattering model solvers to both each other, and to external models.

Recommendation RTSP-20 to RT developers

Encourage the comparison / validation of full scattering solvers. This should include the computational efficiency, specifically including the adjoint model.

Recommendation RTSP-21 to RT developers

For aerosol scattering computations, more research is needed to characterize the regimes where fast RT approximations are effective.

Recommendation RTSP-22 to RT developers

To look at the importance of simulating radiances in turbulent layers in coordination with model developers.

2.1.7 Validation of RT Model physical assumptions and RT calculations

In the pursuit of traceability, improved accuracy, knowledge of uncertainties, and in support of development of reference models, careful validation datasets must be made available to the community for use in RT calculation assessments.

Action RTSP-7 on Benjamin Johnson and Marco Matricardi

To maintain and update list of "golden" field experiments (variety of observations, high data quality, good sensor overlap/coverage), need input from instrument scientists and other key users/developers.

Action RTSP-8 on Marco Matricardi

To provide link on MAGIC campaign calibrated datasets.

2.1.8 Fast RT Model Intercomparison

The working group plans to continue CRTM/RTTOV/ARMS model intercomparisons and expand it slightly to cover both clear-sky and cloudy RT comparisons.

Action RTSP-9 James Hocking and Benjamin Johnson

To coordinate the CRTM/RTTOV/ARMS model intercomparison effort. JEDI/UFO is a possible framework. Aim toward developing a standardized intercomparison framework for testing new coefficient files / scattering tables, etc. And to reach out to ARMs developers to include them in the effort.

2.1.9 Coordination of Recommendations

Fostering communication between various working groups is essential to reduce the duplication of effort and to promote collaborative cross-group activities.

Action RTSP-10 to the RTSP-WG Co-Chairs and members

Share RTSP recommendations with other relevant working groups (e.g., ITSC, IPWG, ICWG, IWWG, ISWG, ISDA, and other groups where reference radiative transfer will be of interest). Individuals from RTSP-WG should volunteer to present recommendations at their respective meetings.

Recommendation RTSP-23 to the RT model development community

Promote the extension of RT models to the simulation of active/passive data (e.g., Radar/LIDAR/Scatterometers), and to UV, Visible, and Far-Infrared portions of the spectrum. An accurate treatment of atmospheric and surface polarization (linear and circular) should also be considered in support of these bands.

2.1.10 Future RT Outlook

Fast RT models should be responsive to upcoming requirements arising from NWP or other communities. We specifically identify areas of importance that need to have some early attention and discussion. It is expected that these items will move up into other areas as requirements and research progress.

Recommendation RTSP-24 to the RT modeling community and partners

Support the development of a set of community models for building a reference standard radiative transfer model, but using existing reference models where available (e.g., LBL, Spectroscopic databases).

Action RTSP-11 on the "IRRTM" team

Deliver whitepaper and present on the International Reference Radiative Transfer Model ("IRRTM") status and planning to ITSC, IPWG, ICWG, IWWG, ISWG, ISDA, and other groups where reference radiative transfer will be of interest.

2.2 CLIMATE

Web site: http://cimss.ssec.wisc.edu/itwg/cwsg/

Nathalie Selbach (Co-Chair, DWD), Cheng-Zhi Zou (Co-Chair, NOAA), Bruna Barbosa Silveira (Meteo-France), Bill Bell (ECMWF), Martin Burgdorf (Uni. Hamburg), Fabien Carminati (MetOffice), Jordi Chinaud (CNES), Eui-Seok Chung (IBS Center for Climate Physics), Cyril Crevoisier (CNRS/LMD), Adrien Deschamps (CNES), Larry Flynn (NOAA), Songyan Gu (NSMC/CMA), Viju John (EUMETSAT), Heikki Pohjola (WMO), Lei Shi (NOAA), Nadia Smith (STC/NOAA/NASA), Bomin Sun (NOAA/STAR), Ling Sun (NSMC/CMA), Joe Taylor (UW-SSEC), Christoforos Tsamalis (MetOffice), Peng Zhang (CMS/NSMC), Daniel Zhou (NASA), Lihang Zhou (NOAA)

2.2.1 Introduction

The ITSC-22 Working Group on Climate convened on Saturday, 2 November 2019, and discussed actions and recommendations from earlier meetings and new topics related to climate relevant topics. The Climate WG enjoyed a lively and useful discussion. Six new actions and eight recommendations arose from the discussions.

2.2.2 Follow-up on actions from earlier meetings

All except one remaining action from ITSC-20 and ITSC-21 have been closed and the status is summarized below.

- **Action Climate20-1 on WG Co-Chairs**
  Coordinate the update of the webpage of the Climate WG once the new Content Management System (CMS) is available and the ITWG pages as well as the subgroup pages have been migrated to the new systems.
  Status: Closed. The content of the webpage has been updated on the current system, as the new CMS is not yet available. The current content is planned to be migrated to the new CMS once it becomes available and updates will be implemented as needed.

- **Action Climate20-2 on Cheng-Zhi Zou**
  NESDIS to look at the possibility of merging AIRS, IASI and CrIS with its recently developed SSU stratospheric temperature climate data record.
  Status: Closed. The project for merging AIRS/IASA/CrIS with SSU has been funded. Results will be presented elsewhere when available.

- **Action Climate20-6 on Rob Roebeling**
  Provide information to the Climate WG webpage on different inter-calibration activities for Level-1 FCDR data, e.g. HIRS, AMSU, AVHRR, etc.
  Status: Closed. Rob Roebeling provided an update of the information, which has now been included on the Climate WG webpage (related to Action Climate-1 from ITSC-20).

- **Action Climate21-1 on WG Co-Chairs**
  Establish how requirements from the climate community are collected as input for development of new satellite sensors and provide the information to the group. Establish whether there is a clear role for the ITWG Climate group on the definition of climate requirements for new satellite sounding sensors.
  Status: Ongoing. Requirements are usually collected for ECVs or Level-2/3/4. The responsibility for this process lies with GCOS. For sensor data at Level-1 this is normally done at each individual agency during its mission planning. One needs to

figure out whether climate requirements are considered systematically by agencies in mission planning. This will be further discussed in the Climate WG and input from satellite agencies on this topic is highly appreciated.

- **Action Climate21-2 on WG Co-Chairs**
  Links to data, especially FCDR data, recovered data, information on calibration/ inter-calibration of instruments should be fed into a WMO based system. WMO should give a recommendation which of their systems should be used for this purpose.
  Status: Closed. The Co-chairs have been in contact with J. Schulz (EUMETSAT) and received the following information: The joint CEOS/CGMS Working Group (JWG) on Climate will take care of this. In addition to the ECV Inventory, the JWG plans to have at least a list of available FCDR data. This list (as the ECV Inventory) is linked with the WMO OSCAR Space. The JWG is currently sorting out definitions for FCDR, (T)CDR, and ICDR as currently existing definitions do not reflect the needs, e.g., with respect to uncertainty characterization. This process is currently ongoing and will most likely be finished towards the end of 2019. Based on this set of definitions, the JWG will start to collect information on the L1 data and generate the above-mentioned list.
  Currently, information on FCDRS is also available within the ECV Inventory (https://climatemonitoring.info/ecvinventory/) under the Accessibility tab in the Details view. However, this information is available for only about 50% of the data records, which indicates a lack in understanding on FCDRs and a lack of availability of them as well. More details are available in the gap analysis report by the CEOS/CGMS WG on Climate.

- **Action Climate21-3 on Lihang Zhou**
  Make the climate reanalysis community aware of the reprocessing efforts for SNPP. Lihang Zhou to forward the request within NESDIS.
  Status: Closed. The request has been forwarded to NESDIS. NESDIS/STAR is documenting the reprocessing efforts and will inform the satellite and reanalysis community on the quality of the reprocessed SNPP observations.

2.2.3 Global Observing System design

OSCAR has been quite stable, no new features have been added since about two years, but there are plans at WMO to update OSCAR with new features. The content of the database is maintained by WMO with focal point at the different agencies, who are asked to provide input on the status of instruments; WMO requests feedback in case of any issues/incorrect input, etc., in OSCAR.

Action Climate-1 on Heikki Pohjola

Provide information on the status of information about FCDRs in OSCAR to the Climate WG. This information will also be added to the Climate WG webpage.

Action Climate-2 on Climate Co-Chairs

Provide information on the CEOS/CGMS Joint Working Group on Climate on the Climate WG webpage (e.g. link to report, etc.).

2.2.4 Gap analysis

GCOS (Global Climate Observing System) and AOPC (Atmospheric Ocean Panel for Climate) are preparing a gap analysis report. Gap analysis is a standing item for CGMS; they

update every year and report. Links to the respective report will be added to the Climate WG webpage with the next update.

Action Climate-3 on Climate Co-Chairs

Provide information on the GCOPS and AOPC gap analysis report to the Climate WG webpage (e.g. link to report, etc.).

2.2.5 Data archiving

The WG stresses that it is important, that satellite data providers archive the original raw data (level 0 data) with all accompanying metadata, sensor specification and laboratory measurements of antenna characteristics. This is especially important with respect to reprocessing of data for e.g. generation of fundamental climate data records, correction of calibration issues also in more near-real-time applications, etc.

Recommendation Climate-1 to satellite agencies

Satellite data providers should allow access to level-0 data for all data after commissioning, and during the commissioning phase ensure some negotiated access regardless of the vendor.

2.2.6 Data continuity and consistency

DMSP F19 failed to transfer data to ground receiving stations in 2016. The U.S. Naval Research Laboratory (NRL) owns and still has the last SSMIS instrument in storage. NRL is currently looking for possible vehicles to launch this SSMIS instrument. If launched, this could be the last SSMIS flying on a satellite.

Recommendation Climate-2 on satellite agencies

Upper stratosphere and lower mesosphere are an important component in the climate system. Satellite agencies should plan ahead in designing sounding instruments to cover atmospheric layers from 1hPa to 0.1hPa when SSMIS is no longer available.

2.2.7 Metrological Traceability

As recognized by other groups (GSICS, CEOS-WGCV, ..) satellite agencies should ensure that accuracy specifications on new missions are underpinned by a requirement on instrument vendors and those responsible for pre-launch characterization to achieve metrological traceability for all measurements affecting level-1 products. As a minimum, this requirement should apply to pre-flight characterization, testing and calibration. A further aspiration, addressed by targeted missions such as CLARREO and TRUTHS, is to achieve metrological traceability for on-orbit measurements.

The anticipated benefits of accomplishing this are two-fold: firstly by enabling the estimation of robust uncertainties for on-orbit measurements, and secondly, by future-proofing climate records against significant changes in remote sensing technology which may offer significant performance advantages but which may challenge the '*more-of-the-same*' model of generating continuous climate records over long periods from similar instruments.

These requirements complement existing recognized requirements for mission overlap and temporal stability.

Recommendation Climate-3 to satellite agencies

When designing, characterizing and calibrating new sensors satellite agencies and instrument vendors should ensure that metrological traceability is achieved for all pre-flight measurements influencing the accuracy of level-1 products. This information should be comprehensively documented and be made available to end users.

The group highly appreciates the efforts done by GSICS on calibration and intercalibration of different satellite sensors. In the context of calibration and intercalibration of level-1 data, traceability of the applied values and algorithms is crucial.

Recommendation Climate-4 to GSICS

GSICS should ensure that traceability is part of their best practices for calibration/inter-calibration.

2.2.8 Requirements for new sensors for climate applications

The NWP community has been effective in shaping mission requirements for new meteorological satellite instruments, and this has been enabled through groups such as the ITWG. Many of the detailed NWP requirements are common to climate applications, however there are particular requirements related (for example) to stability, accuracy and traceability of the measurements that are unique to climate.

In addition, whereas NWP requirements are shaped by the anticipated instrument performance requirements over the next 10-20 years (given the status and anticipated evolution of data assimilation methods and Earth system models) the climate community should anticipate, as far as possible, the likely requirements over much longer timescales. Observations continue to have value for ongoing climate reanalyses for example, as illustrated by the significant investments in the recovery of early satellite data for the 1960s and 1970s.

Recommendation Climate-4 to satellite agencies

The group recommends that satellite agencies support targeted studies aimed at translating GCOS ECV requirements into radiometric, spectral and sampling specifications for new sensors, particularly addressing requirements that are specific and additional beyond those generated from other applications such as NWP, etc.

2.2.9 Two-satellite constellation of same instrument in the same orbit

The value of having e.g. SNPP and NOAA-20 being separated by a half orbit in the 13:30 orbit has been shown during the conference. It is recommended that this configuration should become a standard best practice for all satellite agencies flying polar orbiting satellites. For climate monitoring, the difference between the two satellites (instruments, products) can be monitored on a 16 day or 32 day repeat cycle, because the global average should be identical since both satellites are observing at 13:30 and 1:30. The same approach can be made for identical sensors in the same orbit (same equator crossing time) on different satellites from other agencies. This allows on the one hand to get better confidence in the retrieval of CDRs (e.g., seeing the same behavior of time series seen in product derived from both satellites) and also allows the monitoring of possible issues in one of the satellites (e.g., only one of the instruments seeing a trend or sudden jump in time series).

Recommendation Climate-6 to satellite agencies

The group recommends satellite agencies to keep and/or establish a 2-satellite configuration for the same sensor in the same orbit (same equator crossing time) to improve the confidence in derived CDRs and to also provide a measure to assess the stability and health of the instruments on the two satellites.

2.2.10 Reanalysis, Data Rescue and Data Quality Assessment

Several activities are ongoing to rescue and assess the quality of early (pre-1979) satellite level-1 datasets to support climate reanalysis and other climate studies. In Europe, for example, the Copernicus Climate Change Service (C3S) is supporting the recovery and assessments of early infrared sounding data, including SIRS, IRIS, MRIR, HRIR and THIR. This activity complements similar activities ongoing in the US and China.

Information on the outputs from these types of activity (data and documentation) should be collected in a central portal, to help coordinate future reprocessing efforts and to provide a single authoritative catalogue of status on these activities. Although the main focus of GSICS is the intercalibration of modern-era satellite data records the expertise, interests and communication channels of the group are most closely matched to the early rescue and assessment activities and therefore is the most obvious group to host such a portal.

Action Climate-4 on WG Co-chairs

Co-chairs to ask GSICS for guidance on stewardship of data, documentation and metadata related to the recovery and assessment of early satellite data sets.

2.2.11 Hyperspectral IR sounder uncertainties

An ongoing assessment of the consistency with respect to each other and with respect to radiometric uncertainties of the bias corrections applied to the advanced IR sounder data assimilated in ERA5 (AIRS, IASI and CrIS) is providing useful insights into the performance of the reanalysis. For example, the bias corrections applied to SNPP and NOAA-20 CrIS for most of the 15 μm temperature sounding channels are smaller than the radiometric uncertainties at 3σ. This represents a good consistency check on the mean state of the reanalysis in the recent era, and may provide an important tool in the development of a 'benchmark' reanalysis. Such an analysis should be extended to the other hyperspectral IR instruments currently on orbit, but this requires that the radiometric uncertainties for these sensors are documented and made available to users. It would be beneficial if the uncertainties were estimated in a consistent way across sensors, to facilitate uptake by users. Ideally, this would be made available in a single document, to enable easy cross-comparison of the methodologies.

Action Climate-5 on Climate WG members

To determine the requirements for uncertainty information from all operational hyperspectral IR instruments and document.

Action Climate-6 on Climate WG co-chairs

To ask GSICS to forward the request to the instrument teams at agencies to provide the uncertainty information from all operational hyperspectral IR instruments

2.2.12 Efficient dissemination of hyperspectral IR data

Recommendation Climate-7 to satellite providers

Satellite data providers should distribute a set of selected channels and PC scores for (upcoming) hyperspectral sensors. This way, users could reconstruct the radiances, compare the reconstructed channels with the distributed channels and check if PCs are done correctly and get a feeling about the potential information loss. The archiving and open availability of full L1C data for climate studies should be preserved and re-processed data should be publicized whenever available.

2.2.13 Validation

The WG encourages community to do mutual validation for satellite pairs on the same orbit for similar instruments. Recent comparisons between microwave sounders on different satellites with the same orbit demonstrated that this mutual validation provided better confidence in terms of CDR traceability and stability. In addition, the GCOS Reference Upper Air Network (GRUAN, https://gruan.org), an international reference observing-network of 30-40 sites measuring essential climate variables, provides long-term, high-quality climate data records from the surface through the troposphere and into the stratosphere. GRUAN provides reference quality vertical profile measurements of upper air temperature, water vapor, horizontal winds, and ozone using balloon-borne sensors launched on a regular basis at the 26 existing GRUAN sites. The GRUAN measurements with uncertainty estimate for every data point has been demonstrated very useful for validating satellite sounding observations with good confidence for traceability and stability, particularly if targeted with respective satellite overpass. Network for the Detection of Atmospheric Composition Change **(**NDACC**)** has long-term observations of other trace gases for validating satellite observations of greenhouse observations.

Recommendation Climate-8 to GRUAN

GRUAN should be encouraged to provide subsets of satellite targeted observations (NOAA and MetOp satellites) and EUMETSAT encouraged to support MetOp targeted radiosondes at selected GRUAN sites similar to ongoing JPSS targeted radiosonde programs with NOAA satellites. These are most valuable in the context of climate (and weather) oriented validation.

2.2.14 Training

Training of users in the usage of different CDRs (from FCDRs to TCDRs) is an important issue to support climatologists in applying the products in climate monitoring, climate analysis, and climate modelling. One example is the training activities of the different EUMETSAT Satellite Application Facilities together with the EUMETSAT training and outreach group. Training courses at different knowledge levels are given regularly together with the provision of documented software tools. EUMETSAT supports users in the member states and among the World Meteorological Organization (WMO) members in the application of EUMETSAT data, products, and services, including Copernicus data provided by EUMETSAT. In an international cooperation, EUMETSAT and CM SAF recently supported the development of the COMET training module "Basic Climate Analysis Using the CM SAF R Toolbox." This training module provides an overview of the satellite-based climate data records (CDRs) generated by the CM SAF and shall enable learners to obtain a CDR from the CM SAF and the software packages needed to visualize the CDR data in the CM SAF R Toolbox. The COMET Program was established by UCAR and NOAA's NWS. It uses innovative methods including distance learning materials, onsite and virtual training

events, and support for advancing scientific knowledge to develop training in different areas of environmental sciences. The MetEd website, one of COMET's primary undertakings, hosts lots of education and training material for the geosciences.

2.3 DATA ASSIMILATION AND NUMERICAL WEATHER PREDICTION

Web site: https://groups.ssec.wisc.edu/groups/itwg/nwp

Working group members: Fiona Smith (Co-Chair, Bureau of Meteorology), Andrew Collard (Co-Chair, NOAA/NCEP/EMC), Mathieu Asseray (Météo-France), Thomas August (EUMETSAT), Tom Auligné (JCSDA), Maziar Bani Shahabadi (ECCC), Bruna Barbosa Silveira (Météo-France), Chris Barnet (STC), Kristen Bathmann (NOAA/NCEP/EMC), Joel Bedard (ECCC), Bill Bell (Met Office), Chris Burrows (ECMWF), Bill Campbell (NRL), Brett Candy (Met Office), Fabien Carminati (Met Office), Ming Chen (NOAA/NESDIS), Hyoung-Wook Chun (KIAPS), Olivier Coopmann (Météo-France), David Duncan (ECMWF), Reima Eresmaa (ECMWF), Robin Faulwetter (DWD), Nadia Fourrié (Météo-France), Lawrence Flynn (NOAA/NESDIS), Dmitry Gayfulin (Roshydromet), Mitch Goldberg (NOAA), Jonathan Guerrette (UCAR), Vincent Guidard (Météo-France), Liam Gumley (CIMSS), Chawn Harlow (Met Office), Sylvain Heilliette (ECCC), Dirceu Herdies (CPTEC), Buddhi Prakash Jangid (NCMRWF, India), Ben Johnson (JCSDA), Erin Jones (NOAA/NESDIS), James Jung (CIMSS), Jeon-Ho Kang (KIAPS), Bryan Karpowicz (NASA/GMAO), Christina Köpken-Watts (DWD), In-Hyuk Kwon (KIAPS), Stéphane Laroche (ECCC), Eunhee Lee (KMA), Agnes Lim (CIMSS), Magnus Lindskog (SMHI), Haixia Liu (NOAA/NCEP/EMC), Katrin Lonitz (ECMWF), Qifeng Lu (CMA/NSMC), Cristina Lupu (ECMWF), Marco Matricardi (ECMWF), Silke May (DWD), Stefano Migliorini (Met Office), Emily Morgan (FNMOC), Hidehiko Murata (JMA), Stu Newman (Met Office), Kozo Okamoto (JMA), Marc Pondrom (DWD), Indira Rani (NCMRWF, India), Zied Sassi (CNRM), Karen St. Germain (NOAA), Olaf Stiller (DWD), Christina Stumpf (DWD), Ruth Taylor (Met Office), David Tobin (CIMSS), Ricardo Todling (NASA/GMAO), Maria Toporov (U. Köln), Francesca Vittorioso (CNRM), Zheng Qi Wang (Met.no), Zhipeng Xian (CAS), Ruoying Yin (CAS), Yanqiu Zhu (NOAA/NCEP/EMC)

2.3.1 Standing actions and recommendations

Action DA/NWP-1 on ITWG Co-Chairs

To bring relevant recommendations to the attention of CGMS.

Polar orbiting constellation

Over the years, many observation impact experiments have demonstrated benefits from using MW and IR sounding data from three or more polar orbiting systems in NWP, compared to using data from just two orbits. An even spacing of orbits (early morning, morning, afternoon orbit) ensures most homogeneous coverage, with benefits for forecast impact. The WG strongly supports international cooperation to ensure harmonization of orbits.

Recommendation DA/NWP-1 to all relevant space agencies

The constellation of at least three orbits (early morning, morning, and afternoon), each with full sounding capabilities (IR and MW), should be maintained. The overpass times of operational satellites with sounding capability (IR and MW) should be coordinated between agencies to maximize coverage and include a satellite in early morning orbit.

With the discontinuation of the DMSP satellites, the availability of high altitude temperature sounding channels is in doubt. It is therefore recommended that options to continue this capability be explored. Those using the SSMIS instrument are making good use of the

instrument. No other instrument has comparable upper atmospheric sounding channels and the instrument shows positive impact in FSOI.

Recommendation DA/NWP-2 to the satellite agencies

In support of maintaining a robust global satellite observing system, instrumentation to allow continued sounding of the temperature of the upper stratosphere and mesosphere (as for the SSMIS UAS channels) should be explored.

Recommendation DA/NWP-3 to the NWP centres

Work to assess the impact of the upper atmospheric sounding channels of SSMIS in NWP and determine the information content unique to those channels, e.g. via data denial experiments.

Cal/val of future instruments

The working group believe that the distribution of test data prior to launch is of such importance that the following recommendations should be repeated to ensure that users have adequate test data to fully prepare for future systems.

Recommendation DA/NWP-4 to space agencies

New operational data dissemination infrastructure should be tested at an early stage (well before launch) with simulated data.

Furthermore, NWP data has proven to be a critical resource in the Cal/Val process for new instruments.

Recommendation DA/NWP-5 to space agencies

There should be open and early access to new satellite data for all NWP centres to help with calibration and validation.

Investment to fully realise the potential of new satellites in operational use

New satellite programmes can cost hundreds of millions of Euros and yet it can take many years to learn to properly exploit the data in numerical weather prediction. Additional investment in operational NWP (which while still expensive is only a few percent of the satellites themselves) therefore represents an efficient path for improving the cost/benefit ratio for satellite observations. This investment should focus on improved computational resources (allowing more sophisticated models to be run and more resources for research); development of new assimilation techniques (many centres are still not running 4D assimilation systems thereby reducing the impact of observations with high temporal frequency) and improvement to the forecast models, as well as characterisation of uncertainties and development of methods focused on the particular observations themselves. Investment in operational NWP is preferred as research conducted in this paradigm from the start is more easily transferred to operational status. It is also noted that the larger the number of operational centres able to conduct cutting-edge research, the more likely that breakthroughs will be made in the use of satellite data.

Recommendation DA/NWP-6 space agencies

Satellite agencies should work with their primary user communities to assess the limitations in the exploitation of satellite data, and also engage with users less closely connected to their agencies.

Recommendation DA/NWP-7 to funding bodies of NWP centres and space agencies

Consider, as part of the cost of satellite programmes, providing computational and personnel resources targeted at operational NWP centres to optimise the public's return on investment from these expensive measurement systems.

Radio Frequency Interference

Radio Frequency Interference (RFI) has the potential to seriously impact the usefulness of data used for NWP. Instances of RFI should be documented to provide evidence to spectrum managers who try to safeguard the passive bands that the NWP community rely on. Low-level interference that is hard to detect may be particularly difficult to account for.

Action DA/NWP-2 on NWP WG members

Send any evidence of RFI in the observations to Stephen English (stephen.english@ecmwf.int) and Richard Kelley (barometer@verizon.net) and also the results of experiments investigating the effects of RFI on forecast skill.

Stephen and Richard will coordinate the provision of information and results to CGMS.

Action DA/NWP-3 on NWP WG Co-Chairs

Discuss with Stephen English (stephen.english@ecmwf.int) and Richard Kelley (barometer@verizon.net) where to collate information on RFI in NWP (e.g. DA/NWP-WG web page).

Updated channel characteristics

NWP systems or Simultaneous Nadir Overpass (SNO)-methods have been used to revise channel characteristics such as central pass-band frequencies for microwave instruments or spectral response functions for IR sounders. The group believe that it is still useful to collect this information on the channel characteristics web page of the RT WG, as such updates have been shown to reduce some airmass-dependent biases and therefore aid the assimilation of the affected data.

Action DA/NWP-4 on NWP WG members

If you have estimates of revised channel characteristics resulting from post-launch diagnostics, please email these to the Radiative Transfer Working Group Co-Chairs (Benjamin.T.Johnson@noaa.gov & Marco.Matricardi@ecmwf.int).

2.3.2 WG support to NWP community

The ITWG NWP WG is recognized as an ideal forum to exchange information and inform/update NWP users about new developments, aided by Wiki-pages and a dedicated email list. For several meetings, the survey on the use of satellite data has been capturing the broad developments in the assimilation of sounder data in NWP, with the results posted on the NWP WG web pages. Ahead of ITSC-21, an extra column has been added to allow centres to link in further information (e.g. regarding blacklisting).

Action DA/NWP-5 on NWP centres

Continue to provide information on instrument channels assimilated and their observation errors for inclusion on the NWP Working Group pages in advance of each conference.

The group continues to appreciate the use of the working group mailing list in highlighting problems with operational instruments and members are encouraged to continue to share experiences this way.

Action DA/NWP-6 on Working Group Members
Look at the working group website and make suggestions and corrections.

Action DA/NWP-7 on Working Group Co-Chairs
Review the current mailing list membership and migrate to a new platform (google groups).

2.3.3 Provision of BUFR data

At previous meetings, the group made the recommendation (ITSC-XX/DA/NWP-8) to data providers to agree on a standardized procedure for inclusion of NEdT estimates within BUFR for microwave data.

Since the last meeting, NEDT estimates have been added to the ATOVS BUFR data distributed by EUMETSAT.

However, it remains an issue that the calculation of the NEDT differs between NOAA, EUMETSAT and the Met Office. Jörg Ackermann (EUMETSAT) distributed a report detailing the differences between these approaches. For further progress, working group members should review these approaches and make suggestions as to the preferred method for calculating NeDT.

Recommendation DA/NWP-8 to data providers
Agree on a standardized procedure for calculation of NEdT estimates for inclusion within BUFR for microwave data.

Action DA/NWP-8 on Working Group Co-Chairs
Clarify with Banghua Yan regarding the status of the provision of NEdT estimates in BUFR files for microwave data from NOAA/NESDIS.

The group retained the following two recommendations from previous conferences:

Recommendation DA/NWP-9 to data providers
Include azimuthal viewing and solar angles as appropriate in BUFR for present and future instruments.

Recommendation DA/NWP-10 to space agencies and data providers
When designing new or modified BUFR formats, please circulate drafts to the NWP community via the NWP Working Group for feedback, prior to submission to WMO.

2.3.4 CrIS switch to Full Spectral Resolution data

The switch from Nominal Spectral Resolution (NSR) to Full Spectral Resolution (FSR) CrIS data for the S-NPP satellite has been proposed for 01 April 2020. NOAA-20 data has been available in this format for over a year. Centres are either using FSR in operational assimilation or have strategies to convert between the two formats. NOAA/NESDIS are

providing FSR and NSR in parallel, but EUMETSAT currently distribute only the NSR dataset.

Recommendation DA/NWP-11 to EUMETSAT

Communicate when NSR for S-NPP CrIS will be switched off and provide a parallel stream for a short time (a few weeks) to allow users to transition to the new dataset.

Action DA/NWP-9 on Working Group Co-Chairs

Ensure the April 1st 2020 date for the end of NESDIS distribution of S-NPP NSR CrIS data is communicated to the group.

2.3.6 PC Compression of Hyperspectral Data

We retained the following recommendations from the last conference:

Recommendation DA/NWP-12 to data providers

When using PC compression, noise normalisation should be performed using the full noise covariance matrix.

Recommendation DA/NWP-13 to EUMETSAT

Proceed with work on the use of Hybrid PC compression and investigate practical application of this method, including the incorporation of granule-based vectors in BUFR.

Thomas August (EUMETSAT) confirmed that the IASI PC-compressed data stream will be updated during 2020 to use the full noise covariance matrix, a training data set with updated trace gas events, and an additional five vectors derived from the granule (Hybrid PCA). More than eight weeks notice will be given, as agreed at the last conference.

In addition, EUMETSAT is planning studies on the use of hybrid PCs to prepare for the MTG-IRS user community. MTG-IRS data will be disseminated as hybrid PC Scores.

Recommendation DA/NWP-14 to NWP centres

All centres should use the IASI Hybrid PC-compressed dataset to ensure they are prepared for MTG-IRS. Users are requested to provide feedback to EUMETSAT on the use of these data.

2.3.7 Change management and the NWP community

Unfortunately, despite CGMS agreeing to the recommendations made at the last conference, there were again a number of instances during 2019 where the management of change to the global observing system did not meet the requirements of the NWP and DBNet communities.

Planned changes to the calibration of instruments, in particular to ATMS, were not appropriately notified to the community. In the case of ATMS, notification to the community occurred only via unofficial channels. The group agreed once again that responsibility for advising the users of such changes lies with data providers and that they should unambiguously communicate to users using multiple channels when significant changes such as these are to be made.

In the case of the Metop-A IASI non-linearity correction, the WG would like to thank Stephanie Guedj and Dorothee Coppens for their communications about the IASI change, but

it is not clear that all users will have been reached by these informal channels. The community was advised of the upcoming change via the EUMETSAT UNS weekly operations bulletin, but the message retained the phrase "The exact time will be provided closer to the event" even on the date of the change, which could have been confusing.

The switch of S-NPP CrIS electronics to the B-side was reported to have been well-communicated to users, but some people were not satisfied with updates regarding when the data would be reinstated.

Recommendation DA/NWP-15 to data providers

If a change to data processing results in a change in brightness temperature of 0.1K or 20% of NEdT (whichever is smaller), this should be made clear in notifications to users. These notifications should be made no later than 8 weeks before the change and test data should be provided if possible.

Action DA/NWP-10 on WG Co-Chairs

Provide feedback to CGMS that significant changes to operational datastreams continue to be inadequately communicated to users.

The group wished to retain the following recommendation, noting that the clear sky radiance products for GOES-16 and GOES-17 are not operational at this time.

Recommendation DA/NWP-16 to data providers

The overlap period where one satellite resource is replacing another should be chosen after consultation with the user community and should follow WMO guidelines.

2.3.8 VIIRS/AVHRR cluster information

The group was asked by Nigel Atkinson to provide feedback on timeliness requirements for DBNet data for CrIS, following a request by users to add VIIRS sub-pixel cluster information to the datastream. The AAPP VIIRS cluster algorithm for CrIS delays the L1c product by 4 minutes; an additional 10 minutes is required if MAIA cloud products are produced.

The group agreed that a four minute delay was acceptable, but that the additional cloud product was not a requirement.

Recommendation DA/NWP-17 to DBNet providers

Switch on the production of VIIRS cluster information for DBNet for IASI and CrIS.

As the IASI/VIIRS cluster algorithm is available via AAPP, this should now be added to the global data stream.

Action DA/NWP-11 on Andrew Collard

Check with NESDIS-STAR on plans to implement the VIIRS cluster algorithm for global CrIS data dissemination.

2.3.9 Bias correction

The group have agreed to close a number of actions related to bias correction at this conference. There remain a number of open questions regarding the best methods for

addressing biases in data for assimilation in limited area models, but no specific items were raised at this meeting.

If any discussion is required or requested before the next conference, a teleconference will be arranged via email amongst working group members.

2.3.10 New and future mission evaluation

CMA satellites

At ITSC-XXI, several centres expressed intention to evaluate GIIRS data from FY-4A when made available by CMA. It was proposed that interested centres should therefore coordinate their work. These data are now available. Initial evaluation has been performed by a group including CMA, ECMWF, the Met Office and University of Wisconsin–Madison, and the data is considered to be satisfactory for evaluation by the wider NWP community.

Action DA/NWP-12 on Chris Burrows and Qifeng Lu

Seek expressions of interest on coordinating evaluation of GIIRS and HIRAS data.

Evaluation of FY-3E data will be critical to support requests for satellites in the early morning orbit, and impact assessments will be sought by CMA.

Action DA/NWP-13 on WG members

Share impact assessment results for FY-3E with the group and CMA as soon as possible after data becomes available, in particular to provide evidence to support the early morning orbit.

Meteor-M2 IKFS-2

ECMWF have started to evaluate data from the IKFS-2 instrument from the Russian Meteor-M2 satellite. The instrument appears to be performing well, and it is recommended that other centres participate in evaluation studies. There are, however, issues with the timeliness of the delivery of the data, which is currently available via EUMETCast.

Recommendation DA/NWP-18 to NWP centres

Evaluate IKFS-2 data.

Recommendation DA/NWP-19 to data providers

In order to facilitate evaluation of new data by NWP centres, aim for distribution in near-real time.

Metop-C

Many centres have begun to use Metop-C data, including ATOVS, IASI and ASCAT. The instruments are reported to be performing well, and quality of the data are comparable to the Metop-A and -B instruments.

Anecdotally, the impact from adding Metop-C on top of the full observing system appears to be rather variable, but the reasons for the mixed results are not understood and are likely to be related to the specifics of thinning algorithms, DA systems and observation errors.

Action DA/NWP-14 on Working Group Co-Chairs

Coordinate collation of information on impact of Metop-C instruments in operational NWP, along with information regarding thinning algorithms and error correlations used and share the collated information with working group members.

IASI-NG

Vincent Guidard reported that Meteo-France have been developing a channel selection for IASI-NG for use by the NWP community, presented at this conference by Francesca Vittorioso.

2.3.11 Impact of DBNet Data

To ensure continuation of the DBNet network, evidence should be provided on the importance of these data on forecast skills. This is expected to be particularly important in regional models. There were several posters at this conference demonstrating the importance of DBNet data (Youngchan Noh: 12p.08, Shuang Xi: 12p.11, David Howard: 1p.03), but more studies and evaluation would be useful.

Recommendation DA/NWP-20 to NWP centres

Produce impact studies for DBNet and low latency data and present results at the Seventh WMO Workshop on the Impact of Various Observing Systems on NWP in Seoul in May 2020.

Action DA/NWP-15 on Mitch Goldberg

Forward existing studies on the impact of DBNet data to the Working Group.

2.3.12 JPSS Field of View Size Followup

Following the recommendation from this working group on field of view size for JPSS, it was reported that the JPSS team took this recommendation and have studied this further. This is considered to be a successful recommendation from NWP working group. The change probably will not be implemented for CrIS but our views were taken into account for future sounders.

2.3.13 Monitoring

Christina Koepken-Watts (DWD) reported on the monitoring activities of the NWP-SAF. Data timeliness and quality plots are provided, along with automated alerts from the ECMWF monitoring system and information about DBNet data provision. In addition there are quality assessments of AMVs, DFS and FSO diagnostics from Meteo-France and a new service providing reports on radiance evaluation for new satellite missions.

The NWP-SAF request feedback from users on the current suite of products and ideas for implementation during the next operational phase (CDOP-4). A survey will be circulated in the coming weeks.

The group were able to report that the NWP-SAF monitoring site is in wide and regular use by the community, and new additions to the site are greatly appreciated.

Action DA/NWP-16 on Working Group Co-Chairs

Circulate the NWP-SAF survey on user requirements for monitoring activities.

Action DA/NWP-17 on Working Group members
Complete NWP-SAF survey on user requirements for monitoring activities

Thomas Auligné (JCSDA) reported on work being undertaken to extend a multi-centre FSOI intercomparison study undertaken by the WMO working group on observation impacts into near-real time. This study could be linked into the NWP-SAF website.

Action DA/NWP-18 on Thomas Auligné
Contact Samantha Pullen (samantha.pullen@metoffice.gov.uk) to discuss circulation of FSOI intercomparison study.

Cristina Lupu spoke on behalf of Mohamed Dahoui (ECMWF) about a proposal to provide the community with a list of instrument events (changes to calibration, drop-outs). It could be interesting to add example plots for these events.

Recommendation DA/NWP-21 to NWP-SAF
Share ECMWF instrument event records with the community, together with illustrative monitoring plots where appropriate.

Action DA/NWP-19 on Working Group Co-Chairs
Add a link to ECMWF instrument event records to the Working Group web page when such a link is provided by the NWP-SAF.

2.3.14 NWP SAF Cloud and Aerosol Detection Software

The developers of the NWPSAF Cloud and Aerosol Detection Software are also looking for user requests for improvements to be included in the next release (next summer) and beyond.

Action DA/NWP-20 on users of the NWPSAF Cloud and Aerosol Detection Software
Provide feedback to Reima Eresmaa (Reima.Eresmaa@ecmwf.int) on requirements for future upgrades.

2.3.15 Instrument requirements

NOAA does not have a requirement for maximum allowed inter-detector calibration differences. It was noted that EUMETSAT do have such a requirement for the IASI-NG.

Action DA/NWP-21 on Thomas August and Fiona Smith
Determine whether the IASI-NG End Users Requirements Document can be shared. If any questions remain, discuss at ISSWG how to help NOAA formulate a requirement on maximum inter-detector calibration differences.

In addition, it is noted that the Advanced Sounder Working Group made a recommendation at ITSC-20 for a 50mK calibration match between detectors.

2.3.16 Aqua AIRS end-of-life planning

As propellant is finally running low, Aqua is moving out of the A-train and the orbit will drift over the next seven years. From 2022 to 2025 it will move to 15:30 orbit and then to 17:30 in the following year before being deorbited. Current plans are for Aqua to be switched off in October 2022. It is recommended that Aqua is kept alive and providing data throughout the orbital drift phase to evaluate the impact of different orbits (provided AIRS can still be properly calibrated).

Recommendation DA/NWP-22 to NASA and NESDIS

Continue to provide AIRS Aqua data in real-time to NWP centres for as long as calibration of the instrument is possible.

2.3.17 Plans for future NOAA Satellite Constellation

Karen St. Germain (NOAA) outlined NOAA's current announcement of opportunity to industry to propose instrumentation for the next generation of meteorological satellites from 2030. Various options are being considered.

Questions arising from the presentation include:

1) Disaggregation (flying instruments on different platforms): Which instruments do we require to be flown together?
2) Which trade-offs need to be studied? E.g. Spectral bands vs accuracy and resolution (horizontal and vertical); spectral resolution vs spatial resolution vs noise.
3) Small satellites vs large buses: IR instruments proposed for small satellite platforms tend to not have the 15 micron band. Is this acceptable?
4) Mission lifetimes: Can we effectively use instruments with shorter lifetimes, say 3 years?
5) How should NOAA stagger development of new technologies to get greatest impact out as soon as possible whilst retaining agility?

In addition it was noted that NWP systems are likely to evolve dramatically in the next 10-20 years and evaluation of future systems should take this into account.

Given the limited time for discussion at the meeting, it is proposed that a virtual working group be set up by the Working Group chairs to discuss these proposals and provide feedback.

Action DA/NWP-22 on Karen St. Germain

Send to WG co-chairs the target performance and reference architecture for the Broad Area Announcement to industry for next-gen instrument proposals, including identified areas for potential trade-offs.

Action DA/NWP-23 on Working Group Co-Chairs

Send out an email to the DA/NWP WG members containing supporting documentation from Karen St. Germain inviting participation in a working group to make recommendations to NOAA on the proposals for next-generation satellites.

Action DA/NWP-24 on NWP Working Group members

Respond to the request from Karen St. Germain and DA/NWP WG co-chairs to join a working group to provide feedback to NOAA on proposals for next-generation satellites.

2.4 ADVANCED SOUNDERS

Web site: http://cimss.ssec.wisc.edu/itwg/aswg/

Working Group members: Dorothee Coppens (Co-Chair, EUMETSAT), Dave Tobin (*Co-Chair, SSEC/UW-Madison*), *Mathieu Asseray (CNRM/CEMS), Nigel Atkinson (Met Office), Thomas August (EUMETSAT), Nancy Baker (NRL), Alain Beaulne (Meteorological Service of Canada), Chris Barnet (Science and Tech. Corp.), Chris Burrows (ECMWF), Xavier Calbet (AEMET), Philippe Chambon (Météo-France), Junye Chen (GST), Keyi Chen (Chengdu University of Information & Technology), Yong Chen (NOAA/STAR UMD), Chu-Yong Chung (NMSC/KMA), Andrew Collard (IMSG@NOAA/NCEP/EMC), Olivier Coopmann (CNRM, Université de Toulouse, Météo-France, CNRS), David Duncan (ECMWF), Reima Eresmaa (ECMWF), Robin Faulwetter (DWD), Nadia Fourrie (CNRM, Météo-France, CNRS), Louis Garand (ECCC), Dmitry Gayfulin (Hydrometeorological Centre of Russia), Mitch Goldberg (NOAA), Songyan Gu (NSMC, CMA), Vincent Guidard (Météo-France), Liam Gumley (SSEC/UW-Madison), Chawn Harlow (Met Office), Erin Jones (UMD CISESS), James Jung (CIMSS), Eric Jurado (CNES), Norio Kamekawa (JMA), Hee-Jung Kang (NMSC/KMA),Bryan Karpowicz (GESTAR/USRA/NASA GMAO), Dieter Klaes (EUMETSAT), Christina Koepken-Watts (DWD), Bjorn Lambrigtsen (JPL), Stephane Laroche (ECCC), Heather Lawrence (ECMWF), Zhenglong Li (CIMSS/SSEC), Agnes Lim (CIMSS/SSEC), Qifeng Lu (NSMC), Clement Luitot (CNES), Silke May (DWD), Masami Moriya (JMA), Kozo Okamoto (JMA/MRI), Marc Pondrom (DWD), Chengli Qi (NSMC), Kirsti Salonen (ECMWF), A.K. Sharma (NOAA/NESDIS), Eric Simon (UCAR/NRL), Karen St Germain (NOAA/NESDIS), Ruth Taylor (Met Office), Ricardo Todling (NASA/GMAO), Maria Toporov (University of Cologne), Francesca Vittorioso (CNRM, Météo-France, CNRS), Zhipeng Xian (IAP), Hu (Tiger) Yang (University of Maryland), Ryoying Yin (IAP), Dan Zhou (NASA), Lihang Zhou (NOAA/NESDIS/STAR)*

2.4.1 Existing and planned sensors and data

Chinese satellites

The upcoming FY-3E and FY-4B satellites will be launched in the next year. FY-3E will be in the early morning orbit and includes an improved HIRAS with a 3x3 versus 2x2 FOV array and also possible removal of the FY-3E HIRAS spectral gaps. There was a request to have full spectral resolution (FSR) version of the HIRAS data available from the start of the operational mission. FY-4B will include an improved GIIRS, as compared to the research GIIRS on FY-4A. For both platforms, commissioning is expected to take six months, with data available afterwards.

Recommendation AS-1 to space agencies (CMA)

Disseminate the HIRAS and GIIRS data six months after launch if possible, and not only via EUMETCAST but also to the Global User Community.

Recommendation AS-2 to space agencies (CMA)

Consider to make available as soon as possible the HIRAS spectra at full spectral resolution for all bands. This also applies to all future hyperspectral sounders.

Recommendation AS-3 to space agencies (CMA)

FY-3D GIIRS data has good noise performance below the current longwave cutoff of 700 1/cm; CMA to investigate and consider extending the output range of FY-3D GIIRS spectra to ~680 1/cm.

Action AS-1 on ITWG Co-chairs
Bring these recommendations to the attention of space agencies at CGMS.

Russian satellites

Regarding IKFS-2 data and the possibility to have direct broadcast: it will be possible but only for the one from 2025 on. We will keep then the recommendation from ITSC-21.

Recommendation AS-4 to space agencies (Roshydromet and Roscosmos)
ASWG recommends establishing a Direct Broadcast capability for the data on the Meteor-M satellite, in particular for the hyperspectral IKFS-2 data.

Action AS-2 on ITWG Co-chairs
Bring this recommendation to the attention of space agencies at CGMS.

Meteor-M N2-2 will be launched in July 2019 and data will be released in 2 or 3 months (probably in January 2020).

Action AS-3 on ASWG co-chairs
To follow the data release date and circulate the information to the ASWG.

European satellites

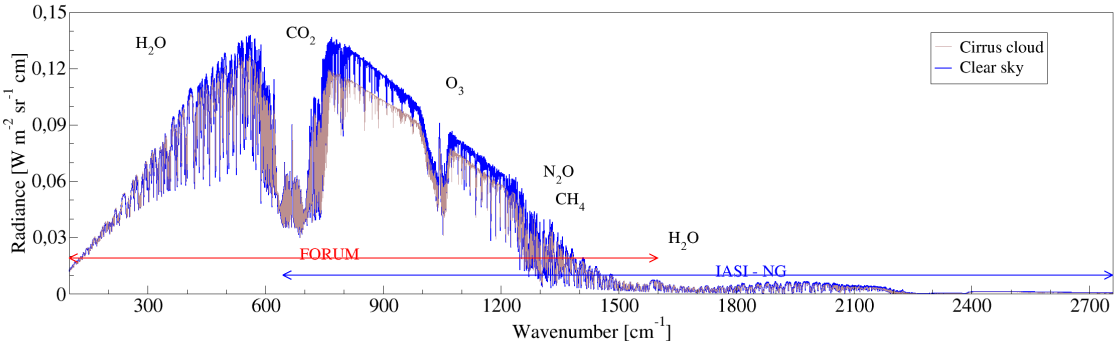
The MTG-IRS mission was presented, showing the interest in such a mission: GEO hyperspectral sounders are providing high spatial and temporal resolution and coverage, a unique dynamic view of the atmosphere, 3D winds, which are important for NWC and NWP. It supplements the forecasts, independent observations, gaining precision and lead-time in issuing warnings.

Particular attention on the amount of data it implies in terms of downlink and dissemination has been addressed. The dissemination will be done in Principal Component with a new methodology called hybrid approach, discussed in section 2.4.3.

Action AS-4 on ASWG co-chairs
To circulate to ASWG members the information on the bandwidth for the MTG IRS L1 PC dissemination as soon as it is available.

The future mission FORUM (Far-infrared Outgoing Radiation Understanding and Monitoring) was presented and discussed. FORUM is an ESA Earth Explorer 9 with a 3-year lifetime mission with the following characteristics:

- 100-1600 cm^{-1}: highly sensitive to upper tropospheric water vapour and to cirrus clouds;
- Nadir viewing only;
- Sun-synchronous orbit at an altitude of about 817 km, flying in tandem with IASI-NG; and
- Ground footprint is a single pixel of about 15 km.



This mission will be further discussed at future ITSC meetings.

2.4.2 Next generation sensors and data

NOAA is moving forward with the pre-phase A for new missions. Several studies on what NOAA could have with LEO/GEO orbits, trying to identify mixed-capabilities and Tundra orbit have been initiated.

Karen St. Germain presented NOAA's view: a constellation with a mission in Tundra orbit, GEO ring, and NOAA imagers.

Note that the GOES-R series and JPSS will carry the same instruments until 2035 which means there is no evolution in terms of instrument improvement.

GEO-LEO trade-off

NOAA is looking at the minimum importance for applications to decide what to do. Currently, the "reference constellation" includes East and West GEO platforms with Imagers, and LEO "Sounder satellites" (IR + MW). The US is thinking of quantity (several small LEO instruments), versus quality. This is mainly for NWP applications. The typical useful lifetime of small satellites is based on 3 years of design life.

Particular attention has been put on having IR+MW sounders on the same platform; the imagers could be on another one. Most important is to ensure good inter-satellite calibration and consistency for both IR and MW.

Action AS-5 on Karen St. Germain

To provide information on the new NOAA trade study mission.

Action AS-6 on ASWG Co-chairs

To organize ASWG members and provide feedback to NOAA on all aspects of the proposed mission(s).

Recommendation AS-5 to space agencies

To keep IR and MW sounders together on the same platform.

Recommendation AS-6 to space agencies

To study whether or not to have the imager on the same platform.

Recommendation AS-7 to space agencies

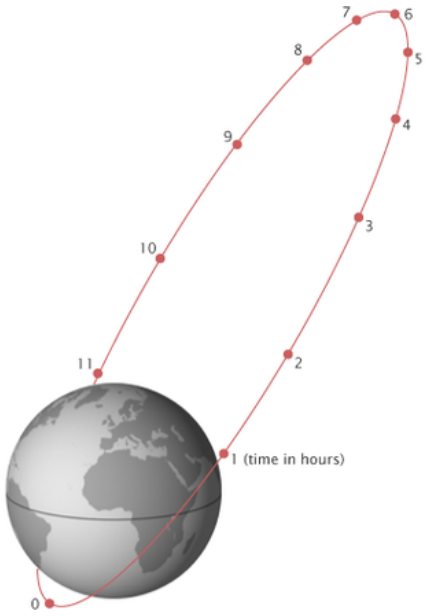
To keep good inter-satellite calibration and consistency for both IR and MW.

Action AS-7 on ITWG Co-chairs

Bring these recommendations to the attention of Space Agencies at CGMS.

Tundra orbits

For the Tundra orbits, ECCC has studied largely those orbits, and while they are considered a good option, they are not the preferred option.



Action AS-8 on Louis Garand

To send documentation on those studies to ASWG.

2.4.3 Efficient dissemination of Hyperspectral IR data

From the last CGMS: Develop efficient standardized data handling for high-resolution imaging and hyperspectral instruments, employing novel methods like dissemination of hyperspectral infrared data based on Principal Component Analysis.

EUMETSAT has presented their hybrid PC methodology for MTG-IRS L1 products to address all user needs (including Atmospheric Composition). EUMETSAT reported that they have initiated several studies with NWP centers to assimilate PC. DWD and Meteo-France have observed no difference when using PC in comparison with original radiances. More study results are expected in the future from the Atmospheric Composition user community.

The hybrid method of EUMETSAT has already been endorsed by the NWP WG at ITSC-21.

Moreover, which noise should we use when using PC? The answer was that the observation error matrices can and should be constructed in the same way as is done empirically when using original radiances, i.e., to include error correlations coming at least from the forward modelling.

Recommendation AS-8 to ASWG

To look at available PC and give feedbacks to ASWG co-chairs.

Recommendation AS-9

The hybrid method of EUMETSAT should be taken as the best practice to establish PC for IRS on MTG.

Additionally, as opposed to using a relatively small subset of spectral channels that are used in some applications, PCs enable the full information and signal-to-noise advantage of high spectral resolution spectra to be conveyed to the users. Refer to appendix A for more information on this topic.

Recommendation AS-10 to NWP centers

To investigate the use of theoretical PC reconstructed radiances, for a representative set of spectral channels, to be used in the radiance assimilation process.

2.4.4 Re-iterating previous high priority ASWG recommendations

Recommendation AS-11 to satellite agencies (NOAA, JAXA)

Consistent with numerous previous ITWG and ASWG recommendations, and consistent with the WMO Integrated Global Observing System (WIGOS) Vision for the Global Observing System in 2025 and 2040, the ASWG strongly recommends that space agencies develop and implement plans to fill the gaps in IR hyper-spectral sounding within the Geostationary constellation.

Recommendation AS-12 to satellite agencies

The constellation of at least three polar orbits (early morning, morning, and afternoon), each with full sounding capabilities (IR and MW), should be maintained. The overpass times of operational satellites with sounding capability (IR and MW) should be coordinated between agencies to maximize their value.

Recommendation AS-13 to satellite agencies

Implement high spatial resolution and contiguous sampling detector arrays in future hyperspectral infrared sounding instruments.

Recommendation AS-14 to satellite agencies

To develop, test, and implement an SI-traceable radiometric standard in space as soon as feasible.

Action AS-9 on ITWG Co-chairs

To re-iterate these recommendations to space agencies via CGMS.

Appendix A to the Advanced Sounder Working Group report

To: ITWG Advanced Sounder Working Group

From: William L. Smith, Past WG Co-Chair

Background
There generally seems to be a lack of understanding of the source of vertical resolution information content of hyper-spectral resolution measurements. Improved vertical resolution results from the reduced weighting function width, resulting from their higher spectral resolution that acts to avoid the smearing of on-absorption line atmospheric radiance contributions with in-between absorption line atmospheric radiance contributions to individual channel radiances. However, this improvement in individual spectral channel radiance weighting function resolution is only about 15-20%.

Instead, it has been shown that the improved vertical resolving power comes from the order of magnitude improvement in signal-to-noise (S/N) provided by the use of the complete radiance spectrum of hyper-spectral radiances, which contains 1000s of noise independent radiance observations rather than the 10s of channels of observations as provided by multi-spectral satellite sounding sensors (e.g., HIRS and AMSU). An order of magnitude S/N improvement is consistent with the "Square Root Law" defined in probability theory (i.e., the accuracy of $\bar{X}$ n as an estimator of μ is inversely proportional to the square root of the sample size n). The atmospheric signal increases to the first power of the number of spectra radiances being used but the noise, being spectrally random, increases to the square root of the number of spectra radiances being used.

Thus, the S/N of the atmospheric signals being sensed with radiance spectra tends to increase by the square root of the number of spectral channels being used in the atmospheric signal retrieval process. Since 1000/10 = 100, the S/N enhancement of hyper-spectral sounders relative to multi-spectral sounders tends to be an order of magnitude, i.e., square root (100). This S/N enhancement is critical in trying to resolve small vertical scale feature signals contained within a system of low vertical resolution radiance measurements.

Problem
Most Numerical Weather Prediction center users believe that it is proper to use a small subset of the channel radiances, provided by the hyper-spectral sensors, in order to optimize computational efficiency. The rationale is that the information being provided by other channels with weighting functions similar to those channels within the subset are only providing redundant atmospheric information. Although this argument is valid with respect to the atmospheric signal contained in the radiance within single spectral channels, this argument does not recognize the detrimental consequence of channel selection regarding the large reduction in atmospheric vertical feature S/N contained in the small subset of observations relative to that contained in the complete system of observations being used to resolve these vertical features. As a consequence, these hyper-spectral observation data are not being used to achieve their full potential to improve weather prediction. One promising exception is that ECMWF has stated that it is beginning to use PC reconstructed radiances for a representative set of spectral channels. Since the PCs represent the entire spectrum of the hyper-spectral radiance measurements, the desired S/N enhancement of vertical resolution is being achieved by this process, assuming that the exact same PCs are used to create the model background calculated radiances required for the radiance assimilation process.

Also, it is important that the PCs used for the radiance reconstruction process be based on theoretical radiative transfer model calculations of the hyper-spectral radiance spectrum for a diverse sample of surface and atmospheric conditions (e.g., obtained from surface and atmospheric measurement climatology or possibly model background specified surface and atmospheric conditions for a large number of cases). Using radiative transfer calculated radiances, as opposed to actual observations, trace gas, cloud and aerosol, and surface emissivity contributions to the observed radiances can be accounted for without the influence of state variable vs. radiance observation time and location mismatch noise and radiance measurement noise. Both measurement "mismatch" and instrument noise act to decrease the ability of the PCs to extract the full atmospheric information content of the radiance measurement spectra used in the model radiance assimilation process.

2.5 INTERNATIONAL ISSUES AND FUTURE SYSTEMS

Working Group members: Peng Zhang (CMA, Co-chair), Stephen English (ECMWF, Co-chair), Alan Beaulne (ECCC), Nancy Baker (NRL), Niels Bormann (ECMWF), Pascal Brunel (Météo-France), Philippe Chambon (Météo-France), Keyi Chen (CULT), Yong Chen (NOAA), Chu-Yong Chung (KMA), Louis Garand (ECCC), Ben Johnson (JCSDA), Masahiro Kazumori (JMA), Richard Kelley (NOAA), Dieter Klaes (EUMETSAT), Heather Lawrence (ECMWF), Heikki Pohjola (WMO), Ben Ruston (NRL), Joe Taylor (UW-SSEC), Christoforos Tsamalis (Met Office).

