

A Report on The Twenty-third International TOVS Study Conference

**A virtual conference
24– 30 June 2021**

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Météo France

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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 summarizes the outcomes of the Twenty-third International TOVS Study Conference (ITSC-23), a virtual conference, between 24-30 June 2021. 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.

ITSC-23 benefited from the support of CIMSS/SSEC/UW-Madison for the virtual venue using the Webex system. We wish to thank all attendees for all around the world, who had to attend at very varied local times, including very late and very early local times. We also acknowledge the support of NOAA/NESDIS/JPSS and Meteo France for ITSC-23 organization.

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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A virtual conference: 24-30 June 2021

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ITSC-23 Group Photo



**ITSC-23 virtual conference
24-30 June 2021**



TABLE OF CONTENTS

FOREWORD	I
1. EXECUTIVE SUMMARY	1
1.1 INTRODUCTION.....	1
1.2 SUMMARY OF MAJOR CONCLUSIONS AND RECOMMENDATIONS	2
1.3 FUTURE PLANS	4
1.4 ACKNOWLEDGEMENTS	4
SUMMARY OF ACTIONS AND RECOMMENDATIONS	5
2. WORKING GROUP REPORTS.....	17
2.1 RADIATIVE TRANSFER AND SURFACE PROPERTY MODELLING	17
2.2 CLIMATE.....	22
2.3 DATA ASSIMILATION AND NUMERICAL WEATHER PREDICTION	30
2.4 ADVANCED SOUNDERS.....	44
2.5 INTERNATIONAL ISSUES AND FUTURE SYSTEMS.....	51
2.6 PRODUCTS AND SOFTWARE.....	57
3. TECHNICAL SUB-GROUP REPORTS	67
3.1 RADIO FREQUENCY INTERFERENCE	67
3.2 RTTOV/CRTM.....	72
LIST OF ACRONYMS	76
ITSC-23 AGENDA.....	79
ITSC-23 ABSTRACTS	90

1. EXECUTIVE SUMMARY

1.1 INTRODUCTION

The Twenty-Third International TOVS Study Conference, ITSC-23, was hosted by the University of Wisconsin–Madison and Météo France as a virtual conference, between 24-30 June 2021. The conference was attended by 258 participants from 52 organizations, providing a wide range of scientific and technical contributions. Nineteen countries and three international organizations were represented: Argentina, Australia, Canada, China, Finland, France, Germany, India, Italy, Japan, Norway, Russia, Senegal, 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.

The success of ITSC-23 was largely due to a large attendance despite very different time zones, 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 56 oral presentations and 76 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:

- Radiative Transfer and Surface Property Modelling,
- Climate,
- Data Assimilation and Numerical Weather Prediction,
- Advanced Sounders,
- International Issues and Future Systems,
- 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-22 in Saint-Sauveur, Québec, Canada were presented in a dedicated session of Working Group status reports. Technical sub-groups also met just before ITSC-23 to discuss developments and plans concerning specific software packages, shared and in common use. The Radio Frequency Interference technical sub-group has been revived.

Due to the COVID-19 pandemic situation between ITSC-22 and ITSC-23, fewer major steps forward have been presented this time. Nevertheless, the number of presentations and posters was still high, which is a good signal from the community.

Advances from NWP centers covered the all-sky assimilation of both infrared and microwave radiances, and the further use of hyperspectral infrared sounders both on polar and geostationary orbits.

As recommended by CGMS, a dedicated session was set up to exchange information with other CGMS working groups (IPWG and the newly formed IESWG), as well as from the International Telecommunication Union Radiocommunication Sector

The conference agenda and PDF versions of the oral presentations and posters can be viewed at the ITSC-23 website at <https://cimss.ssec.wisc.edu/itwg/itsc/itsc23/>.

1.2 SUMMARY OF MAJOR CONCLUSIONS AND RECOMMENDATIONS

The ITSC-23 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 developers:** The group recommends the development of cloudy RT model validation datasets.
2. **To community:** Coordinate efforts for LS Emissivity modeling to cover spectral and physical requirements, development of modeling framework.
3. **To community:** New SST / SSE measurements across all spectral ranges highly encouraged, in coordination with RT model developers / researchers with particular emphasis on temperature dependence.