2.5.1 Introduction

The ITSC-22 Working Group on International Issues and Future Systems (IIFS) convened on Saturday 2nd November 2019 and discussed actions and recommendations from ITSC-21 and topics requiring coordination between agencies. The IIFS enjoyed a lively and useful discussion. Overall there were 25 new actions, 15 recommendations, many important statements arising from the discussions.

2.5.2 Summary of open ITSC-19, 20 and all 21 Actions and Recommendations

All past actions from ITSC-19, 20 and 21 are now closed. The actions that were open at the end of ITSC-21, including all new ones at ITSC-21 as well as older ones carried over from past ITSCs are summarised below.

- **Action IIFS19-1**: Steve English to request ITWG (involving the NWP Group) to provide input to CGMS WG III – via Jérôme Lafeuille – for updating the CGMS Contingency Plan.
  CLOSE. WMO (Werner Balogh and Lars-Peter Riishojgaard) confirm this is now closed, comments received have been noted.

- **Recommendation IIFS19-3**: WMO to pursue SATURN, and all agencies to actively contribute information to this portal (and two associated actions).
  CLOSE. SATURN is now well established. Suggest at each ITSC soundings be made about use of SATURN and feedback to WMO. This Recommendation does not need on-going reporting.

- **Recommendation IIFS20-12**: IIFS and other ITWG members to provide information on current usage of protected bands to Rich Kelley. (Action: Stephen English to provide copy of recent ECMWF submission to Ofcom, and to request Met Office to provide copy of their submission as well as encourage other NMSs to provide similar information where it exists).
  CLOSE. The successful ECMWF workshop (see below and b.01 presentation) provides a mechanism. Recommendation does not need on-going reporting.

- **Recommendation IIFS20-13**: To make MW SRFs available to facilitate RFI investigations when needed. (Action: Stephen English to ask co-chairs to combine with Recs from other WGs and communicate to CGMS).
  CLOSE. Some MW SRFs have been made available. Suggest this Recommendation does not need on-going reporting, but situation should be kept under review.

- **Recommendation IIFS20-14**: Update Steve English's study from 2005 on the value of individual MW protected bands. (Action: Sid Boukabara to ask Thomas Auligné to

consider making this part of the FSOI intercomparison study and presenting to the WMO impacts workshop in Shanghai in 2016).
CLOSE. See response to Action IIFS21-10. Recommendation does not need to continue to be reported on.

- **Action IIFS21-1**: Mikael Rattenborg to note IIFS comments in next draft of the HLPP.
Status: Done. Mikael Rattenborg reflected the discussions at the IIFS at ITSC-21 in the HLPP paper that went to CGMS-46 in Bangalore. Mitch Goldberg, as ITWG rapporteur to CGMS, of course contributed to this.

- **Action IIFS21-2**: Christoforos Tsamalis to provide input to Mikael Rattenborg on item 3.4.1 (new common vocabulary and methodology for the errors associated with validation data).
Status: Done. New Action IIFS22-A1 arising (see below).

- **Action IIFS21-3**: Claude Camy-Peyret to provide more information to IIFS members on the FORUM proposal.
Status: Done. Information about FORUM was presented at ITSC-22. FORUM has now been selected as ESA Earth Explorer-9.

- **Action IIFS21-4**: IIFS members to provide science questions and undertake studies, and encourage others to do so, to WMO (Lars Peter Riishoejgaard at riishojgaard@wmo.int) to support this as a significant theme of the next OSE workshop.
Status: Done. Some science questions from the Working Groups were received by LPR via CGMS.

- **Action IIFS21-5**: S. English / P. Zhang to bring this* to attention of major NWP centres and TROPICS mission. *This = "evaluation of TROPICS mission."
Status: Done. S. English presented TROPICS to WMO/IPETSUP, Bill Blackwell visited ECMWF and many NWP centres, detailed information was made available.

- **Action IIFS21-6**: Mikael Rattenborg to discuss with GODEX-NWP members how this* initiative could be implemented (next meeting Autumn 2018). *This = "sharing of evaluation of higher risk research missions."
Status: Done. This was discussed and reported at GODEX-NWP. The activity has been adopted by GODEX-NWP.

- **Action IIFS21-7**: In partnership with the NWP WG the IIFS WG co-chairs to devise a set of criteria for this CGMS procedure to follow.
Status: Done. A criterion was proposed by the NWP WG, and that WG will take forward discussion in this area.

- **Action IIFS21-8**: Mikael Rattenborg and the IIFS co-chairs to draft a letter for ITWG co-chairs to send to Roscosmos and Roshydromet explaining the importance of access through DB-Net and processing of real time MTVZA-GY and MSU-MR data (Alexander Uspensky to advise full postal address of whom to send to).
Status: Done. This was done by Mikael Rattenborg and the letter sent. Note IPWG also sent a letter on another topic, and the implications for coordination are discussed in Section 2.5.5.

- **Action IIFS21-9**: Peng Zhang to check status of reference sites in China and their availability.
  Status: Done. Dunhuang Gobi desert site and Qinghai lake site are organized by CMA. Dunhuang Gobi desert site for solar reflection bands and Qinghai lake site for thermal emission bands. Dunhuang Gobi desert site is prepared to be the site of RadCalnet through CEOS WGCV.

- **Action IIFS21-10**: Steve English to ask ECMWF if it is willing to host a short workshop (1-2 days) to present updated information with respect to Recommendations IIFS20-14 and IIFS20-15.
  Status: Done. The workshop was held 13-14 September 2018, with a workshop report available. The general verdict is that the workshop was very successful. Outcomes were presented in item b.01 at ITSC-22.

- **Action IIFS21-11**: Steve English and Peng Zhang to bring these suggested changes* to WMO teams considering these questions (CGMS, IPETSUP, ICT-IOS…). *These suggested changes = changes to a WMO policy document on the growing role of commercial satellite observation providers.
  Status: Stephen English brought this to attention of CGMS and WMO/IPETSUP and through WMO/IPETSUP minutes other WMO teams.

- **Recommendation IFS21-1 to IRC**: Development of a new unified model for describing spectroscopic and water vapour continuum absorption.
  Status: This was also discussed by the RT WG and at the CMA-ECMWF-JCSDA workshop at Tianjin on Radiative Transfer Models. IIFS will not pursue this as the Recommendation was transferred to the RT WG.

- **Recommendation IIFS21-2 to ITWG members**: ITWG members to familiarise themselves with the HLPP.
  Status: This was done for the HLPP version presented at ITSC21. The task needs to be repeated with each update of the HLPP, and there is a new action (IIFS-20) from IIFS22.

- **Recommendation IIFS21-3 to CGMS**: To show orbital coverage and other details when orbital configuration and formation flying is under discussion for new research missions that may benefit from synergy flying with existing operational missions.
  Status: This remains valid and a new action (IIFS-23) will actively seek a response to this Recommendation.

- **Recommendation IIFS21-4 to multiple agencies**: Evaluation of TROPICS mission to be undertaken by appropriate agencies in partnership with TROPICS mission (e.g., NWP centres).
  Status: This remains valid, but was reformulated at IIFS22 to emphasise that NRT data provision is necessary to persuade NWP centres to engage.

- **Recommendation IIFS21-5 to GODEX-NWP**: For GODEX-NWP to organise and oversee agreed sharing of the evaluation of instruments not considered to be "core" by NWP centres.
  Status: This has been adopted by GODEX-NWP so the Recommendation is closed.

- **Recommendation IIFS21-6**: Note the growing evidence of likely benefits from hyperspectral geostationary soundings, and where possible to work towards the provision of such instruments in plans for future geo systems.
  Status: This remains valid but as this forms part of the CGMS baseline, there is no need to repeat this Recommendation again to CGMS.

- **Recommendation IIFS20-7 to CGMS**: Re-emphasize best practise is to consider latency requirements early in the planning stage of new missions, including research and pre-operational.
  Status: This remains valid but has been reformulated into a number of Recommendations and Actions from ITSC-22.

- **Recommendation IFS21-8 to CGMS**: Recognizing the growing need for assessment and on-orbit optimization of the accuracy of operational hyperspectral IR sounders, the traditional approaches for pre-flight SI traceability and post-flight validation should be enhanced by flying a CLARREO-like on-orbit reference standard capability (featuring on-orbit SI verification) with orbits designed to provide inter-calibration capability for refining the calibration of the international fleet of operational sounders.
  Status: This Recommendation remains valid and will be communicated again to CGMS.

- **Recommendation IIFS21-9 to AOPC GCOS**: Maintain and where possible expand GRUAN and ARM sites.
  Status: This was brought to the attention of Kenneth Holmlund, current chair of GCOS AOPC. (Peng Zhang is also a member of AOPC). There is a new action to check if the IIFS-21 outcome was sufficient.

- **Recommendation IIFS21-10 to CGMS**: Space agencies to develop, where possible, improved capability to detect RFI in level-0 data.
  Status: This Recommendation is still valid but has been reformulated at ITSC22 with specific new actions (see text).

- **Recommendation IIFS21-11 to CGMS**: Space agencies to ensure that provision of SRFs for MW instruments is routine practise for future instruments and published on the SATURN portal. Furthermore to obtain wherever possible and practical the SRFs for existing and old instruments, and also to provide on the SATURN portal.
  Status: This was reported to CGMS by Mitch Goldberg and brought to the attention of the GSICS EP chair at the GSICS EP meeting in Sochi, Russia in 2019.

- **Recommendation IIFS21-12 to WMO**: WMO to pursue SATURN, and all agencies to actively contribute information to this portal (and two associated actions). Reported. Still valid.
  Status: This remains valid, but questions were raised at ITSC-22 about the uptake of SATURN. Therefore a new Action arose at IIFS22 to validate why the SATURN update has been slow.

2.5.3 Follow-up to Actions and Recommendations from ITSC-21

Action IIFS21-A2 was closed as described above because it came to the attention of the group that a meeting dedicated to this topic was held at the National Physics Laboratory in the UK in September 2019, and this has produced a draft white paper. The group considered

the best course of action was to review this, see if ITWG can endorse it, and provide feedback as appropriate to the authors. This resulted in Action IIFS-1:

Action IIFS-1

Stephen English to obtain copy of the White Paper from the NPL meeting on traceable calibration and circulate for comment, then feed back comments to White Paper authors.

The IIFS also noted that the Recommendation IIFS21-9 may merit further discussion to inform what more ITWG could do to assist with the long term future of GRUAN and super-sites for calibration and validation. This resulted in Action IIFS-A:

Action IIFS-2

Peng Zhang to discuss with Ken Holmlund if further action or comment is needed from ITWG on this topic (Link to Recommendation IIFS21-9).

2.5.4 Spectrum management issues

The World Radiocommunication Conference 2019 (WRC19) was taking place in Egypt at the same time as ITSC-22. We will know the outcome of WRC19 in December or January. There was concern that the position taken by WRC19 may not offer adequate protection to EESS at 24 and 50 GHz. Therefore IIFS considered that Space Agencies needed to consider what more could be done to detect and report RFI in their instruments, to protect their investment and users. This resulted in Recommendation IIFS-1 to CGMS to encourage such activities. Furthermore, it was noted that some work presented at ITSC (Simon E., 1p19) showed use of AI to detect anomalies and other work is known to be sponsored by ESA to examine what steps can be taken to detect and report RFI. It was felt that the IIFS should collect and share information on all such efforts. This discussion resulted in Actions IIFS-3 and 4.

Recommendation IIFS-1 to CGMS WG I

Space Agencies to consider building in as much RFI screening and mitigation into their ground segment processing as possible, noting efforts already starting at ESA and in research groups in the US, Japan and China.

Action IIFS-3 on IIFS members

To provide a summary of known activities, such as the ESA initiative (Link to Recommendation IIFS-1).

Action IIFS-4 on Rich Kelley

To contact Chris Kummerow about efforts in his team and report to ITWG (Link to Recommendation IIFS-1).

The IIFS recognised the high value of the ECMWF RFI workshop report, available at https://www.ecmwf.int/en/learning/workshops/radio-frequency-interference-rfi-workshop

This report not only documents the current impact of passive microwave bands in NWP, it also assesses the socio-economic benefits. The IIFS encouraged to bring the report to the attention of all Space Agencies, as evidence of the value of passive MW measurements. This resulted in Action IIFS-5.

Action IIFS-5 on Stephen English

To bring ECMWF RFI workshop report to the attention of all space agencies and CGMS.

The IIFS noted that the Radio Astronomy community is better organised in living with RFI than the weather community, as increasingly is the L-band community. These two communities organise a regular "Living with RFI" workshop. In order to engage with the weather community, it is likely the next workshop will be held at ECMWF. This may be followed immediately by a repeat of the ECMWF RFI workshop, which has different goals (about communicating value of the spectrum to society through meteorology, whereas the Living with RFI is about how to minimise the impact of RFI). It is also likely ECMWF will organise a telecall half day workshop to exchange updates on the 2018 workshop. It was also encouraged to present relevant studies to the WMO OSE workshop. It is vital that ITWG strongly support these efforts, if Spectrum Managers are to have high quality up to date information and evidence to use in negotiations. Hence Recommendation IIFS-2 and Action IIFS-6.

Recommendation IIFS-2 to ITWG members

ITWG members to plan to participate as actively as possible in consecutive RFI-related workshops at ECMWF in 2021.

Action IIFS-6 on Stephen English

To send information to the ITWG mailing list about RFI Workshops once dates are known (Link to Recommendation IIFS-2).

The IIFS heard that both in the USA and UK statements had been made suggesting a possible deregulation above 95 GHz. This increases significantly the risk to passive bands of MHS, ATMS and MWHS-2 and similar instruments, notably the channels centred on 183 GHz. It is useful therefore to anticipate the threat and begin to collate evidence of the value of these channels.

Recommendation IIFS-3 to ITWG members

ITWG to begin to assemble evidence of the value to society of bands above 95 GHz through their use in meteorology.

Action IIFS-7 on Stephen English

To ensure specific requests are made for studies of the value of bands above 95 GHz in preparation for workshops in 2021 (Link to Recommendation IIFS-3).

2.5.5 Near real time data exchange

The IIFS noted the remarkable progress of DBNet, now supplying near global coverage microwave sounding with typical timeliness better than 30 minutes. This complements nicely global data exchange, which usually has a timeliness of 1-3 hours, though the group also noted examples of using new approaches to facilitate global data exchange with excellent timeliness. Not all data is available within the requirements listed in the WMO Rolling Review of Requirements. The group continues to appreciate the efforts in Russia to provide high quality observations, and at ITSC-22 it was shown that the Russian hyperspectral sounder in particular appears very good. However the timeliness of the Russian data remains an issue. Independently IPWG and ITWG sent letters to Roscosmos and Roshydromet concerning Russian satellite data, albeit on different topics. ITWG and IPWG have a

common interest in the Russian programme and face similar challenges. It was agreed that closer collaboration between ITWG and IPWG on this and other data exchange issues would be of value, resulting in Action IIFS-8.

Action IIFS-8 on Stephen English and Philippe Chambon (Co-Chair, IPWG)
To discuss joint ITWG-IPWG efforts on DBNet and science issues with respect to the Meteor-M programme.

In addition to DBNet, EUMETSAT have been working to try and improve timeliness of Russian global data. This effort is strongly supported by IIFS. The group agreed to confirm to EUMETSAT the appreciation of their effort and encourage similar effort by other centres supporting collection and regional dissemination. This resulted in Action IIFS-9.

Action IIFS-9 on Stephen English
To thank EUMETSAT for their efforts regarding Russian data and to confirm ITWG's on-going requirement for observations with good timeliness.

IIFS recognises the outstanding progress in delivering MW sounder data quickly via DBNet. There is a requirement for hyperspectral IR data to be made available with equally good timeliness. In some cases it appears local network bandwidth to remote DBNet stations is the limiting factor. The group recognised WMO's effort to facilitate improvements and support continued effort in this area, resulting in Recommendation IIFS-4 and Action IIFS-10.

Recommendation IIFS-4 to WMO
To continue to work with Permanent Representatives (PRs) in countries with DBNet ground stations to encourage provision of sufficient bandwidth to redistribute the hyperspectral IR sounder observations in addition to the MW sounder observations.

Action IIFS-10 on Heikki Pohjola
To raise Recommendation IIFS-4 with the WMO.

IIFS note that the benefits of timely observations in NWP has increased, thanks to improved DA methods (e.g., continuous DA) and convective scale NWP whose requirements are close to nowcasting requirements. Therefore, the value of initiatives such as DBNet and provision of timely global data has increased the value of satellite programmes. The group welcomes continued innovation to enable more timely provision of observations, and welcomes WMO's leadership in this area, resulting in Recommendation IIFS-5 and Action IIFS-11.

Recommendation IIFS-5 to WMO
To note increasing importance of timely observations and, with CGMS and Space Agencies, to continue to explore innovative methods, such as used by GPM, to provide global data with excellent timeliness for next generation satellite programmes.

Action IIFS-11 on Heikki Pohjola
To raise Recommendation IIFS-5 at WMO Space Secretariat.

IIFS recognises that it is often difficult to use core ground segment processing software to support DBNet. However, if planned from day-1, software could be developed flexibly to support both applications. Therefore the group made Recommendation IIFS-6 for Space

Agencies and associated Action IIFS-12 to consider DBNet application of software in the early planning of the core ground segment software development.

Recommendation IIFS-6 to CGMS

Space Agencies to consider DBNet requirements when designing core ground segment software, and then to make software available to DBNet operators.

Action IIFS-12 on Peng Zhang

To ensure Recommendation IIFS-6 is communicated to Space Agencies via CGMS.

2.5.6 New generation small satellites

IIFS noted that in future there may be new opportunities arising from small satellites. By small satellites we mean platforms range from a 3U Cubesat through to moderate sized multiple instrument platforms, but still far smaller than the big platforms like FY3, JPSS and Metop. This creates new opportunities, but these opportunities will not be realised without also addressing some issues specific to smaller platforms. In particular, it needs a strong engagement from the user community.

At ITSC-21 the IIFS made this recommendation*: Recommendation IIFS-4 to multiple agencies: Evaluation of TROPICS mission to be undertaken by appropriate agencies in partnership with TROPICS mission (e.g. NWP centres)*. This recommendation is still valid however there remain concerns over the availability of NRT TROPICS data, in common with many Cubesat programmes. Therefore although the group remains committed to evaluation of TROPICS if NRT data is made available, it is important data providers understand that without a commitment to NRT data, it is difficult for operational centres to justify evaluating the data. Many mission programmes have a stated goal of improving operational services such as NWP. This requires engagement from the NWP centres to evaluate the new observations. To gain the engagement of these centres there is a choice between committing to NRT data provision or funding the evaluation. Specifically for TROPICS this resulted in Action IIFS-13, though the point applies to all missions.

Action IIFS-13 on Philippe Chambon and Niels Bormann

To inform TROPICS team of continued ITWG interest in TROPICS but stressing that to ensure engagement from the ITWG community delivery of a large proportion of TROPICS data in NRT is necessary.

The IIFS noted that TEMPEST-D Cubesat data has already been evaluated at some centres. It would be ideal to share experience with Cubesats, and to explore quality and timeliness issues. This could be a topic for IIFS at ITSC-23 and hence Recommendation IIFS-7 and Action IIFS-14 were made.

Recommendation IIFS-7 to ITWG Co-Chairs

To actively invite contributions from users and providers on experiences with Cubesats and small satellites to ITSC-23.

Action IIFS-14 on IIFS Co-Chairs

To assist ITWG Co-Chairs with Recommendation IIFS-7.

As noted earlier TROPICS and other Cubesat missions have difficulties in meeting NRT requirements due to budget constraints, which may lead to non-engagement from operational

centres, which for many such missions is an important element of their Cal/Val. It is in general more efficient to plan NRT provision at an early design stage. Therefore Recommendation IIFS-8 encourages agencies planning missions to consider NRT data provision and provide budget to ensure it.

Recommendation IIFS-8 to CGMS

If a mission needs engagement from application areas with a NRT data requirement, budget should be allocated to provide this.

Action IIFS-15 on ITWG Co-Chairs

To report Recommendation IIFS-8 to CGMS.

IIFS noted that issues for small satellites can fall into three areas: 1) General issues related to the small platform size; 2) Non-compliance with best practise; 3) constraints when operated by commercial entities. The question of non-compliance with best practise is the most easily addressed, by bringing to their attention documents describing best practise. However IIFS felt it would be good for IIFS members to review documents that exist on best practise, prior to engaging with new operators on these questions. Therefore, Action IIFS-16 will ensure this review, compare to practise by existing small satellite operators, and then agree on next steps.

Action IIFS-16 on Stephen English and Heikki Pojhola

To circulate Critical Satellite Data Paper and papers on CGMS and WMO best practise to IIFS members, who will provide feedback to what extent these are being adhered to by small satellite operators.

New commercial operators tend to favour small satellites, and in particular Cubesats, for obvious reasons. If observations from commercial satellites can't be licensed for free-exchange, then this will reduce their uptake. This is a complex issue, but IIFS consider that CGMS could consider a role to coordinate global access to observations from commercial satellite operators. The IIFS recognises that this is challenging. At this stage no recommendation or action is proposed.

Another important point related back to Section 2.5.4, as IIFS recognises that there is a bandwidth issue for command and control with very large constellations of Cubesats. This may in future bring them into conflict with EESS bands, including bands used for command and control of weather satellites. There is no recommendation or action at this time, but this is an issue IIFS members should keep watch over.

2.5.7 Traceable calibration for satellites and models

IIFS consider that a traceable calibration for core satellite observations would be of value to both climate and NWP application areas. Very well calibrated and stable core missions, including some devoted to in-flight inter-calibration of other missions to a reference mission, could help inter-calibrate the entire space component. The NWP requirement for this needs to be stressed as it is often assumed not to be an issue for NWP and to emphasise this point IIFS made Recommendation IIFS-9 and Action IIFS-17.

Recommendation IIFS-9 to CGMS

Space Agencies to note that the strong requirement for traceable calibration comes from NWP as well as the climate application area.

Action IIFS-17 on ITWG Co-Chairs
To ensure Recommendation IIFS-9 is communicated to CGMS.

Several Space Agencies are considering missions to perform reference quality calibration in flight. At ITSC-21 the following recommendation was made: *IIFS21-R8 Recommendation to CGMS: Recognizing the growing need for assessment and on-orbit optimization of the accuracy of operational hyperspectral IR sounders, the traditional approaches for pre-flight SI traceability and post-flight validation should be enhanced by flying a CLARREO-like on-orbit reference standard capability (featuring on-orbit SI verification) with orbits designed to provide inter-calibration capability for refining the calibration of the international fleet of operational sounders.* This recommendation remains valid and needs to be recommunicated until there is a firm commitment to such a mission. Therefore IIFS agreed on Action IIFS-18, to ensure this existing Recommendation is communicated again.

Action IIFS-18 on ITWG Co-Chairs
To ensure Recommendation IIFS21-8 is again communicated to CGMS.

IIFS strongly supports the GSICS effort and was grateful for the thorough presentations given on GSICS in the GSICS Workshop at ITSC-22. Peng Zhang will ensure through Action IIFS-19 that this message is passed on to other members of GSICS.

Action IIFS-19 on Peng Zhang
To report to GSICS the appreciation of the IIFS WG for the GSICS effort and the presentations at ITSC-22.

2.5.8 WMO

The IIFS noted the availability of an updated High Level Priority Plan (HLPP). IIFS members agreed to review and provide comments within one month of receiving the HLPP (Action IIFS-20).

Action IIFS22-20 on Stephen English
To circulate HLPP to IIFS members, then pass all comments received within one month to CGMS via Mitch Goldberg.

IIFS noted again the remarkable success of OSCAR/Space, which is an indispensable tool for all working in satellite meteorology. However IIFS noted anecdotal evidence that uptake of SATURN has been very slow by comparison. At a show of hands nobody at ITSC-22 said they had used SATURN as part of their preparation for new missions. This is disappointing given how long SATURN has now been available. The reasons need to be understood. IIFS members reported that they have no difficulty finding the information they need directly on Space Agency web pages. Therefore a question arises if SATURN is needed. IIFS agreed that before deciding it is not, renewed effort is needed to publicise SATURN, ensure the consistency of information available, and proactively seek feedback, perhaps through a survey. This resulted in Recommendation IIFS-10 and Action IIFS-21.

Recommendation IIFS-10 to WMO
Link SATURN pages from relevant OSCAR pages to encourage uptake of SATURN as OSCAR is an indispensable tool and is therefore widely used. If uptake remains low, carry out a survey to establish if there is a requirement for SATURN, and if so

what is preventing uptake. If there is no requirement for SATURN, to discontinue and concentrate resources on OSCAR.

Action IIFS-21 on Heikki Pohjola

To bring Recommendation IIFS-10 to attention of WMO Space Secretariat.

IIFS noted that on several occasions observations from new satellite launches have been accessible to a small number of users (sometimes only one) during a long evaluation phase, while other users have had no access until a very long period after launch. There are diverse reasons for this, it is often not because the originating Space Agency was slow to release data, it can be other issues in the dissemination chain. IIFS noted that the benefits of missions are maximised when early evaluation is undertaken by many centres. Therefore both users and the originating Agency would benefit if the blocks to making data available quickly to multiple centres for initial evaluation could be identified and removed. This resulted in Recommendation IIFS-11 and Action IIFS-22.

Recommendation IIFS-11 to space agencies (and agencies involved in re-transmission of satellite data) via CGMS

Space agencies to note that the benefits of satellite missions to the ITWG community are increased when early evaluation is undertaken by many independent centres. Facilitating early access to new data is therefore highly recommended.

Action IIFS-22 on ITWG Co-Chairs

To ensure Recommendation IIFS-11 is brought to the attention of CGMS.

2.5.9 Orbital configurations

At ITSC-21 the following Recommendation was made: *IIFS21-R3 Recommendation to CGMS: To show orbital coverage and other details when orbital configuration and formation flying is under discussion for new research missions, that may benefit from synergy flying with existing operational missions.* The IIFS suggests that provision of data coverage plots for individual instruments from future satellites, especially when options are being compared, would lead to easier and better decisions on best future configuration. Therefore IIFS would like to actively seek feedback from Space Agencies via CGMS on Recommendation IIFS21-3 (Action IIFS-23).

Action IIFS-23 on Stephen English and Peng Zhang

To ask for feedback from CGMS on CGMS response to this recommendation (link to Recommendation IIFS21-3).

The plans from CMA and Roshydromet/Roscosmos to put satellites in planes well spaced from other operators remains very welcome. Most centres in the ITWG community have confirmed they will be able to commit to a fast evaluation of observations in new orbital planes if/when requested to ensure continuity in these orbital planes if results are encouraging: This is most likely to apply in the near future to FY-3E E-AM by CMA and WMO and Meteor-M N2 (mid pm) by Roshydromet and WMO. The populating of multiple orbital planes with different ECTs provided by different agencies is extremely valuable. No action or recommendation was associated with these two important statements.

2.5.10 Relationship of ITWG to other CGMS science working groups and IRC

ITWG has tended to operate in isolation from other CGMS sub-groups, with little or no communication. This has led to missed opportunities (e.g. Roshydromet letter, see Section 2.5.5). IIFS consider that this could be improved, resulting in Recommendations IIFS-12 and 13 and Action IIFS-24.

Recommendation IIFS-12 to ITWG Co-Chairs

ITWG co-chairs to share actions and recommendations from ITWG with co-chairs of other groups, and to consider the actions and recommendations from all groups prior to CGMS and identify actions and recommendations that are common to more than one group. These could be presented to CGMS as joint recommendations, given them stronger visibility.

Recommendation IIFS-13 to ITWG Co-Chairs

To continue to pursue very actively the IRC/IAMAS relationship, to gain more support for ITWG initiatives regarding Radiative Transfer.

Action IIFS-24 on IIFS Co-Chairs

To assist ITWG Co-Chairs with Recommendations IIFS-12 and IIFS-13.

2.5.11 Distributed software and data product development

The IIFS recognises the remarkable achievement of the EUMETSAT SAFs, in particular 20 years of the NWP and Climate SAFs. EUMETSAT is warmly congratulated on the success of the SAF innovation. IIFS considers that EUMETSAT's SAFs provide an excellent model for other agencies to emulate. This resulted in Recommendation IIFS-14 and Action IIFS-25.

Recommendation IIFS-14 to space agencies

To consider if the SAF concept would be beneficial for them, as it has been for EUMETSAT.

Action IIFS-25 on ITWG Co-Chairs

To ensure Recommendation IIFS-14 brought to attention of CGMS and to pass on ITWG congratulations on 20 years of the NWP and Climate SAFs to EUMETSAT.

2.6 PRODUCTS AND SOFTWARE

Web site: http://cimss.ssec.wisc.edu/itwg/pswg

Working group members: Graeme Martin (Co-Chair, SSEC/UW), Nigel Atkinson (Co-Chair, Met Office), Martin Burgdorf (Univ Hamburg), Dorothee Coppens (EUMETSAT), Geoff Cureton (SSEC/UW), David Howard (BoM), Norio Kamekawa (JMA), Hee-Jung Kang (KMA), Scott Mindock (SSEC/UW), Masami Moriya (JMA), Hyunjong Oh (KMA), Pascale Roquet (Meteo-France), Nathalie Selbach (DWD), AK Sharma (NOAA), Kathy Strabala (SSEC/UW), Lihang Zhou (NOAA)

2.6.1 Introduction

The scope of the working group covers:

- Both Level 1 and Level 2 satellite products;
- Software tools and packages for generating, analyzing, and visualizing products;
- Enabling end users to obtain or generate the products they need;
- End user feedback and training;
- Exchange of information for validation of products;
- Informing the user community about requirements for future missions; and
- Informing agencies about requirements of the users.

2.6.2 Review of open actions and recommendations from ITSC-21

- **Action PSWG21-2**: KMA and SSEC to come up with a plan to make the GK-2A software available to DB users.
  Hyunjong Oh reported that L2 software (source code) is still at the validation stage. It could be provided to SSEC to wrap up into CSPP. The software relies on level 1B input data; these data can be obtained by ftp on application to KMA (1 party per country). Alternatively, to receive UHRIT the user would need to purchase an antenna system with the L1 software. This is commercial software (Soletop). There may be a licensing fee. An encryption key is needed. Specification and other information is available on the NMSC/KMA web site. Interested users of GK-2A data access and GK-2A L2 algorithm should contact Hyunjong Oh and Hee-Jung Kang respectively.
  The action remains open.

- **Action PSWG21-3**: NCEP to clarify requirements on VIIRS cloud products within the CrIS FOV, and to discuss with the AAPP and CSPP teams the possible implementation in DBNet.
  The discussions have taken place and provision has been made for VIIRS cloud and cluster products in AAPP.
  Therefore, the action is closed. However, NOAA have not yet been able to implement the VIIRS clustering in their products. To facilitate this a new action is proposed:

  Action PSWG-1 on Nigel Atkinson
  To provide Lihang Zhou with information on the VIIRS to CrIS clustering in AAPP.

- **Action PSWG21-4**: Nigel Atkinson to look at the CrIS PC product and compare the implementation with that used for IASI.

The CrIS PCA product is not currently being produced. However, the NUCAPS team has been asked to resume the product generation. It will be available on PDA and CLASS.
The action remains open.

- **Recommendation PSWG21-3 to DB data users**: Any DB data users interested in the provision of software to generate their own wind products should contact the CSPP team to register their interest.
  There is significant interest in generating winds from GOES satellites, and this is planned in CSPP-GEO. However, note that substantial processing resources would be needed. One user (NWS) would like to do the same from Himawari – the feasibility of this is TBD.
  Close the recommendation, as actions are in hand.

- **Recommendation PSWG21-8 to NOAA and the CSPP team**: Support the creation of VIIRS products for nowcasting, similar to the existing MODIS products.
  IMAPP had some nowcasting products but with the end of NASA funding for IMAPP these are no longer supported. There was no strong interest from the group members, but there may be interest from the wider ITWG.

- **Recommendation PSWG21-12 to data users**: Users should note that L2 profile datasets for validation are available from the NPROVS team, and are encouraged to use them.
  This recommendation is still valid. Any users interested in comparing L2 products should contact the NPROVS team.

- **Recommendation PSWG21-18 to researchers involved in L2 studies**: Continue to publish the results of L2 comparisons, particularly those that involve NPROVS, and report to future ITSC meetings.
  Kathy Strabala noted that comparisons of operational products with CSPP products are routinely performed before releasing software. They are different implementations, so expect some differences.

- **Recommendation PSWG21-9 to NOAA**: Where possible, provide historical LUTs that are compatible with the latest version of the CSPP SDR processing software.
  This is an issue that arose in GSICS re-processing work. Most DB users are not involved in re-processing, but some are. Also, there is sometimes a need to re-process L0 data from CLASS. The problem is that LUT formats have changed with time and are not compatible with a single version of the L1 software. However, it is thought that a solution could be found:

  Action PSWG-2 on SSEC (Scott Mindock)
  To work with NOAA to obtain and make available LUTs for VIIRS, ATMS, CrIS.

- **Recommendation PSWG21-10 to NOAA:** Consider improving the CLASS interface to allow scripted retrieval of historic data.
  Nathalie Selbach reported that DWD (within the CM SAF project) have succeeded in doing scripted retrievals from CLASS, for specific cases. But it's not clear that CLASS would support making this method widely available.

Action PSWG-3 on Lihang Zhou
To discuss with the CLASS team whether a scripted retrieval from CLASS can be supported to allow easier access to larger/historic data amounts

NOAA has a 90-day rolling archive of the most recent data available, which does not require retrieval of data from the CLASS archive

Action PSWG-4 on Lihang Zhou
To circulate a link to the NOAA 90-day rolling archive.

- Recommendation PSWG21-11 to CMA: Consider implementing a subscription-based anomaly/event notification service, similar to that provided by NOAA and EUMETSAT.
  It was felt that this recommendation should be widened as it does not only apply to CMA:
  Recommendation PSWG-1 to agencies
  To implement subscription-based notification of anomalies or events that impact users.

Several of the other actions (notably those related to (i) RFI and (ii) provision of source code) are still relevant but it was not felt necessary to explicitly repeat them.

2.6.3 New topics for ITSC-22

Software packages

Maintaining support for old operating systems was discussed. It was noted that CentOS6 will reach end of life in Nov 2020. A package built under CentOS6 will run under CentOS7, but not the other way round. Some organisations will want to upgrade OS sooner than others. CSPP Leo is planning to transition to CentOS7 builds in Jan 2020; Geo in Nov 2020. CSPP prefers to avoid providing multiple versions.

Recommendation PSWG-2 to software providers
To give advance notice of plans for moving to new operating systems. One year is considered reasonable notice.

Users can expect to receive the CSPP SDR 3.2 release in December 2019, which will include polarisation correction for CrIS as well as ATMS updates.

AAPP v8.5 will be released in November 2019. It will consolidate various calibration updates, bug fixes and new ecCodes utilities.

There was interest within the group for use of "containers" such as Singularity or Docker, to reduce problems with external dependencies. Nigel Atkinson reported that some notes from Liam Gumley on Singularity have been recorded in an AAPP "Frequently Asked Questions" page https://www.nwpsaf.eu/site/software/aapp/documentation/aapp-faqs/.

Recommendation PSWG-3 to software providers
We encourage software providers to explore the use of containers for packaging their software.

The group was asked how often is it reasonable to update the various software packages … frequent small updates or infrequent larger ones. In general, having fewer updates is preferred, though it is recognised that sometimes emergency fixes are needed (e.g. if the status of an instrument changes).

Recommendation PSWG-4 to software providers

To avoid frequent package updates. As a guide, not more than twice per year is recommended, excluding patches.

New sensors (recently launched and upcoming satellites)

KMA: A LEO mission is under consideration, starting its development in 2022, if approved. To include an ATMS-like sounder and/or a CrIS-like sounder. Early morning orbit. To include direct broadcast (and accompanying L1 software).

JMA: The GOSAT-2 FO mission, with AMSR-3, was mentioned.

NOAA: Support for Metop-C is already provided, with the exception of their IASI BUFR product which is delayed to 2020 (due to software freeze and migration to new platform). NOAA are planning a demonstration of doing the product generation via the Cloud, for both LEO and GEO. Distribution would still be via PDA.

Both EUMETSAT and SSEC are also looking at making use of cloud processing for certain tasks. EUMETSAT confirmed that their archiving would remain at EUMETSAT.

Although Cloud processing has its attractions, concern was expressed that this could lead to an organisation losing technical expertise, and that product distribution via the cloud may result in high costs for users for data processing and egress.

EUMETSAT reported that IASI L1 and L2 from Metop-C are disseminated via EUMETCast. GIIRS is also disseminated (EUMETCast Terrestrial). The Hybrid approach for IRS PCs was mentioned. Sample data are being provided and User Preparation workshops are about to be held. For test data, the main interest for PSWG is that the format is correct. Also, test datasets of Eigenvectors are needed for MTG-IRS.

Recommendation PSWG-5 to EUMETSAT

To provide a schedule for release of different types of test data for both EPS-SG and MTG.

Processing of EPS-SG direct readout was discussed. Hardware requirements are an important issue: some organisations struggle with resources and connectivity. At present the design of the DB software for EPS-SG is not yet decided, i.e., whether it will be based on the global processor (which is not optimal for the short passes that a DB user typically receives) or on prototype software. Users may need 100 cores, though this may not be so much of a problem in 4 years time as it appears now.

Recommendation PSWG-6 to Agencies

When designing software, keep DB users in mind from the outset in order to minimise costs at the user end.

EUMETSAT are putting a lot of effort into preparations for EPS-SG and MTG. Can any of that effort be used to benefit other missions? Thinking, for example, of data format. On the US side it is probably too early to answer that question.

DBNet

At past ITSCs, the possibility of obtaining DB software for ASCAT L1 processing has been raised. Our understanding is that the software is complex and would not be well-suited to DB processing from a single station because the amount of calibrated data available from a single pass would be small. However, there is still interest in this possibility for remote regions, e.g., Alaska. Dorothée Coppens reported that Stephanie Linow is now in charge of ASCAT at EUMETSAT.

Action PSWG-5 on PSWG co-chairs

To ask EUMETSAT for an update on the feasibility of providing ASCAT processing software to DB users.

Studies on the impact of DBNet are of interest to the PSWG group, but the initiative would probably have to come from the NWP group.

Transition of SNPP CrIS from NSR to FSR in DBNet data: A transition in April 2020 was proposed, which is believed to correspond to the time of withdrawal of NOAA's NSR product. Note that there have been various changes recently in CSPP to reduce the run-time when generating this product, including multiple cores running a string of granules.

Miscellaneous

It was noted that it could also be possible to reduce context requirements for CrIS, by making use of CrIS level 1B NASA software. This is an alternative implementation, involving different averaging of the calibration views.

Recommendation PSWG-7 to CSPP team

To look into reducing the latency and improving the coverage of CrIS products.

In a wider discussion of timeliness, GMI was cited as an excellent example of timely data provision (see plots on the NWP SAF web site at https://www.nwpsaf.eu/site/monitoring/nrt-availability/data-timeliness/). It is believed that a satellite re-broadcast facility is used.

SSEC/UW currently runs AMSR-2 level 1 code. This code is not available to ordinary users from JAXA, but some users would like it (e.g., Alaska NWS).

Recommendation PSWG-8 to JAXA

To consider providing AMSR-2 L1 software for release to the DB community. The CSPP team could host it.

Note that GCOM-W direct broadcast is only active over limited regions of the world, due to the transmitter being shared with the global downlink.

Related to the question of whether an imager is necessary for generation of sounder products, the group had the following recommendation:

Recommendation PSWG-9 to Agencies

Where a sounder and imager are on the same platform, a means should be provided to map the imager data to the sounder fields of view, so that the users have ready access to this information.

RFI on data reception was discussed.

Recommendation PSWG-10

The frequencies used in DB reception (L band and X band) should be preserved, to ensure continued fidelity of downlink reception.

Finally the PSWG web site was discussed. The CIMSS web site is planned to be migrated to Wordpress in the next year. It was agreed that this would form the basis for a new version of the web site, giving co-chairs (and perhaps other members) the ability to edit web pages. Old links (from the days before PSWG) should be made less visible.

Action PSWG-6 on PSWG co-chairs

To update the group web page by next ITSC, assuming Wordpress is implemented by CIMSS as planned.

LIST OF ACRONYMS

AAPP: Advanced ATOVS Processing Package
AIRS: Atmospheric InfraRed Sounder
AMSR: Advanced Microwave Scanning Radiometer
AMSU: Advance Microwave Sounding Unit
ARM: Atmospheric Radiation Measurement
ATMS: Advanced Technology Microwave Sounder
ATOVS: Advanced TIROS Operational Vertical Sounders
AVHRR: Advanced Very High Resolution Radiometer
BUFR: Binary Universal Form for the Representation of meteorological data
CDR: Climate Data Record
CGMS: Coordination Group for Meteorological Satellites
CIMSS: Cooperative Institute for Meteorological Satellite Studies
CLARREO: Climate Absolute Radiance and Refractivity Observatory
CLASS: Comprehensive Large Array-data Stewardship System
CMA: China Meteorological Administration
CNES: Centre National d'Etudes Spatiales
CrIS: Cross-track Infrared Sounder
CRTM: Community Radiative Transfer Model
CSPP: Community Satellite Processing Package
DB: Direct Broadcast
DMSP: Defense Meteorological Satellites Program
DWD: Deutscher Wetterdienst (German Weather Service)
ECMWF: European Center for Medium Range Weather
ECV: Essential Climate Variables
EPS: EUMETSAT Polar Satellite
ESA: European Space Agency
EUMETSAT: European Organization for the exploitation of meteorological satellites
FCDR: Fundamental Climate Data Record
FOV: Field of View
FY-3: LEO satellite from China
GAIA-CLIM: Gap Analysis for Integrated Atmospheric ECV CLImate Monitoring
GCOM-W/GCOM-W2: Global Change Observation Missions
GCOS: Global Climate Observing System
GIIRS: Geostationary Interferometric Infrared Sounder
GMI: Global Precipitation Measurement (GPM) Microwave Imager
GOES: Geostationary Operational Environmental Satellite
GPM: Global Precipitation Measurement
GRUAN: GCOS Reference Upper Air Network
GSICS: Global Space-Based Inter-Calibration System
GTS: Global Telecommunications System
HIRAS: Hyperspectral Infrared Atmospheric Sounder
HIRS: High-Resolution Infrared Radiation Sounder
HLPP: High Level Priority Plan
IAMAP: International Association of Meteorology and Atmospheric Physics
IASI: Infrared Atmospheric Sounding Interferometer
IASI-NG: IASI- Next Generation
ICI: Ice Cloud Imager
ICWG: International Cloud Working Group

IPWG: International Precipitation Working Group
IR: Infrared
IRC: International Radiation Commission
ITSC: International TOVS Study Conference
ITWG: International TOVS Working Group
IWWG: International Winds Working Group
JAXA: Japan Aerospace Exploration Agency
JPSS: Joint Polar Satellite System
LBL: Line By Line
LEO: Low Earth Orbit
LTE: Local Thermodynamic Equilibrium
LUT: Lookup Table
MetOp: Meteorological Operational
MHS: Microwave Humidity Sounder
MODIS: Moderate-resolution Imaging Spectroradiometer
MTG-IRS: Meteosat Third Generation - Infrared Radiometric Sounder
MTVZA: Russian Imaging/Sounding Microwave Radiometer
MW: Microwave
MWHS: Microwave Humidity Sounder
NASA: National Aeronautics and Space Administration
NEdT: Noise Equivalent Delta Temperature
NESDIS: National Environmental Satellites, Data, and Information Service
NOAA: National Oceanic and Atmospheric Administration
NPROVS: NOAA PROducts Validation System
NRL: Naval Research Laboratory
NWP: Numerical Weather Prediction
OPS: Operations
OPS-LRS: Operational Software – Local Reception Station
OSCAR: Observing Systems Capability Analysis and Review
PC: Principal Component
PSWG: Products and Software Working Group
RFI: Radio Frequency Interference
RT: Radiative Transfer
RTM: Radiative Transfer Model
RTTOV: Radiative Transfer for TOVS
SAF: Satellite Application Facility
SATURN: Satellite User Readiness Navigator
SDR: Sensor Data Record
SNO: Simultaneous Nadir Overpass
SRF: Spectral Response Function
SSEC: Space Science and Engineering Center
SSMIS: Special Sensor Microwave Imager/Sounder
SSU: Stratospheric Sounding Unit
STAR: Center for Satellite Applications and Research
TOVS: TIROS Operational Vertical Sounder
TROPICS: Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats
VIIRS: Visible/Infrared Imager Radiometer Suite
WG: Working Group
WMO: World Meteorological Organization

ITSC-XXII AGENDA

Thursday, 31 October 2019

8:30 – 9:00	Welcome	Liam Gumley and Vincent Guidard (ITWG Co-Chairs)
	Welcome by ECCC	**Louis Garand**
	Local arrangements	**Louis Garand, Liam Gumley**
	Review of agenda	**Liam Gumley and Vincent Guidard (ITWG Co-Chairs)**

9:00 – 10:00 Session 1: Direct readout (oral presentations - 12 minutes) **Chair-persons: Pascale Roquet, David Tobin**		
1.01	Nigel Atkinson *Met Office*	20 years of the NWP SAF
1.02	Pascal Brunel (for Mikael Rattenborg) *Meteo France*	Status of the Direct Broadcast Network for globally coordinated real-time acquisition, processing and fast delivery of satellite direct readout data, an initiative of the World Meteorological Organisation
1.03	Liam Gumley *UW-Madison/SSEC/CIMSS*	The DBNet Cloud Service for providing low-latency sounder data to NWP centers
1.04	Kathleen Strabala *UW-Madison/SSEC/CIMSS*	The Utility of CSPP Atmospheric Sounding Products

10:00 – 10:15 Session 1: Direct readout (poster introductions - 1 minute: no visual aids) **Chair-persons: Pascale Roquet, David Tobin**		
1p.01	Hyunjong Oh (for Dahye Bae) *KMA*	Current status and plans of Direct-readout LEO satellite data processing in NMSC/KMA
1p.02	Liam Gumley *UW-Madison/SSEC/CIMSS*	CSPP LEO for JPSS, Metop, NOAA, and FY-3 satellites: New features and enhancements
1p.03	David Howard *Bureau of Meteorology*	Generation of direct readout sounding data products at the Bureau of Meteorology
1p.04	Masami Moriya *Japan Meteorological Agency*	Current Status and Future Plan on direct readout activity in MSC/JMA
1p.05	Mathieu Asseray *CNRM/CEMS*	IASI cloud mask comparison between global broadcast and local processing
1p.06	Pascale Roquet *Météo-France*	Porting the OPS AVHRR clusters algorithm to VIIRS in CrIS footprint
1p.07	Scott Mindock *UW-Madison/SSEC/CIMSS*	CSPP SDR and CSPP VIIRS ASCI Level 1 and 2 products for your Direct Broadcast System
1p.08	Kathleen Strabala (for David Hoese) *UW-Madison/SSEC/CIMSS*	Polar2Grid and Geo2Grid: Open Source Software for Creating High Quality Images

1p.09	Graeme Martin *UW-Madison/SSEC/CIMSS*	Community Satellite Processing Package for Geostationary Data (CSPP Geo) Level 2 Products and Image Generation for Direct Broadcast

10:15 – 10:45 Health Break

10:45 – 12:15 Session 1: Radiative Transfer and Community Software (oral presentations - 12 minutes) **Chair-persons: Kathleen Strabala and Nigel Atkinson**		
1.05	Benjamin Johnson *UCAR/JCSDA*	Recent Advances in the Community Radiative Transfer Model
1.06	James Hocking *Met Office*	RTTOV development status
1.07	Lise Kilic *Paris Observatory*	Comparisons of ocean radiative transfer models with satellite observations from 1.4 to 89 GHz
1.08	Ming Chen *CICS-ESSIC, University of Maryland*	Advances of the Community Surface Emissivity Models (CSEM) in Support of NWP Data Assimilation
1.09	Raymond Armante *LMD/CNRS*	How it could be possible to evaluate the spectroscopic parameters: the example of the new release of GEISA-2019
1.10	Zhenglong Li *UW-Madison/SSEC/CIMSS*	An alternative method to quantify NLTE radiances

12:15 – 12:30 Session 1d: Radiative Transfer and Community Software (poster introductions - 1 minute: no visual aids) **Chair-persons: Kathleen Strabala and Nigel Atkinson**		
1p.10	Xavier Calbet *AEMET*	Effects of Field of View Inhomegeneities in Radiative Transfer
1p.11	Nicholas Nalli *IMSG Inc. at NOAA/NESDIS/STAR*	CRTM Infrared Sea Surface Effective-Emissivity (IRSSE) Model Upgrade Status
1p.12	Cristina Lupu *ECMWF*	Evaluation of the RTTOV in the ECMWF NWP system
1p.13	Pascal Brunel (for Jérôme Vidot) *Météo-France*	RTTOV for hyperspectral far infrared (FIR) instruments : the FORUM example
1p.14	Philippe Chambon *Météo-France*	Development of an active sensor module for the RTTOV-SCATT radiative transfer simulator
1p.15	Benjamin Johnson (for Patrick Stegmann) *UCAR/JCSDA*	Progress towards a Polarized CRTM
1p.16	Raymond Armante *LMD/CNRS*	The 4A/OP model from NIR to TIR: new developments and validation results within the frame of international space missions

1p.17	Raymond Armante *LMD/CNRS*	Status of the new GEISA-2019 spectroscopic database
1p.18	Hu (Tiger) Yang *University of Maryland*	Comparison of Two Data Resampling Algorithms for Processing of Microwave Sounding Observations
1p.19	Eric Simon *UCAR/NRL-Monterey*	Automated Identification of Anomalous SSMIS Brightness Temperatures Using a Neural Network

12:30 – 13:30 Lunch

13:30 – 14:00 Poster viewing (Sessions 1, 2, 3)

14:00 – 15:20 Session 2: Calibration, validation (oral presentations - 12 minutes) **Chair-persons: Dorothée Coppens, Raymond Armante**		
2.01	Laura L Barbier *CNES*	IASI on-board METOP-C : instrument status L1 calibration/validation results
2.02	Dorothée Coppens (for Stéphanie Guedj) *EUMETSAT*	EUMETSAT activities for IASI-C commissioning
2.03	David Tobin *UW-Madison/SSEC/CIMSS*	Studies of the CrIS Noise and Calibration Covariances
2.04	Chengli Qi (for Chunqiang Wu) *NSMC/CMA*	FY-3D HIRAS Radiometric Calibration and Accuracy Assessment
2.05	Martin J. Burgdorf *Universität Hamburg*	Checking Beam Performance of HIRS and MHS With the Moon

15:20 – 15:30 Session 3b: Calibration, validation (poster introductions - 1 minute: no visual aids) **Chair-persons: Dorothée Coppens, Raymond Armante**		
2p.01	Chengli Qi *NSMC/CMA*	HIRAS on-orbit performance and future development
2p.02	Jordi Chinaud *CNES*	Radiometric and spectral intercomparison of IASI-C with other infrared sounders
2p.03	Yong Chen *GST, Inc., NOAA/STAR*	Latest Improvements for CrIS Sensor Data Records
2p.04	Joe K. Taylor *UW-Madison/SSEC*	Implementation of a Polarization Correction for the Cross-track Infrared Sounder (CrIS) Sensor
2p.05	Junye Chen *GST*	Progress of the Metop-C AMSU-A Lunar Contamination Correction Algorithm at NOAA/STAR
2p.06	Gu Songyan *NSMC/CMA*	The common re-calibration technology for long-term FY-3 microwave sounding data
2p.07	Yong Chen (for Flavio Iturbide-Sanchez) *GST, Inc., NOAA/STAR*	Status of S-NPP/CrIS SDR Product After the Loss of the MWIR Band

15:30 Group photo

15:45 – 16:15 Health break

16:15 – 16:45 Session 4a: Calibration, validation (oral presentations - 12 minutes) **Chair-persons: Nathalie Selbach, Andrew Collard**		
2.06	Chris Burrows *ECMWF*	An assessment of data from the GIIRS instrument
2.07	Peng Zhang *NSMC/CMA*	Retrospective Calibration of Historical Chinese Fengyun Satellite Data

16:45 – 16:50 Session 2: Calibration, validation (poster introductions - 1 minute: no visual aids) **Chair-persons: Nathalie Selbach, Andrew Collard**		
2p.08	Lihang Zhou *NOAA/NESDIS/STAR*	NOAA-20 Calibration/Validation and algorithms improvements
2p.09	David Duncan *ECMWF*	Evaluation of using measured SRFs in the radiative transfer for microwave sounders at ECMWF, UK Met Office, and DWD
2p.10	Yong Chen (for Denis Tremblay) *GST, Inc., NOAA/STAR*	NOAA-20 CrIS Noise Assessment
2p.11	Withdrawn	
2p.12	Bomin Sun *IMSG at NOAA/STAR*	NOAA-JPSS dedicated radiosonde database in support of satellite data calibration/validation
2p.13	Ling Sun *NSMC/CMA*	Long-term assessment and recalibration of FY-1/3 VIRR and MERSI reflective solar bands

16:50 – 17:30 Session 3: NWP centre reports (poster introductions - 3 minutes: 1 slide) **Chair-persons: Nancy Baker, Mitch Goldberg**		
3p.01	Alain Beaulne *ECCC*	Recent updates to the ECCC Global and Regional Prediction Systems
3p.02	Christina Köpken-Watts *DWD*	Overview of radiance data assimilation developments at DWD since ITSC-21
3p.03	Andrew Collard *IMSG @ NOAA/NCEP/EMC*	Progress and plans for the use of radiance data in the NCEP global and regional data assimilation systems
3p.04	S. Indira Rani *NCMRWF*	NCMRWF MWP Status
3p.05	Niels Bormann ECMWF	Recent changes in the use of passive sounding data in the ECMWF NWP system
3p.06	Nadia Fourrié *CNRM Météo-France and CNRS*	Ongoing developments on satellite radiance assimilation at Météo-France

3p.07	Chawn Harlow *Met Office*	Recent upgrades in the use of satellite radiance observations within the Met Office global NWP system
3p.08	Fiona Smith *Bureau of Meteorology*	Satellite radiance assimilation at the Bureau of Meteorology
3p.09	Norio Kamekawa *Japan Meteorological Agency*	Recent upgrades of satellite radiance data assimilation at JMA
3p.10	Haixia Liu (for Xiaoyan Zhang) *IMSG @ NOAA/NCEP/EMC*	Overview of Satellite Radiance Data Assimilation in NCEP FV3 Regional System
3p.11	Eunhee Lee *KMA*	Progress and plans for satellite data assimilation in KMA operational NWP system

Friday, 1 November 2019

8:30 – 9:30 Session 4: Assimilation of geostionary infrared sensors (oral presentations - 12 minutes) **Chair-persons: Fiona Smith, Philippe Chambon**		
4.01	Haixia Liu *IMSG @ NOAA/NCEP/EMC*	Assimilation of Infrared Radiances from Geostationary Satellites at NCEP
4.02	Withdrawn	
4.03	Marc Pondrom *DWD*	Assimilation of geostationary water vapour clear sky radiances with an Ensemble Kalman Filter
4.04	Nancy Baker *NRL Marine Meteorology Division*	All-Sky Radiance Assimilation for COAMPS-TC Tropical Cyclone Track and Intensity Prediction

9:30 – 9:35 Session 4: Assimilation of geostionary infrared sensors (poster introductions - 1 minute: no visual aids) **Chair-persons: Fiona Smith, Philippe Chambon**		
4p.01	Nadia Fourrié *CNRM Météo-France and CNRS*	Towards the use of a bayesian approach for the assimilation of all-sky IASI radiances
4p.02	Nancy Baker *NRL Marine Meteorology Division*	All-Sky Radiance Assimilation for COAMPS-TC Tropical Cyclone Track and Intensity Prediction
4p.03	Ebony Lee *Ewha Womans University*	Assimilation of cloud-contaminated radiances in regional air quality model: a case study using GEMS synthetic radiance data

9:35 – 10:20 Session 4: All-sky assimilation of geostionary infrared sensors (oral presentations - 12 minutes) **Chair-persons: Fiona Smith, Philippe Chambon**		
4.05	Kozo Okamoto *JMA/MRI*	Evaluation and assimilation of all-sky infrared radiances of Himawari-8 in the regional and global data assimilation system
4.06	Jonathan Guerrette *NCAR, MMM*	Evaluating the impact of assimilating cloud-affected infrared radiances from GOES-16 ABI on the forecast of a severe storm in the Midwest U.S.
4.07	Zhiquan Liu *NCAR*	4D variational and ensemble/variational assimilation of every 10-min AHI clear-sky and all-sky radiances at convective-scale

10:20 – 10:50 Health break

Action Items from ITSC-21
Moderators: Liam Gumley and Vincent Guidard

10:50-11:05 CGMS and IRC reports

11:05-12:30 Working group action items from ITSC-21 (15 minutes)

- **NWP (Fiona Smith and Andrew Collard)**
- **Radiative transfer and surface properties (Marco Matricardi and Benjamin Johnson)**
- **Advanced Sounders (Dorothee Coppens and Dave Tobin)**
- **Products and Software (Nigel Atkinson and Graeme Martin)**
- **Climate (Nathalie Selbach and Cheng-Zhi Zou)**
- **International and Future Systems (Stephen English and Peng Zhang)**

12:30 – 13:30 Lunch

13:30 – 14:00 Poster viewing (Sessions 4, 5, 6)

14:00 – 15:00 Session 5: All-sky assimilation for microwave sensors (oral presentations - 12 minutes) **Chair-persons: Nadia Fourrié and Peng Zhang**		
5.01	Brett Candy *Met Office*	Towards all-sky MHS: Observation Preprocessing and NWP Suite Design
5.02	Philippe Chambon *Météo-France*	Assimilating cloudy and rainy microwave observations within the ARPEGE global model
5.03	Katrin Lonitz *ECMWF*	All-sky assimilation over land for surface sensitive microwave channels
5.04	Yanqiu Zhu *IMSG @ NOAA/NCEP/EMC*	Studies of all-sky radiance assimilation at NCEP

15:00 – 12:15 Session 5: All-sky assimilation for microwave sensors (poster introductions - 1 minute: no visual aids) **Chair-persons: Nadia Fourrié and Peng Zhang**		
5p.01	Stefano Migliorini *Met Office*	All-sky assimilation of moisture-sensitive radiances at the Met Office
5p.02	Niels Bormann (for Peter Weston) *ECMWF*	Assimilation of AMSU-A in the presence of cloud and precipitation
5p.03	Benjamin Johnson (for Emily Huichun Liu) *UCAR/JCSDA*	The use of precipitation-affected MW radiances in FV3-GFS Hybrid Data Assimilation System
5p.04	Katrin Lonitz *ECMWF*	Updates from the all-sky assimilation of microwave radiances at the ECMWF
5p.05	Zhipeng Xian *Institute of Atmospheric Physics, Chinese Academy of Sciences*	All-sky Assimilation of the MWHS-2 Observations and Evaluation the Impacts on the Forecasts of Typhoons
5p.06	Masahiro Kazumori *Japan Meteorological Agency*	All-sky microwave radiance assimilation in the JMA global NWP system
5p.07	Katrin Lonitz *ECMWF*	Assessing the impact of different liquid water permittivity models on the assimilation of microwave radiances
5p.08	Victoria Galligani *CIMS-CONICET*	Microphysical properties of ice particles as revealed by satellite microwave polarimetric measurements and radiative transfer modeling

15:15-15:45 Health break

15:45 – 16:15 Communication from sibling working groups (oral presentations - 12 minutes) **Chair-persons: Vincent Guidard, Liam Gumley**		
a.01	Philippe Chambon *Météo-France*	Research Highlights from the International Precipitation Working Group (IPWG)
a.02	Benjamin Ruston *NRL*	Assimilation of spectrally-adjacent pairs of IASI channels
a.03	Benjamin Johnson *UCAR/JCSDA*	Report on the International Cloud Working Group

16:15 – 17:00 Session 6: Climate (oral presentations - 12 minutes) **Chair-persons: Christina Köpken-Watts, Fabien Carminati**		
6.01	Cyril Crevoisier *LMD/CNRS*	Establishing times series of essential climate variables from 3 successive Metop/IASI
6.02	Cheng-Zhi Zou *NOAA College Park*	Toward Improved Climate Data Record Using Stable SNPP/ATMS Observations as References

6.03	Christoforos Tsamalis *Met Office Hadley Centre*	Validation of the 183 GHz C3S/EUMETSAT FCDR using ERA5 simulations, SNOs and operational datasets

17:00 – 17:15 Session 5: Climate (poster introductions - 1 minute: no visual aids) **Chair-persons: Christina Köpken-Watts, Fabien Carminati**		
6p.01	Cyril Crevoisier (for Virginie Capelle) *LMD/CNRS*	Stand alone night-time sea surface temperature retrieved by the IASI/Metop suite: Toward long time series
6p.02	Cyril Crevoisier (for Virginie Capelle) *LMD/CNRS*	A long time series of Metop/IASI observations of Saharan aerosols distribution using AOD-Altitude-Surface temperature triplets
6p.03	Daniel K. Zhou *NASA*	Surface skin temperature and its trend from recent 12-year IASI observations
6p.04	Bruna Barbosa Silveira (for Jérôme Vidot) *CNRM/Météo-France*	RTTOV for a C3S project on early satellite data rescue
6p.05	Nathalie Selbach *DWD*	Climate Data Records and user service of the EUMETSAT Satellite Application Facility on Climate Monitoring
6p.06	Nathalie Selbach (for Karsten Fennig) DWD	The EUMETSAT CM SAF Fundamental Climate Data Record of Microwave Imager Radiances
6p.07	Nathalie Selbach (for Hannes Konrad) DWD	Towards a climate data record of precipitation merging satellite observations by passive microwave sounders and imagers
6p.08	Nathalie Selbach (for Marc Schröder) DWD	The GEWEX water vapor assessment (G-VAP): final results from first phase and the future of G-VAP
6p.09	Mitch Goldberg *NOAA*	The Value of Two Satellites in the Same Orbit for Nowcasting and Climate Monitoring
6p.10	Dirceu L. Herdies *CPTEC/INPE*	The increase in the impact of the observations in a multi-year Reanalysis on the tropical region with emphasis on the Amazon basin
6p.11	Lei Shi *NCEI, NOAA*	Satellite-Derived Upper Tropospheric Humidity Datasets and Comparison with Total Column Water Vapor
6p.12	Viju John *EUMETSAT*	EUMETSAT's Contribution of Fundamental Climate Data Records (FCDR) to Copernicus Climate Change Service (C3S)

17:15 – 18:00 Session 6: Reanalysis (oral presentations - 12 minutes) **Chair-persons: Christina Köpken-Watts, Fabien Carminati**		
6.05	Bill Bell *ECMWF*	The Assimilation of Radiance Data in the ERA5 Global Reanalysis
6.06	S. Indira Rani *NCMRWF*	Satellite era retrospective analysis over the Indian region

6.07	Ricardo Todling *NASA GMAO*	Assessing the impact of observations in a multi-year Reanalysis

18.30-20.30 GSICS workshop

Saturday, 2 November 2019

8:30 – 12:30 Working group meetings (10:15 – 10:45 Health break)

- Advanced Sounders
- Climate
- Radiative transfer and surface properties

12:30-13:30 Lunch

13:30 – 17:00 Working group meetings (Break at 15:15 – 15:45)

- NWP
- Products and software
- International and Future Systems

17:00-18:00 Technical Sub-group Meeting

- RTTOV/CRTM

Sunday, 3 November 2019

Day Free

Monday, 4 November 2019

8:30 – 10:00 Session 7: Assimilation of new hyperspectral infrared instruments (oral presentations - 12 minutes) **Chair-persons: Keyi Chen, Chris Burrows**		
7.01	Ruoying Yin (for Wei Han) *IAP*	Assimilation of high temporal GIIRS radiance in GRAPES
7.02	Chris Barnet *Science and Tech. Corp.*	Information content of the CrIS instrument and recent data denial experiments relevant to operational use of sounder data
7.03	Fabien Carminati *Met Office*	Implementation and assessment of FY-3D Hyperspectral Infrared Atmospheric Sounder (HIRAS) in the Met Office system
7.04	Reima Eresmaa *ECMWF*	New IR sounders in the ECMWF NWP system
7.05	Dmitry Gayfulin *Hydrometeorological Centre of Russia*	Assessment and assimilation of observations of the hyperspectral IR sounder IKFS-2 on board the Russian Meteor-M N2 satellite
7.06	Ruoying Yin *IAP*	The evaluation of GIIRS longwave temperature sounding channels using 4DVar

10:00 – 10:15 Session 8b: Assimilation of new hyperspectral infrared instruments (poster introductions - 1 minute: no visual aids) **Chair-persons: Keyi Chen, Chris Burrows**		
7p.01	Kirsti Salonen *ECMWF*	Impact assessment of IASI temperature and humidity retrievals in the ECMWF system
7p.02	Sylvain Heilliette *ECCC*	Evaluation of the performance of CrIS instrument under various assimilation scenarios
7p.03	Silke May *DWD*	Operational use of inter-channel correlations for IASI in the DWD EnVar and investigation into the use of Reconstructed Radiances
7p.04	Reima Eresmaa *ECMWF*	Detection of aerosol- and trace-gas-affected IR radiances at ECMWF
7p.05	James Jung *UW-Madison/SSEC/CIMSS*	Quantifying the effects of the CrIS-FSR Radiance Polarization Corrections using the NCEP Global Data Assimilation System

10:15 – 10:45 Health break

10:45 – 11:15 Session 8: Space agency posters (poster introductions - 5 minutes: 2 slides) **Chair-persons: Vincent Guidard, Liam Gumley**		
8p.01	Kozo Okamoto *JMA/MRI*	Status report of space agency: JMA and JAXA
8p.02	Dieter Klaes *EUMETSAT*	The Current EUMETSAT Polar System
8p.03	Karen St. Germain (for Mitch Goldberg) *NOAA*	NOAA Agency Report
8p.04	Peng Zhang *NSMC/CMA*	CMA Report
8p.05	Dmitry Gayfulin *Hydrometeorological Centre of Russia*	Russian Meteorological Satellite Programs
8p.06	Chu-Yong Chung *KMA*	KMA Agency Report

11:15 – 12:30 Session 9: Advances in the assimilation of infrared sensors (oral presentations - 12 minutes) **Chair-persons: Nadia Smith, Brett Candy**		
9.01	Erin Jones *UMD CISESS*	Assimilation of Hyperspectral Infrared Shortwave CrIS Observations in the NOAA Global Data Assimilation System
9.02	Kirsti Salonen *ECMWF*	Enhancing the hyperspectral infrared radiance assimilation in the ECMWF system

9.03	Olivier Coopmann *CNRM, Université de Toulouse, Météo-France, CNRS*	4D-Var assimilation of IASI ozone-sensitive radiances in operational global model ARPEGE
9.04	Christina Köpken-Watts (for Liselotte Bach) *DWD*	Assimilating solar satellite channels in a convective-scale LETKF
9.05	Bryan M. Karpowicz *GESTAR/USRA/NASA GMAO*	Improvements to Ozone Analyses using Hyperspectral Sounders in the 9.6um Band

12:30 – 13:30 Lunch

13:30 – 14:00 Poster viewing (Sessions 7, 8, 10, 11, 12)

14:00 – 15:00 Session 10a: Retrievals (oral presentations - 12 minutes) **Chair-persons: Kirsti Salonen, Dieter Klaes**		
10.01	Thomas August *EUMETSAT*	Status of regional IASI L2 products at EUMETSAT and studies in view of MTG-IRS
10.02	Bjorn Lambrigtsen *Jet Propulsion Laboratory*	The New NASA Multi-mission Microwave Sounder Retrieval System
10.03	Nadia Smith *Science and Tech. Corp.*	Continuity in Sounding Products from Multiple Platforms – examples from examples from CLIMCAPS and NUCAPS
10.04	Yoann Tellier *CNRS, LMD*	Retrieval of the radiative flux and atmospheric vertical heating rate profiles in the thermal infrared with the IASI instruments onboard the Metop platforms

14:45 – 15:10 Session 10: Retrievals (poster introductions - 1 minute: no visual aids) **Chair-persons: Kirsti Salonen, Dieter Klaes**		
10p.01	Hee-Jung Kang *NMSC/KMA*	Atmospheric profile retrieval using rapid scan observation of Geo-KOMPSAT-2A Satellite
10p.02	Thomas August *EUMETSAT*	First results from the Metop-C IASI Level 2 cal/val
10p.03	Thomas August *EUMETSAT*	An adaptative OEM retrieval for IASI
10p.04	Geoff Cureton *UW-Madison/SSEC/CIMSS*	Near Real Time Active Fires and GAASP Level-2 Products Via Direct Broadcast Using the Community Satellite Processing Package
10p.05	Hyun-Sung Jang *NASA LaRC*	Comparison of PCRTM-derived CrIS retrievals of temperature, water vapor, and trace gases (O3, CO, CH4, and N2O) with in-situ measurements
10p.06	Withdrawn	

10p.07	Awdhesh K. Sharma NOAA	Sounding Data Products generated at NOAA/NESDIS Using High Spectral Resolution Infrared and Advanced Microwave Sounders (CrIS/ATMS)
10p.08	Nadia Smith (for Rebekah Esmaili) *Science and Tech. Corp.*	Expanding the capability of real-time temperature, humidity, and trace gas retrieval products in field campaigns
10p.09	Zied Saddi *CNRM/Météo-France and CNRS*	Towards A Further Use Of Satellite Observations For A Better Definition Of Surface Temperature
10p.10	Dorothée Coppens (for Mayté Vasquez) *EUMETSAT*	IASI L1 and L2 reprocessing status at EUMETSAT
10p.11	David Duncan *ECMWF*	An experimental 2DVAR retrieval using AMSR2

15:15 – 15:45 Health break

15:45 – 16:30 Session 11: Validation (oral presentations - 12 minutes) **Chair-persons: Thomas August, Benjamin Ruston**		
11.01	Maria Toporov *University of Cologne*	Combining satellite- with ground-based measurements for near-real-time monitoring of atmospheric stability, atmospheric water vapor and liquid water
11.02	Michelle Feltz *UW-Madison/SSEC*	Investigating the Comparisons of Hyperspectral IR Sounders, Radio Occultation, and Radiosondes in Radiance Space
11.03	Fabien Carminati *Met Office*	Characterisation of NWP Model Biases and Uncertainties in the MW and IR Spectral Domains

16:30 – 16:40 Session 11: Validation (poster introductions - 1 minute: no visual aids) **Chair-persons: Thomas August, Benjamin Ruston**		
11p.01	Fabien Carminati *Met Office*	Extended characterisation of NWP model biases and uncertainties across the microwave and infrared domains
11p.02	withdrawn	
11p.03	Christina Stumpf *DWD*	Application of the fast visible radiative transfer model RTTOV-MFASIS: comparison to RTTOV-DOM and use for model cloud validation of ICON
11p.04	Nicholas R. Nalli *IMSG @ NOAA/NESDIS/STAR*	Validation of the Environmental Data Record (EDR) product suite from the SNPP/NOAA-20 NOAA Unique Combined Atmospheric Sounding System (NUCAPS)
11p.05	Joe K. Taylor *UW-Madison/SSEC*	FIREX-AQ ER-2: A Summary of Scanning High-resolution Interferometer Sounder (S-HIS) Observations

11p.06	Eui-Seok Chung *IBS Center for Climate Physics*	Reconciling opposing Pacific Walker circulation trends in observations and climate model projections
11p.07	Olaf Stiller (for Leonhard Scheck) *DWD*	Generating synthetic visible satellite images with RTTOV
11p.08	Olaf Stiller	Using ensemble based diagnostics to identify sub-optimally used observations

16:45 – 17:30 Session 12: Satellite data impact in NWP (oral presentations - 12 minutes) **Chair-persons: Cristina Lupu, Cyril Crevoisier**		
12.01	Niels Bormann *ECMWF*	Global observing system experiments in the ECMWF assimilation system
12.02	Buddhi Prakash Jangid *NCMRWF*	Impact of Hyperspectral Radiances in 4D-VAR data assimilation system
12.03	Bruna Barbosa Silveira *CNRM/Météo-France*	Assessment of assimilating Metop combined retrieval L2 product in AROME-France

17:30 – 17:55 Session 12: Satellite data impact in NWP (poster introductions - 1 minute: no visual aids) **Chair-persons: Cristina Lupu, Cryil Crevoisier**		
12p.01	S. Indira Rani *NCMRWF*	Assessment of the impact of zonal component of Radiosonde winds: A prelude to the assimilation of Aeolus winds
12p.02	Hyoung-Wook Chun *KIAPS*	Assessment of impact of satellite radiances on analysis in KIAPS
12p.03	Robin Faulwetter *DWD*	Extended Use of Humidity sensitive Radiances in the DWD System
12p.04	David Duncan *ECMWF*	Assessment of the FY-3D microwave instruments at ECMWF
12p.05	Jisoo Kim *Ewha Womans University*	Impacts of cloud screening algorithm of the ATMS on numerical weather prediction model: Scattering index
12p.06	Magnus Lindskog *SMHI*	Use of microwave radiances in the MetCoOp operational HARMONIE-AROME limited-area data assimilation
12p.07	Stuart Newman *Met Office*	Extending use of microwave humidity data over land at the Met Office
12p.08	Youngchan Noh *UW-Madison/SSEC/CIMSS*	Impact of NOAA Low Latency LEO DBNet Constellation Infrared Sounder Data on NCEP GFS forecasts
12p.09	withdrawn	
12p.10	William F. Campbell	Background Fit to Satellite Observations
12p.11	Chengli Qi (for Shuang Xi) *NSMC/CMA*	Let more Polar Orbiting Satellite Data available in Regional NWP in CMS DBNet Data, its potential, application and questions

12p.12	Niels Bormann *ECMWF*	Evaluation and assimilation of MW sensors on NOAA-20 and Metop-C
12p.13	Niels Bormann *ECMWF*	Continuous Data Assimilation at ECMWF and implications for satellite observation timeliness
12p.14	Brett Candy *Met office*	Current Use of FY-3 microwave instruments and Future Plans
12p.15	Keyi Chen *Chengdu University of Information & Technology*	Assimilating FengYun-3C Microwave Sounding Data over Land in the Southwest Vortex Precipitation in China
12p.16	Benjamin Ruston *NRL*	Unified Observation Processing
12p.17	Hidehiko Murata *JMA*	Operational Use of NOAA-20 ATMS and CrIS Radiance Data in JMA's Global NWP System

Tuesday, 5 November 2019

8:30 – 10:00 Session 13: Advances in satellite data assimilation (oral presentations - 12 minutes) **Chair-persons: Heather Lawrence, Kozo Okamoto**		
13.01	Maziar Bani Shahabadi *ECCC*	Implementation of slant-path radiative transfer in Environment Canada's Global Deterministic Weather Prediction system
13.02	Hyo-Jong Song *KIAPS*	Impact of the mid-loop for satellite radiance on a hybrid data assimilation skill
13.03	Ruth B. E. Taylor *Met Office*	Observation selection for variational bias correction
13.04	Kristen Bathmann *IMSG @ NOAA/NCEP/EMC*	Surface Dependent Correlated Infrared Observation Errors in the FV3 Framework
13.05	Joël Bédard *ECCC*	Understanding the link between satellite radiance thinning and observation error variance inflation in global 4D-EnVar
13.06	Cristina Lupu *ECMWF*	Surface skin temperature for satellite data assimilation at ECMWF

10:00 – 10:15 Session 13: Advances in satellite data assimilation (poster introductions - 1 minute: no visual aids) **Chair-persons: Heather Lawrence, Kozo Okamoto**		
13p.01	Kwangjae Sung *KIAPS*	Local Unscented Transform Kalman Filter for Highly Nonlinear System
13p.02	Jeon-Ho Kang *KIAPS*	Impact of SSMIS BC method considering background-error in KIAPS DA system
13p.03	withdrawn	
13p.04	In-Hyuk Kwon *KIAPS*	Evaluation of Variational Bias correction using an iterative bias correction against analysis

13p.05	withdrawn	
13p.06	Marco Matricardi *ECMWF*	The assimilation of the IASI full spectrum using reconstructed radiances
13p.07	Agnes Lim *UW-Madison/SSEC/CIMSS*	Quantifying the Sensitivity of NCEP's s GDAS/GFS to CrIS Detector Differences
13p.08	withdrawn	

10:15 – 10:45 Health break

10:45 – 12:30 Session 14: Preparation for new hyperspectral instruments (oral presentations - 12 minutes) **Chair-persons: Karen St. Germain, Niels Bormann**		
14.01	Dorothée Coppens *EUMETSAT*	MTG-IRS: scientific improvements for a user-friendly mission
14.02	Francisco Bermudo *CNES*	IASI-NG Program: General Status Overview
14.03	Adrien Deschamps *CNES*	IASI-NG L1 processing: how to estimate the instrument response function in real-time?
14.04	Eric Jurado, Clemence Le Fevre *CNES*	Development and Verification challenges of the IASI-NG system
14.05	Francesca Vittorioso CNRM, Météo-France, CNRS	Evaluation of a first IASI-NG channel selection for Numerical Weather Prediction
14.06	Lucie Leonarski *Université de Lille - LOA*	Ice cloud properties, an information content analysis from high spectral resolution measurements in the thermal infrared: Application to IASI and IAS-NG
14.07	Karen St. Germain *NOAA/NESDIS*	Accelerating Toward NOAA's Next-Generation Observing Architecture

12:30 – 13:30 Lunch

13:30 – 14:00 Poster viewing (Sessions 13, 14, 15, 16)

14:00 – 14:45 Session 15: Polar regions (oral presentations - 12 minutes) **Chair-persons: Erin Jones, Reima Eresmaa**		
15.01	Heather Lawrence *ECMWF*	Arctic Observing System Experiments at ECMWF for the APPLICATE project
15.02	Zheng Qi Wang (for Roger Randriamampianina) *Norwegian Meteorological Institute*	Impact of observations on the AROME-Arctic regional model

15.03	Louis Garand *ECCC*	Continuous observation of high latitudes from space: a review of medium Earth orbit (MEO) and highly elliptical orbit (HEO) options

14:45 – 14:50 Session 15: Polar regions (poster introductions - 1 minute: no visual aids) **Chair-persons: Erin Jones, Reima Eresmaa**		
15p.01	Zheng Qi Wang *Norwegian Meteorological Institute*	PRECISE: Production of a regional Reanalysis for Europe within the Copernicus climate change Services
15p.02	Zheng Qi Wang (for Harald Schyberg) *Norwegian Meteorological Institute*	The Arctic Regional Reanalysis of the Copernicus Climate Change Service
15p.03	Stéphane Laroche *ECCC*	Impact of Terrestrial and Satellite Observations over the Polar Regions on the ECCC Global Weather Forecasts during the YOPP Special Observing Periods

14:50 – 15:20 International (oral presentations - 12 minutes) **Chair-persons: Vincent Guidard, Liam Gumley**		
b.01	Stephen English *ECMWF*	Communicating the value of passive bands used by TOVS-heritage microwave instruments in the context of radio frequency interference and spectrum allocation
b.02	Richard Kelley *Alion Science for DOC/NOAA/NESDIS*	Update to World Radiocommunication Conference 2019 and WRC-23 items of interest

15:20 – 15:50 Health break

15:50 – 16:05 International (oral presentations - 12 minutes) **Chair-persons: Vincent Guidard, Liam Gumley**		
b.03	Heikki Pohjola *WMO*	WMO Space Programme Update

16:05 – 16:50 Future missions (oral presentations - 12 minutes) **Chair-persons: Bill Bell, Stephen English**		
16.01	William Smith Sr. *UW-Madison/SSEC/CIMSS*	Combined Polar Hyper-spectral and Geo-multispectral Data - Demonstration of the Need for Geo-Hyper-spectral Sounder
16.02	Joe K. Taylor (for Hank Revercomb) *UW-Madison/SSEC*	Hyperspectral Imaging Infrared Sounding from geostationary orbit
16.03	moved to 14.07	
	(poster introductions)	
16p.01	Dieter Klaes *EUMETSAT*	EUMETSAT Plans

16:50 – 17:30 Working groups finalise reports

Wednesday, 6 November 2019

8:30-10:10 Working Group Reports (15 minutes)
Co-Chairs: Vincent Guidard, Liam Gumley

- **NWP**
- **Radiative transfer and surface properties**
- **Advanced sounders**
- **Products and software**
- **Climate**

10:10-10:30 Health break

10:30-10:50 Working Group Reports (15 minutes)
Co-Chairs: Vincent Guidard, Liam Gumely

- **International and Future Systems**

10:50-11:00 Technical Sub-Group Reports (5 minutes)
Co-Chairs: Vincent Guidard, Liam Gumley

- **RTTOV and CRTM**

12:30 – 12:45 Closing Session
Co-Chairs: Vincent Guidard, Liam Gumley

ITSC-XXII ABSTRACTS

Session 1: Direct readout (oral presentations)

1.01 20 years of the NWP SAF

Presenter: Nigel Atkinson, Met Office
Authors: Nigel Atkinson, Sam Pullen, James Hocking, Roger Saunders, John Eyre, Pascal Brunel, Pascale Roquet

At the end of 2018, the NWP SAF celebrated an important milestone – 20 years since the agreement was signed for the creation of the Satellite Application Facility on Numerical Weather Prediction. Coordinated and funded by EUMETSAT, the NWP SAF was led by the UK Met Office with ECMWF, Météo France and KNMI as partners. Following a period of development, the NWP SAF became operational in 2004, and has been providing satellite data processing software and monitoring services to users ever since. In the latest phase DWD joined the SAF, replacing KNMI which consolidated its NWP activities in the OSI SAF.

The software packages AAPP and RTTOV have been NWP SAF software deliverables for the whole of that time, and evolved through many different versions to support new satellites and instruments. We have also seen the development of direct broadcast retransmission services based on AAPP, pioneered by EUMETSAT in their EARS services, and supported by NWP SAF monitoring facilities.

The talk will present some highlights of the last two decades, and will also look forward to upcoming NWPSAF developments, such as support for instruments on EPS Second Generation and Meteosat Third Generation.

1.02 Status of the Direct Broadcast Network for globally coordinated real-time acquisition, processing and fast delivery of satellite direct readout data, an initiative of the World Meteorological Organisation

Presenter: Pascal Brunel, Meteo France (for Mikael Rattenborg)
Authors: Mikael Rattenborg (WMO), Pascal Brunel (Meteo France) and Werner Balogh (WMO)

The Direct Broadcast Network (DBNet) is a highly successful collaborative undertaking of the World Meteorological Organization and its Members. The DBNet system provides fast acquisition, processing and delivery of satellite products from direct readout data, primarily for Numerical Weather Prediction (NWP) applications with stringent timeliness requirements. Since about 10 years, sounding data from the ATOVS suite of instruments has been acquired by receiving stations around the globe, which has improved the availability and impact of satellite sounding data on short-term regional and global NWP. DBNet is now being extended to cover the acquisition of advanced satellite sounder data from instruments such as METOP/IASI and SNPP/CrIS.

The paper will present the DBNet status and implementation plans, with particular emphasis on the numerous areas where feedback is required from the ITSC community to guide its further development.

1.03 The DBNet Cloud Service for providing low-latency sounder data to NWP centers

Presenter: Liam Gumley, Space Science and Engineering Center, University of Wisconsin-Madison
Authors: Liam Gumley, Bruce Flynn

The WMO Direct Broadcast Network (DBNet) is a worldwide group of DB antenna operators who acquire and process infrared and microwave sounder data from operational meteorological satellites in low earth orbit. The calibrated and geolocated Level 1B data are converted to BUFR format and then disseminated with low latency to NWP centers for assimilation in regional and global models.

The traditional DBNet approach requires each participating DB antenna site to install, configure, operate, and maintain the various sounder data processing packages, including AAPP, OPS-LRS, CSPP SDR, and FY3 DB. Furthermore, each site must convert the resulting Level 1B data to an approved BUFR format with GTS headers, name the BUFR files according to conventions specified for DBNet, and then disseminate the files via GTS or a retransmission service such as EUMETCAST. This approach has been successful when utilized by meteorological and satellite agencies such as Meteo France, EUMETSAT, NOAA, Met Office, IMD, NSMC, INPE, Roshydromet, and BoM.

However, it can be difficult for DB antenna operators to maintain these capabilities over the long term and ensure that they adapt to new satellites, sensors, and software packages. As DB software packages evolve and become more complex, they require more capable servers to run

them and newer operating systems to host them. Some DBNet operators do not have the ability to update their hardware and operating systems to meet the requirements of new DB software package versions, with the result that even if they can receive the sounder data from a new satellite, they are not able to process it. In addition, there are many DB antenna sites that are owned and operated by other entities, such as universities and remote sensing agencies. These sites have the potential to contribute to DBNet (especially in areas where DBNet coverage is poor or non-existent) but it can be challenging for operators at these sites to install and maintain the required software systems.

The DBNet Cloud Service will provide a centralized cloud-based ingest, processing, and delivery service for infrared and microwave sounder data. The service is intended to provide an easy and convenient way for DB antenna operators to contribute sounder data to the WMO DBNet without having to install, configure, validate, operate, and maintain the latest versions of the various sounder data processing packages. It will provide a local access point for antenna operators to upload their Level 0 data files immediately after a satellite overpass (the ability to upload a file after a pass is provided by all major DB antenna vendors). Upon receipt of a new Level 0 data file, the DBNet Cloud Service will immediately starts processing the data using the latest recommended version of the relevant sounder data processing software (e.g., AAPP, OPS-LRS, CSPP SDR). After Level 1B products have been created, conversion to BUFR is done using the recommended formatting, metadata, and naming conventions described in the WMO Guide to DBNet. Finally, the BUFR products will be delivered to an endpoint (e.g., NOAA, EUMETSAT) for dissemination on GTS and EUMETCAST. The DBNet Cloud Service will make it easier for existing DBNet antenna sites and operators to contribute sounder data to DBNet with low latency, high reliability, and good data quality. It will also allow new antenna sites to contribute data to DBNet with relatively little effort. The service will ensure that NWP centers receive high quality infrared and microwave sounder data from all DBNet sites regardless of site location or operator.

This presentation will provide an overview of the DBNet Cloud Service implementation, current prototype status, and benefits to the DB and NWP communities.

1.04 The Utility of CSPP Atmospheric Sounding Products

Presenter: Kathleen Strabala, UW-Madison/SSEC/CIMSS
Authors: Kathleen Strabala, Liam Gumley, Elisabeth Weisz, James Davies, Geoff Cureton

The Community Satellite Processing Package (CSPP) is a NOAA funded effort that provides portable stand alone software to create a myriad of polar orbiter meteorological satellite calibrated and level 2 science retrieval products. Although the primary goal of this effort is to support direct broadcast operational decision makers, it can also be used by students and researchers who want to process and investigate specific events. The current suite of CSPP software includes four different techniques for deriving temperature and moisture soundings. The NOAA/NESDIS/STAR Unique Combined Atmospheric Processing System (NUCAPS) algorithm combines hyperspectral and microwave instruments, CrIS/ATMS on NOAA-20 and S-NPP satellites as well as IASI/AMSUA/MHS on Metop-A and Metop-B. These retrievals are currently being used operationally by the US National Weather Service for wide ranging applications including identifying regions of destabilization in the mid-latitudes and areas of very cold air aloft in the polar regions. NUCAPS is the official NOAA sounding product for JPSS. The CSPP NOAA/NESDIS/STAR Microwave Integrated Retrieval System (MIRS) software provides microwave retrievals from 7 different instruments including NOAA-20 and S-NPP ATMS, and Metop-A and Metop-B AMSU-A and MHS. CSPP also includes the University of Wisconsin single Field-of-View (FOV) hyperspectral instrument statistical dual regression retrievals from CrIS, IASI and the AIRS instrument on the Aqua satellite. These retrievals are being used in combination with GOES-R temperature and moisture retrievals to identify regions of rapid atmospheric destabilization. Finally, the legacy International ATOVS Processing Package (IAPP) is also supported by CSPP to allow those who want to create consistent climate quality retrievals from NOAA-15, NOAA-16, NOAA-18, NOAA-19, Metop-A and Metop-B HIRS, AMSU-A and MHS instruments. This presentation will include a number of examples on how the retrievals are being used by the environmental decision making community.

As is the case with all CSPP retrieval software, it is freely distributed, includes up to date algorithms, is pre-compiled for 64-bit Intel Linux operating systems, is designed specifically to be easy to install and operate, and runs efficiently on modern hardware.

Session 1: Direct readout (poster presentations)

1p.01 Current status and plans of Direct-readout LEO satellite data processing in NMSC/KMA

Presenter: Hyunjong Oh, National Meteorological Satellite Center of Korea Meteorological Administration (for Dahye Bae)
Authors: Dahye Bae, Hyunjong Oh, Ahyoung Shin, Yongsang Kim
National Meteorological Satellite Center(NMSC)/Korea Meteorological Administration(KMA) is processing various direct-readout Low-Earth-Orbit(LEO) satellite data such as Advanced TIROS Operational Vertical Sounder(ATOVS), Infrared Atmospheric Sounding Interferometer(IASI), Advanced Technology Microwave Sounder(ATMS) and Cross-track Infrared Spectrometer(CrIS) radiance data for NWP data assimilation and weather analysis.

Currently, NMSC is operating ATOVS and AVHRR Pre-processing Package (AAPP), Community Satellite Processing Package (CSPP) and International ATOVS Processing Package (IAPP) for direct readout data processing. KMA has provided the direct-readout ATMS and CrIS level 1C data of Suomi-NPP (NPOESS Preparatory Project) satellite via GTS for Direct Broadcast Network (DBNet) activity since 2018, and is working on processing the direct-readout ATMS and CrIS data of NOAA-20 satellite which will be shared via GTS too.

In this paper, we describe the current status and future plans of KMA's direct-readout LEO satellite data processing to support NWP assimilation including the quality check activities.

1p.02 CSPP LEO for JPSS, Metop, NOAA, and FY-3 satellites: New features and enhancements

Presenter: Liam Gumley, Space Science and Engineering Center, University of Wisconsin-Madison
Authors: Liam Gumley, Kathy Strabala, Scott Mindock, Nick Bearson, James Davies, Geoff Cureton
The Community Satellite Processing Package (CSPP) for low earth orbit (LEO) satellites has continued to evolve with the addition of support for new satellites and sensors; updates and improvements to existing products; and support for new geophysical products. Support for the new NOAA-20 operational satellite (launched in November 2017) has been added to the CSPP LEO suite to allow creation of geolocated and calibrated sensor data records (SDRs) for ATMS, CrIS, and VIIRS. NOAA-20 support was also added to atmospheric profile retrieval software packages including NUCAPS, MIRS, and HSRTV. New geophysical product generation software packages for flood and wildfire detection (both supporting NOAA-20 VIIRS) were added to the CSPP LEO suite, and the Polar2Grid image creation toolkit was updated to fully support NOAA-20 VIIRS and Metop-C AVHRR. A new atmospheric profile retrieval system (IASI-NUCAPS) was introduced for Metop-A and Metop-B IASI. New CSPP LEO releases include

- VIIRS cloud, aerosol, cryosphere, and land surface geophysical products for SNPP and NOAA-20;
- ACSPO SST product updates to support NOAA-20 VIIRS and Metop-C AVHRR;
- CLAVR-x cloud product updates to support NOAA-20 VIIRS and Metop-C AVHRR;
- GAASP AMSR2 cryosphere products;
- Polar2Grid support for FY-3B/C VIRR and FY-3D MERSI-2 imagery

This presentation/poster will review the status of the current CSPP LEO software suite and provide examples of new capabilities and products that have been recently added.

1p.03 Generation of direct readout sounding data products at the Bureau of Meteorology

Presenter: David Howard, Bureau of Meteorology
Authors: David Howard, Fiona Smith, Susan Rennie, Leon Majewski, Nigel Atkinson
The Bureau of Meteorology receives data from eight local reception stations; six on the Australian continent and two on Antarctica. We are now acquiring direct-readout data from ATOVS, IASI, CrIS, ATMS and AIRS which is processed to L1d using AAPP for assimilation in our NWP models. The data is of particular value for our six city-scale convective model configurations (see poster by Smith et al) because of its improved timeliness over global data streams. This poster will give some examples of the data in use in our city models. We will also be making this data available to the international community via DBNet during 2020.

1p.04 Current Status and Future Plan on direct readout activity in MSC/JMA

Presenter: Masami Moriya, Japan Meteorological Agency
Authors: Masami Moriya

Meteorological Satellite Center (MSC) of Japan Meteorological Agency (JMA) has received and processed direct broadcast data from Low Earth Orbit (LEO) satellites for more than fifty years. In JMA, these products have been utilized not only for monitoring volcanic ash, the Asian dust, sea surface temperature and sea ice but also for numerical weather prediction (NWP) through assimilation in NWP division. On December 2018, MSC began to process direct broadcast data from NOAA20. At present, MSC processes direct broadcast data from 6 LEO satellites in total, i.e. NOAA-18, 19, 20, S-NPP and Metop-A, B. Direct broadcast data from Metop-C is also planned to be received in the near future. Besides the direct broadcast data received at Kiyose station in Japan, MSC also processes those received at Syowa station in Antarctica with the cooperation of the National Institute of Polar Research of Japan. These products are very important for JMA's meteorological operation. On the other hand, some of our products related to CrIS, ATMS and ATOVS are shared with other NWP centers via the Direct Broadcast Network (DBNet) and cooperative organization (Wisconsin/CIMSS). This contributes to meteorological operation in other countries.

This presentation will show current status and future plan of JMA/MSC LEO activities.

1p.05 IASI cloud mask comparison between global broadcast and local processing

Presenter: Mathieu Asseray, CNRM/CEMS
Authors: Mathieu Asseray

The comparison between global EUMETSAT cloud mask and local MAIA cloud mask applied with AVHRR projection in IASI pixel allows us to localize the main differences on cloud fraction by using the two retrievals.

The first step of the comparison consists in displaying cloud fraction in IASI pixel maps for global and local granules in order to highlight the localization of the differences for each mask. The study has been lead on many single orbits situation, in January 2019. An histogram is established for each case and present the number of different pixel according the spread global-local. After processing on the whole studied granule, the first results indicate that most of pixels present no or low differences (between -0.05% and +0.05% of cloud fraction). However the histogram shows an overestimation of the local cloud mask and the map shows some sea and land influences on the overestimation. the AVHRR cloud type from MAIA and the SEVIRI cloud type product are mapped for each situation. They are used to identify the nature of the cloud structures. These comparisons show an eventual correspondence between cloud fraction difference and cloud type, especially with low level fractional clouds. Further study will be lead in order to validate this assumption. Meanwhile these results will be run in production on the purpose of forecast and research.

The second step consists in processing monthly data and producing a similarly histogram but by using a longer period and more orbits. This work will help to understand the sea/land and day/night/twilight/sunrise effects on the cloud fraction difference. This will help also to best understand the differences between the two masks by looking at the algorithms used by each of them. The use of the independent AVHRR products will help in understanding the difference.

1p.06 Porting the OPS AVHRR clusters algorithm to VIIRS in CrIS footprint

Presenter: Pascale Roquet, Météo-France
Authors: Pascale Roquet

At ITSC-XX, was first expressed a recommendation that the AVHRR cluster algorithm available in AAPP should be used for all hyperspectral sounders. In OPS, the software which processes IASI, a method called "Nuees Dynamiques" groups the AVHRR pixels in each IASI field of regards by clusters of homogeneous scenes. In the IASI BUFR file, for each IASI FOV, the user can retrieve the numbers of pixels by clusters as well as the mean and the standard deviation of the AVHRR radiances. These information can be used in order to improve the data assimilation of IASI radiances in numerical weather prediction models. In AAPP, this method was adapted in 2018 to VIIRS and CrIS for S-NPP and JPSS NOAA20 satellites. This poster describes how this was done and how a direct broadcast user can use the cluster software for S-NPP and JPSS NOAA20.

1p.07 CSPP SDR and CSPP VIIRS ASCI, Having your cake and eating it too!

Presenter: Scott Mindock, SSEC /CIMSS
Authors: Scott Mindock, Ray Garcia, Graeme Martin, Kathy Strabala, Nick Bearson, Liam Gumley, Allen Huang

The CSPP SDR The CSPP (Community Science Processing Package) Team at SSEC/CIMSS has created the CSPP VIIRS ASCI 1.0 software to

support SNPP and JPSS-1 Level 2 product creation. The CSPP VIIRS ASCI package creates Enterprise Level, Cloud, Ice, Snow, Ash and Aerosol products using NOAA/NESDIS Enterprise Level algorithms. The CSPP SDR package creates Level 1 (SDRs) from SNPP and J01 RDRs acquired from Direct Broadcast.

CSPP SDR and CSPP ASCI work together with your antenna system to create an easy to use and maintain processing system. If you mission requires CrIS and you want CSPP! If you need ATMS you need CSPP! VIIRS is yours with CSPP, and now with CSPP ASCI you can have Clouds, Snow, Ice and Aerosols, with the CSPP ease and reliability.

1p.08 Polar2Grid and Geo2Grid: Open Source Software for Creating High Quality Images

Presenter: Kathleen Strabala, UW-Madison/SSEC/CIMSS (for David Hoese)
Authors: David Hoese and Kathleen Strabala

Creating high quality images from meteorological instruments on polar orbiter and geostationary satellites poses significant challenges, including how to read the data (input formats), the type of instrument that observed the data (Imager, Sounder, etc.), what software generated the data files, and the what tool will be used to display the end product (output formats). To simplify this process, NOAA has funded the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin to create a pair of open source command line tools called the Community Satellite Processing Package (CSPP) LEO Polar2Grid and CSPP Geo Geo2Grid. These toolkits provide an easy interface for reprojecting and reformatting imager instruments and a selected number of science products into a variety of output formats including GeoTIFF, the US National Weather Service AWIPS NetCDF format, NinJo, Binary and KMZ. Commands are carried out through simple bash shell scripts that wrap underlying self-contained python code. These tools handle all of the complexity involved in this conversion including resampling to custom uniform grids or regions of interest, perceptual enhancements, atmospheric corrections, and RGB, including true color, image creation. While the tools provide simple interfaces, they do not sacrifice performance and can complete the conversions in seconds on large swaths of data by taking advantage of new open source tools such as Dask parallel processing. Polar2Grid is the toolkit currently used at direct broadcast receiving stations to provide Polar Orbiter imagery from VIIRS, MODIS and AVHRR imager to the US National Weather Service Forecast offices in the Continental United States, as well as Alaska, Hawaii, Puerto Rico, and Guam within minutes of an overpass of the satellites. Geo2Grid version 1.0 software which supports GOES-16 and GOES-17 ABI and Himawari-8 AHI was released on 1 March 2019. By default, images of all ABI/AHI imager bands plus true and false color output image files are generated at the highest possible resolution with each execution of the run script. Creation of true color imagery includes atmospheric correction, band sharpening, and the creation of a pseudo-green band for the ABI instruments as part of the default geo2grid.sh execution.

As is the case with all CSPP LEO and Geo software, it is freely distributed, is pre-compiled for 64-bit Intel Linux operating systems, is designed specifically to be easy to install and operate, and runs efficiently on modern hardware.

1p.09 Community Satellite Processing Package for Geostationary Data (CSPP Geo) Level 2 Products and Image Generation for Direct Broadcast

Presenter: Graeme Martin, UW-Madison SSEC/CIMSS
Authors: Graeme Martin, Liam Gumley, Nick Bearson, Jessica Braun, Alan DeSmet, Geoff Cureton, Dave Hoese, Ray Garcia, Tommy Jasmin, Scott Mindock, Eva Schiffer, Kathy Strabala

The Community Satellite Processing Package for Geostationary Data (CSPP Geo) project is funded by the NOAA GOES-R Program to create and distribute software allowing users to process direct broadcast data received from geostationary weather satellites. CSPP Geo software easy to install and run, with no compilation or installation of external dependencies required. The software is provided free of cost due to the ongoing support of NOAA.

The US GOES-16 and GOES-17 satellites are supported, in addition to the legacy GOES-13 and -15 satellites and the Japanese Himawari-8 satellite. Capabilities include processing of raw GRB data received from the GOES-16 and -17, generating products from the Advanced Baseline Imager (ABI), Geostationary Lightning Mapper (GLM) and space weather instruments in real time. Level 2 geophysical products can be generated from ABI data using research versions of the operational GOES-R science algorithms, running in an application known as the NOAA Algorithm Integration Team (AIT) Framework. Level 2 products can be generated from Advanced Himawari Imager (AHI) data using adapted GOES-R

algorithms running in the Geostationary Cloud Algorithm Testbed (GEOCAT). The recently released Geo2Grid software allows generation of high-quality, full-resolution single-band and composite RGB images including true color, natural color, airmass, ash, dust, fog, and night microphysics. True images contain Rayleigh correction, artificial green band and sharpening to 500m.

This presentation will focus on current CSPP Geo Level 2 product and image generation capabilities, and touch on future plans.

Session 1: Radiative Transfer and Community Software (oral presentations)

1.05 Recent Advances in the Community Radiative Transfer Model

Presenter: Benjamin Johnson, JCSDA
Authors: Benjamin T. Johnson (JCSDA), Patrick Stegmann (JCSDA), Thomas Greenwald (JCSDA), James Rosinski (JCSDA), Emily Liu (EMC), Ming Chen (ESSIC), Andrew Collard (EMC), Tong Zhu (CIRA)

The Joint Center for Satellite Data Assimilation (JCSDA) Community Radiative Transfer Model (CRTM) is a fast, 1-D radiative transfer model used in numerical weather prediction, calibration / validation, etc. across multiple federal agencies and universities. The key benefit of the CRTM is that it is a satellite simulator, in that it provides a highly accurate representation of satellite radiances by making appropriate use of the specific sensor response functions convolved with a line-by-line radiative transfer model (LBLRTM). CRTM covers the spectral ranges consistent with all present operational and most research satellites, from visible to microwave (L-Band). The capability to simulate ultraviolet radiances are being added over the next two years.

This talk will focus on recent advances in the ability of the CRTM to simulate satellite radiances, in particular improvements in cloudy radiance simulation, aerosol impacted radiances, improvements in surface emissivity modeling, the addition of full polarization support (experimental), updated coefficient files in support of new and upcoming sensors, L-Band support, active sensor forward modeling (space-based radar and lidar), and many other features coming online over the next year. These changes represent a significant and necessary expansion of the CRTM capabilities to allow it to continue to perform in an all-weather, all-surface, all-sensor environment.

1.06 RTTOV development status

Presenter: James Hocking, Met Office
Authors: Pascal Brunel, Ana Fernandez del Rio, Alan Geer, Stephan Havemann, James Hocking, Christina Köpken-Watts, Cristina Lupu, Marco Matricardi, Pascale Roquet, David Rundle, Roger Saunders, Leonhard Scheck, Olaf Stiller, Emma Turner, Jérôme Vidot

Since ITSC-21, two new minor releases of RTTOV, v12.2 and v12.3, were made available to users. These updates include various developments. RTTOV has been extended to enable simulations in the far-infrared up to 100 microns, and in the sub-mm to support MetopSG ICI. Microwave coefficient files are now available based on measured spectral response functions. The MFASIS fast model for visible cloudy simulations has been incorporated into RTTOV enabling its use for real-time applications. New optical properties are available for cloud liquid water, ice cloud and aerosols in visible/infrared scattering simulations, and a new tool is available for users to generate custom aerosol optical property files for use with RTTOV. Updates to the microwave scattering model, RTTOV-SCATT, include new options for the liquid water permittivity parameterisation (the same options are also available in RTTOV for cloud liquid water absorption), the option to use optical properties for non-spherical particles from the ARTS single-scattering database, and a new optional output structure is available containing the information necessary for all-sky surface emissivity retrievals. Improvements to the treatment of the surface include the new CAMEL climatology atlas (based on a multi-year climatology), a new solar sea BRDF model, and new options related to Lambertian vs specular surfaces. PC-RTTOV has been updated to enable simulations with additional variable trace gases and OPAC aerosols. The implementation of the HTFRTC fast radiative transfer model has been substantially improved and extended, for example, to enable all variable trace gases and optionally output overcast radiances. An overview of the new capabilities will be presented along with a look ahead to planned developments for the next major release, RTTOV v13, in September 2020.

1.07 Comparisons of ocean radiative transfer models with satellite observations from 1.4 to 89 GHz

Presenter: Lise Kilic, Paris Observatory
Authors: Lise Kilic, Catherine Prigent, Stephen English, Jacqueline Boutin, Thomas Meissner and Simon Yueh

Satellite observations are required to monitor, understand and predict the state of the ocean and atmosphere and to quantify the energy and hydrological cycles. The oceans exchange large amounts of heat, moisture and gases with the atmosphere at time scales from days (e.g., mixing associated with atmospheric storms), to years (e.g., El Niño) and to centuries (climate change). The sea surface temperature (SST), ocean wind speed (OWS) and sea surface salinity (SSS) are fundamental variables for understanding, monitoring and predicting the state of the ocean and atmosphere. They are needed to correctly describe air-sea interactions occurring at different scales, up to oceanic mesoscale, and to drive coupled ocean-atmosphere Numerical Weather Prediction (NWP) models.

The analysis of these ocean parameters from passive microwave satellite measurements require a Radiative Transfer Model (RTM) in order to interpret the satellite Brightness Temperatures (TBs) in terms of SST, SSS, and OWS. Usually ocean RTMs are developed for a specific application and/or instruments, i.e. a selected range of frequencies and incidence angles. For the first time, with the Copernicus Imaging Microwave Radiometer (CIMR) mission (Kilic et al., 2018), 1.4 GHz (L-band) observations will be combined with 6.9, 10.6, 18.7 and 36.5 GHz (C, X, Ku, and Ka-bands) observations and will provide coincident SST, SSS, and OWS measurements. Therefore, an overview of the existing RTMs working at these frequencies and a comparison between them is needed.

In this study, we propose to compare three different ocean RTMs from 1.4 to 89 GHz to satellite observations from SMAP and AMSR2. This comparison exercise required the development of a dataset of satellite observations from SMAP and AMSR2, collocated with surface and atmospheric parameters. Consistent ECMWF ERA-Interim and Mercator reanalysis data are chosen. The database samples the global oceans over a year.

The selected ocean RTMs are (1) the LOCEAN RTM developed for the SMOS mission (Dinnat et al., 2003 and Yin et al., 2016) (2) the FAST microwave Emissivity Model (FASTEM) parameterized from a full physical model (Liu et al., 2011), (2) the Remote Sensing System (RSS) empirical model, fitted with SSM/I and WindSat observations between 6 and 9 GHz (Meissner and Wentz 2004, 2012) and with Aquarius at 1.4 GHz (Meissner et al., 2014, 2018).

The simulations were carefully compared to the observed TBs. Firstly, global systematic errors between simulations and observations were computed. The biases tend to increase with frequency, and are generally higher at horizontal than at vertical polarizations. This is partly due to the increasing effect of the atmospheric contribution with frequency (essentially undetected clouds), especially at horizontal polarization. Part of it can also stem from AMSR2 calibration issues. Secondly, the analysis focused on the accuracy of the RTMs as a function of the key ocean variables, SST, SSS, and OWS (once the global biases are subtracted).

Major discrepancies with the observations were found at frequencies above 1.4GHz, for OWS higher than 7m/s, with the LOCEAN and the FASTEM models, with differences strongly increasing with increasing OWS. Possible model improvements were discussed. The analysis tended to show that a frequency dependence needs to be added to the foam cover model or / and on the foam emissivity model. The study also stressed that these two components have to be considered consistently and jointly, all over the frequency range. Efforts should be devoted to the modeling of the foam contribution, taking into account the OWS, but also the frequency dependence, and possibly the wave dissipative energy.

Cold SSTs were also identified as a source of disagreement between the simulations and the observations, regardless of the model. This is a critical issue, especially at vertical polarization at 6 GHz which is the key channel for the SST analysis from satellite. Large uncertainties still exist in the modeling of the dielectric constants of sea water, particularly at low SSTs. New laboratory measurements of the dielectric properties of ocean water have recently been undertaken at 1.4 GHz: their extension to higher frequencies should be encouraged, insisting on the uncertainty estimation and with special attention to the 6 GHz.

References

E. P. Dinnat, J. Boutin, G. Caudal, and J. Etcheto. Issues concerning the sea emissivity modeling at L

band for retrieving surface salinity. Radio Science, 38(4), aug 2003. ISSN 00486604

L. Kilic, C. Prigent, F. Aires, J. Boutin, G. Heygster, R. T. Tonboe, H. Roquet, C. Jimenez, and C. Donlon. Expected performances of the copernicus imaging microwave radiometer (cimr) for an all-weather and high spatial resolution estimation of ocean and sea ice parameters. Journal of Geophysical Research: Oceans, 123(10):7564–7580, 2018.

Q. Liu, F. Weng, and S. J. English. An improved fast microwave water emissivity model. IEEE Transactions on Geoscience and Remote Sensing, 49(4):1238–1250, 2011. ISSN 01962892.

T. Meissner and F. J. Wentz. The Emissivity of the Ocean Surface Between 6 and 90 GHz Over a Large Range of Wind Speeds and Earth Incidence Angles. IEEE Trans. Geosci. Remote Sens., 50(8):3004–3026, Aug 2012. ISSN 0196-2892.

T. Meissner, F. J. Wentz, and L. Ricciardulli. The emission and scattering of l-band microwave radiation from rough ocean surfaces and wind speed measurements from the aquarius sensor. Journal of Geophysical Research: Oceans, 119(9):6499–6522, 2014.

X. Yin, J. Boutin, E. Dinnat, Q. Song, and A. Martin. Roughness and foam signature on smos-miras brightness temperatures: A semi-theoretical approach. Remote sensing of environment, 180:221–233, 2016.

1.08 Advances of the Community Surface Emissivity Models (CSEM) in Support of NWP Data Assimilation

Presenter: Ming Chen, CICS-ESSIC, University of Maryland

Authors: Ming Chen, Kevin Garrett and Yanqiu Zhu

The Community Surface Emissivity Models (CSEM) developed at NOAA/NESDIS/STAR is a feature-rich surface radiative transfer modelling system in support of the data assimilation of surface sensitive channel observations, the quality control of sounding channels, and the physical retrieval of surface features. With the OOP design, CSEM may be coupled with multiple host models, e.g., CRTM, RTTOV, or used as a stand-alone research tool. New models and model improvements may be easily implemented as options into the CSEM algorithm repository and compared with other existing kindred models, and ultimately transferred for various operational applications (e.g., data assimilation). The first version of CSEM (CSEM V1.0.0) has been integrated with CRTM REL-2.3.x and tested in FV3 GSI. CSEM V1.0.0 includes a number of new and expanded model capabilities in addition to all the existing CRTM surface RT modules. CSEM will be released with the next major CRTM release 3.0.0.

This presentation focuses on our latest modeling efforts that have been carried out to support the microwave radiance data assimilation over non-snow land surfaces, which includes the model physics improvements to account for the thermal heterogeneity of the land covers and the underlying soil, the implementation of the tangent linear and adjoint models for sensitivity analysis and variational data assimilation of land surface skin temperature, soil moisture and essential land cover parameters. The model validation and calibration at global scale will be particularly addressed in reference to the monthly averaged emissivity retrieval atlas TELSEM and the real-time analytical emissvity retrieval from GSI. Due to the large data dimensionality at global scale, machine learning is utilized in the model parameter optimization and the quantification of model uncertainties. The model improvements may significantly reduce the model bias rooted in the model built-in parameters, e.g., leaf thickness and the dominant inclination angle of canopy leaves. With the case studies at ATMS channels, comprehensive analysis on the improved model performance in GSI will be demonstrated in the presentation.

1.09 How it could be possible to evaluate the spectroscopic parameters: the example of the new release of GEISA-2019

Presenter: Raymond Armante, LMD/CNRS

Authors: R. Armante, N. Scott, A. Chédin, L. Crepeau

The latest release of GEISA in 2015, including line parameters, cross-sections as well as aerosols, has been described in Jacquinet et al [1]. GEISA and associated management software facilities are implemented and freely accessible on the AERIS/ESPRI atmospheric data center website geisa.aeris-data.fr. It is used on-line in various domains like atmospheric physics, planetology, astronomy and astrophysics. The actual context of management and contents of the new release of GEISA-2019 version are independently presented in a poster by Armante et al.

With more and more sophisticated instruments like IASI, IASI-NG, CrIs, OCO2, … and requiring higher spectral and radiometric performances, the needs in the precision of the spectroscopic

parameters are more and more important. Today, the GEISA database stays the reference for current or planned TIR/NIR space missions, such as for IASI, IASI-NG, MERLIN, Microcarb.

Based on a strong experience in CAL/VAL activities at LMD, we have developed a validation chain, called SPARTE [2], aiming to compare the differences between results of model simulations and satellite observations remote data. The simulations are made with the radiative transfer algorithm 4AOP developed and validated at LMD (see dedicated poster Armante et al). For the thermal infrared, we have used the richness of the observation data provided by space born satellite instruments IASI A, B and C (2006, 2012, 2019). In the Near InfraRed, we have used all the potential of one of the highest resolved instruments called TCCON. For the first time, SPARTE has made it possible to evaluate GEISA-2015 before its public distribution via the AERIS/ESPRI atmospheric chemistry data center website.

The next version (GEISA-2019) being planned for mid-2019, we have in parallel applied the SPARTE chain to assess the quality of the new release of main contributors, in various domains like the R6 manifold of CH4 (MERLIN), the 2.1, 1.6 and 0.76 µm bands for CO2, O2, H2O (MicroCarb, OCO-2), and the 1.27 µm of O2 (MicroCarb). This presentation will be focus on the main results we have obtained in the evaluation of the spectroscopic parameters for the IASI/IASI-NG spectral intervals.

References:
[1] N. Jacquinet-Husson, et al. J. Mol. Spectrosc., 327, 31-72, http://dx.doi.org/10.1016/j.jms.2016.06.007 (2016)
[2] R. Armante et al, J. Mol. Spectrosc., 327, 180-192, http://dx.doi.org/10.1016/j.jms.2016.04.004 (2016)

1.10 An alternative method to quantify NLTE radiances

Presenter: Zhenglong Li
Authors: Zhenglong Li, W. Paul Menzel, James Jung, Agnes Lim, and Jun Li

The 4.3 um CO2 shortwave Infrared (SWIR) radiances are more sensitive to temperature than the 15 um CO2 longwave IR (LWIR) ones. However, none of the operational centers is assimilating the SWIR radiances from hyperspectral IR (HIR) sounders, such as AIRS, IASI, and CrIS. One important reason is the Non-Local Thermodynamic Equilibrium (NLTE) impact on the SWIR CO2 channels, which may contribute more than 10 K in observed brightness temperature (BT). In recent years, significant progress has been made in fast radiative transfer (RT) simulating daytime NLTE emission. Despite of the overall good agreement between observations (O) and calculations using NWP field as background (B), studies have shown unexplained large discrepancies over winter-side high latitude region, in both daytime and nighttime. This study introduces a new alternative method to quantify the SWIR NLTE radiances, the differences between the observed and the NLTE-free SWIR radiances, which can be accurately predicted from LWIR ones due to channel correlations. This technique is applied to process the CrIS full spectral resolution (FSR) radiances, and the comparisons between O and B using ECMWF analysis profiles are carried out. The results show that the new method characterizes the NLTE radiances well with comparable standard deviations (STD) of the differences between O and B as CRTM and NEdT during the daytime, and smaller STDs during night, indicating nighttime NLTE is not negligible. The new method also shows smaller biases (less than 0.3 K in absolute value) than CRTM simulation (mostly more than -1 K). Detailed analysis of the biases show that the new method overestimates the NLTE by 0.5 to 1.0 K due to CRTM LTE bias in training process, and CRTM underestimates both LTE and NLTE by 0.5 to 1.0 K. The new alternative method can be used together with RT NLTE simulation to improve the quality of SWIR radiance assimilation.

Session 1: Radiative Transfer and Community Software (poster introductions)

1p.10 Effects of Field of View Inhomegeneities in Radiative Transfer

Presenter: Xavier Calbet
Authors: Xavier Calbet

The effects in radiative transfer of water vapor inhomogeneities or, equivalently, turbulence within the Field of View (FOV) of microwave and infrared sounders is explored. This effect is not negligible and should be accounted for if consistency between modelling and measurement systems is to be achieved. This physical effect is further exploited and retrievals of temperature, water vapor profiles and also turbulence are explored. Retrievals of turbulence at a global scale could be extremely useful in many application areas.

1p.11 CRTM Infrared Sea Surface Effective-Emissivity (IRSSE) Model Upgrade Status

Presenter: Nicholas Nalli, IMSG Inc. at NOAA/NESDIS/STAR
Authors: Nicholas R. Nalli, J. Jung, B. Johnson, T. Zhu, M. Chen, E. Liu, and L. Zhou

For satellite IR remote sensing applications, the surface emissivity/reflectance spectrum must be specified with a high degree of absolute accuracy; a 0.5% uncertainty can result in ?0.3–0.4 K error in LWIR window channels. In the mid-2000s the Joint Center for Satellite Data Assimilation (JCSDA) supported the development of an IR effective-emissivity (IRSSE) model for the Community Radiative Transfer Model (CRTM) in an effort to obtain improved agreement (over conventional emissivity models) with surface based radiance observations (viz., MAERI spectra) over the usual range of satellite zenith angles, IR wavelengths, and surface wind speeds. However, although there was a known dependence on surface temperature, it was not until recent findings of Liu et al. (2017 JCSDA Workshop) that a significant systematic bias (as much as 1 K) was revealed to occur on a global scale in cold waters (i.e., the North Atlantic and Southern Oceans). This has brought attention back to this issue, which has since led to FY19-FY20 JCSDA AOP support for model upgrades to address this problem, in addition to other upgrades (e.g., reduction in residual biases in the SWIR band). This presentation will provide an overview the CRTM IRSSE model along with the upgrade plan and progress.

1p.12 Evaluation of the RTTOV in the ECMWF NWP system

Presenter: Cristina Lupu, ECMWF
Authors: Cristina Lupu, Alan Geer, Marco Matricardi

The poster gives an overview of the evaluation of the RTTOV radiative transfer model in the ECMWF system. RTTOV has been updated to version 12.1 in the IFS model cycle 45r1 (5 June 2018) and to version 12.2 in the operational model cycle 46r1 (11 June 2019). The latest NWP-SAF released version 12.3 has been also evaluated for inclusion in the next IFS model cycle. These are a broad scientific and technical upgrade which allows RTTOV to use the most accurate science possible and prepares the way for future sensors (e.g., band corrections are implemented for all microwave sensors improving accuracy of simulated microwave radiances; the scattering radiative transfer package does its radiative transfer in terms of radiance improving accuracy by several tenths of a Kelvin in some channels; simulations for infrared sensors with updated concentrations of CO2 to current values in the mixed gas transmissions and a different training set of diverse atmospheric profiles are under way). An overview of the performance in the IFS will be presented along with a look ahead to future evaluation of planned RTTOV developments (e.g., new optical depth predictors).

1p.13 RTTOV for hyperspectral far infrared (FIR) instruments: the FORUM example

Presenter: Pascal Brunel, Meteo-France (for Jerome Vidot)
Authors: Jerome Vidot, Pascal Brunel, James Hocking, Marco Matricardi and Roger Saunders

The fast radiative tranfer model RTTOV is developed in the frame of the EUMETSAT NWP-SAF project for the assimilation of satellite observations in NWP models. RTTOV is also more and more used for satellite retrievals as well as for predicted satellite imagery. In the infrared, RTTOV is currently able to simulate multi-spectral or hyperspectral instruments between 3.3 and 50 microns. However, there are scientific interests to extend the capability of RTTOV in the far infrared (FIR) up to 100 microns. This is a valuable challenge for the RTTOV team and we present here its application for the Far-infrared Outgoing Radiation Understanding and Monitoring (FORUM) hyperspectral instrument. FORUM will measure in the 100-1600 cm-1 (6.25–100 micron) range at an expected spectral resolution of 0.3 cm-1. But this extension is not straightforward and as this extension cover different topics they will all need particular attention. The first topic is related to the atmospheric transmittance calculation which is based on predictors and coefficients. The RTTOV coefficients are trained from line-by-line simulations with LBLRTM knowing the instrument spectral response function. Since LBLRTM cover the spectral region between 50 and 100 microns, the RTTOV coefficients for FORUM were calculated and the accuracy compared to current hyperspectral IR sounders. We also show the capability of RTTOV to simulate cloudy radiances and Jacobians by extending the current cloud optical properties and surface emissivity models to FIR.

1p.14 Development of an active sensor module for the RTTOV-SCATT radiative transfer simulator

Presenter: Philippe Chambon, Météo-France
Authors: Philippe Chambon, Alan Geer

Active microwave sensors are becoming widely used observations within the Numerical Weather Prediction community, either for validating model forecasts or for assimilation purposes. Like for the forward simulation of passive microwave

observations, radar data simulations require to make assumptions on the scattering properties of hydrometeors. With the objective of simulating both active and passive microwave instruments within a single framework using the same radiative transfer assumptions into a widely-used tool in the NWP community, an active sensor module is currently under development within the RTTOV-SCATT software. The first simulations of the GPM/DPR instrument as well as the Cloudsat/CPR instrument with this simulator will be shown, based on the AROME model running operationally at Météo-France over five domains in the Tropics. In particular, some model biases highlighted with these first comparisons will be discussed.

1p.15 Progress towards a Polarized CRTM

Presenter: Benjamin Johnson, JCSDA (for Patrick Stegmann)

Authors: Patrick Stegmann, Benjamin Johnson, and Tom Greenwald

In this presentation we summarize the progress in the development of a polarized CRTM version for the release REL-3.0. The CRTM is a fast and accurate scalar radiative transfer model [1] specif-ically developed for satellite radiance data assimilation in numerical weather models. For this pur-pose, the CRTM includes specific tangent-linear, adjoint, and Jacobian (K-matrix) functions in addition to the baseline forward model. In order to extend the CRTM to compute a subset or all elements of the Stokes vector two new radiative transfer models currently stand in competition. The first model is a straightforward extension of the current default scalar Advanced Doubling-Adding model of the CRTM [2] developed by Dr. Quanhua Liu and the second model is a Small-Angle Approximation code [3] developed at Texas A&M University.

Other issues to extend the CRTM towards polarized radiation are the computation of Müller matri-ces for the hydrometeor and aerosol scattering properties and the provision of new polarized sur-face emissivities.

References

[1] Ding, S., P. Yang, F. Weng, Q. Liu, Y. Han, P. Van Delst, J. Li, and B. Baum, 2011: Validation of the community radiative transfer model. J. Quant. Sp. Rad. Trans. 112, 1050-1064.

[2] Liu, Q., and C. Cao, 2019: Analytic expressions of the Transmission, Reflection, and source function for the community radiative transfer model. J. Quant. Sp. Rad. Trans. 226, 115-126.

[3] Sun, B., and G. W. Kattawar, 2017: An Improved Small-Angle Approximation for Forward Scattering and Its Use in a Fast Two-Component Radiative Transfer Method. J. Atm. Sci. 74, 1959-1987.

1p.16 The 4A/OP model from NIR to TIR: new developments and validation results within the frame of international space missions

Presenter: Raymond Armante, LMD/CNRS

Authors: R. Armante, V. Capelle, N.A. Scott, A. Chédin, E. Jaumouillé, P. Lafrique, D. Jouglet, C. Pierangelo, Bojan Sic, Mahmoud El Hajj, L. Chaumat, E. Durand, N. Meilhac et J. Zeghoudi

The Automatized Atmospheric Absorption Atlas (4A) is the LMD (Laboratoire de Météorologie Dynamique) fast and accurate line-by-line radiative transfer model for the computation of transmittances, radiances and Jacobians (http://ara.abct.lmd.polytechnique.fr/index.php?page=4a), currently covering the Near IR to the Thermal IR spectral domain. It has been developed, improved and validated by LMD, CNES and NOVELTIS. Regularly updated or extended to process more and more spectrally resolved cloud free observations as well as observations involving scattering effects by clouds or aerosols (through DISORT, LIDORT or VLIDORT), the “operational” version 4A/OP is freely distributed to registered users.

4A/OP is currently adopted by research and operational groups involved in forward and inverse radiative transfer problems for simulations covering a wide spectral range [20 µm – 0.75 µm]. Extension to UV/Vis is planned for a next version.

In particular, 4A/OP is the reference model used by CNES for several in-flight (IASI/MetOp) or planned space missions (IASI-NG, MicroCarb and MERLIN). Within the frame of research and operational approaches, new developments and validation studies have been performed.

This poster will describe and discuss recently implemented additional or updated capabilities as:

- The impact of the use of the last (2019) updated version of the spectroscopic database GEISA http://ara.abct.lmd.polytechnique.fr/index.php?page=geisa-2
- The improvement of the modelling of the H2O, N2 and O2 continua.
- The new developments (as the LSI method) made to significantly reduce the computation time in the scattering mode with mastered and limited impact on the accuracy.

- The development of a more flexible 4A/OP-User interface offering a wider choice of input/output possibilities (infinite resolution versus ISRF convolved Jacobians, selection of the emissivity database, wavenumber/wavelength units,…).
- A description of the validation studies (approach, results) made on a semi-operational basis, and based on time/space colocations between the ARSA database and/or ECMWF analyses and IASI in the infrared (including MetOp A, B and C) as well as in the near-infrared using TCCON stations/observations.

1p.17 Status of the new GEISA-2019 spectroscopic database

Presenter: Raymond Armante, LMD/CNRS
Authors: R. Armante, A. Perrin, N. Jacquinet, N. Scott, A. Chédin, L. Crepeau

The accuracy of molecular spectroscopy in atmospheric research has entered in a new phase in the frame of remote sensing applications (meteorology, climatology, chemistry) with the advent of highly sophisticated and resolved instrumentations. The latest release of GEISA in 2015, including line parameters, cross-sections as well as aerosols, has been described in Jacquinet et al [1]. For the first time, the corresponding line parameters sub-database has been intensively validated using the powerful approach of the SPARTE chain [2] developed at LMD. This chain had an important impact, particularly is the release of molecules as H2O, CO2 and CH4.

GEISA and associated management software facilities are implemented and freely accessible on the AERIS/ESPRI atmospheric data center website geisa.aeris-data.fr. It is used on-line in various domains like atmospheric physics, planetology, astronomy, astrophysic. Today, the GEISA database is the reference for current or planned Thermal IR/Near IR space missions, such as for IASI, IASI-NG, MERLIN, Microcarb.

We have now initiated the next release planned for the mid 2019. On this poster, we will present the status of this new GEISA 2019 release. Examples of validations we have already made for major molecules such as H2O, CO2 and CH4 will be presented in a dedicated poster/presentation.

Especially needed by the spatial agencies like CNES, it is important to estimate which could be the precision of the spectroscopic parameters (for a given instrument) to reach its scientific objectives. A part of this poster will be reserved to show how at LMD we have tried to answer to this question.

References:

[1] N. Jacquinet-Husson, et al. J. Mol. Spectrosc., 327, 31-72, http://dx.doi.org/10.1016/j.jms.2016.06.007 (2016)
[2] R. Armante et al, J. Mol. Spectrosc., 327, 180-192, http://dx.doi.org/10.1016/j.jms.2016.04.004 (2016)

1p.18 Comparison of Two Data Resampling Algorithms for Processing of Microwave Sounding Observations

Presenter: Hu Yang, University of Maryland
Authors: Hu Yang

For microwave sounding instrument, data resampling processing can be used to reduce the spatial resolution difference between observations from different channels and different instrument, and generate one single data stream for NWP applications. Which is important for correctly classifying cloud-affected data in data assimilation. Currently, there are two different data resampling algorithms being developed for microwave instrument, one is based on antenna pattern B-G optimum cost function method, which has been used to generate ATMS remapping SDR dataset, another is based on Modulation Transfer Function, which is adopted by EUMETSAT AAPP package. In this work, we will evaluate the impact of two remapping algorithms on SDR data quality based on the sub-pixel high resolution simulate datasets, for both resolution downgrade and enhancement cases. Results of the study are expected to be useful for NWP user community to fully explore the benefit of microwave sounding instrument observations.

1p.19 Automated Identification of Anomalous SSMIS Brightness Temperatures Using a Neural Network

Presenter: Eric Simon, UCAR / NRL-Monterey
Authors: Eric Simon, Steve Swadley

Spurious anomalies and radio frequency interference appear with some regularity in the SSMIS K-band brightness temperature data. Various images of known incidents show that some involve just one or a few isolated scenes, some appear as narrow streaks spanning several scans, and others are larger clusters that appear regularly in specific geographic areas. Radiative transfer models can be used to find scenes where brightness temperatures differ from a background model, but it would be computationally prohibitive

to employ this on a long history of data. Instead, we identified possible incidents using observed brightness temperatures which are classified as excessively high or low, as well as abnormally large departures from surrounding scenes. This technique found more than 16,000 suspected incidents from 2004-2018. Upon review, many of these were the result of temporary instrument calibration issues which we did not want to focus on, yet filtering these out using conventional methods proved challenging. So to identify the incidents a Convolutional Neural Network was trained on a random subset of manually labeled incidents, which had some initial success. Next by using uncertainty sampling, or taking the incidents of which the neural network was the least certain, the neural network was further trained, resulting in a much improved performance. Reapplying this model to the 16,000 incidents the model identified 12,000 incidents not related to calibration issues. To explain the anomalous incidents, a variety of possible trends or correlations were considered, including time of day, season of the year, satellite number, multi-year trend, look angle, and geographic region. While many of these proved insignificant, nearly all incidents exhibit look angle dependency. Additionally some locations had a multi-year trend, or persisted for multiple years but not over the whole record. Analysis based on look angle and multi-year trend offers evidence for possible causes of and relationships between some incidents, but also raises additional questions. Insights to potential causes will be presented and discussed in this study as well as the applicability to other sensors and platforms.

Session 2: Calibration, Validation (oral presentations)

2.01 IASI on-board METOP-C: instrument status L1 calibration/validation results

Presenter: Laura Le Barbier, CNES
Authors: Laura Le Barbier, Jordi Chinaud, Elsa Jacquette, Claire Maraldi, Laurence Buffet, Olivier Vandermarcq, Clémence Pierangelo, Antoine Penquer, Rémi Braun, Bernard Tournier, Anais Vincensini, Océane Lasserre, Yannick Kangah, Bernard Delatte

IASI (Infrared Atmospheric Sounding Interferometer) is a key payload instrument on-board METOP satellites. It has been developed by CNES with Thales Alenia Space as industrial prime contractor, in the framework of a cooperation agreement with EUMETSAT. Three identical IASI flight models were built. The first two ones, launched on-board Metop-A and Metop-B respectively in 2006 and 2012, have been fully operational. The last instrument, was launched on-board Metop-C the 7th of November 2018 from Kourou.

The L1 Calibration/Validation (Cal/Val) activities consist mainly in the characterization of the instrument performance and the tuning of level 0 and level 1 processing parameters. IASI-C L1 Cal/Val was performed from December 2018 to June 2019. It involved the IASI Center of Expertise in CNES Toulouse with the support of EUMETSAT for the operations. The full dissemination of L1 products by EUMETSAT dedicated to numerical weather prediction, atmospheric chemistry monitoring and climate studies, started then.

In this presentation, we will give a status of IASI-C instrument and illustrate the high level of quality of L1 data reached at the end of the Cal/Val in the radiometric, spectral and geometric domains.

2.02 EUMETSAT Activities for IASI-C Commissioning

Presenter: Dorothée Coppens, EUMETSAT (for Stephanie Guedj)
Authors: Stéphanie Guedj, Mayte Vasquez and Dorothée Coppens

The Infrared Atmospheric Sounding Interferometer on board Metop C (IASI-C) delivered its first spectrum on the 12/12/2019. With IASI being fully activated and in good health, the calibration and validation (Cal/Val) phases, also called the commissioning phase has been started. EUMETSAT is working together with the CNES/TEC to provide 1) a detailed performance characterisation with regard to the mission requirements, 2) an evaluation/validation of the measurement with independent instruments and 3) a tuning of the on board/ground data processing parameters.

As part of the cooperation, EUMETSAT is generating daily reports to insure the operational monitoring of IASI-C level 0 and level 1 products. It includes a wide range of information such as the instrument mode, data quality flags and gaps, housekeeping data and processing parameters related to spectral, radiometric and geometric calibration. Most of anomalies or changes along the full processing chain is reflected and characterized in these reports. Results are permanently discussed with CNES/TEC and a selection is presented in the poster.

In addition, EUMETSAT is providing rigorous statistics on inter-pixels comparison (in term of NeDT), and on the so-called OBS minus CALC. In the latter, OBServed radiances are compared with CALCulated radiances that use the RTTOV radiative transfer model and ECMWF atmospheric profiles as input. Moreover, tools have been developed to compute radiances massive average allowing the comparison between IASI-A, -B, -C and other independent instruments such as CrIS, HIRAS or even AVHRR.

As part of the Cal/Val, EUMETSAT is also analysing some valuable feedback from a selection of user partners (ECMWF, Météo-France, Met-Office, LMD, NOAA …) that will benefit from the Early Dissemination of IASI-C, probably around mid-March 2019. The fully operational dissemination of IASI-C data will start at the end of the Cal/Val activities, most likely around June 2019.

2.03 Studies of the CrIS Noise and Calibration Covariances

Presenter: David Tobin, CIMSS/SSEC/UW-Madison
Authors: David Tobin, Joe Taylor

This poster will show results of investigations of CrIS observation covariance. This will include the CrIS sensor noise and its covariance based on analysis of large ensembles of internal calibration blackbody and deep space view data, including the effects of the calibration processing and user apodization. It will also include various contributions to the CrIS calibration uncertainty and its associated covariance computed for a range of atmospheric conditions. These (relatively small) contributions to "observation" error and covariance will be compared to noise and covariance estimates computed from large ensembles of colocated clear sky CrIS observations and clear sky calculated spectra, with a goal of estimating the additional contributions due to the RT model, undetected clouds, and model representation.

2.04 FY-3D HIRAS Radiometric Calibration and Accuracy Assessment

Presenter: Chunqiang Wu, CMA
Authors: Chunqiang Wu, Chengli Qi, Xiuqing Hu, Mingjian Gu, Tianhang Yang, Zhongdong Yang and Peng Zhang

The High-spectral Infrared Atmospheric Sounder (HIRAS) is a Fourier transform spectrometer onboard the fourth Polar-orbiting FengYun 3 satellite (FY-3D). The FY-3D HIRAS provides interferogram measurements of Earth view radiance spectra in three infrared spectral bands at 29 cross-track positions, each with a 2×2 array of Field Of Views (FOVs). The HIRAS level 1 radiance data covers the spectral bands from 650 cm-1 to 1135 cm-1 (Long-wave Band, LW), 1210 cm-1 to 1750 cm-1 (Mid-wave Band, MW), and 2155 cm-1 to 2550 cm-1 (Short-wave Band, SW) with a spectral resolution of 0.625 cm-1. The radiometric calibration algorithm and the methods of refining the nonlinearity and the polarization correction coefficients on orbit are summarized in this paper. The nonlinearity correction coefficients are derived by minimizing the spread of the responsivity functions derived from the measurements of the internal calibration target with varying temperatures. The polarization correction coefficients are derived from the cold space observations and the routine Earth scene measurements. The radiometric accuracy is assessed by comparing the HIRAS measurements to the collocated Cross-track Infrared Sounder (CrIS) observations and radiance simulations. The results show that, compared to CrIS, the radiometric differences are about 0.3 K and 0.7 K for the LW and MW bands, respectively, and 0.5 K for the CO absorption and window regions in the SW band. The consistency of the radiometric calibration among the four FOVs is estimated to be within 0.2 K for most of the spectral domain. Some remaining issues for the FY-3D HIRAS are also discussed.

2.05 Checking Beam Performance of HIRS and MHS With the Moon

Presenter: Martin Burgdorf, Universität Hamburg
Authors: Martin J. Burgdorf, Thomas G. Müller, Marc Prange, and Stefan A. Buehler

The time needed by the Moon to move through the deep space view of a microwave sounder depends on its beam size. We analysed several Moon intrusions from different instruments and calculated the FWHM of their beams for all channels with an accuracy of 0.02 degrees. Significant discrepancies of up to 20% were found to the values in reports from ground tests. We determined also the brightness temperature of the Moon in each channel and by combining these values with the beam sizes, we could put constraints on the beam efficiencies. Again we found disagreements, in this case of up to 4%, between our measurements and the results obtained on ground. We compare the brightness temperatures of the Moon between 89 and 190 GHz, calculated with our new, improved values for the beam performance, with the predictions by a widely used thermophysical model and demonstrate that it does not reproduce correctly the difference between waxing and waning Moon.

A similar investigation was carried out with appearances of the Moon in the deep space view of HIRS/2, /3, and /4 on various platforms. Different values for the diameters of the field-of-view of these instruments can be found in different documents, and we could rule out some of them on the basis of the brightness temperatures of the Moon they would imply. The size of the field-of-view of HIRS/4 differs among all satellites by less than 2 percent for channels operating in the thermal infrared.

Because of the high accuracy of the brightness temperature of the Moon that is achievable with meteorological research satellites in the thermal infrared and with microwaves, these measurements can provide unique constraints on models of the bulk composition of its regolith.

Session 2: Calibration, Validation (poster introductions)

2p.01 HIRAS on-orbit performance and future development

Presenter: Chengli Qi, National Satellite Meteorological Center
Authors: Chengli Qi

High spectral Infrared Atmospheric Sounder (HIRAS) is a Fourier Transform Michelson interferometer instrument, which is the first hyper spectral sounder in a series of Chinese FengYun 3(FY-3) polar orbit meteorological satellite and was launched on 15 November 2017. HIRAS provides infrared (IR) measurements of radiance spectra in three spectral bands: the long wave IR (LWIR) band from 650 to 1136 cm-1, middle wave IR (MWIR) band from 1210 to 1750 cm-1, and short wave IR (SWIR) band from 2155 to 2550 cm-1, with spectral resolution of 0.625cm-1. There are 29 steps scan observations in each scan line and with 2×2 field of views in each observation. HIRAS was in operational status at Jan, 2019. For operational L1 products, the radiance noise levels meet the specifications, the absolute spectral frequency biases are less than 3ppm for all the three bands, and spectral bias standard deviations are less than 3 ppm in the LWIR and MWIR bands and are about 3~5 ppm in the SWIR band. The radiometric calibration uncertainties were assessed by the comparisons of the radiance spectra between HIRAS and other IR hyper-spectral sensors on different satellites. The radiance differences of the cross-sensor comparisons are in general less than 0.3, 0.7 and 1.0 K in the LWIR, MWIR and SWIR bands, respectively. HIRAS is providing a wealth of data of high accuracy and resolution on atmospheric temperature and humidity with which to improve weather prediction, and also on various components of the atmosphere to further our understanding of atmospheric processes and the interactions between atmospheric chemistry, pollution and climate.

The third batch in FY-3 series consists of four satellites and HIRAS will fly on three of them, in which the first is FY-3E on an early-morning orbit with local time of descending node is around 6:00 A.M and plan to launch on 2020. The results from the orbit simulation and the observing system experiments (OSE) indicate that the early-morning orbit satellite together with the morning orbit and the afternoon orbit satellites can provide the initial meteorological field for the numerical weather prediction (NWP) model without any blank left on the global scale every 6 hours so that the forecast period and the forecast accuracy can be improved for both the hemispheric and the regional scales. In the new batch HIRAS will upgrade to HIRAS-II, with improvements in detectors from 2×2 change to 3×3, and the NEdT as well as calibration accuracy specifications are much improved.

2p.02 Radiometric and spectral intercomparison of IASI-C with other infrared sounders

Presenter: Jordi Chinaud, CNES
Authors: Jordi Chinaud, Laura Le Barbier, Claire Maraldi, Laurence Buffet, Antoine Penquer, Bernard Delatte, Jean-Christophe Calvel, Claire Baqué, Bernard Tournier, Yannick Kangah, Rémi Braun, Anaïs Vincensini, Olivier Vandermarcq, Stéphanie Guedj, Dorothée Coppens

IASI (Infrared Atmospheric Sounding Interferometer) has been developed by CNES with Thales Alenia Space as industrial prime contractor. It is a key payload instrument on Metop satellites, a series of three polar orbiting meteorological satellites which form the space segment component of the overall EUMETSAT Polar System. IASI-A and IASI-B have been operational for years. The third and last in-flight model, IASI-C, was launched on board Metop-C the 7th of November 2018 from Kourou.

IASI-C Calibration/Validation (CalVal) activities mainly took place at the IASI Center of Expertise in CNES Toulouse from December 2018 to June 2019. At the end of the CalVal, IASI-C spectra will officially be delivered to users worldwide for numerical weather prediction, atmospheric chemistry monitoring and climate studies.

We will detail how IASI-C radiometric and spectral performances have been validated against other sounders. In particular, the radiometric intercomparison of IASI-C with IASI-A, IASI-B, AIRS and CrIS-N20 using common observations, massive averaging of spectra, or double differences will be detailed. It demonstrates the very good calibration of IASI-C data, and confirms the fact that IASI sounders are a reference in the infrared domain.

2p.03 Latest Improvements for CrIS Sensor Data Records

Presenter: Yong Chen

Authors: Yong Chen, Denis Tremblay, Flavio Iturbide-Sanchez, Joe Taylor, Xin Jin, Mark Esplin, and Dave Tobin

The Cross-track Infrared Sounder (CrIS) on board the Suomi National Polar-Orbiting Partnership (S-NPP) Satellite and NOAA-20 have provided the hyperspectral infrared observations for profiling atmospheric temperature, moisture and greenhouse gases globally. CrIS is a well calibrated instrument through its excellent instrument design, well-conducted pre-launch and post-launch validations. The excellent performances of CrIS include noise below specification, high spectral and radiometric accuracy, high geolocation accuracy, as well as long-term stability. Previous studies demonstrated that the CrIS Sensor Data Records (SDRs) data not only meet calibration requirements, making it an exceptional asset for weather applications, but also very stable for climate applications. CrIS SDRs for S-NPP and NOAA-20 were declared to the validated status on February 20, 2014 and October 2, 2018, respectively. The operational CrIS SDR data quality is continuously being monitored and improved. Important algorithm improvements have been carried out recently, including the optimization of the spike detection and correction algorithm (operational implemented on October 3, 2018), optimization of the lunar intrusion detection algorithm (operational implemented on December 17, 2018), and the implementation of the polarization correction algorithm, which currently is in evaluation stage (planned operational implementation in later 2019). In this study, the improvements in the CrIS SDR data quality will be presented.

The specific areas of improvement to be covered in this work are as follows. 1) The spike detection and correction algorithm, which detects and corrects the interferograms hit by the high energy particles, and reduce the distorted earth view radiance spectra especially in the South Atlantic Anomaly (SAA) region. 2) The new lunar intrusion (LI) detection algorithm, which has the major purpose to remove the deep space (DS) spectra contaminated by lunar contribution in the calibration DS sliding window, and as a result to improve the quality of the ES radiances during lunar intrusion events. First, the new algorithm efficiently finds a contamination-free DS spectrum in the DS 30-scan calibration moving window to use as the reference spectrum. Second, based on the phase characteristics of the complex raw DS spectra during LI events, the lunar intrusion band-dependent thresholds were derived to effectively reject the contaminated DS spectra and make the valid DS window size consistent among the CrIS three bands. 3) The recently developed polarization correction algorithm, which is for correcting the calibration bias due to the instrument polarization effect for the earth radiances. Evaluation results show that polarization correction slightly reduces the brightness temperature difference between observation and simulation in numerical weather prediction models, makes the brightness temperature difference more symmetric around nadir FORs than without the correction. These improvements in the ES radiances will have positive impacts to the downstream users for profiling global atmospheric temperature, moisture, greenhouse gases as well as monitoring the climate trending.

2p.04 Implementation of a Polarization Correction for the Cross-track Infrared Sounder (CrIS) Sensor

Presenter: Joe Taylor, UW-SSEC

Authors: Joe K. Taylor, Henry E. Revercomb, David C. Tobin, Robert O. Knuteson, Michelle L. Feltz, Graeme Martin, Yong Chen, Flavio Iturbide

The potential for polarization errors contributing significantly to the uncertainty budget of infrared remote sounding sensors has been well recognized and documented, particularly due to polarization dependent scene select mirrors and grating based instruments. The issue is equally applicable to FTS based sensors.

Rotation of a scene select mirror is typically used to direct calibration or scene radiance into a remote sensing instrument. The CrIS sensor utilizes a “barrel-roll” scene select mirror that rotates about an axis that is 45° from the mirror normal, preserving the angle of incidence at the mirror and optical axis for all calibration and scene views.

It is well known that the reflection on an inclined surface will always induce some polarization. As a

first order effect, the polarization induced by the 45° scene select mirror will be constant for all scene select mirror rotation angles, since the incident angle at the scene mirror is constant regardless of rotation angle. Secondly, the polarization induced by the other components in the instrument optical chain, including the interferometer and aft-optics, is not dependent on the position of the 45° scene mirror, and is constant for all scene mirror positions. However, the plane of reflection at the scene mirror rotates with the scene mirror rotation, and it is reasonable to assume that the instrument itself will have polarization sensitivity. As a result, it can be assumed that the rotation of the reflection plane at the scene mirror will create a modulation of the signal measured at the detector. Early analysis, which only included transmission effects, prior to the launch of SNPP CrIS indicated that this was not expected to be a significant effect for CrIS. However, when the polarized emission from the scene mirror is included in the analysis, the effect becomes non-negligible for cold scenes and a correction is warranted.

A polarization correction will be added to both the NOAA and NASA CrIS processing in 2019. The model for the polarization induced calibration bias and the associated correction is presented for the CrIS instrument, along with details of the model parameter determination, and the impact of the correction on the calibrated radiances for a range of scene temperatures and types.

2p.05 Progress of the Metop-C AMSU-A Lunar Contamination Correction Algorithm at NOAA/STAR

Presenter: Junye Chen, GST
Authors: Junye Chen and Banghua Yan

The European MetOp-C satellite, launched on November 7th, 2018, carries the last one of the Advanced Microwave Sounding Unit (AMSU-A) instruments on-board a series of Polar Orbiting Environmental Satellites (POES), including NOAA-15, 16, 17, 18, 19, MetOp-A, B, C. NOAA/STAR undertakes the major cal/val work for the US instruments on-board MetOp-C, including AMSU-A. The Lunar Contamination Correction is one of the most challenging tasks in the MetOp-C AMSU-A cal/val activities.

Originally, the AMSU-A Lunar Contamination Correction algorithm was developed by Kigawa and Mo (2002), and was implemented in the NOAA AMSU-A L1-B operation system. As a calibration effort for the MetOp-C AMSU-A, the lunar contamination correction algorithm has been revisited and advanced. In this presentation, we will comprehensively review the Lunar Contamination Correction process, the algorithm improvement, and the pre-launch and post launch coefficients estimation. Emphasis will be put on the derivation of the Lunar coefficients in pre-launch phase based on antenna pattern data and in post-launch phase based on time series of deep space cold counts when lunar contamination happens. Corresponding validation and comparison of the Lunar Contamination Correction results between those based on the pre-launch coefficients and the post-launch coefficients will illustrate the big improvement from the post-launch calibration work.

2p.06 The common re-calibration technology for long-term FY-3 microwave sounding data

Presenter: Gu Songyan, National Satellite Meteorology Center, CMA
Authors: GU Songyan, Wang Zhenzhan, Zhang Shengwei, Guo Yang, He Jieying

The microwave atmospheric sounding payloads of Fengyun 3 series satellite have been gave us 11 years database. The common technology of microwave sounding history data re-calibration will break through the key technologies such as composite analysis of microwave payload channel decay, multi-payload space-time and spectrum matching, the changing trend of calibration parameters and its physical mechanism of response, and the fine re-calibration of microwave historical data of long time series satellites. We will break through the coupling analysis of microwave load on-orbit antenna-feed system and the reconstruction technology of radiometer system's non-linear response, establishing the full-link and dynamic response model of microwave radiometer on-orbit and the evolution model of on-orbit time-varying characteristics, developing the reference transfer model based on cosmic background microwave radiation, and realizing multi-satellite radiation reference with SNO Technology Based on the reanalysis data.

2p.07 Status of S-NPP/CrIS SDR Product After the Loss of the MWIR Band

Presenter: Yong Chen, Global Science & Technology, Inc, NOAA/STAR (for Flavio Iturbide-Sanchez)
Authors: Flavio Iturbide-Sanchez, Yong Chen, Dave Johnson, Dave Tobin, Larrabee Strow, Lawrence Suwinski, Clayton Buttles, Joe Predina, Denis Tremblay, Warren Porter, Xin Jin and Banghua Yan

On March 26, 2019, the Joint Polar Satellite System (JPSS) Interface Data Processing Segment (IDPS) stopped producing the operational Suomi

National Polar-orbiting Partnership (SNPP) Cross-track Infrared Sounder (CrIS) Sensor Data Record (SDR) product, due to an identified anomaly on the Mid-wave (MW) Infra-Red (MWIR) band. The CrIS SDR product is a JPSS Key Performance Parameter (KPP) Data presently being assimilated into Numerical Weather Prediction (NWP) models by weather forecast centers, including ECMWF and NCEP. The CrIS SDR data is critical for the derivation of global sounding data, including thermodynamic parameters, and trace gas species. The loss of the SNPP/CrIS MWIR band has represented the loss of SNPP products derived by the NOAA Unique Combined Atmospheric Processing System (NUCAPS), which is the official NOAA system retrieving vertical temperature, and water vapor profiles from the processing of CrIS and ATMS SDRs. After the MWIR anomaly, the CrIS SDR Team has been working to ensure that the Long-wave (LW) and Short-wave (SW) IR bands are operating nominal, and meeting the JPSS requirements. Anomaly investigation results have helped to identify a failure on the SNPP/CrIS MW Signal Processor (SP) circuit card assembly (CCA). The SNPP/CrIS instrument has been operating using Side-1 electronics since first science data was produced on January 18, 2012. Commanding the instrument to operate using the redundant Side-2 electronics has been identified as the main option to recover the MW band, with minimal risk. The results of performing the switch to Side-2 redundant circuitry will be reported as part of this work, as well as reporting the most up-to-date status of the quality of the SNPP/CrIS SDR science data.

Session 2: Calibration, Validation (oral presentations)

2.06 An assessment of data from the GIIRS instrument

Presenter: Chris Burrows, ECMWF
Authors: Chris Burrows, Tony McNally, Marco Matricardi, Reima Eresmaa

GIIRS is a hyperspectral infrared sounder which is carried on the Chinese satellite FY-4A, and is the first instrument of its kind on a geostationary platform. Therefore, it is a precursor to IRS which will be part of the Meteosat Third Generation series. Full-resolution spectral data from GIIRS became available in January 2019, and this presentation will describe the results of the subsequent work of analysing these data, in particular, comparing the observations with simulations based on ECMWF model fields. Before these data can be assimilated, it is necessary to perform a careful assessment of the data, and consider aspects such as quality control, cloud and aerosol detection, channel selection etc. and the status of these assessments will be presented here.

2.07 Retrospective Calibration of Historical Chinese Fengyun Satellite Data

Presenter: Peng Zhang, National Satellite Meteorological Center
Authors: Peng Zhang, Xiuqing Hu, Songyang Gu, Lin Sun, Na Xu, Lin Chen

The first Chinese meteorological satellite was launched in 1988. So far, the Chinese meteorological satellite has been continuously observed for nearly 30 years. Satellite replacement and on-board sensors upgrade make the old and new observation data uneven in terms of accuracy, stability and consistency, and can not meet the basic needs of long-term sequence climate and environmental change research.

To enhance the capability on the space-based essential climate variable (ECV), a new National Key Research&Development Program of China was funded since 2018 to re-calibrate the historical Chinese Earth Observation satellite data including the Chinese Fengyun Meteorological Satellites (FY), the Chinese Haiyang Oceanic Satellites (HY), and the Chinese Ziyuan Resource Satellites (ZY).

In this paper, the progress on the re-calibrating the 30-years' historical Chinese FY satellites will be introduced. The historical Chinese FY satellites include thirteen meteorological satellites (FY-1A, FY-1B, FY-1C, FY-1D, FY-2A, FY-2B, FY-2C, FY-2D, FY-2E, FY-2G, FY-3A, FY-3B and FY-3C) and seven varieties on-boarded instruments (VIRR, VISSR, MERSI, IRAS, MWTS, MWHS and MWRI). The vicarious China radiance calibration site (CRCS) calibration, the pseudo invariant calibration sites (PICS) calibration, the deep convective clouds (DCC) calibration, and the lunar calibration have been considered in the procedure of the re-calibration for solar reflectance bands. New on-board calibrator models will be built for infrared and microwave bands re-calibration. In addition, some initial results for the re-calibration will be reported in this paper.

Session 2: Calibration, Validation (poster introductions)

2p.08 NOAA-20 CALIBRATION/VALIDATION AND ALGORITHMS IMPROVEMENTS

Presenter: Lihang Zhou, NOAA/NESDIS/STAR
Authors: L. Zhou, M. Goldberg, M. Divacarla, X. Liu, T, Atkins, and S. Kalluri

The successful launch of the Joint Polar Satellite System (JPSS) -1 (JPSS-1, now named as NOAA-20) is providing an array of atmospheric, land, and ocean data products from four major instruments: The Visible Infrared Imaging Radiometer Suite (VIIRS), the Cross-track Infrared Sounder (CrIS), the Advanced Technology Microwave Sounder (ATMS), and the Ozone Mapping and Profiler Suite (OMPS). These instruments are similar to the instruments currently operating on the Suomi National Polar-orbiting Partnership (S-NPP) satellite. Accounting to the lessons learned through S-NPP product Cal/Val and based on the characterization of the NOAA-20 instruments, the JPSS science teams have developed necessary algorithm upgrades for NOAA-20 algorithms. The science teams have also been performing the NOAA-20 Cal/Val through the Early Orbit Checkout (EOC), Intensive Cal/Val (ICV), and Long-Term Monitoring (LTM) phases according to the Cal Val plans. The Integrated Calibration and Validation System (ICVS), and the S-NPP Long Term Monitoring System (LTM) developed for S-NPP have been upgraded to the NOAA- 20 for spacecraft/sensor health and satellite product display/monitoring, respectively. The JPSS science teams have completed the transition of the science algorithms to the Enterprise Algorithms, which use the same scientific methodology and software base to create the same classification of product from differing input data.

In this paper, we present an update of the NOAA-20 and SNPP Cal/Val and an overview of the algorithms' improvements for the NOAA-20 data products. In addition, the operational implementation statuses of JPSS enterprise algorithms for product generation and science data product reprocessing are also going to be briefed.

2p.09 Evaluation of using measured SRFs in the radiative transfer for microwave sounders at ECMWF, UK Met Office, and DWD

Presenter: David Duncan, ECMWF
Authors: David Duncan, Emma Turner, Peter Weston, Niels Bormann, Robin Faulwetter, Christina Koepken-Watts

Measured spectral response functions (SRFs) have been gathered and implemented in RTTOV for some currently operational microwave sounders (ATMS, AMSU-A), with the goal of improving data usage by utilising more accurate radiative transfer modelling in the assimilation. The effect of using these updated SRFs, in contrast with previous 'top hat' SRFs, is assessed in the data assimilation systems of three NWP centres: ECMWF, UK Met Office, and DWD. Results are shown in terms of O-B (observed minus background) and bias correction statistics for the three centres and compared between sensors. Comparison of the statistics from different centres provides a measure of the influence of bias in the background fields in this assessment. While most SRF changes are not drastic, the impacts on simulated radiances at upper tropospheric and stratospheric channels are significant. The resulting changes in assimilation trials can be evaluated using other observations with sensitivity in the upper atmosphere such as GPS-RO, hyperspectral IR, and radiosondes.

2p.10 NOAA-20 CrIS Noise Assessment

Presenter: Yong Chen, NOAA/GST (for Denis Tremblay)
Authors: Denis Tremblay, Yong Chen, Flavio Iturbide-Sanchez, Xin Jin, Erin Lynch

This work reports on the on-orbit performance of the CrossTrack Infrared Sounder (CrIS) that is currently flying on-board the NOAA-20 satellite that was launched into orbit on November 18th 2017. The noise equivalent differential radiance (NEdN) is one component of the CrIS instrumental performance. The operational algorithm estimates the NEdN by taking into account the calibration measurements of the internal calibration target (ICT) and the deep space (DS) views only. The ICT radiance is calculated over the sliding window, that contains 30 scans, and the NEdN is estimated by calculation the standard deviation at each frequency bins. The NEdN meet the requirements with margin to the exception of MWIR FOV9 which is borderline. An alternative noise calculation methodology uses the Principal Component Analysis (PCA) that uses only Earth scene views. The results shows that the operational NEdN is underestimated for LWIR FOV5 by 30%. The NEdN is higher for hot Earth scene compared with the operational NEdN by up to 50%. The full covariance matrix calculated with PCA shows correlated noise for off-diagonal frequencies due to the instrument line shape effects. Moreover, correlated noise was found at the 668 cm-1 frequency.

Accurate noise estimates is very important for downstream products. It is used as weighting function of the various channels that are assimilated into the weather forecasting system and the retrieval of trace gases.

2p.11 Calibration of NOAA-20 ATMS
Presenter: Quanhua (Mark) Liu

2p.12 NOAA-JPSS dedicated radiosonde database in support of satellite data calibration/validation
Presenter: Bomin Sun
Authors: Bomin Sun, Anthony Reale, Cheng-Zhi Zou, Xavier Calbet, Manik Bali, and Ryan Smith
The Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN) is a reference observing network designed to provide fully characterized data records for upper-air climate change detection. A concerted effort to utilize GRUAN to supplement the Global Space-based Inter-Calibration System (GSICS) in the monitoring and assessment of environmental satellite sensors was initiated at the GSICS Annual meeting in 2017. Those sensors include the Cross-track Infrared Sounder (CrIS), the Infrared Atmospheric Sounding Interferometer (IASI), the High-resolution Radiation Sounder (HIRS), the Advanced Technology Microwave Sounder (ATMS) and the Advanced Microwave Sounding Unit (AMSU).

In this work, the feasibility of using GRUAN observations to monitor satellite sensor data are explored in two areas. One is to compare the GRUAN temperature observations with polar satellite microwave data in trends and inter-annual variability. The satellite microwave dataset includes calibrated fundamental Climate Data Records (FCDRs) generated by NOAA Center for Satellite Applications and Research (STAR). The second is to understand the consistency of GRUAN radiosonde humidity observations with satellite water vapor sensitive sensor data. This is achieved by using Radiative Transfer Model (RTM) simulation to convert GRUAN atmospheric profiles into the radiance space for comparison with collocated hyperspectral infrared sensor data. Collocation uncertainty and uncertainty in satellite sensor, GRUAN and RT model are taken into account in the assessment.

This work supports GSICS and GRUAN objectives to monitor microwave and infrared sensors from space based platforms including the determination of absolute accuracy of the sensors.

Session 3: NWP Centre Reports (poster introductions)

3p.01 Recent updates to the ECCC Global and Regional Prediction Systems
Presenter: Alain Beaulne, ECCC
Authors: A. Beaulne, J. St-James, S. Laroche, S. Heilliette, I. Mati, S. Macpherson, M. Reszka, E. Lapalme, T. Milewski, M. Deshaies-Jacques, L. Garand
Observations from recently-launched geostationary and polar-orbiting satellites are assessed in preparation for operational implementation in ECCC (Environment and Climate Change Canada) global and regional prediction systems. More specifically, from the GOES-R series, GOES17 AMVs (Atmospheric Motion Vector) replace those from GOES15 and CSRs (Clear Sky radiance) from the three water vapour (WV) sensitive channels of GOES16 are added. Likewise, the evaluation includes observations from instruments on board the JPSS (Joint Polar Satellite System) NOAA20 satellite, in particular AMVs retrieved from VIIRS (Visible Infrared Imaging Radiometer Suite), radiances from ATMS (Advanced Technology Microwave Sounder) as well as the CrIS (Cross-track Infrared Sounder) FSR (Full Spectral Resolution) product. As for the SNPP (Suomi National Polar-orbiting Partnership) satellite, radiances from the CrIS FSR product are also considered for operational implementation as a replacement for the NSR (Nominal Spectral Resolution) product. Marine wind vectors retrieved from the ASCAT (Advanced Scatterometer) instrument on board the last satellite in the EUMETSAT (European Organisation of the Exploitation of Meteorological Satellites) Polar System programme, MetOp-C, are also examined. In addition, ground-based GPS (Global Positioning System) measurements of zenith total delay (ZTD) from the U.S. SuomiNet network provided by the University Corporation for Atmospheric Research (UCAR) are evaluated as a replacement for the previously-received NOAA observations. Cumulative effects of the above observations are assessed by examining observation-minus-background errors, as well as forecast scores against both radiosonde observations and analyses.

3p.02 Overview of radiance data assimilation developments at DWD since ITSC-21

Presenter: Christina Köpken-Watts, DWD
Authors: Ch. Köpken-Watts, R. Faulwetter, O. Stiller, A. Walter, S. May, M. Pondrom, K. Raykova, R. Potthast

This overview poster describes the upgrades to DWD's operational global ICON and hybrid ensemble based EnVar data assimilation system introduced over the last two years in the field of satellite radiance assimilation.

A particular focus of the last years was on using humidity sensitive radiances which could never be assimilated with benefit in the previous NWP system. Now, all current operational instruments, IR and MW humidity sounders as well as MW imagers have been technically implemented. After extensive testing, IR humidity channels from the hyperspectral IASI, and the geostationary imagers SEVIRI, GOES, AHI, ABI, as well as from the MW sounder channels from MHS, ATMS, SSMIS, GMI have been introduced operationally with a sound positive impact. Tests with MWHS-2 are ongoing and MW imagers are currently used for validation with assimilation tests about to start.

Further upgrades addressed a retuning of the horizontal thinning for several instruments, the introduction of full observation error covariance matrices and an update of cloud-screening for IASI. The new NOAA-20 and METOP-C instruments have been evaluated and results from recent data impact experiments addressing the impact of broad data categories are shown. A last section will briefly present ongoing developments that are not described in other conference contributions, e.g. concerning the retrieval of emissivity for IR and MW to enhance data usage over land.

3p.03 Progress and plans for the use of radiance data in the NCEP global and regional data assimilation systems

Presenter: Andrew Collard, IMSG@NOAA/NCEP/EMC
Authors: Andrew Collard, Yanqiu Zhu, Haixia Liu, Emily Liu, Kristen Bathmann, Li Bi, Russ Treadon, Jim Jung, Daryl Kleist, Catherine Thomas, Xu Li, Xiaoyan Zhang and Erin Jones

Since the last International TOVS Study Conference in December 2017, there has been one major operational upgrades to the data assimilation system at NCEP (in June 2019). This upgrade was primarily to replace the spectral dynamical core of the forecast model with the Finite Volume Cubed-Sphere (FV3) core developed by the NOAA Geophysical Fluid Dynamics Laboratory (GFDL).

The most significant data assimilation advances in this period were:

1. Upgrade ATMS to assimilate radiances in all-sky conditions
2. Include IASI humidity channels
3. Use full spectral resolution (FSR) data for CrIS including the use of humidity channels
4. Add the use if Saphir and Meteosat-11 SEVIRI radiances
   Assimilate radiances from AMSU-A, MHS and IASI on MetOp-C

The next scheduled upgrade to the Global Forecast System is in January 2021 which will be focussed on increasing the number of model levels from 64 to 127, but will include DA upgrades such as the introduction of spectrally correlated observation errors and improved use of cloudy radiances.

3p.04 NCMRWF NWP Status

Presenter: S Indira Rani, NCMRWF
Authors: S. Indira Rani, John P. George, V. S. Prasad, Sumit Kumar, Bushair M.T., Buddhi P Jangid, A Lodh, Gibies George, and E.N. Rajagopal

The NCMRWF NWP Systems are used for both operational and research purposes. NCMRWF is the Analysis centre for National Weather Service, IMD. Recently updated the assimilation and forecast system and included radiances from state of the art meteorological satellites.

3p.05 Recent changes in the use of passive sounding data in the ECMWF NWP system

Presenter: Niels Bormann, ECMWF
Authors: Niels Bormann, Stephen English, Mohamed Dahoui, Phil Browne, Massimo Bonavita, Chris Burrows, David Duncan, Reima Eresmaa, Alan Geer, Elias Holm, Heather Lawrence, Peter Lean, Katrin Lonitz, Cristina Lupu, Marco Matricardi, Tony McNally, Kirsti Salonen, P Weston

The poster gives an overview of the status of the assimilation of passive sounding data, and highlights recent relevant changes in the ECMWF NWP system. At the time of writing, ECMWF assimilate radiance observations from 20 MW instruments, 5 hyperspectral IR sounders, and 5 geostationary satellites. Additions since ITSC-21 have been NOAA-20, Metop-C, as well as GOES-16 and Meteosat-11.

There have been two major system upgrades since ITSC-21, cycles 45r1 (5 June 2018) and cycle 46r1 (11 June 2019). Key changes for the use of IR sounder data have been the assimilation of non-surface-sensitive infra-red (IR) channels over land

(45r1), a substantial increase in the number of assimilated WV channels for IASI (46r1), updates to the aerosol detection (46r1), as well as an overhaul of the assimilation of geostationary radiances (extended disk, slant-path, correlated observation error, 46r1). Highlights for MW radiances cover inter-channel observation error correlations for ATMS (46r1), activation of constrained variational bias correction for the top-most temperature-sounding channel on AMSU-A and ATMS (45r1), update of the permittivity model in RTTOV-SCAT (46r1), and the addition of SSMIS-F17 150h GHz and GMI 166 v/h GHz channels (46r1). In addition, the RTTOV radiative transfer model has been updated to version 12 (in 45r1) and 12.2 (in 46r1), together with an update to the MW coefficient files.

Cycle 46r1 also saw the introduction of continuous data assimilation, a major reconfiguration of our data assimilation suite that allows us to assimilate more observations and increases the benefit of observations with short timeliness. Other relevant data assimilation changes include a move to 50 members in the Ensemble of Data Assimilations (EDA) which allows a better estimation of background errors, as well as the introduction of weakly coupled data assimilation for sea-surface temperature in the tropics, continuing the trend towards more coupling in data assimilation and a wider Earth System approach.

3p.06 Ongoing developments on satellite radiance assimilation at Météo-France

Presenter: Nadia Fourrié, CNRM Meteo-France and CNRS
Authors: N Fourrié, Ph Chambon, V. Guidard, O Coopmann, Z Sassi, P Moll, D Raspaud and JF Mahfouf

A large part of assimilated observations in the global model of Météo-France ARPEGE come from satellites radiances (mostly on polar orbiting satellites). Satellite radiances are also assimilated in the meso-scale model AROME-France but represent a smaller fraction of observations with a dominance of MSG SEVIRI. This poster intends to give an overview of the radiance usage in the French Numerical Weather Prediction models and the status of the current developments. The relative weight of each radiance type will be given in terms of degrees of signal for Freedomand the summary of recent changes in data usage in the future 2019 operational suite will be presented.

Among the various developments, highlights will be given on the use of observation error cross-correlations for infrared hyperspectral radiances from IASI and CrIS, the use of the surface temperature retrieval for the assimilation of IASI radiances over continents, the assimilation of 5 ozone IASI channels in the global model, the assimilation of all-sky SAPHIR and MHS microwave radiances.

3p.07 Recent upgrades in the use of satellite radiance observations within the Met Office global NWP system

Presenter: Chawn Harlow, Met Office
Authors: Chawn Harlow, Brett Candy, Nigel Atkinson, James Cameron, Fabien Carminati, Amy Doherty, Stephan Havemann, Stefano Migliorini, Stuart Newman, Ed Pavelin, David Rundle, Andy Smith, Fiona Smith, Laura Stewart, Ruth Taylor, Michael Thurlow, Simon Thompson

Improvements in the assimilation of satellite radiance observations have led to significant performance gains in the Met Office global model over the last two years. Upgrades in the treatment of satellite radiance data have occurred at model upgrades PS40 (Feb 2018), PS41 (Sep 2018), PS42 (Mar 2019) and PS43 (anticipated Nov 2019). Highlights of these upgrades include the following:

- Significant increase in the use of AMSU-A Channels 4 and 5 due to all skies assimilation efforts. This required development of an error model for liquid water effects on radiances in these channels. Retrievals of cloud liquid water are used within the Observation Processing System (OPS) to inflate the error on these channels used in assimilation.
- Upgrade from RTTOV-11 to RTTOV-12. This included the capability to treat scattering due to cloud and precipitation in the microwave via RTTOV-SCATT which is important for future development of the assimilation of 183 GHz humidity sounding data. Interfaces with HT-FRTC and PC-RTTOV were provided to enable trialling of their schemes based on principal components.
- Use of RTTOV-12 on 70 model levels instead of 43 coefficient levels. This eliminates the need to interpolate between coefficient levels and model levels within the assimilation system and provides a more consistent treatment of model fields therein.
- Novel developments in the treatment of microwave humidity sounding data over land. This required better techniques for detecting cloud over heterogeneous land surfaces and the development of a 1dvar

retrieval scheme for land emissivities within OPS.

- Introduction of new instruments including two new microwave imagers FY-3C MWRI and GPM GMI and the instruments on NOAA-20: the microwave sounder ATMS and the hyperspectral IR sounder CrIS. These instruments provide redundancy to previous instrumental systems as well as giving better spatial and temporal coverage.
- Improved quality control for cloud screening was applied to GMI, AMSR, and MWRI, based a test on the background departure at 36H plus a new one based on anomaly difference between 36 and 89 GHz.
- Assimilation of geostationary clear-sky radiances from GOES-16 ABI. Replacement for GOES-13 allows continuity of these geostationary measurements on the eastern seaboard of the US as well as added value due to seven additional channels.

These upgrades were in addition to upgrades to the assimilation of products such as AMV's, scatterometer and Radio Occultation. There were also upgrades elsewhere in the NWP system including updates to the model as well as the data assimilation scheme. The land surface scheme was upgraded to GL8 which included a new multi-layer snow scheme and improved surface drag. The data assimilation upgrades included hourly cycling of background fields in 4DVar in order to obtain a more timely first guess. There was also an ensemble upgrade which yielded better information about the background covariances which had a positive impact on the assimilation.

This poster will focus on the improvement of satellite data processing and assimilation during this period.

3p.08 Satellite radiance assimilation at the Bureau of Meteorology

Presenter: Fiona Smith, Bureau of Meteorology
Authors: Fiona Smith, Jim Fraser, David Howard, Jin Lee, Leon Majewski, Susan Rennie, Andrew Smith, Peter Steinle, Chris Tingwell, Yi Xiao

The Bureau of Meteorology operates a global model, six city-scale models and a relocatable tropical cyclone model. By 2020, all of these models will include data assimilation incorporating satellite radiance data. This poster will provide an update on these systems relative to the last conference.

Satellite radiance data continue to provide significant impact in our forecast system. Our global configuration assimilates brightness temperatures from ATOVS, IASI, ATMS, CrIS, AIRS, and from 2019 we have added AMSR-2 and Himawari-8. We are currently working on the addition of all-sky microwave data assimilation, in line with the Met Office scheme. The six capital-city convective-scale model configurations and the new TC model use data from ATOVS, IASI, ATMS, CrIS and AIRS, from both global and direct readout sources. In the near future we hope to add brightness temperatures and 'GeoCloud' retrievals from Himawari to the city systems.

3p.09 Recent upgrades of satellite radiance data assimilation at JMA

Presenter: Norio Kamekawa, Japan Meteorological Agency
Authors: Norio Kamekawa, Hidehiko Murata, Masahiro Kazumori, Izumi Okabe

This poster overviews recent upgrades of satellite radiance data assimilation into the numerical weather prediction (NWP) system at the Japan Meteorological Agency (JMA) since the last ITSC-21 in November 2017.

JMA began to assimilate surface-sensitive clear-sky radiance (CSR) data from Himawari-8 for areas over land and Meteosat Second Generation (MSG) data for areas over land and oceans into its global NWP system on October 18 2018. In order to assimilate surface-sensitive CSR data for areas over land, a new radiative transfer calculation method involving the use of data from the Wisconsin University land surface emissivity atlas and land surface temperatures retrieved from window-channel CSR observation data was developed.

JMA also began to assimilate surface-sensitive CSR data from Himawari-8 into its mesoscale NWP system covering Japan and its surrounding areas on March 26 2019, and the new radiative transfer calculation method used in its global NWP system was applied.

JMA has assimilated radiance data from the Advanced Technology Microwave Sounder (ATMS) and Cross-track Infrared Sounder (CrIS) onboard NOAA-20 into its global NWP system following those of Suomi-NPP since 5 March 2019. NOAA-20 data quality is similar to or better than that of Suomi-NPP, and the additional use of NOAA-20 data improved the first-guess and forecast fields.

The Suomi-NPP/CrIS radiance data was switched from NSR (Normal Spectral Resolution) to FSR (Full Spectral Resolution). ATMS and CrIS radiance data delivered from Direct Broadcast Network (DBNet) have been added to the Early Analysis of global NWP system (cut-off time 2h20m) and the available data are increased.

In future plan, GOES-16 CSR data, all-sky microwave radiance data, and ATOVS data on Metop-C will be incorporated in the JMA operational global data assimilation system in this year.

3p.10 Overview of Satellite Radiance Data Assimilation in NCEP FV3 Regional System

Presenter: Xiaoyan Zhang
Authors: Xiaoyan Zhang, Haixia Liu, Andrew Collard and Jacob Carley

NOAA's next generation Numerical Weather Prediction systems are based on the concept of unifying around the Finite Volume Cubed-Sphere (FV3) dynamical core. The FV3 is used for global NWP and will be for convective-scale applications as well. For convective-scale NWP a limited area version of the FV3 dynamic core is used and is known as the Stand Alone Regional (FV3-SAR). This limited area configuration is poised to underpin the rapidly updated, convection allowing ensemble system in the NCEP production suite as the Rapid Refresh Forecast System (RRFS) in the 2022-2023 timeframe.

The early phase of testing and development with the 3 km FV3-SAR leverages a configuration similar to the current operational 3 km NAM CONUS nest which features a 6-hour long assimilation cycle, with hourly forecast/analysis components, ending with a free forecast. The assimilation is conducted using a hybrid 3DEnVar method. The current developmental system assimilates the same satellite radiances as is done with the operational NAM, which features radiances from the following instruments onboard polar orbiting satellites: AMSUA, MHS, IASI, AIRS, and CRIS/. The performance of these satellite radiance data assimilation will be evaluated in the new FV3-SAR configuration.

However, observations that feature continuous, low-latency coverage over a high-resolution limited area CONUS domain are of particular importance in the emerging RRFS framework. Therefore radiances from the newest generation of GOES stand to be particularly valuable and hence this work also examines the assimilation of GOES-16 radiance data. The new-generation GOES-16 geostationary meteorological satellite was successfully launched on November 19, 2016. GOES-16 carries the Advanced Baseline Imager (ABI) which observes Earth with 16 different spectral bands, including two visible channels, four near-infrared channels, and ten infrared channels. GOES-16 provides coverage over a 1000x1000km box with a temporal resolution of 30 seconds, and spatial resolution of 0.5 to 2km. Notably, there is a significant improvement in spectral, spatial and temporal resolution, each of which has benefits for data assimilation. ABI Clear Sky Radiance (CSR) data produced from GOES-16 radiance observation have been distributed to the Numerical Weather Prediction (NWP) community by NOAA/NESDIS. CSR data are box-averages of 15x15 pixels containing information on tropospheric humidity under clear-sky condition. In this study, the impact of GOES-16 CSR data assimilation in NOAA's developmental, 3km FV3-SAR system will be investigated.

3p.11 Progress and plans for satellite data assimilation in KMA operational NWP system

Presenter: Eunhee Lee, KMA
Authors: Eunhee Lee, Hye-Young Kim, Youngsoon Jo, EunHee Kim, Mee-ja Kim, Yong-Hee Lee

The Korea Meteorological Administration (KMA) has recently introduced several upgrades to the use of satellite data in its Global Data Assimilation and Prediction System (GDAPS) based on Unified Model. Since the last ITSC, KMA has newly assimilated Himawari-8 CSR, MT-SAPHIR, GCOM-W1/AMSR2, FY-3C/MWHS-2, LEOGEO winds and GNSS-RO from TanDEM-X, TerraSAR-X, GRACE. MT-SAPHIR and AMSR2 data enhanced convective activities in middle and lower tropospheric layers over Tropics and they had an effect on increasing the initial specific humidity in the DA process. The impacts for global model showed slightly positive improvements in wind and humidity.

This year, the KMA has two important issues. One is the introduction of a new Korean global numerical weather prediction (NWP) model, and the other is the use of the 2nd geostationary satellite of Korea, Geo-KOMPSAT-2A (GK-2A) was launched successfully in 5 Dec. 2018, in a NWP system.

The KMA has carried out a project to develop a Korean global NWP model in order to improve the prediction accuracy of the weather phenomenon on the Korean Peninsula and to ensure the identity of meteorological technology. Since the project is scheduled to end at the end of this year, KMA has put large effort into introducing the developed

Korean global NWP model as an operational model of KMA. KMA's new global model has its own data assimilation system using hybrid 4D-EnVar. The KMA has been dedicating to improve the satellite data assimilation system. The model including data assimilation system was developed for a limited period of 10 years. Therefore, much improvements and optimization is still needed. Current status and plans for this new system will be briefly introduced in ITSC-22.

The data of COMS, the first geostationary satellite of Korea, has been successfully assimilated in KMA NWP system. The GK-2A satellites will inherit the mission of COMS to observe the weather and strengthen the national capability to monitor the meteorological phenomena around the Korean Peninsula. The preliminary results from the assimilation of GK-2A CSR (Clear Sky Radiance) and AMV (Atmospheric Motion Vectors) data show a slightly positive impact on the middle and higher tropospheric humidity and wind fields, significant improvements are shown in Asia region. To make better use of the GK-2A data, quality control and data assimilation method has been investigated. The GK-2A data will be disseminated via GTS from the end of this year in near-real time.

Session 4: Assimilation of Geostationary Infrared Sensors (oral presentations)

4.01 Assimilation of Infrared Radiances from Geostationary Satellites at NCEP

Presenter: Haixia Liu, IMSG, NOAA/NCEP/EMC
Authors: Haixia Liu, Andrew Collard

Geostationary satellites provide high temporal and spatial resolution imagery of the Earth at visible and infrared wavelengths, however, due to their data volume being too large at their original pixel level, numerical weather prediction (NWP) centers usually assimilate Clear-Sky Radiance (CSR) or All-Sky Radiance (ASR) products in their global systems. National Centers for Environmental Prediction (NCEP) has been actively assimilating the CSR data from the SEVIRI two infrared water vapor channels. We started using the data from MSG10 in August 2013 and just switched recently to the CSR from MSG11. The CSR from MSG08 has been available but not been investigated yet. The CSR from the AHI on board of Himawari8 has been available but only monitored in the operation. Since last year, to help improve the algorithm to generate the CSR from ABI_GOES16, we have evaluated several versions of the ABI_GOES16 CSR data using our operational configuration. In this presentation, evaluation of these versions of the GOES-16 CSR data will be discussed. The CSR products from SEVIRI_M08, SEVIRI_M11, AHI_Himawari8 and ABI_GOES16 together form a good coverage in the tropical and middle-latitude regions. On June 12, 2019, NCEP has implemented the Global Forecast System (GFS) v15 which uses the Finite-Volume Cubed-Sphere (FV3) dynamical core and GFDL microphysics. We are going to evaluate these CSR data quality not only for the water vapor channels, but also the surface channels through studying the statistical characteristics of these data compared with the simulated model equivalence (OmF) using the newly-implemented GFS v15 model. The assimilation experiment will then be conducted using the CSR data from only the water vapor channels of all the above-mentioned instruments and results will be discussed.

In addition, the ASR data from ABI_GOES16 has been developed along with the CSR at the University of Wisconsin and will be disseminated at NOAA/NESDIS soon. Initially the baseline version of the ASR will be implemented in the NESDIS operational data stream, but the enterprise version is available for testing purpose. Both versions of ASR BUFR data will be briefly investigated and discussed in this presentation.

4.02 Research on assimilation of FY-4A AGRI radiance in GRAPES Global Forecast System

Presenter: Hao Wang, National Meteorological Center of CMA
Authors: Hao Wang

Information about moisture distribution is very import for nowcasting and forecasting. The Advanced Geosynchronous Radiation Imager (AGRI) on board the Chinese new stationary satellite FY-4A, the second generation of geostationary imager among global meteorological observation system. The AGRI on board FY-4A has 3 visible, 3 near-infrared, and 8 infrared channels, provides high temporal and spatial resolution moisture information that useful for NWPC. Now FY-4A AGRI radiance are assimilated in GRAPES_GFS and relevant assimilation techniques and approaches have been developed. The assimilation experiment are verified against NCEP analysis show positive impact on the vertical distribution of the root mean square error of the East Asian water vapor field. According to the anomaly correlation scores (ACC) of geopotential height, the assimilation experiment illustrate that the anomaly correlation scores of forecast 500-hPa geopotential heights are increased slightly in East Asian, significantly from day 1 to day 8.

Assimilation of FY-4A AGRI radiance data has a positive impact in GRAPES_GFS forecast.

4.03 Assimilation of geostationary water vapour clear sky radiances with an Ensemble Kalman Filter

Presenter: Marc Pondrom, Deutscher Wetterdienst
Authors: M. Pondrom, C. Köpken-Watts, A. Rhodin, R. Faulwetter

Water vapour radiances measured by satellite instruments not only contain information about the water vapour distribution in the atmosphere but also on the wind field through the displacement of the water vapour structures. This information can be exploited through the direct tracking of these movements, done e.g. in the derivation of so-called water vapour atmospheric motion vectors, but also in a data assimilation (DA) system. The impact of geostationary clear sky water vapour radiances (CSRs) of the Spinning Enhanced Visible Infra-Red Instrument (SEVIRI) on board Meteosat 8 and 10 on specific humidity, temperature and wind analyses and forecasts of the operational global ensemble variational assimilation system of the German Weather Service (DWD), has been investigated. This system consists of the global ICON model and an EnVar data assimilation using a 40 member LETKF (local ensemble transform kalman filter) to estimate the flow dependent background error covariance matrices. The study uses on the one hand a set of observing system experiments performed under idealised conditions with synthetic observations based on a model 'nature' run ("twin experiments"), and on the other hand impact experiments with real data. In both cases, the verification scores show that the assimilation of CSRs from the two water vapour (WV) channels at 6.25 and 7.35 μm improve the forecast skills not only for humidity but also for the dynamic variables, especially in the high and middle troposphere and in the region covered by MSG 1 and 3. The different results obtained from the idealised experiments show that the improvement is due to the interaction between specific humidity, temperature and wind through the model dynamics and physics during the forecast step as well as through the improved spatial correlations and cross-correlations between variables of the updated background error covariance matrix derived from the ensemble.

4.04 Impact of Geostationary Clear Sky radiances assimilation on the wind field over the Indian Ocean region

Presenter: M.T. Bushair, NCMRWF
Authors: M.T. Bushair; Buddhi Prakash Jangid; S. Indira Rani and John P. George

Meteosat second generation (MSG-2) satellite, Meteosat-8 was relocated to the Indian Ocean Data Coverage Service (IODC) location by replacing the MSG-1 satellite Meteosat-7 on 01 February 2017. This paper analyses the impact of SEVIRI Clear Sky Brightness Temperature (CSBT) in the NCMRWF Assimilation and Forecast System. The impact of Water vapor (WV) channel derived Clear Sky Brightness Temperature (CSBT) from geostationary satellites in the 4D variational (4D-VAR) assimilation systems are vivid in the humidity field. In the variational assimilation systems, the change in one variable cannot happen in isolation; the change in humidity field can affect both temperature and wind fields as well. This paper discusses a series of Observing Simulation Experiments (OSEs) analyzing the impact of the radiance from Spinning Enhanced Visible and Infra-Red Imager (SEVIRI) onboard Meteosat-8 satellite, that provides the Indian Ocean Data Coverage (IODC) service. The assimilation and forecast system used in this study is NCMRWF's Unified Model (NCUM). NCUM operationally assimilates both SEVIRI CSBT and the AMVs from Meteosat-8 along with other conventional and satellite observations. NCUM routinely assimilates INSAT-3D sounder CSBT and the AMVs derived from INSAT-3D Imager. Since both Meteosat-8 and INSAT-3D have approximately same geographical coverage, INSAT-3D observations, both CSBT and AMVs are restrained in the OSEs to quantify the impact of CSBT and AMVs from Meteosat-8. OSEs are designed in such a way that along with other global observations, i) CSBTs (EXP1), ii) AMVs (EXP2), iii) both CSBTs and AMVs (EXP3) from Meteosat-8 and iv) no CSBTs and AMVs (EXP4) from Meteosat-8. The fourth one is considered as the baseline experiment and the impact of CSBT and AMVs are analyzed in terms of the baseline experiment in both assimilation and forecast system. Impact of SEVIRI radiance assimilation is computed in terms of different meteorological parameters like Relative Humidity, Temperature, and wind. In some experiments a positive impact on upper-level wind fields (around 200 hPa) is seen, this was mainly due to the assimilation of WV channel CSBT. A reasonable sensitivity is observed in forecast due to the assimilation of SEVIRI CSBT in NCUM system.

Session 4: Assimilation of Geostationary Infrared Sensors (poster introductions)

4p.01 Towards the use of a bayesian approach for the assimilation of all-sky IASI radiances

Presenter: Nadia Fourrié, CNRM Meteo-France and CNRS
Authors: Imane Farouk, Nadia Fourrié, Vincent Guidard, Philippe Chambon and Fabrice Duruisseau

The current generation of advanced infrared sounders is one of the most important sources of observations in data assimilation systems in numerical weather prediction (NWP) models. Currently the "all-sky" assimilation for infrared sounders is underway. As a prerequisite, the evaluation and improvement of homogeneous scene detection algorithms based on the colocation of observations with other imagers was studied. Different criteria for selecting homogeneous scenes are proposed. By conducting assimilation experiments and evaluating the impact of these proposed selection criteria on the quality of long-term forecasts, one of the proposed tests stands out from the others by keeping a significant amount of clear sky observations and demonstrating neutral to slightly positive impacts on the forecasts (Farouk et al., 2019).

To address the issue of all-sky radiance data assimilation, the two-step assimilation technique, already used for radar reflectivity assimilation in AROME (Wattrelot et al., 2014), was evaluated for IASI radiances in the ARPEGE model in a case study. This method based on Bayesian inversion has recently been adapted for satellite microwave observations (Duruisseau et al., 2018). In a simplified framework, several sensitivity tests were carried out on the different parameters of the algorithm, with the objective of preparing for future work on infrared all-sky assimilation.

4p.02 All-Sky Radiance Assimilation for COAMPS-TC Tropical Cyclone Track and Intensity Prediction

Presenter: Nancy Baker, Naval Research Lab Marine Meteorology Division
Authors: Dr. Nancy L. Baker, Dr. Allen Zhao, Dr. Yi Jin and Dr. Jim Doyle

Scientists at the Naval Research Laboratory Marine Meteorology Division are partnering through an ONR-sponsored collaboration with scientists at Penn State University (PSU) to enable new data assimilation capabilities to improve the US Navy's COAMPS® and COAMPS-TC tropical cyclone and other high-impact storm forecasts. The effort has two main components, (1) implementation and testing of the PSU ensemble Kalman Filter (EnKF) data assimilation system, and (2) assimilation of all-sky radiance, together with airborne Doppler radar and other in-situ observations.

This presentation will present the data assimilation approach and initial results for COAMPS-TC® using the PSU EnKF for TC inner core assimilation of GOES-13 water vapor all-sky radiances (channels 8-10) using the Community Radiative Transfer Model (CRTM), together with airborne radar data, and other in-situ observations. The initial goal for this research is to evaluate whether this configuration can improve the COAMPS-TC intensity forecasts for Hurricane Patricia (2015). We will compare the results with the COAMPS-TC forecasts using both NAVGEM (NAVy Global Environmental Model) initial and boundary conditions, and GFS initial and boundary conditions.

COAMPS® is a registered trademark of the Naval Research Laboratory.

4p.03 Assimilation of cloud-contaminated radiances in regional air quality model: a case study using GEMS synthetic radiance data

Presenter: Ebony Lee, Ewha Womans University
Authors: Ebony Lee and Seon Ki Park

As the impact of air quality on human health and socioeconomic issues becomes more evident, we are endeavoring to make accurate air quality forecasting. Recently, many researches have focused on the assimilation of satellite observations into the air quality models since satellite data have the advantage of spatiotemporal coverage. The Geostationary Environmental Monitoring Spectrometer (GEMS) is planned to be launched in late 2019 or early 2020, with missions to monitor and provide measurements of atmospheric composition (e.g., O3, NO2, SO2, HCHO, and aerosols) in Asia. The GEMS observations are expected to contribute to improving the accuracy of the air quality monitoring and forecasting. Since the satellite-measured radiance data are deteriorated (contaminated) when clouds are present, it is common to use cloud screening to remove the deteriorated data and use only clear-sky data for assimilation. To compensate for the data loss by cloud screening, studies on the all-sky radiances assimilation have been actively conducted in numerical weather prediction. In this study, we assimilate the synthetic radiances of GEMS into WRF-Chem to investigate the characteristic aspects in the air quality prediction. The synthetic radiances are produced by a radiative transfer

model, called VLIDORT, by considering the spectral and spatial resolution of GEMS. To assess the impact of the cloud contaminated data and the loss of information by cloud screening, we will compare the model results: (1) by assimilating the radiances calculated under the full clear-sky condition; (2) by assimilating the cloud-affected radiances; and (3) by assimilating the clear-sky radiances after cloud screening.

Session 4: All-sky Assimilation of Geostationary Infrared Sensors (oral presentations)

4.05 Evaluation and assimilation of all-sky infrared radiances of Himawari-8 in the regional and global data assimilation system

Presenter: Kozo Okamoto, JMA/MRI
Authors: Kozo Okamoto, Yohei Sawada, Masaru Kunii, Tempei Hashino, Masahiro Hayashi, Masayuki Nakagawa, Keiichi Kondo

This study investigates the benefit of assimilating infrared radiance observations from satellites in all-sky conditions. We have been developing the all-sky radiance (ASR) assimilation for Himawari-8 in the regional and global data assimilation system, and plan to extend it to hyperspectral infrared sounders. The development includes a band selection based on observation error correlation, a cloud-dependent quality control (QC) procedure and observation error model.

The impact of ASR assimilation was compared with the CSR assimilation using a regional LETKF assimilation system. The ASR assimilation brought better fit of first-guess to radiosonde observations and more stable improvement in a severe rainfall prediction due to more secure data coverage. Testing bias correction (BC) for the ASR assimilation showed no additional positive impacts over the ASR assimilation without BC, suggesting a harmful cloud-dependent bias was mitigated by increasing observation errors with cloud effect.

The similar development of the ASR assimilation in the operational global data assimilation system is underway. As the first step, we compared ASR observations with simulations to understand the reproducibility of our global model and radiative transfer models. The minimization procedure is examined in the ASR assimilation in the operational global 4D-Var assimilation system and preliminary results will be presented.

4.06 Evaluating the impact of assimilating cloud-affected infrared radiances from GOES-16 ABI on the forecast of a severe storm in the Midwest U.S.

Presenter: Jonathan Guerrette, NCAR, MMM
Authors: Jonathan (JJ) Guerrette, Zhiquan (Jake) Liu, Chris Snyder

Constraining a convection-permitting atmospheric model around the truth requires a data assimilation approach that uses observations that resolve convection and microphysics at relevant scales and considers flow-dependent model uncertainties. In this work we use radiances produced by the Advanced Baseline Imager's (ABI) three water-vapor (WV) sensitive infrared channels onboard the GOES-16 satellite. The ABI WV channels record a new full-disk image every 15 minutes with nominal 2 km resolution at nadir. The radiances are simulated using the Community Radiative Transfer Model (CRTM) version 2.3. We use a hybrid 3DEnVar technique with 3km grid spacing and a flow-dependent model error representation in the Weather Research and Forecasting Model Data Assimilation system (WRFDA). Our study focuses on a severe storm with verified reports of tornadoes and hail on 1 May 2018, which impacted a broad region spanning central Kansas to eastern Nebraska. The storm system was initially predicted with relatively good lead-time by operational convection-permitting forecasts. We investigate whether the ABI radiances can improve the spatial positioning of the most intense regions of the storm while also maintaining or increasing forecast lead-time. In addition to hourly Global Telecommunication System (GTS) and 6-hourly Global Navigation Satellite System Radio Occultation (GNSSRO) observations, a control hourly cycling experiment (CLRSKY) assimilates ABI pixels that have passed an online IR-only cloud-detection algorithm in WRFDA. A separate ALLSKY experiment additionally uses ABI pixels affected by hydrometeors, which are currently excluded from operational forecast systems. ALLSKY uses an observation error inflation (OEI) mechanism that scales linearly with a cloudiness parameter evaluated for each pixel. OEI enables cloudy pixels to be used that would otherwise fail background error quality checks or degrade the DA analysis. Both experiments are cycled for 24 hours beginning at 00Z, 20 hours before the first reported hail and 22 hours before the first reported tornado. We will discuss the impacts of the cloud-affected radiances on forecasted spatial and phase distribution of water mass and forecast verification statistics throughout both experiments. Finally, we will assess whether these

observations can improve the predictability of this North American continental severe storm.

4.07 4D variational and ensemble/variational assimilation of every 10-min AHI clear-sky and all-sky radiances at convective-scale
Presenter: Zhiquan Liu
Authors: Zhiquan Liu, Yali Wu, and Dongmei Xu
Himawari-8 AHI radiance data assimilation (DA) is implemented in NCAR's community WRF Data Assimilation (WRFDA) system, which allows the assimilation of high temporal- and spatial-resolution AHI data using various schemes such as 3DVAR, multi-resolution incremental 4DVAR (MRI-4DVAR), and hybrid-3D/4DEnVar at convective-scale. 3DVAR and MRI-4DVAR experiments with and without AHI's three water vapor (WV) channels' clear-sky radiances were conducted to evaluate the impact on the prediction of a record-breaking (500 mm within 24 hours) warm-sector torrential rainfall (WSTR) event occurred in Guangzhou city on 7 May, 2017. WRF and WRFDA is configured with a 3-km grid spacing to better resolve this very local storm event, for which all operational centers failed to predict its timing, location, and intensity. While 3DVAR experiment with or without AHI is less skillful to predict this event, 4DVAR without AHI prominently improved convection initiation (CI) forecast and extra every 10-min AHI radiance data used in 4DVAR improved the second-stage convection evolution and precipitation forecasts. For the fractional skill scores (FSS) of 20-h accumulated precipitation forecasts, 4DVAR with 10-min AHI radiances improved 2%–4.5%, 1%–3%, 6%–20%, and 8%–24% for 5 mm, 20 mm, 50 mm, and 80 mm thresholds, respectively, comparing to 4DVAR without AHI. More recent development allows the assimilation of all-sky AHI radiances by introducing the so-called "symmetric error model" following Okamoto et al. (2014) and Harnisch et al. (2016), scattering CRTM, and cloud analysis variables. All-sky AHI radiance assimilation impact is evaluated using WRFDA's hybrid-3D/4DEnVar techniques at 3-km grid spacing for severe storm events over China. Comparison results of hybrid-3DEnVar vs. hybrid-4DEnVar (with 10-min AHI data) and clear-sky vs. all-sky AHI data will be presented.

Session 5: All-sky Assimilation for Microwave Sensors (oral presentations)

5.01 Towards all-sky MHS: Observation Preprocessing and NWP Suite Design
Presenter: Brett Candy, UK Met Office
Authors: Brett Candy and Stefano Migliorini
Currently at the Met Office we are working on extending the assimilation of microwave humidity channels into regions where there is significant scattering. For the 183 GHz channels the primary sources of scattering are cirrus clouds and rain droplets.

To account for scattering in our scheme requires both improvements to the radiative transfer model and also the preprocessing of the data, especially the 1D-Var component. In this presentation we will look at both aspects. We show that 1D-Var continues to play an important part in the quality control process and will discuss how 1D-Var has been augmented to include information on ice clouds and rain.

Another important aspect of the data assimilation scheme that has been tested in preparation for the operational use of all-sky MHS is the use of outer loop cycling within 4D-Var minimisation. We shall give an overview of our suite design and present some initial studies, including examining the role of quality control as the outer loop cycle proceeds.

5.02 Assimilating cloudy and rainy microwave observations within the ARPEGE global model
Presenter: Philippe Chambon, Météo-France
Authors: Philippe Chambon, Marylis Barreyat, Jean-François Mahfouf
Within the ARPEGE 4D-Var global data assimilation system in operations at Météo-France, only clear-sky microwave observations are presently used. A new framework is currently under investigation to assimilate as well microwave observations in cloudy and rainy areas. This method is called 1D-Bay+4D-Var and corresponds to a two-step process: (i) a Bayesian inversion algorithm to retrieve profiles of temperature and humidity from the microwave radiances, (ii) the 4D-Var assimilation of these retrieved profiles. The 1D-Bay+4D-Var method is an alternative to both 1D-Var+4D-Var and direct all-sky assimilation. Within this framework, a new error model has been developed aiming at modeling radiative transfer errors in scattering conditions, based on an ensemble of forward simulations with multiple microphysical assumptions. Results from the assimilation of SAPHIR and MHS radiances in cloudy sky over a three-month period will be presented. In particular, the impacts of these microwave sounders data on tropical winds and hurricane forecasts will be discussed.

5.03 All-sky assimilation over land for surface sensitive microwave channels

Presenter: Katrin Lonitz, ECMWF
Authors: Katrin Lonitz, Alan J. Geer and Niels Bormann

The all-sky assimilation of microwave radiances over ocean has a significant positive impact on forecast scores at ECMWF. Over land only channels which have small sensitivities to the surface are assimilated, that is higher-peaking 183 GHz humidity sensitive channels. The main difficulty in assimilation of surface sensitive channels is the accuracy in the simulated brightness temperatures due to uncertainties in the emissivity and skin temperature over land. All-sky assimilation adds the difficulty of separating errors in cloud and precipitation from those in the description of the surface.

In this study, we test if the current dynamic emissivity retrieval could be used to assimilate additional surface sensitive microwave sounding and imager channels (e.g. 150/166 GHz or 89/92GHz) with the aim of assessing their impact on forecast scores in the Integrated Forecast System.

Furthermore, we assess the spectral variability of emissivity within the all-sky framework depending on time of day, on cloudiness and on land cover type for conical microwave scanners. At the moment the emissivity retrievals performed for the 183 GHz channels are only used at light cloud situations; in very cloudy situations the atlas values are used. We test if a regression of one retrieval at a certain frequency can be used for most surface sensitive microwave channels in all cloud conditions.

5.04 All-sky radiance assimilation over land at NCEP: Approaches and Status

Presenter: Yanqiu Zhu
Authors: Yanqiu Zhu

Both clear-sky and cloudy radiances from AMSU-A over ocean FOVs have been assimilated operationally at NCEP since 2016. As the all-sky approach is extended to the ATMS radiances over ocean FOVs with the implementation of the FV3GFS, it is natural to extend the effort to the radiances over land. So far, only clear-sky radiances are assimilated over land and far fewer radiances are used than over ocean at NCEP. The challenges we are facing in the assimilation of surface-sensitive channels over land mainly come from the uncertainty in simulating microwave land emissivity, the uncertainties of land surface properties, and the problematic cloud detection in the clear-sky radiance assimilation quality control. To address the first two issues, our intermediate goal is to produce real-time analytical emissivity retrieval combined with TELSEM atlas (with or without filter update), and the long-term goal is to perform soil moisture and land surface skin temperature analyses with the improved community surface emissivity model (CSEM) using radiances from low-frequency (e.g. L-band) microwave satellite sensors, such as AMSR2, SMOS, GMI. Major steps towards all-sky radiance assimilation over land will be discussed and the preliminary results of analytical emissivity retrieval from GSI will be presented at the meeting.

Session 5: All-sky Assimilation for Microwave Sensors (poster introductions)

5p.01 All-sky assimilation of moisture-sensitive radiances at the Met Office

Presenter: Stefano Migliorini, Met Office
Authors: Stefano Migliorini and Brett Candy

Cloud-affected radiances from AMSU-A channel 4 and 5 have been assimilated in the Met Office operational weather prediction system since September 2018. This followed from the results of trial experiments which showed RMSE reductions in 500 hPa geopotential height forecasts of about 1% up to day 2, when including non-precipitating scenes observed in these channels. The next step is to increase the amount of assimilated observations by including cloud-affected radiances from MHS that are sensitive to humidity in the 183 GHz band, both in the global and the regional version centred in the UK of the Unified Model. To this end, the all-sky radiance error model used for AMSU-A radiances, dependent on the liquid water path (LWP) estimated from its channels 1 and 2, has been modified to make it dependent on the LWP and ice water path (IWP) estimated from the 1D-Var analyses routinely performed for quality control purposes, before assimilation. Results from single-observation as well as from trial experiments are discussed in this this talk. Results are also shown from a trial experiment where the benefits (as well as its additional costs) from iterating the 4D-Var procedure with updated linearization states (known as outer-loop minimization) are discussed. Finally, a strategy to extend the Met Office all-sky radiance assimilation procedure to precipitation-affected radiances is outlined.

5p.02 Assimilation of AMSU-A in the presence of cloud and precipitation

Presenter: Niels Bormann, ECMWF
Authors: Peter Weston, Alan Geer and Niels Bormann
At ECMWF, AMSU-A observations are currently only assimilated in clear-sky conditions, i.e. without taking into account the effect of cloud and precipitation on the measurements. In recent years it has been shown that assimilating humidity-sensitive microwave radiances in the presence of cloud and precipitation can lead to significant increases in forecast skill. In this poster the impact of extending the existing clear-sky assimilation of temperature-sounding AMSU-A radiances to cloudy areas is investigated.

A number of developments to the all-sky AMSU-A configuration have been researched and tested leading to a significant improvement on previous results. These developments have included changing the interpolation of model fields to observation locations, thinning refinements, additional quality control and improved bias correction. Each of these developments leads to slightly improved results but when combined they lead to a significant improvement, addressing many of the areas of degradation in previous results.

The performance of the all-sky AMSU-A configuration is now very close to the currently operational clear-sky AMSU-A configuration with improvements to extra-tropical short-range humidity and low-level wind forecasts although there are still some small areas of degradation to tropical temperature and wind forecasts. A number of possible future enhancements will also be summarised.

5p.03 The use of precipitation-affected MW radiances in FV3-GFS Hybrid Data Assimilation System
Presenter: Benjamin Johnson, UCAR/JCSDA (for Emily Liu)
Authors: Emily Huichun Liu, Andrew Collard, Daryl Kleist
The operational FV3-GFS hybrid data assimilation system currently assimilates cloud-affected microwave (MW) radiances with the assumption that the cloudy scenes are overcast and the precipitation-affected observaton are excluded. In preparation for assimilating precipitation-affected MW radiances, the performance of the observation operator under scattering condition by hydrometeors has been validated and improved. A two-column radiance calculation was developed in the observation operator to handle fractional cloud coverage. The validation and enhancement made for the operational operator will be described in details in the presentation followed up by the discussion on the impact of the precipitation-affected MW radiances to the analysis and the forecast.

5p.04 Updates from the all-sky assimilation of microwave radiances at the ECMWF
Presenter: Katrin Lonitz, ECMWF
Authors: Alan J. Geer and Katrin Lonitz
We present some highlights from recent updates to the all-sky assimilation of microwave radiances at the ECMWF.

- Changes to consider interchannel correlation in the error model of microwave imagers. For the all-sky assimilation it has been found that a fully-specified covariance matrix that adapts with the cloud amount was needed for this purpose. We find that the tuning of the eigenvectors and the interplay with variational quality control is key to a successful assimilation considering correlated observation errors.
- In the latest ECMWF IFS model cycle SSMIS-F17 150h GHz and GMI 166 v/h GHz channels have been added. This improves medium-range humidity forecasts and decreases the additional drying through the assimilation of microwave imagers by 50%.
- RTTOV-SCATT has been updated to version 12.2 in the latest ECMWF IFS model cycle along with the rest of RTTOV. This update adds the ARTS scattering database with 16 shapes including aggregates, hail and graupel and covering frequencies from 1 to 886 GHz to support all microwave/sub-mm bands: SMOS to ICI. Furthermore, a new liquid water permittivity model (Rosenkranz, 2015) is now as part of RTTOV-SCATT.

5p.05 All-sky Assimilation of the MWHS-2 Observations and Evaluation the Impacts on the Forecasts of Typhoons
Presenter: Zhipeng Xian, Institute of Atmospheric Physics, Chinese Academy of Sciences
Authors: Zhipeng Xian, Keyi Chen, Jiang Zhu
Satellite data assimilation is transitioning from clear-sky to all-sky approach at some operational forecasting centers; the all-sky approach directly assimilates observations under clear, cloudy and precipitating conditions and shows a positive impact on medium-range forecasts. To examine the impact of all-sky assimilation of the Microwave Humidity Sounder-2 (MWHS-2) data from FengYun

(FY)-3C on the high-impact weather process, such as tropical cyclone, three experiments (without MWHS-2 data, with MWHS-2 data in clear-sky conditions and with MWHS-2 data in all-sky conditions) are carried out, and several typhoons (i.e., Typhoons Haitang, Nesat, Nida, Hato and Mangkut) having bad influences on Southern China are selected. RTTOV-SCATT, a fast Radiative Transfer Model for simulating cloud- and precipitation- affected microwave radiances, and a symmetric observation error model for all-sky radiance assimilation are implemented within the Weather Research and Forecasting model data assimilation system (WRFDA) and its three-dimension variational data assimilation scheme is used for all experiments. The results show that the all-sky assimilation makes the average error in track of typhoons reduced 17.9% and 9.6%, and makes a better performance on the forecast of intensity of typhoon. In addition, the forecast of heavy rainfall (100 mm) caused by these typhoons are improved greatly with more cloud- and precipitation-affected observations being assimilated. These encouraging results suggest that all-sky assimilation is able to improve the forecasts of typhoons.

5p.06 All-sky microwave radiance assimilation in the JMA global NWP system

Presenter: Masahiro Kazumori, Japan Meteorological Agency
Authors: Masahiro Kazumori, Takashi Kadowaki and Hiroyuki Shimizu

All-sky microwave radiance assimilation has become increasingly important to produce accurate initial fields for numerical weather prediction. All-sky microwave radiance assimilation can provide new observational information under cloudy conditions. We developed an all-sky microwave radiance assimilation scheme for the JMA global 4D-Var data assimilation system. A data screening method applied in forecast model's biased areas, observation error assignment method based on cloud amount and outer-loop iterations for trajectory updates in the 4D-Var minimization process were introduced in the system.

Microwave radiance data (e.g. microwave imager, AMSR2, GMI and SSMIS, and microwave humidity sounder, MHS) were assimilated under all-sky conditions. To extend the data coverage in the analysis, data quality of unused instruments (e.g. WindSat on Coriolis, MWRI on FY-3B and 3C) were evaluated. We found MWRI had relatively larger orbit dependent biases in the FG departure (observed minus simulated radiance) statistics. For MWRI radiance data, a type of satellite orbit node (ascending or descending) as a predictor in a variational bias correction was crucial to obtain similar data quality as other microwave instruments. Addition of the new microwave radiance data in the all-sky assimilation brought further improvements in the analysis and forecasts. The all-sky microwave radiance assimilation is planned to be incorporated in the JMA operational global data assimilation system in November 2019. The details were presented in the conference.

5p.07 Assessing the impact of different liquid water permittivity models on the assimilation of microwave radiances

Presenter: Katrin Lonitz, ECMWF
Authors: Katrin Lonitz and Alan J. Geer

Permittivity models for microwave frequencies of liquid water below 0°C (supercooled liquid water) are poorly constrained due to limited laboratory experiments and observations, especially for high microwave frequencies. This uncertainty directly translates into errors in retrieved liquid water paths of up to 80?%. Using the ECMWF all-sky assimilation framework we have tested how different liquid water permittivity models imprint themselves on simulated brightness temperatures.

The current permittivity model is compared with five alternatives. The largest differences occur prominently during austral winter in the storm tracks of the Southern Hemisphere and in the intertropical convergence zone with values of around 0.5 to 1.5?K. Compared to the default approach (Liebe, 1989), improved fits between observed and simulated brightness temperatures are visible for the permittivity models of Stogryn et al. (1995), Rosenkranz (2015) and Turner et al. (2016). For these models, a small mean reduction in simulated brightness temperatures of at most 0.15?K at 92?GHz can be seen on a global monthly scale.

In cycling data assimilation these newer models also give small improvements in short-range humidity forecasts when measured against independent observations. Overall, Rosenkranz (2015) is favoured due to its validity up to 1?THz, which will support future submillimetre missions.

5p.08 Microphysical properties of ice particles as revealed by satellite microwave polarimetric measurements and radiative transfer modeling

Presenter: Victoria Galligani, CIMA-CONICET
Authors: V. S. Galligani, D. Wang and C. Prigent

The understanding of cloud microphysical processes and their representation in climate models needs to be urgently improved. Frozen and mixed phase cloud processes, in particular, are the most poorly understood. The measurement of these clouds are difficult to obtain owing to the challenges involved in remotely sensing ice water content (IWC) and its vertical profile, including complications associated with multi-level clouds, mixed phases and multiple hydrometeor types, the uncertainty in classifying ice particle size and shape for remote retrievals, the relatively small time and space scales associated with deep convection.

Microwave radiometry has shown a promising ability in the characterization of frozen particles, as it is able to penetrate and provide insight into the vertical profiles of most clouds, in contrast to infrared and visible observations, which essentially sense cloud tops. Microwave observations, specially at the higher frequency channels (37GHz), are sensitive to cloud scattering signals. The higher the microwave frequency, the larger the scattering signal produced by the interaction of frozen habits with EM radiation. The knowledge regarding the microphysical properties of frozen habits responsible for such scattering (size, density, shape, orientation, composition) is key in radiative transfer and climate modelling and needs to be further discussed.

The difference in the vertically and horizontally polarized microwave measurements (TBV-TBH) at cloud scattering sensitive frequencies have been shown to contain information on ice particle shape (aspect ratio) and orientation. The launch of the Global Precipitation Measurement (GPM) satellite in 2014, which hosts the GPM Microwave Imager (GMI), has extended the availability of microwave polarized observations at higher frequencies (166 GHz), previously only available up to 89 GHz in platforms such as AMSR-E or TMI. Scattering by frozen habits is highly (poorly) polarized in stratiform and anvil clouds (deep convection) resulting from the horizontal orientation of non-spherical frozen habits (random orientation due to turbulence and strong updrafts), as shown in a pre-GPM era by e.g., Prigent et al., 2005, Galligani et al., 2013, Defer et al. 2014, and confirmed by Gong and Wu 2017 who explored GPM's novel 166 GHz polarized channels.

In this study, we analyzed one year of GMI observations at two window channels (i.e., 89 and 166 GHz). Stratiform clouds show larger polarization (up to 10 K in average) due to the deposition and aggregation growth of snowflakes, while the convective regions show smaller (even negative) polarization, as the graupel and/or hail become randomly (even vertically) oriented due to the strong upward air motion. A robust relationship has been found between the polarization difference and vertical polarized brightness temperature for both land and ocean surfaces, and is parameterized using Hermite cubic spline interpolation which can be easily incorporated into radiative transfer models. The regional and seasonal variability has also investigated between different cloud regimes.

In order to support these statistics, sensitivity tests are performed using a radiative transfer (RT) robust modeling framework for a deep convection case study in the highly severe weather producer Southeastern South American region. The Atmospheric Radiative Transfer (ARTS) model is coupled with the Weather and Research Forecasting (WRF) model to explore the sensitivity of polarized signals to frozen habit microphysics parameters such as aspect ratio, orientation or density. The deep convection midlatitude case study exploits coincident GMI-DPR observations, as well as ground radar polarimetric data, and supports physically the relationships parametrized from GMI global observations.

Communication from sibling working groups (oral presentations)

a.01 Research Highlights from the International Precipitation Working Group (IPWG)

Presenter: Philippe Chambon, Météo-France
Authors: Philippe Chambon, Viviana Maggioni, Ziad Haddad, Dong-Bin Shin, Vincenzo Levizzani, Ralph Ferraro

The International Precipitation Working Group (IPWG) is a permanent International Science Working Group (ISWG) of the Coordination Group for Meteorological Satellites (CGMS), co-sponsored by CGMS and the World Meteorological Organization (WMO). IPWG provides a forum for the international scientific community to address issues and challenges related to satellite-based precipitation retrievals. Through partnerships and biennial meetings, the group promotes the exchange of scientific and operational information between the producers of precipitation measurements, the research community, and the user community. Specifically, IPWG furthers the refinement of current estimation techniques and

the development of new methodologies for improved global precipitation measurements, together with the validation of the derived precipitation products with ground-based precipitation measurements. IPWG promotes international partnerships, provides recommendations to the CGMS, and supports upcoming precipitation-oriented missions. This presentation will highlight some of the latest research findings from the IPWG working groups.

a.02 Feedback from last two ISWG meetings
Presenter: Benjamin Ruston, Naval Research Laboratory
Authors: Benjamin Ruston

Session 6: Climate (oral presentations)

6.01 Establishing times series of essential climate variables from 3 successive Metop/IASI
Presenter: Cyril Crevoisier, LMD/CNRS
Authors: C. Crevoisier, R. Armante, V. Capelle, A. Chédin, N. A. Scott, C. Stubenrauch, L. Crépeau, J. Pernin
Since its first launch onboard Metop-A in October 2006, and then onboard Metop-B in September 2012 and Metop-C in November 2018, IASI contributes to the establishment of robust long-term data records of several essential climate variables. Owing to its launches onboard 3 successive Metop platforms, IASI has the potential to monitor the evolution of these variables over two decades, to assess potential trends, and to detect signatures of specific climate events, such as ENSO or other sources of climate variability. To fulfill these objectives, it is mandatory that each successive IASI instruments are spectrally and radiometrically well characterized individually and among themselves.

We will show that the IASI instruments display exceptional spectral and radiometric stabilities, and that the 3 instruments agree at the level required for climate monitoring. Results will be presented at both level1 and level2. For level1, we will rely on IASI radiance monitoring and intercomparison with companion instruments done in the framework of the Global Space-based Inter-Calibration System (GSICS) of WMO. For level2, we will focus on four essential climate variables that are retrieved at LMD: (i) clouds: physical and microphysical properties; (ii) greenhouse gases: mid-tropospheric integrated content of CO2, CH4 and CO; (iii) dust aerosols: AOD, altitude, and radius; (iv) continental surface characteristics: skin temperature and spectral emissivity.

Use will be made on a processing chain of satellite observations that has been developed for many years at LMD and that includes: permanent validation and improvement of the GEISA spectroscopic database and of the radiative transfer code 4A (which are respectively the official database and code for IASI Cal/Val activities at CNES), development of dedicated cloud and aerosol detection schemes, retrieval processes, and validation activities.

As the suite of long time series of climate variables retrieved from IASI continues to expand, we will argue that IASI has already demonstrated that it can and will play a major role in the monitoring and understanding of climate evolution and variability.

6.02 Toward Improved Climate Data Record Using Stable SNPP/ATMS Observations as References
Presenter: Cheng-Zhi Zou, NOAA College Park
Authors: Cheng-Zhi Zou, Xianjun Hao, Hui Xu, and Mitch Goldberg
Observations from the satellite microwave sounders play a vital role in measuring the long-term temperature trends for climate change monitoring. Changes in diurnal sampling over time and calibration drift have been the main sources of uncertainties in the satellite measured temperature trends. We have recently examined observations from the Advanced Technology Microwave Sounder (ATMS) that has been flying onboard the NOAA/NASA Suomi National Polar-orbiting Partnership (SNPP) environmental satellite since late 2011. The SNPP satellite has a stable afternoon orbit that has close to the same local observation time as NASA's Aqua satellite that has been carrying the heritage microwave sounder, the Advanced Microwave Sounding Unit-A (AMSU-A), from 2002 until the present. The similar overpass timing naturally removes most of their diurnal differences. In addition, direct comparison of temperature anomalies between the two instruments shows little or no relative calibration drift for most channels. Our results suggest that both ATMS and AMSU-A instruments have achieved absolute stability in the measured atmospheric temperatures within 0.04 Kelvin per decade. We have also analyzed AMSU-A observations onboard the European MetOp-A satellite that has a stable morning orbit 8 hours apart from the SNPP overpass time. Their comparison reveals large asymmetric trends

between day and night in the lower- and mid-tropospheric temperatures over land.

The high radiometric stability in the SNPP/ATMS and MetOp-A/AMSU-A observations has broad impact on the climate trend observations from the microwave sounders as well as other instruments and could help resolve debates on observed differences in the climate trends. In this presentation, we use stable observations from the SNPP/ATMS and MetOp-A/AMSU-A as references to recalibrate microwave sounders onboard other satellites such as MetOp-B and NOAA POES series. We demonstrate that data quality and consistency from these satellite observations can be largely improved through recalibration. Such recalibrated data will be used to generate microwave atmospheric temperature climate data record (CDR). Improved CDR and trend accuracy are expected from such an approach.

6.03 Validation of the 183 GHz C3S/EUMETSAT FCDR using ERA5 simulations, SNOs and operational datasets

Presenter: Christoforos Tsamalis, Met Office Hadley Centre

Authors: C. Tsamalis, E. Good, R. King, F. Aldred, T. Hanschmann, V. O. John and R. Roebeling

The 183 GHz measurements from microwave (MW) sounders constitute necessary humidity information for both assimilation to reanalyses and creation of Thematic Climate Data Records (TCDRs). For this reason, a new Fundamental Climate Data Record (FCDR) has been developed by EUMETSAT for the Copernicus Climate Change Service (C3S). This FCDR has been generated based on the methodology developed by the Fiduceo project providing the observations in NetCDF files from equator to equator, thus in an easy file format to handle while avoiding the possible duplications of operational datasets. Also, it provides uncertainties per pixel in three categories: independent (or random), structured, and common (or systematic). The FCDR includes measurements from the Microwave Humidity Sounder (MHS) on board the MetOp-A and B satellites, the Microwave Humidity Sounder (MWHS-1/2) on board the FY-3A, -3B, and -3C satellites and the Advanced Technology Microwave Sounder (ATMS) on board the S-NPP satellite. It covers the period October 2006 to December 2018, thus extending over time the FCDR provided by Fiduceo and more importantly including new sounders like MWHS-1, MWHS-2 and ATMS which permit an enhanced sub-daily coverage of the Earth. The FCDR is validated using three approaches: i) ERA5 simulations, ii) Simultaneous Nadir Overpasses (SNOs) and iii) comparisons with the operational datasets. The ERA5 reanalysis brightness temperature (BT) simulations have been performed with the NWP SAF RadSim software, which constitutes an interface to the RTTOV fast radiative transfer model. The validation with ERA5 has been restricted over ocean only within 60°S to 60°N to avoid the complications with land and ice surface emissivities. It's worth noting that ERA5 assimilates the 183 GHz observations from MHS, MWHS-1/2 and ATMS. Criteria used to generate SNOs were time difference within 5 min, Field of View (FOV) distance within 5 km and satellite zenith angle differences within 5°. SNOs have been calculated for all the potential satellite pairs of the FCDR, but also with Sondeur Atmosphérique du Profil d'Humidité Intertropicale par Radiométrie (SAPHIR) MW sounder on board the Megha-Tropiques satellite, which permits an independent validation. The third approach includes the intercomparison with operational datasets provided by NOAA CLASS for MHS and ATMS and by CMA for the MWHS-1 and 2 sounders. First results indicate that MHS and ATMS have a stable performance over time and agree rather well with ERA5 simulations and between them as shown from SNOs analyses. The MWHS-1/2 instruments present some discontinuities in the time series and larger discrepancies against ERA5 simulations, and with SNOs to MHS, ATMS and SAPHIR. The first indications are that the new FCDR is more consistent than the available operational datasets.

Session 6: Climate (poster introductions)

6p.01 Stand alone night-time sea surface temperature retrieved by the IASI/Metop suite: Toward long time series

Presenter: Virginie Capelle, LMD/Ecole Polytechnique

Authors: V. Capelle, J.-M. Hartmann, A. Chédin, R. Armante, H. Tran, N. Scott, C. Crevoisier

SST is one of the essential climate variables for which accurate and global measurements are crucial for improving our understanding of climate evolution, as well as of numerical weather prediction. Within this framework, satellite remote sensing, by providing daily and global observations over long time series, offers good opportunities. In particular, the excellent calibration and stability of the IASI instrument and the planned long time series of observation provided by the suite of three satellites Metop A, B and C, launched respectively in October 2006, September 2012 and

November 2018, is fully consistent with the quality requirement.

Here a full physical algorithm is presented to retrieve SST from IASI. The main advantage of such an approach is to provide a dataset totally independent of in-situ measurements or models. SST is retrieved at the IASI spot resolution (clear sky) for the three Metop platforms, offering so far a continuous record over more than 12 years, which is planned to be extended for at least another decade. Restitutions are compared with in-situ drifting buoys network measurements as well as with other satellite datasets. The difference between the skin surface temperature obtained by IR satellites and the in-situ surface temperature provided by the buoys is investigated and the sensitivity of this difference to the conditions of observation (wind, water vapor content, etc…) is analyzed. Finally, the stability of the restitutions among the 3 satellites is also investigated.

6p.02 A long time series of Metop/IASI observations of Saharan aerosols distribution using AOD-Altitude-Surface temperature triplets

Presenter: Virginie Capelle, LMD/Ecole Polytechnique

Authors: V. Capelle, A. Chédin, R. Armante, N. Scott, C. Crevoisier

Aerosols represent one of the dominant uncertainties in radiative forcing, partly because of their very high spatiotemporal variability, a still insufficient knowledge of their microphysical and optical properties, or of their vertical distribution. Observations from space offer a good opportunity to follow, day by day and at high spatial resolution, dust evolution at global scale and over long time series. Infrared observations allow retrieving dust aerosol optical depth (AOD) as well as the mean dust layer altitude, daytime and nighttime, over oceans and over continents, in particular over desert. Therefore, they appear complementary to observations in the visible. By its excellent calibration and stability and the expected long time series of observation, the Infrared Atmospheric Sounder Interferometer (IASI), on board the suite of European Satellite Metop A, B and C, launched respectively in October 2006, September 2012 and November 2018 is particularly suited for accurate monitoring of dust evolution. Here, observations from the three satellites have been processed pixel by pixel, using a “Look-Up-Table” (LUT) physical approach, providing a time series of more than 12 years of 10µm dust AOD and mean altitude.

Rigorous statistical analysis of the whole time series has been performed in order to 1) detect and estimate day-time and night- time dust AOD trends over Sahara, a region where dust aerosol emissions are frequent and often intense and 2) demonstrate the high stability between the different satellites. Taking benefit of the equal quality of morning and evening IASI measurements, we have started comparing these two sources of AOD-altitude-surface temperature retrieval triplets in order to better understand their differences in relation with the often complex meteorological situations encountered in these regions. First conclusions will be discussed.

6p.03 Surface skin temperature and its trend from recent 12-year IASI observations

Presenter: Daniel Zhou, NASA

Authors: Daniel K. Zhou, Allen M. Larar, and Xu Liu

Surface skin temperature has been retrieved from IASI measurements. Monthly and spatially-gridded surface skin temperature is produced to show some phenomena of its natural variability, which is also reflected in the surface emissivity and/or soil moisture derived from the same time series of measurements. The anomalies of surface skin temperature are used to estimate its trend. Error estimation and/or evaluation has been performed and discussed to understand the uncertainty in the trends. The trend of IASI global surface skin temperature is compared with that of NASA GISS global surface air temperature. Despite the physical differences between surface skin and air temperatures, agreement is shown between these two datasets indicating consistency and global surface warming during the past 12 years. The trend of IASI global surface skin temperature reports an approximate 0.034ºK/yr. increase has evolved during 2007–2019. This warming trend is more pronounced in the northern hemisphere. Retrieving, analyzing, and monitoring surface parameters from such advanced hyperspectral infrared sounders will continue.

6p.04 RTTOV for a C3S project on early satellite data rescue

Presenter: Pascale Roquet, Meteo-France (for Jerome Vidot)

Authors: Jerome Vidot, Emma Turner, Bruna Silveira, Pascale Roquet, Roger Saunders and Pascal Brunel

In the frame of the Copernicus Climate Change Service (C3S), the project 311c Lot1 on rescuing early satellite data has been started in order to evaluate the possibility to use the observations from these satellites in the next ECMWF ERA-6 reanalysis. In this project, we are involved in

studying the capability of RTTOV to simulate some of early infrared and microwave instruments flying in space in the 70s to 90s. A first part of the project is to use the up-to-date information on the instrument spectral response function (ISRF) or channel's pass-band to calculate the so-called RTTOV coefficients. For most IR instruments (HIRS-1 to -4, MVIRI, IRIS-D, VTPR, MRIR, THIR, SSU and PMR) and MW instruments (SMMR, SSM/T2, MSU, SSM/I and SSMI/S), RTTOV coefficients already exist but some of them still need to be consolidated. For example, the ISRF of IRIS-D may be improved when comparing with observations. Additionally, coefficients for instruments such as SIRS-D will be provided. The second part of the project aims at simulating a large set of atmospheric profiles (25000) in order to independently estimate the accuracy of RTTOV coefficients versus LBL models. The third part of the project is to estimate the RTTOV errors due to different versions of LBL model.

6p.05 Climate Data Records and user service of the EUMETSAT Satellite Application Facility on Climate Monitoring

Presenter: Nathalie Selbach, Deutscher Wetterdienst
Authors: Nathalie Selbach on behalf of the CM SAF team

The EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) generates, archives and distributes widely recognized high-quality satellite-derived products and provides services relevant for climate monitoring. The CM SAF product portfolio covers Climate Data Records (CDRs) for Essential Climate Variables (ECV), as required by the Global Climate Observing System (GCOS) implementation plan in support of the United Nations Framework Convention on Climate Change (UNFCCC).

During the current Continuous Development and Operations Phase 3 (CDOP-3, 2017-2022), several new Fundamental-, Thematic- and Interim-CDRs are being released. They primarily describe properties of the atmospheric radiation, clouds, water vapour and precipitation over up to 40 years. Thus, users have access to many parameters of the Earth's water and energy cycle based on operational satellite instruments. The time series of the currently available climate data records range from 8 to more than 35 years with a global coverage for data based on polar orbiting satellites, while those based on geostationary satellite data have a regional coverage (currently Meteosat disk).

CM SAF is offering CDRs generated from ATOVS, AVHRR, SMMR, SSM/I and SSMIS on different polar orbiting satellites as well as from the MVIRI, SEVIRI and GERB instruments onboard the METEOSAT series and similar instruments on further georing satellites. Furthermore, CM SAF will focus on precipitation as an additional new parameter in the current project phase.

These CDRs are made available via a web user interface which also allows applying post-processing procedures, such as the extraction of sub-areas or re-projection.

This contribution will present currently available as well as new releases of CM SAF climate data records, planned for CDOP-3. It will give a general overview of the current and planned re-processing activities at the CM SAF. The concept of providing TCDRs as long term data records in connection with providing related Interim Climate Data Records (ICDRs) with a short time latency suitable for climate monitoring applications will be shown. In addition, the offered user services of CM SAF will be presented.

6p.06 The EUMETSAT CM SAF Fundamental Climate Data Record of Microwave Imager Radiances

Presenter: Nathalie Selbach, Deutscher Wetterdienst
Authors: Karsten Fennig, Marc Schröder

The satellite based HOAPS (Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data) climatology provides climate data records of precipitation, evaporation and the resulting freshwater flux over the global ice-free ocean between 1987 and 2014. The latest version of HOAPS has been released by CM SAF and is available from the CM SAFs web user interface (https://wui.cmsaf.eu/; DOI: 10.5676/EUM_SAF_CM/HOAPS/V002).

The HOAPS climate data records are primarily based on passive microwave measurements from the SSM/I (Special Sensor Microwave/Imager) sensor family. In order to derive reliable long term trend estimates of the global water and energy cycle parameters it is strictly necessary to carefully correct for all known problems and deficiencies of the SSM/I radiometers as well as to inter-calibrate and homogenise the different instruments. Moreover, all applied corrections need to be clearly documented to provide a complete calibration traceability for a Fundamental Climate Data Record (FCDR). Following these recommendations, CM SAF released a FCDR of

SSM/I brightness temperatures (DOI:10.5676/EUM_SAF_CM/FCDR_SSMI/V001) in 2013, freely available from the web user interface (https://wui.cmsaf.eu/). This FCDR has already been used in the ESA CCI Sea ice project and also in the reanalysis ERA5.

In order to further extend the HOAPS dataset in time, the SSM/I successor instrument SSMIS (Special Sensor Microwave Imager Sounder) has to be used from 2009 onwards. CM SAF also reprocessed the SSMIS sensors onboard F16, F17, and F18 to the same standards as the SSM/I data record for the time period 2006 - 2013 and the combined FCDR was released in 2015 (DOI:10.5676/EUM_SAF_CM/FCDR_MWI/V002). Amongst others, known instrument issues like sunlight intrusions, moonlight intrusions, and reflector emissivity have been accounted for and the brightness temperatures have been inter-calibrated to the SSM/I instrument series to allow a seamless continuation of existing TCDRs.

In order to extend the available FCDR to the time period before the SSM/I epoch, CM SAF has now reprocessed available brightness temperatures from the SMMR (Scanning Multichannel Microwave Radiometer) on board Nimbus-7 with the main focus on the inter-calibration of the brightness temperatures to the SSM/I series, using ERA20c as a transfer target. The re-processed data record (DOI:10.5676/EUM_SAF_CM/FCDR_MWI/V003) is available in the same user friendly data format as the existing FCDR editions. The new FCDR release also extends the SSMIS data record with two additional years. Altogether, the FCDR now spans the time period from 1978 to 2015 combining observations from three different platforms SMMR, SSM/I and SSMIS.

This presentation will focus on the inter-calibration of the SMMR and the evaluation of the combined FCDR over the complete time period. A validation of the brightness temperatures is a challenging task as there are no ground-truth reference measurements available for the microwave band. Hence, the homogeneity of the FCDR is evaluated by an analysis of the relative biases between the different instruments before and after the inter-calibration offsets are applied.

It is planned to release a new edition of the FCDR in 2020, extending the SSMIS covered time period to the end 2019. It is also envisaged to improve the uncertainty characterization and to look at new sensors like MWI and AMSR-3 for future usage.

6p.07 Towards a climate data record of precipitation merging satellite observations by passive microwave sounders and imagers

Presenter: Nathalie Selbach, Deutscher Wetterdienst
Authors: Hannes Konrad, Giulia Panegrossi, Anja Niedorf, Paolo Sanò, Marc Schröder, Elsa Cattani, Anna Christina Mikalsen, Nathalie Selbach, Rainer Hollmann

Within the Copernicus Climate Change Service (C3S), the Climate Data Store (CDS) built by ECMWF will provide open and free access to global and regional products of Essential Climate Variables (ECV) based on satellite observations spanning several decades, amongst other things. Given its significance in the Earth system and particularly for human life, the ECV precipitation will be of major interest for users of the CDS.

C3S strives to include as many established, high-quality data sets as possible in the CDS. However, it also intends to offer new products dedicated for first-hand publication in the CDS. One of these products is a climate data record based on merging satellite observations of daily and monthly precipitation by both passive microwave (MW) sounders and imagers (SSMI/SSMIS) on a 1°x1° spatial grid in order to improve spatiotemporal satellite coverage of the globe.

The MW sounder observations will be obtained using, as input data, the FIDUCEO FCDR for AMSU/MHS in a new global algorithm based on the Passive microwave Neural network Precipitation Retrieval approach (PNPR; Sanò et al., 2015) developed specifically for the project.The MW imager observations by SSM/I and SSMIS will be adopted from the Hamburg Ocean Atmosphere Fluxes and Parameters from Satellite data (HOAPS; Andersson et al., 2017), itself based on the CM SAF SSM/I and SSMIS FCDR (Fennig et al., 2017).

Here, we present the status of this product's development. We carry out a Level-2 comparison and obtain first results of the merged Level-3 precipitation fields. Based on this, we assess the product's expected plausibility, coverage, and the added value of merging the MW sounder and imager observations.

Andersson, Axel; Graw, Kathrin; Schröder, Marc; Fennig, Karsten; Liman, Julian; Bakan, Stephan; Hollmann, Rainer; Klepp, Christian (2017):

Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data - HOAPS 4.0, Satellite Application Facility on Climate Monitoring, DOI:10.5676/EUM_SAF_CM/HOAPS/V002, https://doi.org/10.5676/EUM_SAF_CM/HOAPS/V002.

Fennig, Karsten; Schröder, Marc; Hollmann, Rainer (2017): Fundamental Climate Data Record of Microwave Imager Radiances, Edition 3, Satellite Application Facility on Climate Monitoring, DOI:10.5676/EUM_SAF_CM/FCDR_MWI/V003, https://doi.org/10.5676/EUM_SAF_CM/FCDR_MWI/V003.

Sanò, P., Panegrossi, G., Casella, D., Di Paola, F., Milani, L., Mugnai, A., Petracca, M., and Dietrich, S.: The Passive microwave Neural network Precipitation Retrieval (PNPR) algorithm for AMSU/MHS observations: description and application to European case studies, Atmos. Meas. Tech., 8, 837-857, https://doi.org/10.5194/amt-8-837-2015, 2015.

6p.08 The GEWEX water vapor assessment (G-VAP): final results from first phase and the future of G-VAP

Presenter: Nathalie Selbach
Authors: Marc Schröder, Helene Brogniez, Shu-peng Ho, Lei Shi, Nathalie Selbach

A large variety of satellite and reanalyses based water vapor data records is available to date. Without proper background information and understanding of the limitations of available data records, these data may be incorrectly utilised or misinterpreted. Thus, assessments are conducted to objectively and independently evaluate and inter-compare available climate data records (CDRs) in order to point out strengths, differences and limitations and, if possible, to provide reasons for them. The GEWEX Data and Assessments Panel (GDAP) has initiated the GEWEX water vapor assessment (G-VAP) which has the major purpose to quantify the current state of the art in water vapor products (upper tropospheric humidity, specific humidity and temperature profiles as well as total column water vapor) being constructed for climate applications. In order to support GDAP and the general climate analysis community G-VAP intends to answer, among others, the following questions:

a) How large are the differences in observed temporal changes in long-term data records of water vapor on global and regional scales?
b) Are the differences in observed temporal changes within uncertainty limits?
c) What is the degree of homogeneity (presence of break points) of each long-term data record?

A general overview of G-VAP will be given which includes an inventory of available water vapor data records (see also http://gewex-vap.org/?page_id=13) and an introduction to the G-VAP data archive (digital object identifier: 10.5676/EUM_SAF_CM/GVAP/V001). The focus of the presentation will be on observed inconsistencies among long-term data records (eleven TCWV data records and seven specific humidity and temperature profile data records, six of which are based on reanalysis). The inconsistencies are observed by inter-comparisons, comparisons to in-situ observations and the stability analysis. On basis of consistently applied tools major differences in state-of-art CDRs have been identified, documented and to a large extend explained. The results and the answers for TCWV are summarized as follows: On global ice-free ocean scale the trend estimates among long-term data records were generally found to be significantly different. Maxima in standard deviation among the data records are found over, e.g., tropical rain forests. These and other noticeable regions coincide with maxima in mean absolute differences among trend estimates. These distinct features can be explained with break points which manifest on regional scale and which typically do not appear in stability analysis relative to ground-based observations. Results from profile inter-comparisons will also been shown and exhibit, among others, that the observed break points are not only a function of region but also of parameter, i.e., break points observed in specific humidity data are typically not present in corresponding temperature data and vice versa.

With the publication of the WCRP report on G-VAP (16/2017, available at https://www.wcrp-climate.org/resources/wcrp-publications) G-VAP's first phase ends. As agreed upon at the 7th G-VAP workshop G-VAP will continue with unchanged scope, objectives, and governance under the umbrella of GDAP. Also, core activities such as PDF, consistency and stability analysis will be continued to provide a sustained service to the community. Finally, new science activities have been discussed and defined. Among others, these include the analysis of the quality of profile data records over stratus regions and the assessment and characterization of the differences between observations in all sky, cloudy sky and clear sky conditions. Answers to the science questions will

be provided and first results from new analysis will be shown.

6p.09 The Value of Two Satellites in the Same Orbit for Nowcasting and Climate Monitoring

Presenter: Mitch Goldberg, NOAA

Authors: Mitch Goldberg, Lihang Zhou

This paper will show the value of SNPP and NOAA-20 being separated by a half orbit in the 13:30 orbit. We believe this configuration should become a standard best practice for all satellite agencies flying polar orbiting satellites. For nowcasting, two satellites half orbit apart enables better monitoring of the changing environment in the polar regions – such as ice monitoring and even wildfires. For severe weather, (tropical storms, thunderstorms-convective environment), relying on one satellite will not provide the necessary coverage because of limb effects and orbital gaps. For climate monitoring, the difference between the two satellites (instruments, products) can be monitored on a 16 day or 32 day repeat cycle, because the global average should be identical since both satellites are observing at 13:30 and 1:30. We will show stability for ATMS, CrIS, and VIIRS radiances as well as a number of derived products such as land surface temperature, in addition to nowcasting examples.

6p.10 The increase in the impact of the observations in a 40 multi-year Reanalysis on the tropical region with 41 emphasis on the Amazon basin

Presenter: Dirceu Herdies, CPTEC/INPE

Authors: Fabio L. R. Diniz, Dirceu L. Herdies and Ricardo Todling

Conventional and non-conventional atmospheric observations are of fundamental importance to allow reliable weather forecasts and allow researchers to improve the modeling of the atmosphere to create plausible scenarios for climate studies. However, conventional observations make up a very small number of observations available for use in weather forecasts and climate studies. Satellites, the non-conventional observations, observe the Earth System almost continuously in time and generate massive amounts of data that by far dominate the observation blend. Unlike conventional observing networks, satellites observe the Earth indirectly by measuring either emitted or absorbed radiation by the Earth and the instruments they carry, this makes their use somewhat harder than using conventional observations. Assessing how these various observing systems contribute to improving weather forecasts has become an essential tool to help scientists understand how to build future and better observing systems. The present study provides a comprehensive assessment of nearly 40 years of observations used in the Reanalysis procedure, which essentially provides a mixture of model predictions and observations. This particular work examines the regional impact of observations on the Amazon basin during the period 1980 to 2017. On this relatively dense and difficult-to-access tropical forest region, certain observation systems have a particularly greater impact than they normally have when observed on a global scale, such as AMVs. The impact of the observations on short-range reanalysis forecasts has increased slightly over the course of the reanalysis. This increase is largely associated with an increase in available observations on this region.

6p.11 Satellite-Derived Upper Tropospheric Humidity Datasets and Comparison with Total Column Water Vapor

Presenter: Lei Shi, National Centers for Environmental Information (NCEI), NOAA

Authors: Lei Shi, Carl J. Schreck III, Marc Schröder

As part of the activities for the Global Energy and Water Exchanges (GEWEX) water vapor assessment (G-VAP, http://gewex-vap.org), the upper tropospheric humidity (UTH) datasets are inter-compared. With the recent availability of new versions and extended time series of datasets, the analyses are updated. The UTH datasets include both infrared and microwave satellite sounder measurements. The HIRS UTH dataset has also been compared to the total column water vapor (TCWV) time series focusing on their respective patterns during major El Niño events. The examination shows that the difference in UTH and TCWV patterns results in an opposite phase in the time series during a major El Niño event when a tropical average is taken. Though both UTH and TCWV are closely correlated with major climate indices, they have significantly different lag correlations with the Niño 3.4 index in both the sign (positive or negative) and lag time over tropical oceans.

6p.12 EUMETSAT's Contribution of Fundamental Climate Data Records to Copernicus Climate Change Service

Presenter: Viju John, EUMETSAT

Authors: Viju O. John, T. Hanschmann, J. Onderwaater, F. Ruethrich, R. Roebeling, M. Grant, and J. Schulz

The detection of climate change and analysis of climate variability at inter-annual and decadal scales require well-calibrated measurements that can be used to create long-term, homogeneous

time series of climate data records. These data records can be utilised in direct analysis of the climate system but also within Numerical Weather Prediction (NWP) models to create a physically consistent reanalysis such as the ERA-5 generated by the C3S. EUMETSAT has been generating a wide variety of level 1 satellite climate data records, also known as fundamental climate data records (FCDR) and they include data from the following instruments: microwave humidity sounders SSM/T-2, AMSU-B, MHS, MWHS, MWHS-2, and ATMS, infrared sounders IASI and HIRS, infrared imagers MVIRI (also the visible band) and SEVIRI, radio occultation instruments GRAS, COSMIC, and CHAMP, scatterometer ASCAT, and the optical spectrometer GOME-2. All these FCDRs, except of the GOME-2 will be assimilated in the next generation ERA reanalysis.

The presentation will focus on the generation of microwave and infrared FCDRs. The microwave humidity sounding FCDRs were generated using a common algorithm for all the sensors, which is based on principles, developed in the EU Horizon-2020 FIDelity and Uncertainty in Climate data records from Earth Observations (FIDUCEO) project. A thorough analysis of the physical effects in the measurement equation, which could introduce uncertainties to the measurements, is performed, and thus we are providing not only the radiances (brightness temperatures), but also the independent, structured, and common uncertainties which are associated with individual measurements. The latest version of the HIRS algorithm is adapted for the three generations of the HIRS instruments and the FCDRs are accompanied by the independent radiometric noise of the measurements. The MVIRI and SEVIRI infrared channel measurements have been recalibrated using IASI, AIRS, and HIRS measurements. The GRAS radio occultation data were also reprocessed by using the latest wave-optics algorithm to generate the FCDR. The methods as well as the improvements of the these FCDRs over the operational radiances will be demonstrated by time series analyses and comparisons against reference measurements.

Session 6: Reanalysis (oral presentations)

6.05 The Assimilation of Radiance Data in the ERA5 Global Reanalysis

Presenter: William Bell, ECMWF
Authors: Bill Bell, Hans Hersbach, Paul Berrisford, Andras Horanyi, Julien Nicholas, Raluca Radu, Joaquin Munoz Sabater, Dinand Schepers, Adrian Simmons & Cornel Soci

The most recent ECMWF global atmospheric reanalysis, ERA5, covering the period 1979-2019 (soon to be extended to 1950), is now available. It uses a recent version of the ECMWF Numerical Weather Prediction (NWP) forecast model and data assimilation (DA) system to assimilate observations (87 billion for the period 1979 - 2018) to analyse the atmospheric state. Information on uncertainties in the state estimates are provided by a 10-member ensemble of data assimilations (EDA).

Satellite radiance data is a key input to ERA5. The completion of the 1979-2019 period allows us to inspect the evolution of biases evident in the satellite data over the modern satellite era, and in some cases (for example the hyperspectral IR) to compare with independent radiometric uncertainty estimates.

ERA5 also uses satellite data from the early satellite-era. Observations from the Vertical Temperature Profiling Radiometer (VTPR) have been assimilated in the production stream spanning 1972-1978 and have had a beneficial impact on the reanalysis, most notably in the southern hemisphere. Assimilation of this data has also presented some challenges, including the response of the reanalysis in the upper stratosphere (above 5hPa) and in the response of the analysed ozone fields.

In advance of the next C3S global reanalysis (ERA6, due to start 2023) ECMWF, through the Copernicus Climate Change Service (C3S), is supporting satellite data reprocessing and data rescue efforts. These efforts include datasets from operational satellites from the modern satellite era (1979-) as well as some datasets dating from the late 1960s and 1970s. As part of these, methods for the robust definition of observational uncertainties, developed as part of the EU's Horizon-2020 FIDUCEO project, are being adopted where viable. Several options being considered for the application of this uncertainty information will be described.

6.06 Satellite era retrospective analysis over the Indian region

Presenter: S Indira Rani, NCMRWF
Authors: S. Indira Rani, Richard Renshaw, John P. George and E.N. Rajagopal

Satellite era retrospective analysis over India and surrounding regions is carrying out under the National Monsoon Mission (NMM) project of

Ministry of Earth Sciences (MoES), India, with the collaboration among UK Met Office, NCMRWF and India Meteorological Department (IMD). The Indian Monsoon Data Assimilation and Analysis (IMDAA) spans 40 years of reanalysis from 1979 to 2018, which uses the historically archived conventional observations from IMD as well as the state of the art satellite observations viz., geostationary and polar radiances, AMVs and scatterometer winds. There is a considerable progress in the observing system during the course of this re-analysis, particularly the space-borne assimilable meteorological observations, supplemented by conventional observations. This paper describes the satellite data usage in the 4D-VAR assimilation system of IMDAA, with an emphasis to the quantity and quality. Timeline of different satellite radiances assimilated, coverage of satellite observations during the reanalysis period, variational bias correction, background and analysis fits to the satellite observation, etc. are discussed in this paper.

6.07 Assessing the impact of observations in a multi-year Reanalysis

Presenter: Ricardo Todling, NASA/GMAO
Authors: Fabio L. R. Diniz and Ricardo Todling
Operational and quasi-operational weather prediction centers have been routinely assessing the contribution from various observing systems to reducing errors in short-range forecasts for a number of years now. The original technique, Forecast Sensitivity-based Observation Impact (FSOI), involves definition of a forecast error measure and evaluation of sensitivities with respect to changes in the observing system that require adjoint operators of both the underlying tangent linear model and corresponding analysis technique. The present work applies FSOI to Reanalysis and aims at providing an expanded view of the contribution of various observing systems over nearly 40 years of assimilation. Specifically, this study uses MERRA-2 given that its supporting software includes all ingredients necessary to calculate FSOI. Part of this work shows how the quality of forecasts improves over the course of the reanalysis, and examines forecast sensitivities relevant to FSOI. The assessment here finds, for example, that: conventional observations are a major player in reducing forecast error throughout the 40 years of reanalysis, even when their volume reduces from 45\% in the earlier periods to about 5\% in the modern era; satellite radiances, especially microwave instruments are major contributors to error reduction from the early single platform TIROS-N days to the current multi-platform scenario; infrared instruments play a secondary role to microwave but are significant still, with the peculiar result of fractional impacts contribution from modern hyperspectral instruments being roughly similar to those from early infrared instruments. The dependence of results on the chosen error measure is illustrated with further thought on the overall impact of satellite observations.

Session 7: Assimilation of New Hyperspectral Infared Instruments (oral presentations)

7.01 Assimilation of high temporal GIIRS radiance in GRAPES

Presenter: Ruoying Yin, Institute of Atmospheric Physics (for Wei Han)
Authors: Wei Han, Ruoying Yin, Hao Wang, Jincheng Wang, Xueshun Shen
High spectral resolution infrared (IR) sounders from polar orbit satellites have been widely used in global and regional numerical weather prediction (NWP) models and have provided positive impact on weather forecasts. For the first time, a hyper-spectral IR sounder call GIIRS (Geostationary Interferometric Infrared Sounder) is stationed on the geostationary orbit, it is onboard the first satellite of the second generation of Chinese geostationary weather satellites - FengYun-4 series. FY-4A has the capability on providing GIIRS observations every 15 minutes for selected regions where active weather events occur. The GIIRS measurements have been calibrated, geo-located and processed for real-time applications. The RTTOV-GIIRS coefficients have been developed based on local training profiles for assimilation, GIIRS data now have been assimilated in the operational GRAPES (Global/Regional Assimilation Prediction System) global forecast model with 4D-Var assimilation system. Two months' cycle experiments show a positive impact on analyses and forecasts over East Asia. GIIRS temperature sounding channels have been operationally assimilated in GRAPES global 4D-Var since December 25 2018. An analysis on three Typhoon cases in 2018 indicates positive impact on Typhoon forecasts, especially on warm core and track forecasts, which demonstrates the potential added value for high impact weather forecast through assimilating the high temporal resolution sounding information into NWP models.

7.02 Information content of the Cross-trace Infrared Sounder (CrIS) instrument and recent data denial experiments relevant to operational use of sounder data.

Presenter: Christopher Barnet, STC
Authors: Chris Barnet (STC), Sid Boukabara (STAR), Kevin Garrett (STAR), Kayo Ide (UMD), Erin Jones (UMD-CICS), Yingtao Ma (UMD-CICS)

Advanced hyperspectral sounders such as the Advanced Infrared Sounder (AIRS), Interferometric Atmospheric Infrared Sounder (IASI) and the Cross-track Infrared Sounder (CrIS) all invested heavily in providing high signal-to-noise measurements in the short-wave infrared (SWIR) spectral region (defined here as from 3.8 to 5 microns) as well as the long-wave (LWIR, 15.5-9 um) and mid-wave (MWIR, 9-5 um) spectral regions.

The use of the SWIR is complicated by the need to handle solar radiation that is both reflected from the surface and also excites molecules in the upper stratosphere and lower mesosphere into non-equilibrium emission. The AIRS Science Team demonstrated how to properly use the SWIR to derive high-quality temperature, moisture, and trace gases with the launch of Aqua/AIRS in 2002. The NOAA-Unique Combined Atmospheric Processing System (NUCAPS) operationally deployed the AIRS algorithm for the Metop-A/IASI, S-NPP/CrIS, Metop-B/IASI, and the NOAA-20/CrIS instruments since 2008, 2011, 2012, and 2018, respectively.

We will demonstrate the information content (IC) of the CrIS instrument using singular value decomposition of CrIS observations and illustrate the expected IC of various subsets of CrIS channels. This is relevant to both the use of the SWIR band in data assimilation (see presentations at this meeting by co-authors) but also in the context of the recent loss of the MWIR band on the S-NPP/CrIS instrument. We will demonstrate results from an experiment in which various CrIS and/or Advanced Technology Microwave Sounder (ATMS) data were excluded from the operational NUCAPS system. These results are also informative for new small-satellite instrument concepts that may not be able to afford having all 3 bands present.

7.03 Implementation and assessment of FY-3D Hyperspectral Infrared Atmospheric Sounder (HIRAS) in the Met Office system

Presenter: Fabien Carminati, Met Office
Authors: Fabien Carminati (Met Office), Xianjun Xiao (CMA), Fiona Smith (BOM), Nigel Atkinson (Met Office)

Launched late 2017 on board FY-3D, the fourth Chinese polar orbiter of second generation in the FengYun series, HIRAS is a Michelson interferometer of 1370 channels covering three spectral bands (650-1136, 1210-1750, and 2155-2550 cm-1) with 0.625 to 2.5 cm-1 spectral resolution and 16 km nominal resolution at nadir. The instrument has 58 pixels per scan lines arranged in 2 x 2 arrays which cover a total swath of 2250 km. HIRAS processing capability has been implemented at the Met Office. Raw direct broadcast data locally received at the Met Office through the antenna based in Exeter are converted to level 1 geolocated radiances at normal spectral resolution with the China meteorological administration (CMA) FY3 software package and pre-processed with the ATOVS and AVHRR Pre-processing Package (AAPP) before being stored in the data base for later use in the NWP system. The AAPP processing includes conversion from HDF5 to BUFR and application of the channel selection that is also used for CrIS. Two months of global HIRAS observations provided by CMA are being analysed at the time of writing and will serve as a baseline to develop bias corrections for later assimilation experiments. Pending timely near real time data distribution availably, HIRAS pre-operational assimilation testing phase is expected to be completed by October 2019. This submission will present the latest progress towards assimilation of this data in the Met Office NWP system.

7.04 New IR sounders in the ECMWF NWP system

Presenter: Reima Eresmaa, ECMWF
Authors: Reima Eresmaa

ECMWF has assimilated NOAA-20 CrIS radiances since 11 September 2018. Two aspects are currently limiting the operational use: Firstly, due to the spectral properties differing from S-NPP CrIS in the mid-wave IR band, the active use is restricted to the long-wave IR band only. Secondly, observation error covariance is specified identically to the S-NPP CrIS, although the noise covariance is known to differ between the two CrIS's. Preparations are underway towards activating 37 water-vapour-sounding channels later in 2019: this will make use of NOAA-20-specific observation errors.

Metop-C IASI radiances have been available for monitoring and assimilation experiments since April 2019. Preliminary data quality assessment suggests similar noise performance as compared with Metop-B IASI. We expect to start the operational use of 220 channels, applying similar

settings as those for Metop-A and Metop-B IASI's, during Summer 2019.

In addition to NOAA-20 and Metop-C, we recognize the gap-filling potential of Russian and Chinese satellite programs and have started exploring data acquired from Meteor-M N2 and FY-3D satellites. We find both the IKFS-2 and HIRAS sounders slightly noisier than the well-established American and European IR sounders. Nevertheless, we are looking forward to the launch of FY-3E into the early-morning orbit and expect the new IR observations to make a useful contribution to the operational system in the coming years.

7.05 Assessment and assimilation of observations of the hyperspectral IR sounder IKFS-2 on board the Russian Meteor-M N2 satellite

Presenter: Dmitry Gayfulin, Hydrometeorological Centre of Russia
Authors: Dmitry Gayfulin, Michael Tsyrulnikov, Alexander Uspensky

The hyperspectral IR sounder IKFS-2 is part of the payload of Meteor-M series satellites. It is a Fourier-transform spectrometer with spectral range 5-15 microns and spectral resolution 0.4-0.7 cm-1. Currently, data from Meteor-M N2 satellite (flying in a morning orbit) are available. The next satellite in the series, Meteor-M N2-2, is due to be launched into an afternoon orbit in July 2019.

Observed spectra from IKFS-2 on board Meteor-M N2 were compared with a background, the NCEP 6h forecast converted to the radiance space with the RTTOV radiative transfer model. The comparison yielded encouraging results: the accuracy of the IKFS data was found comparable with the accuracy of IASI observations.

Thinned and cloud-cleared IKFS observations in atmospheric temperature channels (in the 660 – 750 cm-1 spectral range) were assimilated into the data assimilation system of the Hydrometcentre of Russia. A significant positive impact on three-day weather forecasts (in the absence of IASI data) was found. The roles of channel selection, quality control, bias correction, and cloud clearing are discussed.

7.06 The evaluation of GIIRS longwave temperature sounding channels using 4D-Var

Presenter: Ruoying Yin, IAP
Authors: Ruoying Yin, Wei Han, Zhiqiu Gao and Di Di

The theory of classical variational assimilation assumes that biases are unbiased Gaussian. This paper investigates the bias characteristic estimate and the bias correction of Geostationary Interferometric Infrared Sounder (GIIRS) on board the FY-4A. Quality control procedures for GIIRS longwave temperature channels brightness temperature include cloud detection based on the Advanced Geosynchronous Radiation Imager (AGRI) and outlier removal. The mean biases for most channels are within ±2K after quality control except for the contaminated channels. Statistical evaluation of the differences between GIIRS observations and model simulations reveal that biases for the longwave temperature channels depend on fields of view (FOVs). The standard deviation is smaller in the principal optical axis of the observation array and becomes larger to the north/south ends, reaching maximum values in the 32nd and 96th FOVs. The latitudinal dependence of the mean biases and standard deviations are apparent (13°N, 20°N, 27.5°N, 35°N, 45°N and 60°N) due to the FOVs array observation mode. Additionally, the diurnal variation of biases is obvious, especially for the upper tropospheric channels, and the biases for high tropospheric channels are smaller than the biases for low tropospheric channels. Finally, off-line bias correction that was used in this study accounts for the field of regard (FOR) dependence and the diurnal variation bias characteristics of GIIRS. After bias correction, the results show that biases of longwave temperature sounding channels are reduced to ±0.02K, and the standard deviations are less than 1K except for the contaminated channels. The probability density function of the differences between observations and simulations for some common assimilation channels is closer to the unbiased Gaussian distribution.

Session 7: Assimilation of New Hyperspectral Infared Instruments (poster introductions)

7p.01 Impact assessment of IASI temperature and humidity retrievals in the ECMWF system

Presenter: Kirsti Salonen, ECMWF
Authors: Kirsti Salonen, Thomas August, Tim Hultberg and Anthony McNally

EUMETSAT is producing forecast independent statistical retrievals of atmospheric temperature and humidity from IASI radiances in preparation for future product generation from MTG-IRS. This poster summarises the key findings of the retrieval quality and impact assessment in the ECMWF system.

The overall quality of the retrievals is good as long as strict quality indicators are applied to exclude cloudy scenes. Generally the clear-sky observation minus model background (OmB) statistics indicate smaller than -0.3 K bias for temperature and small varying in sign bias for humidity. These retrieval OmB standard deviations are comparable in magnitude to similar statistics computed for radiosondes. However, it has been found that the retrieved profiles are rather smooth and typically lack important fine vertical temperature structure during inversions and around the tropopause.

Investigations reveal that the observation errors are also highly correlated between vertical levels. It is essential to take these correlations into account in data assimilation experiments. The error correlations are situation and location dependent and become increasingly stronger for cloud affected profiles.

Assimilation experiments indicate that in clear sky conditions the humidity retrievals have a positive impact on analyses and forecast quality, comparable in magnitude to that obtained when IASI radiances are assimilated. However, the results are very sensitive to the diagnosed observation error correlation that is used. The assimilation of temperature retrievals currently degrades analyses and forecasts, most likely due to smoothing of inversions and tropopause structures.

7p.02 Evaluation of the performance of CrIS instrument under various assimilation scenarios

Presenter: Sylvain Heilliette, Environment Canada
Authors: Sylvain Heilliette, Stéphane Laroche

The Cross-track Infrared Sounder (CrIS) infrared hyperspectral sounding instrument is now flying on board NPP and NOAA20 platforms. This instrument has very good radiometric characteristics in the 15 micron CO2 band. At the Canadian Meteorological Centre (CMC), NPP CrIS observations have been assimilated operationally since December 2015, whereas NOAA20 CrIS observations will soon be assimilated. The goal of this study is to evaluate different configurations of CrIS assimilation and their impact in forecasts. A frequently encountered problem for this type of evaluation is that it is often difficult to see a clear signal given the necessary redundancy in the assimilated observations from various sensors. Therefore, in this study we choose to compare first the different configurations studied with respect to a reduced baseline configuration in which only conventional observations are assimilated. More specifically, we address the following questions: What is the benefit of the two CrIS instruments on top of the baseline configuration? What is the impact of the lost water vapour channels from band 2 on NPP CrIS? Is there a benefit of assimilating more temperature sounding channels in the 15 microns CO2 band? Can the quality control be improved using the VIIRS cloud mask for cloud detection? Finally, the impact of the two CrIS sensors on top of all other assimilated data can also be reevaluated.

7p.03 Operational use of inter-channel correlations for IASI in the DWD EnVar and investigation into the use of Reconstructed Radiances

Presenter: Silke May, DWD
Authors: Silke May, Olaf Stiller, Robin Faulwetter, Christina Köpken-Watts, Roland Potthast

Hyperspectral infrared sounders like IASI or CrIS provide a very large number of channels which are spectrally very dense. This poster focuses on two challenges associated with this: First, observation errors display non-negligible error correlations between the channels that need to be taken into account in the assimilation system. The impact of using a full error covariance matrix R in the operational global ensemble variational data assimilation system (EnVAR) for the global ICON model system of DWD has been tested for IASI radiances. Secondly, in view of the future MTG-IRS for which data transmission is based on principal component compressed data, the use of reconstructed radiances for IASI assimilation is being tested.

Up to now, IASI radiances have been assimilated at DWD using a diagonal R matrix, diagnosed with Desroziers et al. (2005) method, but inflating diagonal elements to account for the neglected inter-channel correlations. A non-diagonal R matrix has been estimated using the Desroziers method and used in assimilation experiments ensuring it is invertible through setting a lower threshold on the size of eigenvalues. Using the non-diagonal R matrix leads to positive impact on NWP forecasts, particularly on the humidity fields visible in a much improved fit to other satellite observations sensitive to humidity. Further experiments on sensitivities of results to different parameters, e.g. applying an additional scaling factor to the R elements or a changed cut-off limit for the eigenvalues of R, are investigated.

In parallel, assimilation tests using reconstructed radiances, in an initial setup treating them similarly to raw radiances, have been run. As with

raw radiances, a full R matrix has been diagnosed and introduced in experiments. As expected much larger inter-channel correlations are visible. Results of the assimilation of reconstructed radiances in comparison to raw radiances will be shown. An extension to the assimilation of CrIS FSR data using full R is ongoing.

7p.04 Detection of aerosol- and trace-gas-affected IR radiances at ECMWF

Presenter: Reima Eresmaa, ECMWF
Authors: Reima Eresmaa, Julie Letertre-Danczak, Tony McNally

NWP system diagnostics indicate towards the need for screening routines specifically to prevent aerosol- and trace-gas-affected infrared radiances from entering the assimilation. In the NWP system at ECMWF, aerosol is detected from observed brightness temperature (BT) differences at window channels both sides of the 9.6 micron ozone absorption band. Positive detection of aerosol currently leads to rejecting all channels, although it is known that the associated radiative effect is typically limited to lower-tropospheric- and surface-sensitive channels. We have recently developed a method to restrict the aerosol-related rejections to affected channels only. The method is based on converting the observed BT difference into a proxy of Aerosol Optical Depth and further into an estimate of aerosol vertical extent at each observation location. The operational implementation, foreseen in 2020, will recover a large number of stratospheric- and upper-tropospheric data. The next step will be to distinguish between volcanic ash and desert dust aerosol and, subsequently, to make the channel-specific aerosol rejections depending on the aerosol type.

In addition to presenting the recent and ongoing work on the aerosol detection, we will review the status of the trace-gas detection at ECMWF. The trace-gas detection scheme was implemented in response to the 2015 Indonesian forest fire episode, during which extra-ordinary amounts of Hydrogen Cyanide (HCN) were released into the atmosphere.

7p.05 Quantifying the effects of the CrIS-FSR Radiance Polarization Corrections using the NCEP Global Data Assimilation System.

Presenter: James Jung, CIMSS
Authors: James Jung and co-authors

The Cross-track Infrared Sounders (CrIS) have polarization effects due to the design of the instrument. These polarization effects may be significant to Numerical Weather Prediction (NWP), especially for the shortwave band. Scientists at the Space Science and Engineering Center (SSEC) have developed a theoretical model and correction for the polarization induced calibration errors. The polarization parameters required for the correction were determined using data acquired by the CrIS instrument during the February 2012 SNPP pitch maneuver. During the pitch maneuver, all of the CrIS cross-track fields of regard that normally view the Earth, were looking to deep space. In this configuration, field of regard and detector dependent differences are dominated by the instrument polarization, making this an ideal dataset for derivation of the polarization parameters. For band 3 (shortwave), the uncorrected polarization induced calibration errors can be as much as several brightness temperature (BT) degrees for cold Earth scenes.

The CrIS Full Spectral Resolution (CrIS-FSR) radiances, from both SNPP and NOAA-20, with and without the polarization correction are assimilated in the NCEP Global Data Assimilation System (GDAS) to quantify differences in assimilation statistics. We will specifically review bias and standard deviation statistics of the nine detectors for all CrIS-FSR 2211 channels. GDAS Analysis differences are also investigated and presented in this poster.

Session 8: Space Agency Reports (poster introductions)

8p.01 Status report of space agency: JMA and JAXA

Presenter: Kozo Okamoto, JMA/MRI
Authors: Kozo Okamoto, Misako Kachi, Kotaro Bessho

JMA started discussing the follow-on satellites of Himawari-8/9, scheduled to launch around 2029. One of possible instruments on the follow-on satellites is a hyperspectral infrared sounder and its impact is evaluated using OSSE. JAXA operates GCOM-W/AMSR2, GCOM-C/SGLI, GPM-core/GPM and GOSAT2, and prepare for EarthCARE/CPR. Their status will be presented.

8p.02 The Current EUMETSAT Polar System

Presenter: K. Dieter Klaes, EUMETSAT
Authors: K. Dieter Klaes

This Paper provides an overview on the products and services of the EUMETSAT Polar System (EPS), highlighting the aspects related to observing and forecasting the weather. EPS is the European contribution to the Polar Meteorological Satellite

Observing System. It forms a part of the Initial Joint Polar System (IJPS), formed with NOAA (National Oceanic and Atmospheric Administration). EUMETSAT is assuring the mid-morning service (9:30 AM LST, descending node), whereas the US partners are assuring the afternoon service (13:30 PM LST, ascending node). Eight meteorological instruments (among 11) are embarked on the Metop satellites (seven on Metop-C). The Metop satellites developed in co-operation with the European Space Agency (ESA) form the space segment of EPS. Metop instrument data – in particular the sounding instruments - provide an essential contribution to global operational Numerical Weather Prediction (NWP). Climate monitoring and atmospheric composition monitoring and ocean and cryosphere observations are further application areas supported by Metop instrument data. There are three Metop satellites in the programme and fly in a sun-synchronous mid morning polar orbit with equator crossing time of 9:30 Local Solar Time (LST) for the descending node. At least 15 years of operations are foreseen to provide measurements from space. All three Metop satellites are in orbit (Metop-A launched 2006 and Metop-B in 2012), with the third, Metop-C successfully launched on the 7 November 2018 (UTC time) from Kourou. After its successful commissioning, there will be three Metop-satellites in orbit for about three years. The paper will also highlight commissioning results of Metop-C and impact already visible from the data on the quality of weather forecasts.

8p.03 NOAA
Presenter: Mitch Goldberg, NOAA
Authors: Mitch Goldberg

8p.04 CMA
Presenter: Peng Zhang, CMA
Authors: Peng Zhang

8p.05 Russian Meteorological Satellite Programs
Presenter: TBC

Session 9: Advances in the Assimilation of Infared Sensors (oral presentations)

9.01 Assimilation of Hyperspectral Infrared Shortwave CrIS Observations in the NOAA Global Data Assimilation System
Presenter: Erin Jones, UMD CISESS
Authors: Erin Jones, C. Barnet, K. Garrett, K. Ide, Y. Ma, S. Boukabara

Though shortwave channels on hyperspectral infrared (IR) instruments are capable of providing good temperature sounding information to users, the numerical weather prediction (NWP) and data assimilation (DA) communities have historically favored the use of longwave hyperspectral IR observations, citing issues with solar impacts on shortwave frequencies. As a consequence, shortwave hyperspectral IR observations from instruments like the Cross-track Infrared Sounder (CrIS) are not used operationally in the NOAA Global Data Assimilation System (GDAS) / Global Forecast System (GFS), regardless of the fact that the capability to simulate and assimilate them exists. Owing to the ease, compared to longwave instruments, with which shortwave instruments can be produced, their smaller size, and the lower costs associated with their manufacture, NOAA's Center for Satellite Applications and Research (STAR) is actively investigating what benefits may be garnered from assimilating CrIS shortwave observations in the NOSS GDAS/GFS, and whether these observations can be assimilated in the GDAS/GFS in place of hyperspectral IR longwave observations without discernable loss in analysis or forecast skill. To be discussed are measures taken to improve GDAS quality control procedures for hyperspectral IR shortwave observations, the specification of errors for shortwave CrIS channels, the performance of shortwave CrIS observations in the GDAS analysis, and the impact of assimilating shortwave CrIS observations on the GFS forecast in experiments denying longwave observations.

9.02 Enhancing the hyperspectral infrared radiance assimilation in the ECMWF system
Presenter: Kirsti Salonen, ECMWF
Authors: Kirsti Salonen and Anthony McNally
The number of assimilated WV channels for Infrared Atmospheric Sounding Interferometer (IASI) has been recently increased from 10 to 39 channels in the ECMWF system. The additional WV channels have a positive impact on short range temperature and humidity forecasts and via the wind tracing mechanism also on the wind forecasts, especially in the tropics. With the addition of the third IASI (Metop-C) the improvements are further enhanced.

Only IASI radiances classified as cloud free are used in the ECMWF system. Currently the used observation errors and error correlations are static. At each IASI sounding location also information on statistical radiance properties within clusters of the Advanced Very High Resolution Radiometer (AVHRR) pixels occupying the IASI field of view (FOV) is available. The AVHRR

radiance standard deviation provides an indication of the scene heterogeneity and increased values suggest the presence of cloud in the IASI FOV. Observation minus background (OmB) statistics indicate that especially for humidity sensitive channels of IASI the magnitude of the OmB standard deviation increases when the collocated AVHRR radiance statistics indicate increased heterogeneity in the FOV. The potential of using this information for scene dependent observations errors is investigated. The presentation will summarise the latest results of the work.

9.03 4D-Var assimilation of IASI ozone-sensitive radiances in operational global model ARPEGE

Presenter: Olivier Coopmann, CNRM, Université de Toulouse, Météo-France, CNRS
Authors: Olivier Coopmann

The infrared hyperspectral sounders on board polar-orbiting satellites provide around 70% of the data assimilated in the global NWP model of Météo-France (ARPEGE), including both IASIs. Infrared measurement is sensitive to surface parameters and numerous atmospheric species. Information on temperature can be retrieved from measurements at various wavelengths (or channels) corresponding to species for which concentration is known. Most of the temperature retrievals from the infrared sensors use channels sensitive to carbon dioxide. Parts of the infrared spectrum are sensitive to ozone but they are not currently used at Météo-France. We note that, in the current versions of the radiative transfer model (RTM) used in the assimilation, concentrations of those gases are constant in space and time. A previous studies at Météo-France showed that using concentrations of ozone coming from Chemistry-transport Models (CTM) led to an improvement of the simulations for IASI. Moreover, assimilation of IASI ozone-sensitive channels allow to improve temperature and humidity analyses (Coopmann et al., 2018).

The goal of this study is to carry out a new channel selection of IASI ozone-sensitive channels to be used in the four-dimensional data assimilation system (4D-Var) by a coupling between the ARPEGE and MOCAGE models for ozone fields. The use of ozone from MOCAGE allows a better use of infrared satellite observations and has a positive impact on the quality of thermodynamic and ozone analyses but also on weather forecasts. Results of assimilation including ozone in the control variable will be presented.

9.04 Assimilating solar satellite channels in a convective-scale LETKF

Presenter: Christina Köpken-Watts, Deutscher Wetterdienst (for Liselotte Bach)
Authors: Liselotte Bach, Leonhard Scheck, Christoph Schraff, Christina Stumpf, Stefan Geiss, Roland Potthast

Convective precipitation and cloud cover are among the most challenging user-relevant variables in convective-scale NWP. We see great potential in improving the representation of these processes assimilating visible channels of the SEVIRI-Instrument on MSG making use of the new fast and accurate forward operator MFASIS (Scheck et. al, 2016), which has recently been implemented into RTTOV.

To allow for accurate warnings ahead of convective precipitation and to approach the goal of a seamless transition from nowcasting to NWP, our objective is to improve the representation of convection already at the stage of its initiation. At this stage, clouds usually form at low levels and at small scales, such that they are likely not detectable in thermal IR (or MW) observations. Therefore, visible channels provide very useful additional information. Further, we explore possibilities for improving the representation of winter time low stratus in initial conditions and forecasts for which, again, reflectance observations during daytime are important complementary observations to IR sounder data.

We show results from data assimilation experiments with the new convective-scale weather prediction model ICON-LAM, currently in development at DWD, using an ensemble based data assimilation approach, the Local Ensemble Transform Kalman Filter (KENDA-LETKF, Schraff et. al, 2016). The focus is on the improvement obtained for cloud cover, precipitation and surface variables. Further, we discuss potential problems related to non-gaussian first guess departures, nonlinearity of the forward operator and ambiguities of the observations.

9.05 Improvements to Ozone Analyses using Hyperspectral Sounders in the 9.6 um Band

Presenter: Bryan Karpowicz, GESTAR/USRA/NASA GMAO
Authors: Bryan M. Karpowicz, Will McCarty, and Krzysztof Wargan

Previously, hyperspectral sounder brightness temperatures assimilated in the Goddard Earth Observing System Atmospheric Data Assimilation System (GEOS-ADAS) were limited to assimilating temperature and moisture. The ozone sensitive

9.6 um region is sensed by several hyperspectral sounders including AIRS (Atmospheric InfraRed Sounder), IASI (Infrared Atmospheric Sounding Interferometer), and CrIS (Cross-track Infrared Sounder). Direct assimilation of brightness temperatures in the 9.6 um region have been operational at ECMWF for several years (Dragani and McNally, 2013; Eresmaa et al., 2017). With this study, similar improvements using the GEOS-ADAS are presented. Channels were selected from available operational subsets evaluating information content and minimizing inter-channel correlation. Additionally, information such as channel selections made by other studies, and vertical sensitivities of ozone and temperature were considered in developing the study. The analyses produced show improvements verified against ozonesondes taken from SHADOZ (Southern Hemisphere Additional Ozonesondes), and WOUDC (World Ozone and Ultraviolet Data Center). Inclusion of inter-channel correlation error to the selected ozone channels are expected to improve ozone analyses further along with improve analyses overall. It is anticipated that inclusion of these ozone sensitive channels will be used to improve NASA GMAO products in the near future.

Session 10: Retrievals (oral presentations)

10.01 Status of regional IASI L2 products at EUMETSAT and studies in view of MTG-IRS

Presenter: Thomas August, EUMETSAT
Authors: Thomas August, Tim Hultberg, Cédric Goukenleuque, Marc Crapeau, Dorothée Coppens, Jochen Grandell

In answer to User request, EUMETSAT has been operating since November 2017 a regional service providing atmospheric temperature and humidity sounding within 30 minutes from sensing from the Polar System EPS. The algorithm exploits in synergy measurements from IASI and from its microwave companions on-board Metop, AMSU and MHS. The satellite data are directly broadcasted at local receiving stations from the EUMETSAT Advanced Retransmission Services (EARS) system and processed with a non-linear statistical method referred to as PWLR3. The retrievals are performed in clear as well as in cloudy pixels. The products are distributed in near-real time through EUMETCast in HDF5 format. They include temperature and humidity profiles together with a series of quality control parameters and uncertainty estimates, which Users can use to perform data selection corresponding to their applications.

Building on the EARS-IASI L2 products and their integration in a growing number of weather monitoring systems, a number of studies have been initiated to explore further the support to very short range forecasts and for the early detection and monitoring of atmospheric instabilities in particular. We provide here a status summary and first conclusions of interactions with European forecasters in that perspective, which will guide the future evolution of the regional service. We discuss for instance the coarser vertical resolution of the satellite sounding as compared to e.g. radiosondes profiles and the lower sensitivity near surface inherent to hyperspectral sounders.

The operational algorithms for IASI form the basis for the Day-1 baseline of the future geostationary hyperspectral sounder IRS on-board Meteosat Third Generation (MTG) sounder platforms (MTG-S). With a much higher spatio-temporal sampling than EPS/IASI (observations every 30 minutes in contiguous pixels sampled at ~7km over Europe with MTG-IRS vs twice-a-day in sparse 12-40km pixels) MTG-IRS has been designed to the monitoring of regional weather developments. The lessons learnt with the EARS-IASI L2 products contribute to the consolidation of the MTG-IRS L2 requirements and the specification of the operational products and their processor. In addition, EUMETSAT has initiated a number of complementary studies to evaluate IRS-specific aspects like the applicability of all-sky sounding in IR-only mode (as IRS has no micro-wave companions) and the challenges and potential of atmospheric sounding from a geostationary viewing geometry. In particular, the variation off Nadir of the theoretical vertical sensitivity, resolution and sounding precision is quantitatively studied e.g. at surface and in the lower troposphere in view of instability monitoring. As a comparison, a large part of Europe will be observed in a viewing regime corresponding to the limit of swath for IASI. We present here an overview and initial results of the IRS-specific studies, limitations and potential at high viewing angles.

10.02 The New NASA Multi-mission Microwave Sounder Retrieval System

Presenter: Bjorn Lambrigtsen, Jet Propulsion Laboratory
Authors: Bjorn Lambrigtsen, Mathias Schreier, Evan Fishbein

NASA has an interest in extending the sounder data time series started with the Aqua AIRS-AMSU-HSB sounder suite beyond Aqua, to support atmospheric and climate research. NASA therefore invested significantly in the Suomi NPP mission, first with the development of ATMS and later with the formation of a broader instrument science team. That team was asked to consider whether the S-NPP sensors, including the CrIMSS sounder suite, can be used to support research beyond Aqua in lieu of a continuing series of dedicated NASA missions. The science team concluded that it is likely that operational missions, such as S-NPP and the NOAA JPSS series, can be used in such a way, but it also concluded that the operational data produced by NOAA are inadequate. NASA therefore solicited proposals to develop new data algorithms that will be used to produce NASA's own data sets from the NOAA sounders. This is particularly necessary to support climate research, since the NOAA data are intended primarily for weather prediction, where continuity and consistency over long time periods is not important, and data are not reprocessed as algorithms are updated. The NOAA data sets are therefore not optimal for research use.

Under this NASA program a new microwave retrieval system has been developed at JPL, called the "Retrieval Algorithm for Microwave Sounders in Earth Science" (RAMSES). An algorithm testbed was constructed that allows plug and play testing of various elements of the retrieval algorithm. The initial version, which is based on optimal estimation, uses a very fast radiative transfer code that is based on the Aqua-AMSU retrieval system. The new retrieval system has been operationalized at the Sounder Science Investigator-led Processing System (Sounder-SIPS) at JPL, which acts as a clearing house for new NASA sounder algorithms, and will soon be delivered to the Goddard Earth Science Data and Information Services Center (GES DISC) for production, archiving and distribution. RAMSES will be used to process all ATMS data from S-NPP and the JPSS series and will also be configured for AMSU and used to reprocess data from both Aqua and NOAA platforms going back to 1998.

We will give an overview of RAMSES and show sample data and will also discuss planned upgrades to the retrieval system, primarily accounting for precipitation by the use of a different radiative transfer code, such as the Community Radiative Transfer Model (CRTM).

10.03 Continuity in Sounding Products from Multiple Platforms – examples from CLIMCAPS and NUCAPS

Presenter: Nadia Smith, Science and Technology Corporation
Authors: Nadia Smith, Chris. D. Barnet, Rebekah Esmaili

Hyperspectral infrared sounders measure emitted radiance at the top of atmosphere. Retrieval algorithms invert these measurements into profiles of temperature, moisture and trace gas species to characterize the atmosphere's thermodynamic structure and chemical composition. Here we introduce the NASA operational algorithm, CLIMCAPS (Community Long-term Infrared Microwave Combined Atmospheric Product System), designed to achieve continuity in global sounding products across multiple decades (from 2002 onwards, starting with the launch of EOS/Aqua) to characterize climate processes. We contrast CLIMCAPS with the NOAA operational algorithm, NUCAPS (NOAA-Unique Combined Atmospheric Processing System), designed to retrieve snapshots of the atmospheric state from polar-orbiting platforms to characterize instantaneous weather and change within the diurnal cycle. Differences in instrument design, spatial sampling, spectral coverage and resolution challenge product continuity in multi-platform operational systems. We present results to characterize these effects and demonstrate how retrieval system design can affect continuity in the information content and systematic uncertainty of retrieval products.

10.04 Retrieval of the radiative flux and atmospheric vertical heating rate profiles in the thermal infrared with the IASI instruments onboard the Metop platforms

Presenter: Yoann Tellier, Centre National de Recherche Scientifique (CNRS), Laboratoire de Météorologie Dynamique
Authors: Yoann Tellier, Cyril Crevoisier, Raymond Armante, Jean-Louis Dufresne and Virginie Capelle

One of the fundamental drivers of our climate system is the balance between the net incoming solar radiation and the outgoing radiation from the Earth and its atmosphere. Outgoing Longwave Radiation (OLR) is the global long wave radiation

outgoing from the Earth-Atmosphere system, integrated over all angles. An accurate estimate of OLR is thus particularly important to study the variability of Earth climate. For the past decades, several spaceborne missions aimed at measuring the outgoing radiation of the Earth system. Since the years 2000s, hyperspectral sounders have allowed the retrieval of vertically resolved atmospheric parameters.

In particular, the hyperspectral sounder IASI, launched onboard the platforms Metop-A (2006), Metop-B (2012) and Metop-C (2018) already offers more than 12 years of measurement of several essential climate variables, with the potential for offering at least two decades of observation. Owing to its coverage of a large portion of the longwave spectrum, it offers the possibility to derived Earth's outgoing longwave radiation (OLR) and vertical longwave cooling rate, and to study their variability on climatic timescales.

In this poster, we will present the retrieval of outgoing longwave radiation and vertical longwave cooling rate from IASI. For this objective, the radiative transfer code 4A has been modified to compute the OLR and the vertical sources and sinks of radiative energy. Validation of the code is performed in the context of the Radiative Forcing Model Intercomparison Project (RFMIP). Using a non linear inference scheme based on neural networks and 4A, OLR and cooling rate are retrieved from IASI observations. We will present the first results if these retrievals and analyze them by characterizing the links existing between the thermodynamic state of the atmosphere and the vertical repartition of the sources and sinks of Earth radiant energy.

Session 10: Retrievals (poster introductions)

10p.01 Atmospheric profile retrieval using rapid scan observation of Geo-KOMPSAT-2A Satellite
Presenter: Hee-Jung Kang, NMSC/KMA
Authors: Hee-Jung Kang, Tae-Myung Kim, Myung-Hwan Ahn, Sung-Rae Chung, and Seonghoon Cheong
The Advanced Meteorological Imager (AMI) on board the Geo-KOMPSAT-2A (GK-2A) launched into the geosynchronous orbit around 128.2 E on 5 December 2018, and will start operation in July 2019 after some functional and integrated performance tests completed. Over Full Disk (FD) and Extended Local Area (ELA) centered on the Korean Peninsula, AMI provides 16 channel imageries covering from the visible to the thermal infrared bands every 10 minutes and 2 minutes, respectively. GK-2A meteorological products have a lot of potential in nowcasting convective activity, tracking movement of aerosols, and improvement of the Numerical Weather Prediction (NWP) model forecasts. It is expected that AMI vertical temperature and humidity profiles will especially contribute to monitoring severe weather because it is used to calculate atmospheric instability indices.

The algorithm for AMI atmospheric profile (AAP) was developed to retrieve it over clear sky, which is identified by GK-2A cloud detection product. The algorithm is based on the one-dimensional variational (1D-VAR) method using bias corrected brightness temperatures (BTs) from AMI 9 channels (6.2 um, 6.9 um, 7.3 um, 8.6 um, 9.6 um, 10.4 um, 11.2 um, 12.4 um, and 13.3 um) and simulated BTs as a first guess. The simulated BTs are generated from the KMA operational global NWP system (Global Data Assimilation and Prediction System; GDAPS) forecasts using the Radiative Transfer for TOVS (RTTOV) v12.1 with AMI coefficients.

It is demonstrated that the algorithm increases the quality of humidity information through an application of the algorithm to Advanced Himawari Imager (AHI) data, as a proxy data, over the FD area. Considering operational use after launching, optimization for the ELA is essential. Because the radiances over the ELA is more biased than radiances over the FD area, the bias correction coefficients statistically calculated from AMI observation and NWP analysis over the ELA should be applied to the algorithm. This presentation will give preliminary results of initial optimization of AAP algorithm for local area using rapid scan measurements.

10p.02 First results from the Metop-C IASI Level 2 cal/val
Presenter: Thomas August, EUMETSAT
Authors: Marc Crapeau, Thomas August, Tim Hultberg, Stefan Stapelberg, Anne O'Carroll, Gary Corlett
Geophysical parameters from the IASI instruments on Metop-A and Metop-B are provided from EUMETSAT's Central Facility in near real time since 2007 for Metop-A and since 2013 for Metop-B. The EUMETSAT IASI Level 2 (L2) suite includes vertical profiles of temperature and humidity, cloud information (coverage and top height), surface skin temperature and emissivity, and atmospheric composition parameters (e.g. CO, O3,

SO2, CH4). Metop-C, the third of a series of three platforms in the EUMETSAT Polar System (EPS) programme was successfully launched November 2018, 7th, bringing the number of flying IASI instruments to three. We present here validation results from the Metop-C IASI Level 2 commissioning.

In particular we provide an overview of the status of the IASI Level 2 products coming from Metop-C and compare their accuracy to the products from the other two platforms. IASI instruments on-board Metop-A and -B have shown very similar levels of performance leading to very close IASI Level 2 products and we can expect a comparable behaviour for Metop-C.

We present performance assessments of the temperature and humidity profiles retrievals from the routine monitoring against sondes measurements and against model analyses. Surface temperature retrievals are evaluated with in situ measurement for the sea surface temperature (buoys), with model analyses as well as with other satellite products (e.g. SEVERI LST). The cloud parameters (mask, top pressure and fractional coverage), which constitute a crucial information for the use of IASI L2 products, are evaluated by visual inspection of the scenes (e.g. with AVHRR) and quantitative comparison to external reference datasets.

10p.03 An adaptative OEM retrieval for IASI
Presenter: Thomas August, EUMETSAT
Authors: Thomas August, Tim Hultberg
Optimal estimation, e.g. as formulated in Rodgers 2000, is popular inverse method for atmospheric sounding. It builds on Baye's theorem and requires accurate observation and a priori errors, assumed of Gaussian statistics. These errors are usually evaluated off-line of the retrieval and applied globally for a given observing system. In the context of the operational IASI L2 processor at EUMETSAT, the observation error has been defined statically as the covariance of observed and calculated radiances, using the first guess state vector and RTTOV as a forward model. Two distinct observation error matrices are defined for land and maritime scenes since the release of IASI L2 v6.3, with the aim to account for usually more accurate knowledge of surface emissivity and temperature over oceans than over continental surfaces. This lead also to more accurate humidity retrieval in the low troposphere.

In this work, we study the feasibility and advantages of dynamically applying scene-dependent observation errors to each individual retrieval instance from IASI.

First, distinct observation classes are established off-line for IASI by application of unsupervised K-mean clustering to a representative set of observations, based on their leading principal components. A different observation error matrix is computed as the covariance of OBS-CALC in each of these classes. We analyse the geographical distribution of the observation classes, their seasonal variations and the amplitude of the corresponding observation errors.

Second, to compensate for systematic differences between observations and forward modelling, a scene-dependent bias correction is regressed as a function of IASI observations and viewing geometry (e.g. satellite zenith angle, elevation).

Finally, during the online retrieval process, each individual observation is associated to its nearest class in the above clustering and the OEM retrieval is configured with the corresponding bias correction and observation error. We will compare the retrievals performed with the static and then adaptative OEM configuration to radiosondes and numerical model analyses. Their respective performances will be discussed, taking also into account the added complexity with growing observation classes.

10p.04 Near Real Time Active Fires and GAASP Level-2 Products Via Direct Broadcast Using the Community Satellite Processing Package
Presenter: Geoff Cureton, Cooperative Institute for Meteorological Satellite Studies, UW-Madison
Authors: Geoff Cureton
The Cooperative Institute for Meteorological Satellite Studies (CIMSS) has a long history of supporting the Direct Broadcast (DB) community for various low-Earth-orbit (LEO) sensors, previously with the International MODIS/AIRS Processing Package (IMAPP) for the NASA EOS polar orbiters Terra and Aqua, and currently with the Community Satellite Processing Package (CSPP) for the NOAA polar orbiters Suomi-NPP and NOAA-20. CSPP has been significant in encouraging the early usage of Suomi-NPP data by US and international weather agencies, and this situation should continue with NOAA-20 and beyond.

CSPP support for NOAA polar orbiters to date has rested upon the Algorithm Development Library (ADL) developed by Raytheon, a refactoring of the science code in the Interface Data Processing

Segment (IDPS), the NOAA operational processing system. More recently various science algorithms are being provided for DB in the Delivery Algorithm Package (DAP) format. Examples of both ADL and DAP packages will be presented: the Active Fires package for S/NPP and NOAA-20, and the GCOM-W1 AMSR2 Algorithm Software Package (GAASP), for the retrieval of total precipitable water (TPW) and cloud liquid water (CLW).

10p.05 Comparison of PCRTM-derived CrIS retrievals of temperature, water vapor, and trace gases (O3, CO, CH4, and N2O) with in-situ measurements

Presenter: Hyun-Sung Jang, NASA LaRC/NASA Postdoc Program
Authors: Hyun-Sung Jang, Xu Liu, and Wan Wu

A physical retrieval algorithm, which uses a Principal Component-based Radiative Transfer Model (PCRTM), was applied on six-year (2013-2018) CrIS measurements aboard Suomi National Polar-orbiting Partnership (S-NPP) satellite to derive thermodynamic properties and trace gases profiles. PCRTM is an ultra-fast forward model that allows the retrieval algorithm to use the principal components of spectral information from all CrIS channels to find an optimal solution. Retrieval results of temperature, water vapor, and ozone are compared with those from GCOS Reference Upper-Air Network (GRUAN) data and Southern Hemisphere ADditional OZonesondes (SHADOZ) data. We also used aircraft measurements from Atmospheric Tomography Mission (ATom) to validate retrieval for traces gases including CO, CH4, and N2O. In this study, we choose in-situ measurements that are temporally and spatially collocated to be within 15 km and 30 minutes of CrIS Field of Views (FOVs). Statistics of bias error, root mean square error, and standard deviation are demonstrated to assess baseline performance of the algorithm. Our results show that the PCRTM-based physical retrieval algorithm can be used for single FOV retrieval under all-sky condition.

10p.06 Satellite Inter-comparison of Geostationary GIIRS and Polar-orbiting IR Sounders CrIS and IASI: Radiances, Thermodynamic Retrievals, and Stability Indices

Presenter: Robert Knuteson, University of Wisconsin-Madison Space Science and Engineering Center
Authors: Robert Knuteson, Jessica Maier, Paul Menzel, Henry Revercomb, W.L. Smith, Sr., David Tobin, and Elisabeth Weisz

The long history of satellite remote sensing of Earth's atmospheric temperature and water vapor vertical profiles led to the development of high spectral resolution thermal infrared emission spectrometers with on-board absolute calibration. The High-resolution Interferometer Sounder (HIS) program at UW-Madison SSEC/CIMSS was started in the 1980's by NOAA and NASA as an airborne demonstration of the value of hyperspectral infrared radiance observations and thermodynamic retrievals. Subsequently the NASA Atmospheric Infrared Sounder (AIRS) was launched on the Aqua satellite in 2002, followed by the METOP series of satellites with the Infrared Atmospheric Sounding Interferometer (IASI) in 2006. The Cross-track Infrared Sounder (CrIS) joined the satellite constellation with on NASA's Soumi-NPP satellite in 2011 and most recently on the NOAA-20 operational satellite in 2018. All these satellites are contributing to the global data assimilation used by numerical weather prediction centers for medium range forecasting. The first hyperspectral IR sounder is the Geostationary Interferometric Infrared Sounder (GIIRS), which is operational aboard the Chinese Fengyun-4A satellite launched in 2016. The geostationary platform has the advantage of sampling the atmosphere over a region at multiple points in the diurnal cycle. The FY4A GIIRS satellite radiances have been routinely distributed since in 24 January 2019 by the China Meteorological Administration (CMA). FY4A GIIRS contains a focal plane array of 128 detectors which uses a Fourier transform spectrometer (FTS) to simultaneously collect 128 interferograms of the Earth scene emission. Periodic views of an internal blackbody and a deep space view are used for calibration. The operational mode of FY4A GIIRS covers the China region with a repeat of about 2 hours. The inter-comparison of the geostationary GIIRS radiances with polar-orbiting satellites (CrIS and IASI) has been made using a matchup technique. Constraints are applied in time, space, and viewing angle. Results are presented as brightness temperature bias spectra and as spectral line shifts. These radiance (or observed brightness temperature) comparisons provide a direct assessment of the calibration accuracy of GIIRS relative to the other satellite sensors which are already routinely inter-compared. A second objective is the inter-comparison of retrieved profiles of temperature and moisture from the various sensors. This is complicated by the multiplicity of organizations and disparate algorithms used to create the vertical profiles. Finally the derived quantities of atmospheric stability (CAPE, CIN, LI, etc.) are compared. In this

study, comparisons are also made between GIIRS-derived vertical profiles of temperature and humidity and local observational data from coincident radiosonde launch sites, e.g. at Shanghai. This paper describes an inter-comparison of observed radiances, thermodynamic retrievals, and derived stability indices among these various satellite sensors and derived products.

10p.07 Sounding Data Products generated at NOAA/NESDIS Using High Spectral Resolution Infrared and Advanced Microwave Sounders (CrIS/ATMS)

Presenter: Awdhesh Sharma, NOAA
Authors: Dr. Awdhesh K. Sharma

The Office of Satellite and Product Operations (OSPO) of NOAA/NESDIS has implemented innovative tools to monitor performance and data quality of the operational sounder and imager products that are being generated using the Cross-track Infrared Sounder (CrIS), in conjunction with the Advanced Technology Microwave Sounder (ATMS). Higher (spatial, temporal and spectral) resolution and accurate sounding data from CrIS and ATMS support continuing advances in data assimilation systems and NWP models to improve short- to medium-range weather forecasts and climate applications. Currently, the NOAA Unique Combined Atmospheric Processing System (NUCAPS) level 2 products from Metop-A/B/C, S-NPP, and NOAA-20 satellites include temperature and humidity profiles; trace gases such as ozone, nitrous oxide, carbon dioxide, and methane; and the cloud cleared radiances (CCR) on a global scale and these products are available to the operational user community. The OSPO tools have been extended to include the CrIS/ATMS SKEW-T (Logarithmic Pressure vs Temperature and Dew Point Temperature) sounding plots over the globe. These plots are updated every hour to show the latest sounding at each grid points (0.5 X 0.5 degrees) over the globe. The last ten soundings are retained to track the changes in the atmospheric conditions. The incorporation of these tools in the OSPO operation has facilitated the diagnosis and resolution of problems when detected in the operational environment.

This presentation will include several of these tools developed and deployed for the sounding products monitoring and data quality assurance which led to improving the maintenance and sustainment of the Environmental Satellites Processing Center (ESPC) processing systems. The presentation will include the discussion on the ESPC system architecture involving sounding data processing and distribution for CrIS and IASI sounding products. Discussion will also include the improvements made for data quality measurements, granule processing and distribution, and user timeliness requirements envisioned from the next generation of JPSS and EUMETSAT satellites. There have been significant changes in the operational system due to system upgrades, algorithm updates, and value added data products and services.

10p.08 Expanding the capability of real-time temperature, humidity, and trace gas retrieval products in field campaigns

Presenter: Nadia Smith, Science and Technology Corp. (for Rebekah Esmaili)
Authors: Rebekah Esmaili, Nadia Smith, Chris Barnet, Colby Francoeur

Intense wildfires can significantly impact regional air quality in the United States and Canada. Sounding products are useful for visualizing the long-range transport of trace gases (CO, O3, CH4, etc.), temperature, and moisture from active fires. This information is valuable for environmental situational awareness during field campaign experiments. However, satellite sounding participation in field campaigns usually occurs after the conclusion of the experiment due to data latency; operational data from polar orbiting satellites can arrive up to 3 hours after an overpass, outside of NOWCASTING requirements. However, with NUCAPS available in the CSPP suite, data latency is below 30 minutes, which allows sounding algorithms to be evaluated alongside in-situ observations. Due to reduced latency, field campaigns can now act as a real-time sounding algorithm product testbed.

Using the direct broadcast network, we show how NUCAPS products from both existing and new satellites (NOAA-20, SNPP, and the MetOp series) were utilized to provide diurnal measurements of trace gases during the FIREX-AQ campaign over North America. For the experiment, we provided direct readout via web-based tools to campaign coordinators. Parameter visualizations were tailored to the coordinators needs as the campaign progressed. This work looks beyond whether a product can meet “requirements;” rather we examine how it can be improved to facilitate real-time planning and forecasting. Through this work, we discuss if sounding products are a viable tool during field campaigns and how products can be improved to rise to the challenge.

10p.09 Towards a Further Use of Satellite Observations for a Better Definition of Surface Temperature

Presenter: Mohamed Zied Sassi, CNRM/Météo-France & CNRS
Authors: Zied Sassi, Nadia Fourrié, Vincent Guidard and Camille Birman

The land surface temperature (LST) is of major interest in surface processes understanding. However, its high variability and dependence on surface parameters make its modelization difficult over land. The satellite observations, produced by Infra-red and Microwave sensors, help defining a good quality LST by using surface sensitive channels and emissivity atlas to retrieve surface temperature.

The first part of this work provides a comparison of the MSG/SEVIRI retrieved LST to local observations from two stations included in AROME-France domain. Diurnal cycles of the local LST and the SEVIRI LST are in good agreement especially in summer period. The second part compares LST values that are retrieved from different Infrared sensors in AROME-France model. We focused on IASI and SEVIRI sensors. First results show encouraging agreement between the infrared sensors IASI and SEVIRI LSTs. A comparison during October and November 2018 under clear sky conditions shows an almost null bias and a standard deviation of about 1.6K. A better synergy is noticed during night-time giving a bias of about 0.7K and a standard deviation of less than 1K. Finally, the simulation of SEVIRI and IASI sensors brightness temperatures by using the fast radiative transfer model RTTOV with different LST is studied. Thus, different simulations have been run covering selected clear sky situations by day-time and night-time and using SEVIRI LST, IASI LST and AROME model LST. The simulated brightness temperatures were then assessed against satellite observations.

10p.10 IASI L1 and L2 reprocessing status at EUMETSAT

Presenter: Dorothee Coppens, EUMETSAT (for Mayte Vasquez)
Authors: Mayte Vasquez, Stephanie Guedj, Dorothee Coppens, Tim Hultberg, Thomas August, Marc Crapeau, Alessio Lattanzio, Marie Doutriaux-Boucher

As part of the payload of the Metop series of polar-orbiting satellites, there are currently three IASI instruments in operation: on Metop-A (launched 19 October 2006), on Metop-B (launched 17 September 2012) and on Metop-C (launched 7 November 2018). IASI instrument is designed around a Michelson interferometer and provides measurements in 8461 spectral channels between 3.6 and 15.6 microns (645-2760 cm-1). 120 spectra are acquired in the cross-track direction with a horizontal resolution of 12 km at nadir from the nominal 815 km high orbit.

In 2018, EUMETSAT has reprocessed the L1c products for IASI on-board Metop-A (IASI-A) for the period 2007-2017. The reprocessing took into account the past evolutions made in the operational IASI L1 processing chain:

- A “Day-2 evolution” algorithms linked to a product format change to extend the on-board quality flags information and to include cloud and land/sea mask;
- A change in the spectral harmonization process in February 2011.

The reprocessed data have been generated with the latest version of the IASI L1 processing chain (version 8.0) and its optimized instrument and processing tuning. It provides continuous data records (gaps have been fulfilled).

We present here the complete reprocessing cycle of IASI level 1 products.

Thanks to the homogeneous and high quality IASI level 1c data, EUMETSAT is also intending to reprocess the level 2 products for the entire period covered by IASI on Metop-A. Preliminary results will be presented using first the statistical ‘all-sky’ retrieval (PWLR3) for the entire period as well as the futures plans.

10p.11 An experimental 2DVAR retrieval using AMSR2

Presenter: David Duncan, ECMWF
Authors: David Duncan, Patrick Eriksson, Simon Pfreundschuh

A two-dimensional variational retrieval (2DVAR) has been developed for the Advanced Microwave Scanning Radiometer-2 (AMSR2) sensor. Overlapping beam patterns at all AMSR2 frequencies are explicitly simulated in the forward model. This permits retrieval of near surface wind speed (WSP) and SST at finer spatial scales than individual antenna beams, with the effective spatial resolution of retrieved parameters shown by analysis of 2DVAR averaging kernels. SST retrievals achieve about 30?km resolution, with WSP reaching about 10?km resolution. It is argued that multi-dimensional optimal estimation permits greater use of total information content from microwave sensors than other methods like Backus-Gilbert. No compromises on target

resolution are needed and instead various targets are retrieved at the highest possible spatial resolution, driven by the channels' sensitivities. All AMSR2 channels can be simulated within near their published noise characteristics for observed clear-sky scenes, though calibration and emissivity model errors are key challenges. This demonstrates the feasibility of 2DVAR for cloud-free retrievals, and opens the possibility of stand-alone 3DVAR retrievals from imagers and sounders that include retrieving hydrometeor fields. The results indicate that spatial oversampling can somewhat mitigate the need for larger antennas in the push for higher spatial resolution. The relevance of field of view modelling for sounding applications and the applicability of these results will also be discussed.

Session 11: Validation (oral presentations)

11.01 Combining satellite- with ground-based measurements for near-real-time monitoring of atmospheric stability, atmospheric water vapor and liquid water.

Presenter: Maria Toporov, University of Cologne
Authors: Maria Toporov, Ulrich Löhnert, Christopher William Frank

Short-term forecasts of current high-resolution numerical weather prediction models still have large deficits in forecasting the exact temporal and spatial location of severe, locally influenced weather such as summer-time convective storms or cool season lifted stratus or ground fog. The thermodynamic instability - especially in the boundary layer - plays an essential role in the evolution of weather events. One way to assess the atmospheric instability offer so-called forecast or stability indices (STI). The temporal and spatial resolution of radiosonde soundings, which are traditionally used for calculation of STI, is not sufficient to capture the initiation and the development of convection. Ground-based remote sensing instruments and instruments on board of geostationary satellites provide high temporally resolved information on vertical structure of the atmosphere and can be used for monitoring of atmospheric stability.

Previous studies showed that microwave profilers (MWR) are well suited for continuously monitoring the temporal development of atmospheric stability (Cimini et al. 2015). However, the vertical resolution of microwave temperature and humidity profiles is best in the lowest kilometer above the surface, decreasing rapidly with increasing height. Typical stability indices (STI) used to assess the potential of convection rely on temperature and humidity values not only in the region of the boundary layer but also in the layers above. Therefore, satellite remote sensing is expected to complement ground-based MWR and DIAL observations.

In this contribution, we present a neural network retrieval of stability indices, integrated water vapor (IWV) and liquid water path (LWP) from simulated satellite- and ground-based measurements based on the COSMO-REA2 reanalysis as truth. In order to make the approach feasible for data assimilation applications, we simulate satellite observations with the standard RTTOV model and use the newly developed RTTOV-gb (ground-based) for the ground-based microwave radiometers (De Angelis et al., 2016). Focusing on the temporal resolution and spatial coverage, the satellite-based instruments considered in the study are the currently operational SEVIRI and the future IRS, both in geostationary orbit. We show the single instrument performance and the synergy benefit in terms of correlation, uncertainty reduction, probability of detection and other forecast skill scores.

The hyperspectral geostationary IRS observations contain significantly more information on vertical humidity and temperature needed for assessment of atmospheric stability than SEVIRI measurements. Thus the error of STI retrieved from simulated IRS observations was shown to decrease by up to 50% compared to SEVIRI. The additional ground-based MWR/DIAL measurements provide valuable improvements not only in the presence of clouds, which represent a limiting factor for infrared SEVIRI/IRS, but also under clear sky conditions.

To assess the spatial representativeness of observations of a single ground-based MWR/DIAL and to estimate the required network density the retrieval is applied to a 150*150km reanalysis domain. The accuracy of fields of STI/IWV/LWP calculated from satellite only and from combined satellite and ground-based observations is estimated and the added value of ground-based observations in a network configuration is discussed.

11.02 Investigating the Comparisons of Hyperspectral IR Sounders, Radio Occultation, and Radiosondes in Radiance Space

Presenter: Michelle Feltz, University of Wisconsin - Madison, SSEC
Authors: Michelle Feltz, Lori Borg, Robert Knuteson, Dave Tobin, Hank Revercomb, Johannes Nielsen

In recent decades the importance of ensuring continuity and consistency between meteorological satellite datasets has been highlighted. As evidence, GSICS was created in 2005 as an international effort to harmonize the quality of operational weather satellites, projects under NASA's MEaSUREs have been funded to create merged data records using pre-existing datasets, and networks like GRUAN have been created to coordinate measurements of essential climate variables.

Less focus, however, has been put on the comparisons of satellite datasets which have different measurement techniques—for example between passive and active remote sensing technologies. Though much work has been previously done to compare the active radio occultation (RO), passive hyperspectral infrared (IR) sounder, and radiosonde retrievals for temperature and water vapor profile validation purposes, less work has been done comparing them in radiance or refractivity units—where each the IR sounder and RO have much smaller uncertainties on their measurements.

This work provides a follow-up to previous studies which proved that hyperspectral IR radiances, with their prescribed uncertainties, can be used as a validation reference for RO temperature retrievals via radiative transfer for channels representing the upper troposphere and lower stratosphere. Case study matchups of hyperspectral IR sounders, RO, and radiosondes are used with radiative transfer to compare these datasets in radiance units for the purposes of 1] further characterizing and understanding their differences over the full IR spectral domain, 2] investigating the feasibility of using the IR sounder radiances as truth for channels which represent different regions of the troposphere, given the increased uncertainties of the radiative transfer algorithm for various spectral channels, and 3] prescribing methodological uncertainties to the comparisons.

11.03 Ground-based remote sensing network for the validation of multi-scale satellite products and numerical models

Presenter: Eric Pequignot, SentinAir
Authors: Eric Pequignot, Javier Andrey

SentinAir was created in April 2018. It is a spin-off of CNES that benefits from its support in the framework of its "swarming program" which aims to promote space innovations and patents.

SentinAir is currently using a patent in the frame of an exclusive license provided by CNES and ACRI-ST on atmospheric tomography following WINTI studies (R&T 2008-2013 and Phase 0 2015-2016). WINTI is a 0.5-1km resolution infrared multi-spectral imager operating in LEO orbit. It performs a tomographic acquisition which consist in a scan from backward to forward limb. Retrievals of atmospheric fields are done by using a tomographic Bayesian scheme.

The objective of SentinAir is to adapt this space technology on ground by deploying and operating autonomous outdoor ground-based camera networks in order to provide retrievals of geophysical variables within the boundary layer (temperature, water vapor, aerosols, trace gases, cloud coverage) at 100 m (horizontal and vertical) with 15 min resolution. Each network would cover typically a 20 x 20 km area. The 2 components of a network are the following

- The AirCams which are autonomous devices embarking different types of state-of-the-art cameras (ultraviolet, visible and infrared). The AirCams are set up on high spots within and around the area to be observed. The AirCams are currently under definition.
- A centralized mission centre that processes the raw images acquire by the AirCams.

The main added values of such a network with respect to satellite product and numerical model validation are the following

- "HR": a continuous measurement over a large area (20x20 km) at high-resolution (100m/15min). This is a unique tool for multi-scale and multi-orbit EO satellite data validation and inter-comparison (chemistry, meteorology and air quality).
- "Scalable product": A product with a scale that can be adapted to different numerical model and satellite data resolution.
- "ABL": 3D Atmospheric Boundary Layer sounding at high vertical resolution (100m)
- "2-in-1": an opportunity to couple in the same project satellite/model validation and a service that could be useful for cities

considering air quality, greenhouse gases and urban heat-island issues.

Session 11: Validation (poster introductions)

11p.01 Extended characterisation of NWP model biases and uncertainties across the microwave and infrared domains

Presenter: Fabien Carminati, Met Office
Authors: Fabien Carminati (Met Office), Stefano Migliorini (Met Office), Bruce Ingleby (ECMWF), Heather Lawrence (ECMWF)

With the improvement of numerical weather prediction (NWP) model skills through advances in modelling, data assimilation, and data usage, the representation of the atmosphere in analyses and forecasts is increasing in reliability. This is not only benefiting the public and private sectors through better weather forecasts and alerts, but also the scientific community that can use NWP fields to evaluate instruments sensing the atmosphere such as satellite microwave and infrared sounders. However, both analyses and forecasts remain subject to non-zero biases and uncertainties whose characterisation and traceability are fundamental steps to properly use NWP models as reference comparators. This is investigated via comparisons between radiosondes of the Global Climate Observing System (GCOS) Reference Upper-Air Network (GRUAN) and NWP temperature and humidity fields mapped to radiance space (the space used for satellite validation). Top-of-atmosphere brightness temperatures simulated from over 15000 GRUAN profiles of temperature, humidity, and pressure (and their associated uncertainties) from 11 sites in 4 geographic areas (northern latitudes, northern mid-latitudes, norther sub-tropical Atlantic, and tropical west Pacific) obtained over the period 2011-2017 and collocated NWP fields from both the Met Office and ECMWF global models have been compared at key frequencies spanning both the microwave and infrared spectrums for a selection of AMSU-A, MHS, ATMS, HIRS, CrIS and IASI channels. Preliminary results suggest biases within ±0.5K at microwave frequencies predominantly sensitive to temperature for uncertainty less than 0.12K, and 0.5 to -1.5K biases at frequencies sensitive to humidity for uncertainties less than 2K. Infrared frequencies are under investigation at the time of writing. Although providing an incomplete picture due to the lack of GRUAN stations in the southern hemisphere, this analysis offers the most detailed and robust estimation of model fields bias and uncertainty in radiance space to date and takes NWP models a step closer to a traceable characterisation to SI standards. Ultimately, this effort can serve to optimise the use of anchor observations in data assimilation and also enhance model evaluation efforts.

11p.02 Enterprise Assessment and Uncertainty Estimates for Satellite Retrievals Using Collocations with Conventional and GRUAN Radiosondes

Presenter: Anthony Reale, NOAA NESDIS STAR
Authors: Tony Reale

Balloon-borne conventional radiosonde observations have played play a critical role in the assessment of derived atmospheric sounding since the operational onset of such products in 1979. Radiosondes provide excellent characterizations of the large scale synoptic weather features and are often valuable to ascertain the overall profile shape and finer scale features in a regional and local context. Problems with conventional radiosondes include the numerous instrument types and processing available globally that can introduce systematic errors in the perceived performance of satellite derived temperature and moisture profiles. Add to this the systematic temporal mismatch arising from comparing predominantly synoptic radiosondes and sun-synchronous satellites, the time duration of radiosondes (1.5 hours to 20hPa), spatial drift (over 100km) and ambiguity of comparing point versus volume quantities. Together, these can manifest as systematic or “Time Alias” errors, however, results shown in this paper suggest such errors are small, beaten down by the very large sample sizes of conventional observations (over 1000 per day) compared to the inherent satellite product error signal. Nonetheless, assessment of regional and/or performance in a given air-mass (or site) typically of interest to users (forecasters) remains prohibitive. A secondary objective of this paper is to address the added information on satellite product performance obtainable from supplemental use of “special” validation data sets containing Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN) radiosondes targeted (courtesy of JPSS) with (NOAA) polar satellite overpass. These data are shown to be much more indicative of regional and local (air-mass) performance and estimates of the satellite sounding uncertainty based on the fully characterized (traceable) GRUAN radiosondes. This reports ultimately traces sounding product performance signals for internationally available operational product suites (NOAA, NASA and EUMETSAT) from the global to regional scales

using conventional and special radiosondes, respectively. The assessments are enterprise in that the different suites are inter-compared against the same (common) sets of radiosondes. Vertical statistics of satellite-minus-radiosonde bias (and standard deviation) and associated estimates of respective product suite uncertainty, including for numerical weather prediction profiles are compared. Impacts due to systematic errors associated with "time alias" effects are shown.

11p.03 Application of the fast visible radiative transfer model RTTOV-MFASIS: comparison to RTTOV-DOM and use for model cloud validation of ICON

Presenter: Christina Stumpf, German Weather Service

Authors: Christina Stumpf, Christina Koepken-Watts, Olaf Stiller, Leonhard Scheck, Liselotte Bach, Roland Potthast

MFASIS is a novel fast radiative transfer method for the simulation of visible satellite images that is fast enough to cope with the computational constraints of operational data assimilation systems and has therefore recently been implemented into RTTOV v12.2 and v12.3. First evaluation and data assimilation experiments using MFASIS in combination with regional models have demonstrated its value by improving the representation of cloud cover and precipitation. As a further step towards using visible satellite images in operational data assimilation, we perform a detailed validation of the accuracy of MFASIS and apply it in evaluating the representation of clouds in DWD's global NWP system ICON+EnVAR in comparison to visible channel observations from the SEVIRI instruments on board MSG.

We evaluate RTTOV-MFASIS by comparing forward simulations to results from the discrete ordinate method RTTOV-DOM based on global ICON model fields which offer a large variety of atmospheric situations. This is done in a suitable test setup with controlled viewing conditions and by studying dependencies on relevant quantities, such as optical depths and cloud heights, to identify any systematic errors resulting from the approximations made in MFASIS. These investigations pave the way for further improvements to MFASIS, e.g. for an improved description of Rayleigh scattering and mixed-phase cloud situations. Additionally, we compare reflectances simulated with RTTOV-MFASIS based on ICON model fields to real visible channel observations using geostationary satellites. This aims at validating the accuracy of the model cloud fields, also in conjunction with all-sky simulations of corresponding IR channels. Here, the visible channel information is complementary especially for the analysis of the representation of low clouds.

11p.04 Validation of the Environmental Data Record (EDR) product suite from the SNPP/NOAA-20 NOAA Unique Combined Atmospheric Sounding System (NUCAPS)

Presenter: Nicholas Nalli, IMSG Inc. at NOAA/NESDIS/STAR

Authors: Nicholas R. Nalli, A. Gambacorta, C. Tan, L. Zhou, T. Reale, B. Sun, J. Warner, T. Wang, and T. Zhu

This presentation overviews current status of the validation of the operational full-spectral resolution Cross-track Infrared Sounder (CrIS) and Advanced Technology Microwave Sounder (ATMS) NOAA Unique Combined Atmospheric Processing System (NUCAPS) onboard the NOAA-20 and SNPP satellites. NUCAPS is a NOAA operational retrieval algorithm designed to provide users with global atmospheric profile environmental data records (EDRs), including temperature, moisture (H2O), ozone (O3) and carbon trace gases (CO, CH4, CO2). NUCAPS EDR product assessments are made with reference to the JPSS Level 1 requirements. For the provisional maturity assessments, the baseline datasets include global ECMWF model, conventional radiosonde observations (RAOBs), limited ozonesonde ensembles (e.g., SHADOZ and WOUDC), dedicated RAOBs (e.g., ARM, GRUAN and AEROSE), and datasets-of-opportunity (e.g., TCCON, ATom, AirCore). Ongoing statistical analyses relative to these baselines have shown that the NOAA-20 NUCAPS temperature, moisture, ozone and carbon monoxide profile EDRs have favorable accuracy and global yield, thus meeting the general qualifications for JPSS provisional maturity.

11p.05 FIREX-AQ ER-2: A Summary of Scanning High-resolution Interferometer Sounder (S-HIS) Observations

Presenter: Joe Taylor, UW-SSEC

Authors: Joe K. Taylor, David C. Tobin, Henry E. Revercomb, Fred A. Best, Ray K. Garcia, William Smith Sr., Elisabeth Weisz, R. Bradley Pierce, Greg Frost, Mitch Goldberg, Olga Kalashnikova, Jay Al-Saadi

The FIREX-AQ (Fire Influence on Regional to Global Environments and Air Quality) is a joint venture led by NOAA and NASA, and provides comprehensive observations to investigate the impact on air quality and climate from wildfires and agricultural fires across the continental United States. FIREX-

AQ brings together scientists from NOAA, NASA and more than 40 partners to explore the chemistry and fate of trace gases and aerosols in smoke with instrumented aircraft, satellites, UAVs and ground-based instrumentation in the northwestern and southeastern U.S. during the summer of 2019.

The overarching objective of FIREX-AQ is to provide measurements of trace gas and aerosol emissions for wildfires and prescribed fires in great detail, relate them to fuel and fire conditions at the point of emission, characterize the conditions relating to plume rise, follow plumes downwind to understand chemical transformation and air quality impacts, and assess the efficacy of satellite detections for estimating the emissions from sampled fires.

The airborne component of the FIREX-AQ effort is centered on the deployment of the NASA DC-8, with two complementarily outfitted NOAA Twin Otters, and will sample wildfire plumes from near the point of emission to downwind on a regional scale. The NASA ER-2 is also deployed for FIREX-AQ and plays a key role in the experiment. The goal for the NASA ER-2 is to serve as a bridge between in-situ and satellite datasets by using an airborne remote sensing instrument suite to help characterize fire development, emission processes, plume evolution, and downwind impacts on air quality, and evaluate and validate recently developed remote sensing approaches and algorithms.

The ER-2 component of the campaign is conducted from Palmdale, California. The NASA ER-2 payload consists of the UW-SSEC Scanning-High resolution Interferometer Sounder (S-HIS), the NASA JPL Airborne Multiangle SpectroPolarimetric Imager (AirMSPI-1), the NASA JPL Classic Airborne Visible and InfraRed Imaging Spectrometer (AVIRIS-C), the NASA GSFC Cloud Physics Lidar (CPL), and the NASA ARC/GSFC Enhanced MODIS Airborne Simulator (eMAS) for the duration of the experiment. The NASA GSFC Geostationary Coastal and Air Pollution Events Airborne Simulator (GCAS) and the NASA LaRC NPOESS Atmospheric Sounder Testbed-Interferometer (NAST-I) are also part of the payload for first half of the experiment, and are replaced with the NASA JPL Hyperspectral Thermal Emission Spectrometer (HYTES) for the second half of the experiment.

This presentation will include an overview of FIREX-AQ ER-2 campaign and present highlights of some of the most notable S-HIS observations made during the campaign.

11p.06 Reconciling opposing Pacific Walker circulation trends in observations and climate model projections

Presenter: Eui-Seok Chung, IBS Center for Climate Physics
Authors: Eui-Seok Chung, Axel Timmermann, Brian Soden, Kyung-Ja Ha, Lei Shi, and Viju John

Surface pressure observations and reanalysis datasets suggest that the Pacific Walker circulation has strengthened over the satellite era (1979-present). Given the limited time period, such changes could arise from either internal variability or a forced response to anthropogenic warming. Here, we evaluate these hypotheses by analyzing satellite observations along with a large ensemble of climate model simulations forced by historical radiative forcings. While the satellite-observed changes differ noticeably from the ensemble mean changes predicted by the models, they also indicate much less strengthening of the Pacific Walker circulation than implied by reanalysis datasets. In particular, the satellite observations reveal anomalously high convective activity over the Philippine Sea and the northwestern part of the Indian Ocean, rather than over the Maritime Continent and the equatorial western Pacific as in the reanalyses. Furthermore, some members of the climate model ensemble are found to reproduce a large part of the observed changes. These findings offer compelling evidence that internal variability, rather than anthropogenic forcing, has had a dominant influence on the recent strengthening of the Pacific Walker circulation.

11p.07 Generating synthetic visible satellite images with RTTOV

Presenter: Olaf Stiller, Deutscher Wetterdienst
Authors: Leonhard Scheck, Olaf Stiller, Christina Köpken-Watts, Bernhard Mayer, Martin Weissmann

Satellite images in the visible spectral range provide a wealth of information about the cloud distribution, cloud microphysical properties and cloud structure and are available from geostationary and polar orbiting platforms at high temporal and spatial resolution. Therefore, these images are seen as a promising type of observation for data assimilation and model evaluation and are in many respects complementary to infrared and microwave sounder data. While thermal infrared and microwave channels have been used for these purposes for some time and are well-supported by

packages like RTTOV, sufficiently fast and accurate forward operators for visible channels have only recently become available. This is related to the fact that multiple scattering makes radiative transfer at solar wavelengths more complicated and computationally much more expensive, if standard radiative transfer methods are used. Here we describe MFASIS, a fast method for the generation of visible satellite images, which is based on a compressed look-up table and has recently been integrated into RTTOV. We discuss the basic design ideas and several recent extensions aimed at improving the accuracy of the method and the covered frequencies, including methods to account for 3D RT effects and the impact of variable water vapor content. Moreover, first results for an alternative approach are shown, in which the look-up table is replaced by a neural network.

11p.08 Using ensemble based diagnostics to identify sub-optimally used observations

Presenter: Olaf Stiller, Deutscher Wetterdienst
Authors: Olaf Stiller

Observation impact diagnostics have been developed to assess the impact of subgroups of observations in the data assimilation (DA) process without the need for performing data denial experiments. These diagnostics are based on a cost function which illustrates the observation impact with respect to some verifying "truth". Here (as in Kalnay et al. 2012) such diagnostics are used for an ensemble system, the ENVAR/LETKF system of the DWD's global ICON model using observations as verifying "truth" (as in Sommer&Weissmann, 2016). While this makes a direct quantitative comparison between the impact of different observation types problematic (the result strongly depends on how well the examined observations are collocated with those used for the verification), these diagnostics allow to identify subgroups of observations which are treated sub-optimally in the assimilation chain. Such sub-optimal treatment may arise from different sources. Therefore, to get more specific insights, this work focuses on different types of consistency relationships which can be inferred from different terms into which the cost function can be decomposed. Furthermore, while the traditional diagnostics try to assess the impact related to denial experiments (what is the contribution of selected observations on the analysis in this system?), we also present an additional diagnostic type yielding the corresponding impact which the selected observations would have if they where assimilated alone (i.e., in absence of the other observations which are assimilated). This can be used as an indicator to which extent the measured impact (or lack of impact) may be related to the redundancy of observational information.

The poster will mainly present results for the impact of well established observation systems like radio sondes, radio occultations and AMSU-A radiances. It is also shown how biases in AMSU-A radiances affect these impact diagnostics. The focus is on very short forecast lead times t which is possible because observations are used for verification. A comparison between results for t=0 (impact on the analysis) and t=3 hours gives some insight of the role of imbalances in the analysis states (spin up/down processes).

Session 12: Satellite Data Impact in NWP (oral presentations)

12.01 Global observing system experiments in the ECMWF assimilation system

Presenter: Niels Bormann, ECMWF
Authors: Niels Bormann, Heather Lawrence, David Duncan, Jacky Farnan

The presentation summarises results from observing system experiments with the ECMWF system for some of the main observation types, covering 8 months over two seasons. The experiments assess the present impact of MW and IR passive sounding radiances in the wider context of impact from conventional in-situ observations, bending angles from GPS radio occultation (RO) and Atmospheric Motion Vectors (AMVs).

Results show that conventional in-situ observations and microwave radiances are presently the main drivers of headline scores, with infrared sounders adding further robustness for a wide range of geophysical variables. The strong impact of the microwave satellite radiances is aided by the availability of an unprecedented number of instruments, providing good spatio-temporal coverage. This contributes to very strong impact on wind analyses and forecasts from the MW sounders, particularly over the Southern Hemisphere. The gradual impact from adding MW sounder data from several orbits will also be discussed, further highlighting the benefits from increased spatio-temporal sampling.

12.02 Impact of Hyperspectral Radiances in 4D-VAR data assimilation system

Presenter: Buddhi Prakash Jangid, National Centre for Medium Range Weather Forecasting
Authors: Buddhi Prakash Jangid, Bushair M T, S. Indira Rani, and John P. George

Accurate estimate of Numerical Weather Prediction (NWP) requires detailed knowledge of the state of the atmosphere. Satellite based observations with high temporal and spatial resolution play a crucial role in NWP. Unlike multispectral instruments onboard many satellites, the hyperspectral instruments provide wide coverage of the atmosphere with fine spatial and temporal resolutions. Different hyperspectral instruments are Atmospheric Infrared Sounder (AIRS) on-board NASA-AQUA satellite, Infrared Atmospheric Sounding Interferometer (IASI) aboard MetOp-A, B, and C, Cross track Infrared Sounder (CrIS) on-board Suomi-NPP and NOAA-20 satellites. AIRS and CrIS have 2378 and 2211 spectral channels respectively, whereas IASI has 8461. Though there are thousands of channels in the hyperspectral instruments, NWP cannot benefit the fullest of these instruments, only a few hundred channels which are very essential for NWP can be assimilated. This study presents the impact of hyperspectral instruments in the NCMRWF's Unified Model (NCUM) assimilation and forecast system. For this study two Observing System Experiments (OSEs) are designed in such a way that i) along with all other conventional and satellite observations, hyperspectral radiances are assimilated (EXP) and ii) hyperspectral radiances are denied (CNTL) for a month period, May 2018. Impact of hyperspectral radiances in the assimilation system is analyzed in terms of the improved assimilation of radiances from other infrared and microwave instruments. 5-day forecasts are produced based on 00 UTC initial condition of each day and the impact of these radiances in the forecast system are analyzed in terms of various skill scores.

12.03 Assessment of assimilating Metop combined retrieval L2 product in AROME-France

Presenter: Bruna Barbosa Silveira, CNRM/Météo-France
Authors: Bruna Barbosa Silveira, Vincent Guidard, Nadia Fourrié, Philippe Chambon, Pierre Brousseau, Patrick Moll, Thomas August, Tim Hultberg

IASI L2 products from the EUMETSAT Advanced Retransmission Service (EARS) are statistical retrievals (piece-wise linear regression) which combine information from IASI and microwave sensors, these sensors are on board Metop satellites. The products are generated by EUMETSAT from direct broadcast at local acquisition centres, such as Lannion (Satellite Meteorological Centre of Météo-France) in Brittany, France. The products are available to regional users within a maximum of 30 minutes from sensing.

Applications of Research to Operations at Mesoscale (AROME)-France model is the operational convective-scale model of Méteo-France since the end of 2008. This model operationally assimilates the Level 1 (L1) radiances from IASI, AMSU-A and MHS, with a positive impact. However, the more recent version of AROME has had the top model changed from 1 to 10 hPa. As a result, the quality of the simulation of channels having a strong contribution from the atmosphere above 10 hPa decreased. In this way, the amount of IASI channels assimilated in AROME changed from 123 to 44 channels.

The main objective of the study is to evaluate the benefits of assimilating Metop L2 products in replacement of L1 products (radiances) from IASI, AMSU-A and MHS into the AROME-France data assimilation system. Firstly, the L2 products observation errors and thinning were defined based on a previously L2 product evaluation. Three assimilation experiments were performed, the baseline (without L1 products from IASI, AMSU-A and MHS, but with other satellite radiances), the control experiment (with L1 product removed in the baseline experiment) and L2 experiment, this experiment assimilates the same observations assimilated in the baseline and L2 products (temperature and specific humidity profiles). The L2 products are assimilated as pseudo-soundes.

The control and L2 experiments were evaluated against the baseline experiment. The observations statistics (Observation Minus Forecast (OMF), standard deviation of OMF and number of observations) and the forecast verification (Bias and RMSE) were assessed to measure the impact of assimilating the L2 products and the radiances from IASI, AMSU-A and MHS into AROME-France data assimilation system.

Session 12: Satellite Data Impact in NWP (poster introductions)

12p.01 Assessment of the impact of zonal component of Radiosonde winds: A prelude to the assimilation of Aeolus winds

Presenter: S Indira Rani, NCMRWF

Authors: S. Indira Rani, Priti Sharma, Bushair M. T., Buddhi Prakash Jangid, Gibies George, Sumit Kumar, John P. George and E.N. Rajagopal

Wind observations are very important for the better atmospheric analysis particularly over the Tropics where wind fields govern the dynamics. There is a lack of homogeneous global coverage of direct wind profile measurements in the current Global Observing System. Uniformly distributed direct wind observations are important for smaller scales and deeper atmospheric structures. Aeolus wind Lidar delivers homogeneous wind suitable for NWP assimilation. The main product from Aeolus is the Horizontally projected Line Of Sight (HLOS) wind component, a single component of wind information, approximately zonal in nature. A Pseudo Observation System Simulation Experiment (POSSE) is conducted with only the zonal component of radio sonde (RS) winds to assess the impact of single component of wind information in the NCMRWF assimilation and forecast system compared to the full vector wind. Same RS profiles are assimilated in both the experiments, but full vector in control and single vector in POSSE. Full vector is decomposed into zonal and meridional components and assimilated only the zonal component in POSSE. Single vector component assimilation reproduces approximately 75-80 % characteristics of full vector assimilation. Differences in meteorological fields like Temperature, Relative Humidity, Wind components, etc., are noticed at higher levels particularly over the tropical orographic regions.

12p.02 Assessment of impact of satellite radiances on analysis in KIAPS

Presenter: Hyoung-Wook Chun, KIAPS

Authors: Hyoung-Wook Chun and Hyo-Jong Song

Quantifying the actual impact of each observation on forecast or analysis is important to verify the subset of the observation make the forecast better or worse. Forecast sensitivity to observation (FSO) methods based on adjoint sensitivity have proven to be a powerful monitoring tool. Korea Institute of Atmospheric Prediction Systems (KIAPS) has been developing an operational NWP model including own data assimilation system which is hybrid 4DEnVar. Unfortunately, KIAPS don't have the adjoint for the forecast model so cannot use the FSO method. KIAPS keep up the effort to assessment of impact of observation with the Kalman gain in observation space. The averaged Kalman gain for the subset of observation is the slope of linear regression between 'analysis increment in observation space' and 'innovation, i.e. background departure from observation' for the given samples. Preliminary results showed that the water vapor sounding channels have larger impact than the temperature sounding channels. And mid-altitude-sensitive channels have larger impact than high-altitude-sensitive channels in KIAPS system. These results are related with the magnitude of background error covariance and inflation factor of observation error covariance.

12p.03 Extended Use of Humidity sensitive Radiances in the DWD System

Presenter: Robin Faulwetter, DWD (German Meteorological Service)

Authors: Robin Faulwetter

In the last years more and more humidity sensitive radiances were introduced into DWD's global ICON+EnVar operational NWP system. Now, humidity channels from IASI, MHS, ATMS, SSMI/S, GMI, SEVIRI, GOES sounder, ABI and AHI are assimilated operationally with a positive impact. In this poster ongoing work about further extending the use of humidity sensitive radiances in the DWD operational system is presented. The introduction of more humidity sensitive radiances into the current system, e.g. additional instruments like MWHS-2, additional channels, adjustments to the overly strict cloud detection or less thinning, degrades forecast scores at least partially. I.e. the system appears to be "saturated" with respect to humidity sensitive radiances. The current assumption is that this is due to a model bias in the uppertropsheric tropical humidity and the interaction between model bias and radiance bias correction. This problem is analyzed, and possible solutions are presented.

12p.04 Assessment of the FY-3D microwave instruments at ECMWF

Presenter: David Duncan, ECMWF (for Heather Lawrence)

Authors: Heather Lawrence, David Duncan, Niels Bormann

The Chinese Feng-Yun (FY) -3D satellite was launched in November 2017, as the fourth satellite of the FY-3 series, and the second to be aimed at operational use. It carries onboard the same microwave instruments as FY-3C, including the MicroWave Temperature Sounder -2 (MWTS-2), the MicroWave Humidity Sounder -2 (MWHS-2) and the MicroWave Radiation Imager (MWRI). In

this poster we present a first assessment of the quality of the data at ECMWF, and discuss implications for assimilation.

Observation minus background (O - B) statistics are assessed and results compared to similar instruments, including those on FY-3C and ATMS, MHS and AMSR-2. First results indicate that both MWHS-2 and MWRI have similar biases and standard deviation of O – B to other instruments, indicating a similar quality. For MWRI statistics are improved compared to FY-3C, with no visible orbital-dependent biases. MWTS-2 has similar global biases to other temperature sounders but a higher standard deviation of O - B, due to more prevalent striping and scan-dependent biases.

12p.05 Impacts of cloud screening algorithm of the ATMS on numerical weather prediction model: Scattering index

Presenter: Jisoo Kim, Ewha Womans University
Authors: Jisoo Kim, Myoung-Hwan Ahn, Han-Byeol Jeong, Chu-Yong Chung

The cloud detection in the pre-processing of satellite data for the numerical weather prediction plays a significant role in selecting quality controlled observation data. One of the cloud detection method used for such efforts is the use of scattering index which utilizes the differential scattering effects of large solid hydrometeors to the different channel frequencies. Here we present preliminary results of improved scattering index, estimated by using real-time clear sky brightness temperature (Tb) instead of global averaged climatological clear sky Tb, on the innovation statistics, analysis field, and forecast fields. Here, the real-time clear sky Tb is obtained by radiative simulation with the model background fields. We apply this method to the pre-processing of the Advanced Technology Microwave Sounder (ATMS) in the Korean Integrated Model (KIM) system. The scattering index is estimated with the difference in the model first guess (FG) departures at 89 GHz and 165 GHz. This reduces the false positive of cloud detection especially over snow/ice covered region. Thereby it contributes to better utilization of ATMS observations to data assimilation system. It has neutral impact on the statistics of the FG departures of observations. Further, the analysis field is evaluated by comparison with the European Centre for Medium-Range Weather Forecasts Integrated Forecast System (ECMWF-IFS). It shows neutral or improved performance than the control system. The scattering index has larger impact on the humidity fields than on the temperature fields. Further results and analysis will be presented in the conference.

12p.06 Use of microwave radiances in the MetCoOp operational HARMONIE-AROME limited-area data assimilation

Presenter: Magnus Lindskog, Swedish Meteorological and Hydrological Institute (SMHI)
Authors: Magnus Lindskog, Roger Randriamampianina, Adam Dybbroe, Ulf Andrae, and Ole Vignes

MetCoOp is a common operational limited-area km-scale numerical weather prediction ensemble system. The cooperation is between the Nordic countries Finland, Norway and Sweden. The system consists of ten ensemble members, including an unperturbed control member. The initial states are produced by 3-dimensional variational data assimilation making use of a large amount of observations from in-situ measurements, weather radars, global navigation satellite system, advanced scatterometer data and satellite radiances from various satellites and instruments.

Here we focus on the use of microwave radiances in the operational system. The current use, restricted to MHS and AMSU-A instruments, is described with respect to data cover, current use and impact on analysis as well as forecast. In addition, the benefit from, in MetCoOp system, recently introduced microwave radiances from instruments on-board the satellites METOP-C, FY-3C and FY-3D are presented. Future plans will be described. These include on the short term introduction of microwave radiances from NOAA-20 and in on a longer term from instruments on-board planned missions of constellation of small micro-satellites. Furthermore, use of cloud affected radiances is considered important, as well as an improved use of near surface sensitive channels. Finally some plans for use of microwave radiances around, 200 GHz, to be provided by the Ice Cloud Ice Cloud Imager (ICI), planned on-board the next generation polar satellites to be launched by EUMETSAT, will be highlighted.

12p.07 Extending use of microwave humidity data over land at the Met Office

Presenter: Stuart Newman, Met Office
Authors: Stuart Newman, Stephan Havemann, Fabien Carminati and Amy Doherty

Microwave humidity observations have typically been assimilated over the oceans only in the Met Office global model. Recent developments mean 183 GHz humidity channels on MHS, ATMS and

MWHS-2 can now be exploited over land. Key changes include:

- Extending a 1D-Var retrieval of microwave emissivity and surface temperature to include MHS frequencies.
- Revising scene-dependent observation errors as a function of surface-to-space transmittance.
- Updating quality controls used to screen out observations strongly affected by clouds and the land surface.

Relative to a full observing system control, global trials show benefits in the extratropics from assimilating the extra observations over land, including for parameters such as geopotential height and temperature fields. Improved background fits to independent humidity-sensitive observations indicate benefits to the short-range forecast. These developments have been included in the package of changes targeted at the next Met Office operational suite upgrade.

12p.08 Impact of NOAA Low Latency LEO DBNet Constellation Infrared Sounder Data on NCEP GFS forecasts

Presenter: Youngchan Noh, CIMSS/SSEC
Authors: Youngchan Noh, Agnes Lim, Allen Huang, and Mitch Goldberg

In operational numerical weather prediction (NWP) system, satellite observations that arrive later than the cut off time are not assimilated. The length of cut off time depends on the frequency of the data assimilation cycle. Thus, the timely arrival of satellite observations at the NWP centers is one of the main factors for maximum usage of satellite observations. The timing of data delivery from the NOAA DBNet depends on the data transmittance speed and the ability of the data processing system. In particular, the low-earth orbit (LEO) satellite are more sensitive to the delivering time of DBNet because the LEO satellites transmit real-time data to the ground stations spread worldwide and then its data are delivered to the GFS system from distant ground stations. Current satellite instruments that can transit via the DNet are the AMSU-A onboard NOAA-15, 18, 19, Aqua, and MetOp-A/B satellite platforms, the MHS onboard NOAA-17, 18, 19 and MetOp-A/B, the AIRS onboard Aqua, the CrIS, the ATMS onboard S-NPP and NOAA-20, and the IASI onboard MetOp-A/B.

At the National Center for Environment Prediction (NCEP), the DBNet is one of the sources where observations are received. In this study, we assess the impact of reduced data latency for LEO satellites on the forecast performance by running, three data assimilation experiments; (a) a control run (ctrl_n20) with the operational configuration, (b) if the data latency is at 20 minutes for all LEO satellites (laten_20m), and (c) if the data latency is at 5 minutes (laten_5m). The trial runs were conducted from 30 June to 22 August 2018. This includes a seven-days spin-up period (30 June – 6 July 2018), using the NCEP GFS at T670. Reducing the latency time to 5 minutes increases the number of assimilated LEO satellite observations up to a maximum of about 20%, compared with the operational setup. Forecast verification shows positive impact on anomaly correlations (AC)s and root mean square errors (RMSEs) of key atmospheric variables with shorter data latency.

12p.09 The Impact of FY3D-MWRI Radiance Assimilation on the Typhoon Shanshan Forecasts with GRAPES 4D-Var

Presenter: Hongyi Xiao, China Meteorological Administration
Authors: Hongyi XIAO, Wei HAN, Hao WANG, Jincheng WANG, Guiqing LIU, Changshan Xu

The assimilation of FengYun-3D MWRI (MicroWave Radiation Imager) satellite microwave imaging data in HDF5 format is performed in GRAPES_GFS (Global/Regional Assimilation and PrEdiction System – Global Forecast System) by 4DVAR (4-dimentional variational) data assimilation. The quality control, cloud detection and bias correction procedures are applied to the data during the period from 0300 UTC 4 August to 0900 UTC 5 August 2018. The quality of satellite data is assessed, and is verified to be improved effectively. The influence of MWRI assimilation is indicated by the analysis increment. Typhoon Shanshan (No. 13 in 2018) is selected to evaluate the impact of MWRI assimilation on the forecasting of tropical cyclones. Compared to the experiment without MWRI assimilation, MWRI assimilation obviously improved both the track forecast and the intensity forecast of typhoon. The behavior of subtropical high is applied to interpret the mechanism that MWRI radiance data assimilation improves the typhoon forecast.

12p.10 Background Fit to Satellite Observations

Presenter: William Campbell, NRL Monterey
Authors: William F. Campbell

Millions of observations that are already monitored and assimilated are also available for verification and diagnostics of 6-hour forecasts. These observations span the globe and cover the depth of the atmosphere far better than the much more limited set of radiosondes currently used for verification in observation space. We have developed a tool to compute a quantitative

measure of the fit of the 6-hour forecast (background) to these global observations, along with uncertainty estimates. This method has several considerable advantages over traditional forecast statistics and scorecards. It requires an NWP simulation of only one to two weeks to accurately evaluate whether the experiment has improved or degraded analyses and forecasts (Alan Geer, ECMWF, personal communication), a much shorter time frame than the three to six months of simulation needed with traditional forecast statistics. The savings in software development time for NWP and DA developers, and in actual compute time for expensive NWP models, is considerable We also produce a scorecard with a decision matrix to determine whether an experiment is a win, loss, or neutral with respect to a control run.

The tool has diagnostic applications as well. For example, we might find that an experiment improves the background fit to radiances sensitive to moisture in the boundary layer, while degrading the background fit to radiances sensitive to stratospheric temperature. This very specific information can inform the experimenter's understanding of what went right and wrong, and provide guidance on how to resolve issues. The software automatically groups the plots and scorecard by atmospheric variable type and vertical location, so it does not require expertise in radiance assimilation to interpret and use the results.

12p.11 Let more Polar Orbiting Satellite Data available in Regional NWP in CMA —DBNet Data, its potential, application and questions

Presenter: Shuang Xi, National Satellite Meteorological Center
Authors: Shuang Xi

It is well proved that microwave thermometer sounding radiance from polar orbiting meteorological satellite have been taken the most important role in NWP.

At present the polar orbiting satellite data is seldom assimilated in regional NWP in China Meteorological Administration (CMA), because of little data available located in the domain and in the assimilating time windows, before the cut-off time.

There are four types of sources of ATOVS AMSU-A data available in CMA, including two DBNet data (RARS and EUMETcast) and two global data (NESDIS and EUMETSAT). There is some difference among different types of sources, such as the satellite kinds and regional coverages.

It's easy to be understood that before the cut-off time, the data collected by regional satellite receiving stations could fill some gaps between the orbits of global data, with longer delay time in receiving courses.

A quasi-real-time NWP is running in National Satellite Meteorological Center (NSMC), based on regional WRF model and WRFDA assimilation with all kinds of AMSU-A data and conventional data.

Both DBNet data and global data are put into the real-time regional assimilation system, meanwhile the data quantities, and coverages were analyzed and compared, with given assimilating time windows and NWP region.

Analysis from June to December 2018 shows that the use of DBNet data increases the total data quantities by more than 100% and the coverages by more than 50%.

It is also pointed out the that there are differences in bright temperature/latitude /longitude, which implies the differences in calibration and positioning in satellite data preprocessing, either among different RARS regional stations or between RARS stations and NESDIS way.

These studies could provide useful examples and advices for applications of multi-source satellite data in NWP in CMA.

12p.12 Evaluation and assimilation of MW sensors on NOAA-20 and Metop-C

Presenter: Niels Bormann, ECMWF
Authors: Niels Bormann, Pete Weston

ATMS observations from NOAA-20 and AMSU-A/MHS data from Metop-C are the most recent additions of MW instruments assimilated in the operational ECMWF system. We report here on the data quality assessment and assimilation experiments that motivated the operational assimilation of the data.

An evaluation of NOAA-20 ATMS data against the ECMWF background shows that the data are of overall good quality with characteristics that are comparable to the S-NPP ATMS, with the advantage of lower instrument noise and less striping in the NOAA-20 observations. Assimilation trials demonstrate the benefits of adding these observations to the operationally used observing

system. NOAA-20 ATMS data were activated in the ECMWF system on 22 May 2018.

A similar evaluation of Metop-C AMSU-A and MHS observations also shows acceptable data quality, with characteristics that are mostly in line with previous such instruments, with the exception of MHS channels 3 and 4 which exhibit larger noise with some striping features. Despite these limitations, assimilation trials suggest a small benefit from adding these observations, which is remarkable since this is the 3rd set of AMSU-A/MHS observations in the 9:30 orbit and the 9th and 11th MW instrument with temperature and humidity sounding capabilities, respectively. Operational assimilation of AMSU-A and MHS from Metop-C started on 14 March 2019.

12p.13 Continuous Data Assimilation at ECMWF and implications for satellite observation timeliness

Presenter: Niels Bormann, ECMWF
Authors: Peter Lean, Massimo Bonavita, Elias Holm, Niels Bormann

Satellites provide a near-continuous stream of data that can be assimilated by operational NWP centres. However, the assimilation process is both computationally intense and time consuming and, at ECMWF, by the time the analysis is complete the most recent observations that went into producing it are nearly two hours old. Here we describe a new configuration of ECMWF's 4D-Var data assimilation system which allows the analysis to benefit from more recent observations. By inserting new observations into the system after the assimilation process has begun we are able to use around one and a half hours more observations while maintaining the current product dissemination schedule. In this new, more continuous, configuration the assimilation window is extended up to the current time to allow all observations that have arrived (including valuable low latency observations at the end of the window) to be assimilated. Results will be presented to highlight how initiatives such as DBNet / EARS which improve the timeliness of satellite observations can lead to improved coverage at the end of the assimilation window and ultimately to better forecasts.

12p.14 Current Use of FY-3 microwave instruments and Future Plans

Presenter: Brett Candy, UK Met Office
Authors: Brett Candy & Fabien Carminati

The microwave humidity sounders on board the chinese satellites FY-3B and FY-3C, make an important contribution to NWP global model analyses and have been routinely assimilated at the Met Office since November 2016. We report on an initial assessment of the microwave instruments onboard FY-3D, using first guess departures from our operational global model. In addition to this we will show our latest impact studies using the MWRI on FY-3C. This instrument has a known significant ascending/descending bias and we will discuss how orbital predictors, updated via the variational bias correction scheme, have been used to account for this. Finally an initiative to improve the impact from MWRI on windspeed over the ocean will be discussed.

12p.15 Assimilating FengYun-3C Microwave Sounding Data over Land in the Southwest Vortex Precipitation in China

Presenter: Keyi Chen, Chengdu University of Information&Technology
Authors: Keyi Chen, Jiao Fan , Zhipeng Xian

The European Centre for Medium-Range Weather Forecasts (ECMWF) have been assimilating the FY-3C MWHS-II (Microwave Humidity Sounders-2) data in the operational forecasting system since the April 4th, 2016. Though it is more difficult to assimilate microwave observations over land and sea ice than over the open ocean due to higher uncertainty in land surface temperature, surface emissivity and less effective cloud screening, Chen et. al. (2018) compare approaches in which the emissivity is retrieved dynamically from MWHS/FY-3B channel 1 (150GHz (V)) with the use of an evolving emissivity atlas from 89 GHz observations from the Microwave Humidity Sounders (MHS) on NOAA and EUMETSAT satellites. The assimilation of the additional data over land with the dynamic emissivity improves the fit of short-range forecasts to other observations, and the forecast impacts are mainly neutral to slightly positive over the first 5 days.

It is also important to study the impacts of assimilating microwave observations on the intense precipitating forecasts over the complex terrain, like the Sichuan Basin, which strengthens the precipitating forecast difficulties. Many cases caused by the Southwest Vortexes are studied by assimilating MWHS-2/FY-3C with emissivity atlas and with dynamic emissivity retrieved from the window channels. Two typical cases are presented here to show the impacts of the assimilation on the forecasts and concluded that the cycling experiments assimilating the MWHS-2/FY-3C observations do show improvements in the initial fields and the forecasts, especially those with the emissivity atlas. More data did be used in the experiments with the dynamic emissivity, but not

in the observed precipitating area, plus the retrieved emissivity might have larger biases than the atlas over the complex terrain, which might reduce the improvements for the initial fields and the forecasts, and more work needs to be done to give detailed explanations.

12p.16 Unified Observation Processing

Presenter: Benjamin Ruston, Naval Research Laboratory
Authors: Benjamin Ruston, Nancy Baker, Pat Pauley, Sarah King and Eric Simon

The amount of data assimilated by the environmental systems is growing rapidly. The strategies for using this data need to be re-examined for reusability and portability. This all aligns very well with many initiatives being undertaken across labs such as JCSDA JEDI Interface for Observation Data Access (IODA) and ECMWF ODB-C and will integrate with techniques such as continuous data assimilation. This involves modifying the current processing chain and assimilation strategy at NRL, and refactoring when necessary to abstract functionality concepts from components and allow them to be used in common for the various data types used. Observations from in-situ and satellite platforms, and from various environmental systems like oceanic or ionospheric, all contain common traits. The handling of the ingest and the basic understanding of the measurement is required, but a focus on defining common attributes the data have in common and defining these into families is a focus going forward. When these are brought into a more common framework, actions on families of attributes can be constructed to do various operations such as data thinning and error assignment which can then be dynamic for the particular application. Environmental observations, particularly in the U.S. are increasingly reliant on commercial providers and the evolving small satellite era. These data will be large in volume, with poorly defined sources and fluctuating quality control approaches. Further we may expect format changes as companies (providers) may fail or be acquired. Moving towards this new strategy will make the system more adaptive to new data types and formats, more accessible to machine learning and artificial intelligence (AI) approaches, and systems should readily adapt to new data types and can more easily be equipped with bias and error mitigation.

12p.17 Operational Use of NOAA-20 ATMS and CrIS Radiance Data in JMA's Global NWP System

Presenter: Hidehiko Murata, Japan Meteorological Agency
Authors: Hidehiko Murata and Norio Kamekawa

The Japan Meteorological Agency (JMA) began to assimilate data from the Advanced Technology Microwave Sounder (ATMS) and Cross-track Infrared Sounder (CrIS) onboard NOAA-20 into its global Numerical Weather Prediction (NWP) system in addition to those of Suomi National Polar-orbiting Partnership (Suomi-NPP) on 5 March 2019. This report outlines the impacts of the added data on the system.

The ATMS instrument is a microwave sounder with 22 channels, including temperature and humidity sounding channels. Quality control (QC) and error handling for the assimilation of NOAA-20/ATMS radiance data, such as channel selection, thinning distance, observation errors, rain/cloud detection and bias correction (static scan bias correction and variational bias correction) follow those implemented for Suomi-NPP/ATMS data assimilation. Currently, tropospheric temperature-sounding channels (6 – 9) and humidity-sounding channels (18 – 22) are assimilated. The CrIS instrument is a hyperspectral infrared sounder with a total of 2,211 channels in full spectral resolution (FSR) mode. QC and error handling for the assimilation of NOAA-20/CrIS radiance data also follow those for Suomi-NPP/CrIS. Currently, 27 channels for temperature-sounding are assimilated. The channels are selected from the CO2 absorption band in the long-wave IR band (LWIR) included in the disseminated 431 channel dataset.

Observing system experiments covering periods in each of boreal summer 2018 and winter 2019 were performed to evaluate the impacts of NOAA-20 instruments on the NWP system. The standard deviations of the first-guess (FG) departure (i.e., the difference between observed and calculated brightness temperature), which are used as an indicator of data quality, were similar to or smaller than those of Suomi-NPP. Against baseline experiments in which the focusing radiance data of both satellites were not assimilated, the impacts of Suomi-NPP and NOAA-20 on FG and forecast-field were similar.

A test assimilation experiment with the addition of NOAA-20/ATMS and CrIS data together was performed. Experiments for individual instruments were also performed to determine their specific contributions. Decreases in the standard deviation of the FG departure of the AMSU-A and MHS microwave sounders, which imply the improvements of temperature and water vapor of FG field, were observed. These improvements with

the temperature sounding channels (AMSU-A/ch4-8) and humidity sounding channels (MHS) are mainly attributable to the assimilation of NOAA-20/ATMS data, and those with the stratospheric temperature sounding channels (AMSU-A/ch9-14) are attributable to the assimilation of NOAA-20/CrIS data.

Improvements in geopotential height forecasts, especially for the mid-latitudes, were observed in the test experiment in which NOAA-20/ATMS and CrIS data were assimilated.

Session 13: Advances in Satellite Data Assimilation (oral presentations)

13.01 Implementation of slant-path radiative transfer in Environment Canada's Global Deterministic Weather Prediction system

Presenter: Maziar Bani Shahabadi, Environment and Climate Change Canada
Authors: Maziar Bani Shahabadi, Mark Buehner, Josep Aparicio, and Louis Garand

In the process of radiance data assimilation, vertical profiles of the trial fields have been so far horizontally interpolated to the location of the radiance observations projected at the surface. In a recent study (Bani Shahabadi et al., Mon. Wea. Rev, 2018), horizontal gradients of atmospheric variables were used offline to approximate the slant line of sight and thus improve the forward operator, especially for high peaking channels. In this approach, analysis increments were still computed assuming vertical columns. Positive impacts were shown for forecasts up to four days.

In a recent development, the slant path interpolation is done inline, i.e. within the assimilation procedure, and is applied for all radiances. Both the trial fields and analysis increments are horizontally interpolated directly onto the slant profile. The procedure is computationally affordable as the size of control vector does not change, and it can be used for any observation type, including radiance and radar observations. This generalized procedure is presented along with results demonstrating the impact on analyses and forecasts.

13.02 Impact of the mid-loop for satellite radiance on a hybrid data assimilation skill

Presenter: Hyo-Jong Song, Korea Institute of Atmospheric Prediction Systems
Authors: Hyo-Jong Song, Ji-Hyun Ha, and Hyoung-Wook Chun

Since 1979 so called the satellite data assimilation era, the quality of numerical weather prediction (NWP) is in the process of continuously improving innovatively. Especially, the data assimilation (DA) skill in the southern hemisphere has been approaching the skill score in the northern hemisphere nearly in this period. In the DA procedure, a proper simulation of radiance data using efficient radiative transfer operator such as Radiative Transfer for TIROS Operational Vertical Sounder (RTTOV) is essential to make the effectiveness of the satellite radiance sounding to the maximum. For this, re-calculation of RTTOV is conducted with an improved guess for the radiance data in the middle of iteration for the cost function minimization, which is called 'mid-loop.' Korea Institute of Atmospheric Prediction Systems (KIAPS) has been developing an operational NWP model, Korean Integrated Model (KIM), which includes its own DA system. It is a shape of hybrid variational-ensemble DA, hybrid 4DEnVar. This study will be a trial for investigating a role of the re-calculation of RTTOV, an observation forward operator for satellite radiance data, in the hybrid 4DEnVar.
Another issue that needs to be considered in this study is the role of re-checking the quality of the brightness temperature during the cost-function minimization. The change in the availability of using the satellite sounding data every mid-loop is expected to yield a significant modification to the resultant analysis increment. In the situation of a semi-operational configuration involving the KIM forecast system, it is investigated the way and the magnitude how the application of mid-loop that includes the re-calculation of RTTOV and re-checking the satellite data affects the hybrid DA skills.

13.03 Observation selection for variational bias correction

Presenter: Ruth Taylor, UK Met Office
Authors: R.B.E. Taylor

Variational bias correction (VarBC) has been used for all satellite radiances assimilated by the Met Office global NWP system since March 2016, and by the UK regional NWP system since June 2017. The introduction of VarBC led to significant improvements in global forecast scores and the system has proved robust and stable [Cameron and Bell, 2018]. The original implementation of VarBC was such that every observation assimilated also influences the bias correction. Here we describe an approach for selecting the radiances which determine the bias correction, according to the circumstances of the observation. This capability becomes particularly desirable as we

seek to extend our use of observations to more complex conditions (for example, by introducing radiances affected by cloud or a wider variety of underlying surfaces). The biases of such observations with respect to modelled equivalents are less well understood and they may have an adverse effect on the derived bias correction, possibly to the extent that positive impacts from their introduction are negated. The results of some initial experiments using observation selection for bias correction in the variational framework will be presented.

Cameron, J. and Bell, W. (2018). The testing and implementation of variational bias correction (VarBC) in the Met Office global NWP system. Met Office Forecasting Research Technical Report 631.

13.04 Surface Dependent Correlated Infrared Observation Errors in the FV3 Framework

Presenter: Kristen Bathmann, IMSG @NOAA/NCEP/EMC
Authors: Kristen Bathmann, Andrew Collard

Research with correlated satellite observation error has been ongoing at NCEP and has primarily focused on estimating and accounting for inter-channel error correlations in AIRS and IASI observations over sea surfaces only. In the Global Forecast System (GFS), accounting for error correlations in IASI observations had a slightly positive forecast impact, whereas results with AIRS have proven to be neutral. This presentation will discuss the assimilation of infrared satellite observations with correlated error in the Finite Volume Cubed-Sphere (FV3) dynamical core. Error correlations over sea surfaces and land surfaces are computed and treated separately. In addition, these experiments adopt stricter quality control that depends on the smaller, diagnosed observation errors, resulting in improved detection of cloud contaminated data. The forecast impact during a two month period in winter 2018-2019 is examined, and compared to previous experiments with the GFS.

13.05 Understanding the link between satellite radiance thinning and observation error variance inflation in global 4D-EnVar

Presenter: Joël Bédard, Environment and Climate Change Canada
Authors: Joël Bédard, Alain Beaulne, Mark Buehner, and Patrice Beaudoin

The model and data assimilation components for a new global numerical weather prediction (NWP) system with 15 km grid spacing are currently being developed and tested. The data assimilation component is based on 4D-EnVar and uses background error covariances partially obtained from a global ensemble Kalman filter with 256 members at 39 km grid spacing. In Environment and Climate Change Canada's currently operational data assimilation systems, all assimilated radiance observations are thinned to a 150 km horizontal spacing. This is justified by the fact that errors associated with dense satellite observations can have significant spatial correlations and assimilation algorithms generally assume spatially uncorrelated observation errors. However, the recent increase in horizontal resolution of the analysis grid should allow for the assimilation of denser observation networks. Within this context, various strategies are being explored to increase the density of assimilated radiance observations for initializing global forecasts. Results from idealized one-dimensional experiments show that analyses can be improved by increasing the density of observations with spatially correlated errors, while still assuming uncorrelated errors within the data assimilation algorithm. However, results also show that when increasing the density of such observations, the observation error variance must be inflated to avoid over-fitting the large scales, which is often overlooked in the literature. The link between observation error variance inflation and spatial thinning is revisited in the context of this new higher resolution global NWP system. Results will be discussed from examining the spectral variances of 1) the hybrid background error covariances and 2) the impact of satellite brightness temperature observations on the analyses for a range of values for the spatial thinning and error variance inflation applied to these observations. Results from fully cycling assimilation and forecasting experiments in a near operational context will also be presented.

13.06 Surface skin temperature for satellite data assimilation at ECMWF

Presenter: Cristina Lupu, ECMWF
Authors: Cristina Lupu, Antony McNally

An accurate specification of the surface temperature is important to the assimilation of radiances providing information on temperature and humidity in the lower troposphere. The surface skin temperature produced by NWP models can have large uncertainties and biases and there is no independent information for what absolute size of error should be assigned to the model's estimate of the surface skin temperature seen by satellites. It is recognized that further progress with the assimilation of surface-sensitive channels in the ECMWF system will require

considerable revision of the methods used to specify the skin temperature.

This presentation highlights work towards improving the handling of skin temperature for satellite data assimilation. Given that in the current hybrid 4D-Var, an Ensemble of Data Assimilations (EDA) is used to generate situation-dependent background errors for the high-resolution deterministic forecast it is proposed here to replace the constant values of the background errors standard deviation for surface skin temperature with estimates from the EDA. The new system introduces the spatial and temporal variability to the assumed skin temperature errors, with the overall scaling of the variance optimised on the basis of trial and error. Results illustrating the impact on analyses (e.g., improved first guess fit to radiosonde temperature data) and forecasts will be presented along with a look ahead to planned developments for evolution towards coupled models and coupled data assimilation.

Session 13: Advances in Satellite Data Assimilation (poster introductions)

13p.01 Local Unscented Transform Kalman Filter for Highly Nonlinear System

Presenter: Kwangjae Sung, Korea Institute of Atmospheric Prediction Systems
Authors: Kwangjae Sung

The LUTKF algorithm can estimate the state of high-dimensional dynamic systems with a small number of ensemble members by combining both the unscented transformation (UT) by Julier and Uhlmann (2004) and the localization method used in the LETKF. Unlike the LETKF, which determines the ensemble members by random sampling at the initial time, the samples (ensemble members) in the LUTKF algorithm are selected deterministically using the UT method in every time step. Hence, the LUTKF algorithm can estimate the state of a system using a smaller ensemble size compared to the LETKF. In the LUTKF algorithm, a minimal set of 2n samples for an n-dimensional system is used to propagate the state estimate and its error covariance (uncertainty) through nonlinear transformations. While the LETKF has an estimation accuracy up to a first order term in a Taylor series of the true value due to linearization for a nonlinear system, the LUTKF can guarantee accuracy up to a third order term in the Taylor expansion by using the UT.

13p.02 Impact of SSMIS BC method considering background-error in KIAPS DA system

Presenter: Jeon-Ho Kang, Korea Institute of Atmospheric Prediction Systems (KIAPS)
Authors: Jeon-Ho Kang, Hyo-Jong Song, Hyoung-Wook Chun, and In-Hyuk Kwon

The SSMIS lower atmospheric sounding (LAS) radiances had been assimilated on the Hybrid 4D Ensemble-Variational (Hybrid-4DEnVar) data assimilation system in KIAPS. We know that there are some biases in the background field as well but it is not easy to separate them within the first-guess departure (O-B) which is used to figure out the biases of the observation. For the accurate bias correction of the SSMIS data to maximize the assimilation impact in the forecast a new method considering the background error for the orbit angle based bias correction was implemented. And assimilating channels are re-selected or newly added in DA system. It would be presented a new strategy designed to reduce the effects of background biases expected to attenuate the accuracy of the bias correction with their impacts on the KIAPS DA cycle experiment.

13p.03 Development and Progress of High Resolution CMA Land Surface Data Assimilation System

Presenter: Shuai Han, National Meteorological Information Center (NMIC)
Authors: Shuai HAN, Chunxiang SHI, Bin XU, Lipeng JIANG, Shuai SUN, Tao ZHANG

This paper reviews the development of HRCLDAS, a high-resolution land data assimilation system, focuses on the important progress and breakthroughs in HRCLDAS research and development, and summarizes the contribution of these developments to HRCLDAS operation. And the paper mainly introduces the 1km resolution meteorological data by using multi-grid variation analysis technique. Based on the data of 1km visible channel, high-resolution terrain and surface albedo of FY-2 satellite, the ground Radiation product quality and spatial resolution has been improved. Simulation of ground solar radiation using hybrid model and ground station sunshine hours, air temperature and so on, and the use of multiple grid variation analysis technology to achieve the integration of these information; to achieve the East Asia satellite integrated precipitation products (EMSIP) and 4 million automatic stations observation. Aiming at the characteristics of high terrestrial simulation resolution and large data volume, a parallel calculation scheme of block parallel and mode is designed to realize efficient soil moisture

simulation. HRCLDAS promotes the meteorological departments at all levels to carry out related operation applications.

13p.04 Evaluation of Variational Bias correction using an iterative bias correction against analysis
Presenter: In-Hyuk Kwon, Korea Institute of Atmospheric Prediction Systems (KIAPS)
Authors: In-Hyuk Kwon, Hyoung-Wook Chun, YuJin Juhn, Ji-Hyun Ha, Hyo-Jong Song and Hanbyeol Jeong
The bias correction (BC) is one of the most important processes in the satellite data assimilation (DA). The Korea Institute of Atmospheric Prediction systems (KIAPS) has developed an operational DA system for the cubed sphere grid global model called Korea Integrated Model (KIM). It assimilates most satellite radiance observations used in the Korea Meteorological Administration (KMA) DA system. The KIAPS has built their own observation processing system called KIAPS Package of Observation Processing (KPOP) to provide qualified real-time observations for the DA system. To remove observation bias, the KPOP performs an adaptive BC method that calculates the BC coefficients against the background at the analysis time rather than using static BC coefficients. This method can make the difference between observation and background (O-B) almost zero. However, the adaptive BC method is likely to push observations to the background too much. A systematic model bias was found in the KIM, which is warm and dry bias around 850 hPa. In this case, we should avoid sending the observation too close to the background. Otherwise, it reinforces the model bias.

Recently the Variational BC (VarBC) method is implemented in the KIAPS DA system, so the bias parameters are updated jointly and simultaneously with the control variables during the minimization in Variational DA system. The VarBC is less affected by model bias. This is because the VarBC tries to fit the observation into the analysis rather than the background. Therefore, it is expected that the VarBC prevents over-fitting the corrected observation with a background.

To better understand the VarBC method in the KIAPS data assimilation system, we have developed an iterative bias correction against analysis. This method minimizes the difference between observation and analysis (O-A) which is the same concept as VarBC. It performs the adaptive BC and DA iteratively. The DA uses the same background, but the adaptive BC uses updated analysis instead of the background. This method is relatively straightforward. This study investigates O-A for each iteration. The iterative bias correction requires a lot of computation time, so it is hard to use in an operational system. However, it will be a useful tool for evaluating VarBC.

13p.05 Leveraging Modern AI techniques in NWP and Enhancing Satellite Data Exploitation
Presenter: Sid Boukabara, NOAA
Authors: S. A. Boukabara, E. Maddy, N. Shahroudi and R. Hoffman
Artificial Intelligence (AI), machine/deep learning techniques (including deep neural networks, DNNs) have advanced considerably in recent years across a number of areas and applications: in medicine, self-driving cars, social media, the finance industry, etc. The astonishing increase in accuracy and applicability of AI has been significant in the private sector, driven by the ease, efficiency, cost-effectiveness, speed and auto-learning features of AI. Significant advances have also been made in application of AI in different areas of meteorology and oceanography. However, until recently, far fewer AI applications were developed in the area of environmental data exploitation of satellite data, high-level information extraction in the area of Numerical Weather Prediction (NWP), data assimilation and forecasting, as well as for extreme weather prediction and nowcasting. There have been encouraging signs that AI is increasingly considered for these applications, with promising results – including predictive skills – and this trend is expected to continue with the ever-increasing volume of satellite data and the increased societal reliance on improved forecasting accuracy and resolutions. The increase of data volume comes from higher resolution satellites and sensors, from a growing list of new sensors (traditional as well as smallsats/cubesats), and from an explosion of new virtual observing systems made possible by the internet of things (IoT). Exploiting all these data sources is expected to present major challenges, and AI has emerged as a potentially transformational and mitigating technology, especially because of the potential of what might be called meta-Transfer Learning – the transfer of knowledge and expertise from field in which AI has been firmly established to NWP and related environmental sciences. This study will present recent results obtained in using AI for satellite data calibration, simulation through radiative transfer, inversion, data assimilation and fusion, as well as

for post-forecast correction, including for extreme weather events.

13p.06 The assimilation of the IASI full spectrum using reconstructed radiances

Presenter: Marco Matricardi, ECMWF
Authors: Marco Matricardi

Work has continued at ECMWF on the assimilation of Principal Component (PC) based IASI data shifting the focus from the direct assimilation of PCs to the assimilation of radiances reconstructed from truncated principal components (hereafter RR). Although at a theoretical level the assimilation of PCs or RRs can be considered equivalent, the latter have the advantage of being able to exploit existing science and infrastructure developed for raw radiance assimilation, in particular cloud and aerosol screening. To this end, the ECMWF 4D-Var data assimilation system has been modified to allow the assimilation of a selected number of 400 IASI reconstructed radiances which effectively encapsulate the information content of the full number of IASI channels in the long-wave band-1 (2221 temperature, surface, and ozone sounding channels) and the mid-wave band-2 (3201 water vapour sounding channels). The latest version of the RR system makes use of new humidity background errors, a modified cloud detection scheme and a fully revised observation error covariance matrix for the IASI reconstructed radiances where different weights have been applied to observations in different IASI spectral regions. Ten months of assimilation trials show that background forecasts produced by the RR system fit radiosonde and satellite observations better than background forecasts produced by the operational system, especially for water vapour. Regarding the quality of the medium range forecasts launched from the analyses produced by the assimilation of reconstructed and raw radiances, the RR system demonstrates an impressive performance advantage over the operational system, especially in the Southern Hemisphere, where 500hPa geopotential scores are improved up to 2.5% in the medium-range.

13p.07 Quantifying the Sensitivity of NCEP's GDAS/GFS to CrIS Detector Differences

Presenter: Agnes Lim, UW-Madison CIMSS/SSEC
Authors: Agnes Lim, Sharon Nebuda, James Jung, Dave Tobin and Mitch Goldberg

Design of Infrared (IR) sounding instruments has advanced to use large arrays of detectors to make simultaneous observations. Different bias, noise and correlation properties between detectors can result in the need to treat observations from each detector differently. Having to treat each detector as an independent instrument is not desirable for Numerical Weather Prediction (NWP) centers. Current radiometric uncertainty and noise-equivalent changes in radiance (NEdN) requirements for IR sounder instruments do not fully address or constrain the noise characteristics between detectors. Detector properties, such as quadratic nonlinearity and detector noise, will contribute to inter-detector bias. No systematic studies have been conducted to determine the degree of match needed between detectors in an array used for IR sounding instruments that support NWP. The goal of this work is to understand what level these inter-detector biases begin to affect NWP analysis and forecast systems and help define the inter-detector design requirements. Instrument providers will need this information to assure that all instrument field-of-views (FOVs) are matched well enough to support NWP radiance assimilation.

A single detector is perturbed with several different detector quadratic nonlinearity parameter characterizations to determine their effect on analyses. Clear sky CrIS spectra radiances are simulated from the NASA GEOS-5 analyses assuming an aqua planet. Instrument noise is then added to these radiances. We will focus on one CrIS surface channel. A control run will be generated. It assimilates conventional data, microwave satellite radiances and simulated CrIS observations with constant instrument noise on all FOVs. The FOV 5 detector (center of a 3x3 array of detectors) NEdN will be used. Experiments will be conducted with the same configuration as the control but will assimilate perturbed CrIS observations at FOV 7. The magnitude of the perturbations will be multiples of the FOV 5 NEdN. Statistics such as FOV selected, O-B bias and RMS, will be determined with respect to each detector and presented.

13p.08 A land data assimilation study based on LIS with FY3C land surface temperature and microwave brightness temperature

Presenter: Chunxiang Shi, National Meteorological Information Center (NMIC), CMA
Authors: Shi Chunxiang, Jia Binghao, Sun Shuai, Zhang Shuai, Liang Xiao, Jiang Lipeng

Due to the spatiotemporal limitations of ground observations and the large uncertainties associated with atmospheric forcing and land surface parameterizations, land data assimilation has become an effective way of synthesizing complementary information from measurements and land surface models (LSMs) into a superior

estimate of geophysical fields of interest (e.g., soil moisture). As a new-generation Chinese polar orbiting meteorological satellite, the FY-3 series consists of two experimental (FY-3A/B) and at least four operational satellites (FY-3C/D/E/F). However, few studies investigated the simultaneous assimilation of microwave brightness temperature (Tb) and land surface temperature (LST) retrievals from FY-3C. This study carried out the first experiment to simultaneously assimilate the microwave Tb and LST retrieval derived from FY-3C into a land surface model, the Noah-MP model. And this study using CLDAS (CMA Land Data Assimilation System) forcing data. Assimilating experiments demonstrate the reasonability of the assimilation scheme developed in this study. It also suggests that the simultaneous assimilation of FY3C LST and Tb has the potential to estimate soil moisture with higher accuracy than the individual Tb observations.

Foundation:
This study was jointly supported by the National Natural Science Foundation of China (91437220), National Department (meteorology) Public Benefit Research Foundation (GYHY201306045; GYHY201206008; GYHY201306022), and International Scientific and Technological Cooperation Project (2011DFG23150).

Session 14: Preparation for New Hyperspectral Instruments

14.01 MTG-IRS: scientific improvements for a user-friendly mission

Presenter: Dorothee Coppens, EUMETSAT
Authors: Dorothee Coppens, Bertrand Theodore, Thomas August, Tim Hultberg, Cedric Goukenleuque, Jochen Grandell

The Meteosat Third Generation (MTG) series of future EUMETSAT geostationary satellites consists of two types of satellites, the imaging (MTG-I) and the sounding (MTG-S) satellites. The Infrared Sounder (IRS) is one of the two instruments hosted on board MTG-S. It is an imaging Fourier transform spectrometer with a spectral resolution better than 0.754 cm-1 in two spectral bands, the Long-Wave InfraRed (LWIR, 700–1210 cm-1) and the Mid-Wave InfraRed (MWIR 1600–2175 cm-1). After its launch in 2023, it will perform measurements over the full Earth disk with particular focus on Europe (that will be revisited every 30 minutes), with a spatial resolution of 4 km at nadir. With such measurements characteristics, the IRS mission is expected to massively impact both numerical weather prediction and nowcasting applications.

In order to enable users to make the most of IRS products, EUMETSAT strives to adapt them to all applications. This includes:

- Timeliness: IRS Level 2 processing has been fully reconditioned, building on the IASI experience to provide atmospheric profiles on the entire disk within 30 minutes after acquisition. IRS Level 1 processing has also been optimized so that calibrated spectra are available in less than 15 minutes;
- Compression: due to the huge amount of data, the IRS spectra will be disseminated as principal component scores. A hybrid approach, in which global PC scores are supplemented by a small number of local PC scores, has been designed to capture possible new spectral characteristics not included in global PCs;
- Information content: the radiances will be uniformised for ease of use and spectral sampling optimized to about 0.6 cm-1 to keep the instrument sampling and avoid introducing harmful artefacts related to resampling. In addition, an evaluation of the cloud fraction and the heterogeneity of the scene within each IRS pixel will be available in contrast to what had been planned in the past;
- User awareness: Users are associated to all decisions regarding the IRS processing through the mission advisory group. Test data are being prepared to train future users of the IRS.

This paper will go through the various improvements brought to the IRS level 1 and level 2 processing, the current results, limitations and the future plan.

14.02 IASI-NG Program: General Status Overview

Presenter: Francisco Bermudo, CNES
Authors: F. Bermudo, E. Jurado, F. Bernard, C. Lefèvre, A. Deschamps, S Guibert

CNES will develop the Infrared Atmospheric Sounding Interferometer New Generation (IASI-NG), a key payload element of the second generation of European meteorological polar-orbit satellites (METOP-SG), dedicated to operational meteorology, atmospheric composition, and climate monitoring. IASI-NG will continue and improve the IASI mission in the next decades (2020-2040) with notable improvements on

performances. The performance objective is mainly a spectral resolution and a radiometric error divided by two compared with the IASI first generation ones.

For the IASI-NG program, a cooperation agreement is implemented between CNES and EUMETSAT. Under this agreement, CNES has oversight responsibility for the development and procurement of the instruments, the definition of instrument in flight operations, the Level 1C data processing software (L1C POP) and the IASI NG Technical Expertise Centre (IASTEC) in charge of the in-flight calibration, validation and continuous performance monitoring. EUMETSAT is in charge of developing the EPS SG System and operating, archiving and distributing IASI-NG data to the users.

The paper reports on latest status of IASI NG program, with specific focus on these new highlights.

The instrument measurement technique is based on wide field Fourier Transform Spectrometer based on an innovative Mertz compensated interferometer to manage the so-called self-apodisation effect and the associated spectral resolution degradation. Further 2 years of instrument definition consolidation and engineering models activities, IASI-NG program will reach an important milestone in fall 2019 with the completion of the Instrument Critical Definition Review(CDR) with Airbus D&S. The design of the instrument, the development status of the main units, critical technologies and sub-systems with the first test results performed on engineering models will be presented. The status of the most recent CNES activities will be also provided: CNES achieved the definition of the Level 1 C data Processing algorithms and started the development of the L1C Operational processor with PDR milestone successfully reached end of 2018. The IASI-NG System Critical Definition review focused on mission performances, validation activities and IASTEC definition is planned in Q1 2020 to conclude the ongoing definition activities.

14.03 IASI-NG L1 processing: how to estimate the instrument response function in real-time?

Presenter: Adrien Deschamps, CNES
Authors: A. Deschamps, C. Luitot, F. Bernard, E. Baldit, A. Penquer

The development of the IASI-NG System, under responsibility of CNES, includes the development and delivery of IASI-NG instruments and Level 0 Processor (ICPU) to be flown on the Metop-SG A Satellites, the development of the Level 1 Processor (L1 POP) as part of the EPS-SG ground segment, and the development of a Technical Expertise Centre (IASTEC) in charge of the in-flight calibration, validation and continuous performance monitoring.

The IASI-NG instrument presents a technological gap compared to the IASI Fourier transform spectrometer. In order to be able to deliver data with both a twice lower radiometrical noise and a twice better spectral resolution, the IASI-NG interferometer design is based on the Mertz principle and uses movable prisms to compensate the so-called self-apodization effects. In order to deliver spectrally consistent data, the instrumental spectral response function (ISRF) of the spectrometer is continuously estimated on-ground and removed by the level 1 processing.

This paper presents the algorithms that have been developed to estimate this ISRF taking benefit from both an instrumental model and observable parameters coming from metrology beams, a Fabry-Perot interferometer or absorption features in the atmospheric spectra. We will describe the two main parts of this algorithmic chain dedicated on one part to the estimation of the spectral shift and on the other part the estimation of the instrumental shape error. The correction of these two effects are corrected simultaneously in the on-ground processing by local deconvolution. The estimated ISRF is then removed and replaced by a perfect Gaussian function. This algorithm is applied to each interferogram and for each wavenumber because of the high chromatic effect (i.e. the variation of the spectral shift with the wavenumber) due to the instrumental concept.

The first validation studies on the ISRF estimation module that have been conducted by the IASI-NG L1 team will be shown. According to these results, the challenging mission requirement to have a residual spectral shift lower than 10-6 within any single orbit should be met. An overview of the status for the other main IASI-NG performances will be finally given.

14.04 Development and Verification challenges of the IASI-NG system

Presenter: Eric Jurado, CNES
Authors: Eric Jurado, Clémence Le Fevre

IASI-NG system, developed under CNES responsibility, aims at producing data for meteorological and atmospheric chemistry user's

community. It is part of the EUMETSAT EPS-SG system.

It is composed of a space segment and a ground segment. The space component is the IASI-NG instrument, one model flying on each of the three METOP-SG A that will be launched between 2022 and 2036. The ground segment, consists in the IASI-NG Level 1 Processor, the so-called L1CPOP, which is integrated in EPS-SG Payload and Data Acquisition Processing ground segment, and in the IASI-NG Technical Expertise Center (IASTEC), in CNES premises, dedicated to performance monitoring of both space and ground segments, anomaly investigation, and development of improved processing software.

In the frame of the cooperation agreement with EUMETSAT for IASI-NG, CNES is responsible for ensuring the functionality and performances of both the IASI-NG instrument flying aboard METOP-SG and the L1C products disseminated through EUMETSAT system.

The IASI-NG system verification approach has to deal with three main challenges: its complex and innovative instrument, the ambitious scientific performances required, and the integration within the EPS-SG system. The validation of performances is reached by analysis or tests considering models with an increasing level of complexity and representativeness, first at instrument level, then with the instrument integrated on-board the satellite, and finally in interface with the EPS-SG ground segment. Several tests campaigns are required to cover all technical topics such as optical, mechanical, thermal, electrical, functional and operational qualification. An important issue is also the validation of the scientific algorithms implemented on-ground within the L1CPOP. In this perspective the Infra-Red Interferometer Simulator (IRIS) is developed to both simulate the instrument behavior and optimize the scientific post-processing.

This presentation will address both the logic and the technical challenges of the development and verification of the performances of this complex system.

14.05 Evaluation of a first IASI-NG channel selection for Numerical Weather Prediction

Presenter: Francesca Vittorioso, CNRM, Météo-France, CNRS
Authors: Francesca Vittorioso

In the framework of the EUMETSAT Polar System-Second Generation (EPS-SG) preparation, a new generation of the Infrared Atmospheric Sounding Interferometer (IASI) instrument has been designed. The IASI-New Generation (IASI-NG) will measure at a doubled spectral resolution compared to its predecessor and with a signal-to-noise ratio reduced by a factor 2. Measurement precision will be improved as well.

The high amount of data arising from IASI-NG will present many challenges in the areas of data transmission, storage and assimilation and the number of individual pieces of information will be not exploitable in an operational Numerical Weather Predictions (NWP) context. For these reasons, an appropriate IASI-NG channel selection is needed, aiming to select the most informative channels for NWP models.

The work has been carried out on a database of simulated observations [Andrey-Andrés et al. (2018)], produced with the specific purpose to serve as a support to the channel selection, in addition to one-dimensional variational (1D-Var) experiments to evaluate temperature and humidity retrievals.

The standard iterative channel selection methodology, which is based on the optimal linear estimation theory [Rodgers (1996), Rabier et al. (2002)], has been applied to a subset of these simulated data. However, the procedure has been adjusted so as to allow spectrally correlated errors to be properly evaluated [Desroziers et al. (2005)].

The entire simulated IASI-NG spectrum has been investigated, finally focusing the channel selection procedure on the wavelength ranges the most interesting for the assimilation.

Methodologies and results on retrieval skills will be more carefully described during the course of the presentation.

14.06 Ice cloud properties, an information content analysis from high spectral resolution measurements in the thermal infrared: Application to IASI and IASI-NG

Presenter: Lucie Leonarski, Université de Lille - LOA
Authors: Lucie Leonarski, Laurent C-Labonnote, Jérôme Vidot, Anthony J. Baran, Philippe Dubuisson

Ice or liquid cloud columns and profile properties retrieval from passive and active measurements respectively help us in reaching a better understanding of climate processes. If the information provided by the latter is complete, it suffers from spatial coverage compared to passive

measurements. It is therefore important to better characterize cloud properties from passive measurements by using, for example, high spectral resolution instruments. Besides their strong contribution to weather forecast improvement through data assimilation in clear-sky conditions, thermal infrared sounders on board polar orbiting platforms are now playing a key role in monitoring changes in atmospheric composition. However, it is notoriously known that clear sky observations are only a small part of the entire set of measurements, the remaining part being poorly used as they are contaminated by either aerosols and/or clouds.

The present study aims to quantify the potential for retrieving ice cloud properties and more specifically, the Ice Water Path (IWP) together with layer position, from thermal infrared sounders such as IASI and the future IASI-NG. To characterise the observing system, we used different ice cloud profile coming from a global database (see https://www.nwpsaf.eu/site/software/atmospheric-profile-data/) where profiles are chosen to encapsulate normal conditions, typical variability and the extremes of the model's behavior. An information content analysis (ICA) based on Shannon's formalism has been used to determine the level and the spectral repartition of the information about the ice cloud properties. Based on this ICA a retrieval algorithm has been developed and tested over the previously defined database.

In this ICA we took into account the Signal-to-Noise ratio of each specific instrument and the inherent non-retrieved atmospheric and surface parameter errors. The forward model used is the fast radiative transfer model RTTOV (Saunders et al., 1999, Matricardi 2004), which has been developped for satellite data assimilation in Numerical Weather Prediction (NWP) models. For operational requirements RTTOV is fast, accurate and stable. The ice cloud microphysical model used in this study is based on the ensemble model (Baran and Labonnote, 2007), where the bulk ice optical properties has been parametrized as a function of the IWC and in cloud temperature.

Results show that this observing system provides information on IWP as well as layer position, and should therefore be well retrieved with expected errors that decrease with cloud opacity until the signal saturation is reached. The number of degrees of freedom for the water vapor profile is significant, leading to the possibility of retrieving humidity profile in case of measurements contaminated by ice clouds. The study of multilayer profiles (i.e. ice cloud above liquid cloud) shows that the information above the liquid cloud is sometime greater because the latter reduces the influence of the surface.

Session 15: Polar Regions (oral presentations)

15.01 Arctic Observing System Experiments at ECMWF for the APPLICATE project

Presenter: Heather Lawrence, ECMWF
Authors: Heather Lawrence, Niels Bormann, Irina Sandu, Jonathan Day, Jacky Farnan, Peter Bauer, Linus Magnusson

In this talk we present a study carried out in the framework of the APPLICATE Horizon-2020 project, to assess the impact of different Arctic observing systems on short and medium range weather forecasts at ECMWF. Observing System Experiments were performed removing different observation types from the full observing system north of 60 degrees, and the impacts on short and medium range forecasts were analysed. The analysis is supported by a comparison to results of Global OSEs, and to Forecast Sensitivity to Observation Impact diagnostics.

All Arctic observations were found to have a positive impact on forecast skill in the Arctic region with the largest imapcts on tropospheric forecasts due to microwave sounding data in the summer and in-situ observations in the winter. Observations in the Arctic were also found to have a positive impact on forecasts in the mid-latitudes at longer lead-times. The lower relative impact of microwave sounding data in winter is likely due to difficulties assimilating the data over snow and sea-ice, but there is also the suggestion of an increased importance of conventional data in winter, and other factors may also play a role.

15.02 Impact of observations on the AROME-Arctic regional model

Presenter: Zheng Qi Wang, Norwegian Meteorological Institute (for Roger Randriamampianina)
Authors: Roger Randriamampianina

In the frame of the Applicate project (https://applicate.eu), ECMWF (European Centre for Medium-Range Weather Forecasts) is running several observations denial experiments. Having access to the results of these experiments opens a good opportunity for us to fulfill our obligation

with the Alertness project to study the impact of Arctic observations on our operational Arctic regional model AROME-Arctic.

In our presentation, we will show in details the impact of different observations on the analyses and forecasts of the AROME-Arctic. The peculiarity of our experiments is that almost each observation denial experiment will be driven by similar experiment using the ECMWF global model. This is very different from what we usually do, where all regional observation denial experiments are driven by the operational ECMWF model using full set of observations. Since ECMWF was kindly providing to us 2 sets of observing system experiments (OSE) – Arctic and global – we are able to check the impact of different observation on our regional model analyses and forecasts through data assimilation and also through lateral boundary conditions (LBCs). Furthermore, we are able to check the impact of non-Arctic observations on our regional model. We will be happy to present the results of this unique opportunity at ITSC-22.

15.03 Continuous observation of high latitudes from space: a review of medium Earth orbit (MEO) and highly elliptical orbit (HEO) options
Presenter: Louis Garand, ECCC
Authors: A. P. Trishchenko, L Garand, and L. D. Trichtchenko
Still today, polar regions are not observed from meteorological satellites at high temporal resolution (10 min or less), that is with similar refresh rates to those currently available from geostationary (GEO) satellites. The number of satellites required to get such refresh rates from Low Earth Orbit (LEO) satellites is prohibitively high (more than 30 at 60 N/S). Several studies have shown the potential to fill the polar gap from a constellation of, at a minimum, two satellites per polar area in a highly elliptical orbit (HEO), or four satellites in medium Earth orbit (MEO, circular). These options are here reviewed. HEO orbits between 12-h and 16-h are considered. In the case of MEO, the 24-h orbit is preferred, characterized by a height very similar to that on GEO (~35,800 km). Most studies based their coverage requirement assuming a maximum viewing angle (VZA) of 70 deg. For several applications, a VZA limit of the order of 62o is more appropriate. As well, an overlap with GEO down to a latitude of about 45o is desirable. With a third satellite in the HEO constellation for each polar area, or two more satellites in the MEO constellation (total of 6), that coverage requirement is met and the pixel resolution is comparable to that achieved from GEO. Criteria other than coverage and resolution must be considered, such as complexity of data processing and potential exposure to ionizing radiation. Overall, both MEO and HEO constellations can achieve continuous imaging of polar regions. Extended sounding capability could be envisioned beyond that available from water vapor sensitive imaging channels.

Session 15: Polar Regions (poster introductions)

15p.01 PRECISE – Production of a regional Reanalysis for Europe within the Copernicus climate change Services
Presenter: Zheng Qi Wang
Authors: Zheng Qi Wang, Semjon Schimanke, Per Undén, Martin Ridal, Lars Berggren, Patrick Le Moigne, Eric Bazile, Roger Randriamampianina
PRECISE (Production of a regional Reanalysis for Europe within the Copernicus clImate change SErvices) is a Copernicus service that will be lunched under summer 2017. The goal of the service is to provide a regional reanalysis (RRA) for the atmosphere, which will be updated in near real-time. In this presentation, we will give an overview on what can be expected from the service within the next years.

In the first phase, PRECISE products will be based on the model system developed in the pre-operational project UERRA. While UERRA produced data sets are for the period 1961-2015, PRECISE will fill the gap throughout 2016 and early 2017. This will be followed by monthly updates in near real-time. Hence, PRECISE will offer a consistent RRA from 1961 to near real time. The onset of the operational monthly updates can be expected in late 2017. All data will be saved with hourly resolution and will be freely available via the Copernicus Data Store (CDS). Details of the production system as well as challenges of producing a RRA operational in near real-time will be discussed.

In the second phase, it is planned to switch to a more advanced system which will be developed while the operational production of the RRA carries on during phase one. The new PRECISE reanalysis system will be built on using and extending the UERRA system in several ways: The horizontal resolution of the data assimilation system will be enhanced from 11 km to 5.5 km and also the vertical resolution will be increased from 65 to about 90 levels. The top of the model will be raised to allow assimilation of satellite radiances.

Moreover, the number of layers in the boundary layer will be increased. The MESCAN surface analysis of temperature and humidity will be integrated in the reanalysis production since no downscaling will be necessary. New input data sets will be tested and integrated. Further, a number of new observation types or instruments will be tested. The lateral boundary will be forced by the global ERA5 reanalysis. The onset of the production with the new system ushers the second phase of the service in, which is scheduled for 2019. The RRA dataset will start in the early 1980's and will be updated operational in near real-time. Details of the advanced system as well as the time schedule will be discussed.

15p.02 The Arctic Regional Reanalysis of the Copernicus Climate Change Service

Presenter: Zheng Qi Wang, Norwegian Meteorological Institute (for Harald Schyberg)
Authors: Harald Schyberg, Heiner Körnich, Roger Randriamampianina, Eivind Støylen, Xiaohua Yang

We will present status and plans for the Arctic regional reanalysis of the Copernicus Climate Change Service (C3S). The project aims at producing an Arctic regional reanalysis over two Arctic subdomains of interest for change processes and economic activities. The reanalysis will cover the period 1997 - 2021 with a horizontal resolution of 2,5 km. Additionally a proof-of-concept for a pan-Arctic reanalysis will be provided for a period of one year.

The system to be used is based on the HARMONIE-AROME Numerical Weather Prediction (NWP) system, with additions and configuration choices for reanalysis purposes with that system. Global reanalysis data from ERA5 will be used for lateral boundaries. The Arctic reanalysis will add value versus the global reanalysis by providing higher-resolution and by using regional data not available in the global reanalysis system.

Developments to adapt the system for reanalysis purpose included modifications in the assimilation setup, 3D-Var background error statistics and uncertainty estimation. The upper air assimilation uses conventional observations and, since there are gaps in the conventional observing system, has emphasis on using satellite datasets which have good coverage in the Arctic. This includes important parts of the satellite observing system such as microwave and infrared radiances, atmospheric motion vectors, scatterometer winds and GNSS radio occultation data. Handling of “cold surfaces” in the surface scheme, such as snow, sea ice and glaciers, which are important in the Arctic, has also received special attention with the aim to give a better representation than in the global reanalysis.

In addition to the development of the system itself, we present the present status of its production and we give an assessment and analysis of the quality of the reanalysis products.

15p.03 Impact of Terrestrial and Satellite Observations over the Polar Regions on the ECCC Global Weather Forecasts during the YOPP Special Observing Periods

Presenter: Stephane Laroche, Environment and Climate Change Canada
Authors: Stephane Laroche and Emmanuel Poan

One goal of YOPP is to make recommendations to WMO and meteorological centers on the future configuration of the observing system in polar regions. With the growing human activities and the implementation of new METEAREAs to provide weather information and forecasts in the Arctic, it is indeed relevant to examine the value of in situ and satellite observations in high-latitude. The role of the various types of observations over the globe in numerical weather prediction at mid-latitude is now well understood. The impact of observations in the Arctic is less clear since terrestrial observations are sparse and satellite observations are affected by ice and snow for which the emissivity properties can be difficult to estimate. Furthermore, there are very few aircraft reports over the polar regions, which are now an important source of observations in the northern hemisphere mid-latitude. YOPP provides a good opportunity to examine the relative importance of the various satellite and terrestrial observations, the forecast skill in the Arctic with respect to that in mid-latitude and the impact of observations in high-latitude on the forecast skill at mid-latitude.

Similar projects were undertaken earlier by ECMWF and a few European meteorological centers under the EU-funded APPLICATE Work Package 4 (WP4). ECMWF carried out a series of Observing System Experiments (OSEs) poleward of 60 degrees over the North and South Poles for the three four-month periods: December to March 2018 and June to September 2016 and 2018. The selected data denied poleward of 60 degrees are the following: microwave radiances, hyperspectral infrared radiances, conventional observations, GPS-RO and AMVs. A few additional OSEs were also conducted to examine the relative impact of temperature and humidity sensitive microwave radiances and the impact of the additional radiosondes and buoys that were launched during

the YOPP special observing periods. At ECCC, we carried out the same OSEs as proposed by ECMWF for the two four-month periods of 2018, in collaboration with WP4 partners. This joined effort enables the comparison of OSEs results from the participating weather centers and a deeper investigation of the role of the various observing systems over the Arctic and Antarctic regions.

In this presentation, we focus on the OSE results obtained at ECCC. The impacts of denying the various observing systems on short to medium-range forecasts using different metrics are shown. The comparison of impacts on 24-h forecasts from the OSEs and FSOI over the Arctic regions is also presented. A particular attention is given to the summer 2018 period (second YOPP SOP) during which a larger volume of additional observations were deployed.

International (oral presentations)

b.01 Communicating the value of passive bands used by TOVS-heritage microwave instruments in the context of radio frequency interference and spectrum allocation
Presenter: Stephen English, ECMWF
Authors: S English, R Kelley, M Dreis, E Daganzo-Eusebio, V Nozdrin, N Bormann, A Collard, R Faulwetter, C Köpken-Watts, M Kazumori, J Mahfouf, C Harlow, Brett Candy, J Eyre, M Banks, M Buehner, C Tingwell, F Smith, I Kwon, R Randriamampianina, S Swadley, et al.
Many applications need radio frequency spectrum. Meteorology and earth system modelling and prediction is just one. In the past telecommunication applications have generally operated in low frequency bands (e.g. P, L, C and X band), where atmospheric attenuation is low. However as their bandwidth requirements increase, and as the amount of available bandwidth at lower frequency is very small, they are increasingly looking to bands at higher frequency, despite the stronger attenuation. For example 5G has requested bands adjacent to the frequencies used by sounders such as AMSU-A, ATMS, MWTS-2, MTVZA-GY and SSMIS at 23.6-24 GHz, 50.2-50.4 GHz and 52.6-53 GHz. It is therefore more important than ever that the value of all passive bands used in meteorology and earth system science and prediction is documented and communicated. It is also important to assess and outline the effect interference would have on the exploitation of the measurement data.

To this end and in response to an action from ITSC-21 ECMWF organised a workshop in 2018 involving many leading Numerical Weather Prediction (NWP) centres and spectrum managers from Europe and the USA, as well as the ITU. The workshop focussed exclusively on the value of the bands in NWP. The workshop presentations showed consistent results from the NWP centres indicating that passive microwave bands are the most important source of observations for meteorology, providing 30-40% of all forecast skill from observations. Furthermore it was shown that their exploitation is becoming ever more sophisticated, being assimilated in all weather conditions over both land and ocean surfaces.

In order to assess the socio-economic impact of a degraded NWP capability, a number of studies were presented at the workshop. These employ different techniques and look at a broad range of countries and economies, but all these studies conclude that there are huge weather forecast benefits to societies both in terms of public safety and also direct monetary benefits. As the quality of satellite data and the forecast systems themselves improve, this benefit will further increase.

It is important that the information collected and reported at this workshop is regularly updated and complemented with more evidence to support agreed interference thresholds in passive bands. Although the workshop organised by ECMWF focussed on NWP applications it is important that all applications of the data are captured in these reports (e.g. climate). ECMWF is committed to contributing to the organisation of regular workshops on NWP applications but encourages ITWG to coordinate a holistic approach to the topic.

b.02 Update to World Radiocommunication Conference 2019 and WRC-23 items of interest
Presenter: Rich Kelley, Alion Science for DOC/NOAA/NESDIS
Authors: Fred Mistichelli, Rich Kelley
The dates of the next World Radiocommunication Conference will span those of ITSC-22. Therefore WRC outcomes will be unknown. This talk will review and update items of interest during WRC-2019 and discuss possible items for the WRC in 2023.

b.02 WMO Space Programme Update
Presenter: Heikki Pohjola, WMO

Session 16: Future Missions

16.01 Combined Polar Hyper-spectral and Geo-multispectral Data - Demonstration of the Need For Geo-Hyper-spectral Sounder

Presenter: William Smith, SSEC
Authors: W. Smith Sr., R. Knuteson, H. Revercomb, E. Weisz, and Q. Zhang

Polar hyperspectal sounding and geo-multi-spectral imagery data are now routinely combined to provide a high spatial and temporal resolution soundings similar to those that could be provided by a geo-hyperspectral sounding instrument. The combined vertical profile retrieval product accuracy is generally good when the geographical regions observed and the observation times of Polar-hyperspectral and Geo-multispectral data are relatively close, dependent upon the atmospheric condition. It is shown that accuracy of analyses of soundings derived from combined high vertical resolution Polar hyperspectral and high horizontal and temporal resolution geo-multispectral sounding imagery, is usually superior to that based only on the relatively poor horizontal space and time resolution polar hyperspectral sounding retrievals. This result clearly demonstrates the importance of the high horizontal and temporal resolution sounding information that is provided by a geostationary satellite instrument.

However, the combined sounding product accuracy can degrade significantly due to rapid localized changes in atmospheric conditions, such as those associated with convective weather development. The dependence of the combined satellite product accuracy on both space and time differences of the two sets of data is quantified with respect to the atmospheric condition being observed. The potential impact of these errors on forecast accuracy is discussed. The results strongly support the need for a geo-hyperspectral sounder to improve the accuracy of forecasts achievable from today's polar hyperspectral and geo-multispectral radiance data.

16.02 Hyperspectral Imaging Infrared Sounding from geostationary orbit

Presenter: Joe Taylor, UW-SSEC/CIMSS (for Hank Revercomb)
Authors: Hank Revercomb, Bill Smith, Bob Knuteson, Dave Tobin, Joe Taylor, Fred Best, Jon Gero

Measurements from an advanced Hyperspectral Imaging IR Sounder (HIIS) over the US would form the basis for severe weather warnings with significantly longer advance times than currently possible. When combined with independent surface data, HIIS observations would provide a unique ability to detect rapid changes in atmospheric stability and the moisture flux convergence that serves both as a triggering mechanism for initial storm development and a fuel source for continued storm growth. The geostationary orbit allows for rapid repeat times (as high as 5-15 minutes) and opportune spatial sampling; the advanced imaging IR sounder is unmatched in its ability to sense vertically resolved temperature, moisture, and cloud/moisture-tracked wind vectors with spatial resolutions as high as 2-4 km horizontal and 1 km vertical.

Many of these important capabilities of the GEO advanced sounder have been demonstrated by the highly positive impact on global weather prediction of high spectral resolution infrared sounders in polar orbit (IASI on MetOp spacecrafts and CrIS on Suomi NPP and JPSS). This demonstration of the impact of vertical information on the global scale makes a strong case for what will be possible from GEO observations that combine the same type of detailed vertical profile information with rapid time sequencing. Vertical profile information well beyond the capability of GEO imagers is needed to exploit the next frontier offered by rapid sampling data for forecasting high impact severe weather events including tornadoes and hurricanes.

As will be summarized, technological feasibility has been well proven in the US by previous studies funded by NASA and NOAA dating back to 2006, and innovative approaches have been defined to make reasonably rapid implementation possible. We will also show results from the first inflight proof of concept by China (on FY4-A in late 2016) that are encouraging for the future flights with significantly upgraded capability planned for the next several years. Also, as is well known, EUMETSAT will fly the IRS with a very sophisticated capability on MTG in 2022-23.

To help satisfy WMO requirements for a global constellation, and to protect our own citizens, the US should put high priority on providing this capability as soon as possible.

16.03 Accelerating Toward NOAA's Next-Generation Observing Architecture

Presenter: Karen St. Germain, NOAA/NESDIS
Authors: K. St. Germain, F. Gallagher, M. Maier, D. Spencer

NOAA has begun planning for the future observation architecture that will augment and

eventually replace the JPSS and GOES-R program capabilities. In support of this effort, NOAA recently completed a future architecture analysis to examine space capability options in the 2025 to 2050 time period. Informed by this analysis, NOAA is weighing different combinations of spatial, spectral, and temporal resolution for atmospheric sounding capabilities. We seek to optimally balance mission performance, cost, and agility in the future atmospheric sounding architecture. This paper will discuss NOAA's current thinking and seek feedback from the ATOVS community on how to weight and optimize these options.

16p.01 EUMETSAT Plans

Presenter: K. Dieter Klaes, EUMETSAT

Authors: K. Dieter Klaes

This paper will summarize EUMETSAT's current status and the plans of the future programmes. This will include the current and future mandatory programmes in LEO and GEO orbits, EPS, MSG as well as EPS-SG and MTG. Third party and optional missions, including Copernicus Missions will be addressed as well, and also the ground segments.