Climate

4. **To satellite agencies:** Satellite agencies should ensure a frequency continuity for all instruments in future sensor designs for developing credible climate data records.
5. **To satellite agencies:** Satellite agencies shall establish programs to conduct absolute calibration or inter-calibration for hyperspectral IR sounders during their life cycles and document and publish the results.
6. **To CGMS:** WG recommends that CGMS emphasize the need to establish an improved global climate benchmark with multiple standards as soon as possible for verifying international progress toward dealing with the threat of climate change.

Data Assimilation and Numerical Weather Prediction

7. **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.
8. **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.
 9. **To Satellite Operators:** New operational data dissemination infrastructure should be tested at an early stage (well before launch) with simulated data.
 10. **To Satellite Operators:** There should be open and early access to new satellite data for all NWP centers to help with calibration and validation.
 11. **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.
 12. **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.
 13. **To Satellite Operators:** When using PC compression (for hyperspectral infrared sounder data), noise normalisation should be performed using the full noise covariance matrix.
 14. **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.
 15. **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.
 16. **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.
 17. **To Satellite Operators:** In order to facilitate evaluation of new satellite data by NWP centers, aim for distribution in near-real time.
 18. **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

19. **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.
20. **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.
21. **To CMA:** Investigate and consider extending the output range of FY-3D GIIRS spectra to ~680 1/cm.
22. **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.
23. **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.

24. **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.
25. **To Space Agencies:** Implement high spatial resolution and contiguous sampling detector arrays in future hyperspectral infrared sounding instruments.
26. **To Space Agencies:** To develop, test, and implement an SI-traceable radiometric standard in space as soon as feasible.

International Issues and Future Systems

27. **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.
28. **To Space Agencies:** Consider DBNet requirements when designing core ground segment software, and then to make software available to DBNet operators.
29. **To Space Agencies:** Note that the strong requirement for traceable calibration comes from NWP as well as the climate application area.
30. **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.
31. **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

32. **To satellite operators:** Implement subscription-based notification of anomalies or events that impact users.
33. **To EUMETSAT:** Provide a schedule for release of different types of test data for both EPS-SG and MTG.
34. **To JAXA:** Consider providing AMSR-2 L1 software for release to the DB community. The CSPP team could host it.
35. **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 early 2023. 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 LBL model developers

Include full line mixing and speed dependent Voigt line shape when relevant.

Action RTSP-1 to Sergio DeSouza-Machado

Report on the development of the Harvard CO₂ line mixing model especially with regard to possible issues related to full line mixing calculations around ~730 cm⁻¹ and negative optical depths in first-order line mixing calculations.

Recommendation RTSP-2 to LBL model users

To share LBLRTM input file (TAPE5) generation processors (perhaps having a discussion group online for sharing).

Action RTSP-2 to the group

Report on the development/availability of LBL model error covariance datasets, especially those including high water vapour loading situations. Need to review the work of Cimini et al., LBL error covariance and spectroscopic parameter perturbation in the MW available in several publications.

Recommendation RTSP-3 to the group

Report and/or suggest specific studies/methodologies used for spectroscopic error propagation.

Recommendation RTSP-4 to LBL model users

For terrestrial applications, when available, include in the LBL calculations the effect of CO₂ line broadening by water vapour.

Action RTSP-3 to Sergio DeSouza-Machado

Communicate to the group results of the study on spectroscopic parameter perturbation effects on radiances.

Recommendation RTSP-5 to the group

Support an ISSI proposal to do visible RTM intercomparisons and developments (due January 2022).

Recommendation RTSP-6 to developers

Ensure that AI/ML Jacobians are properly evaluated and possibly corrected using, for instance, regularization techniques.

Recommendation RTSP-7 to developers

The group encourages the development of fast models in the UV.

Recommendation RTSP-8 to developers

Improve the training of NLTE fast models by including larger solar angles, ozone variability and state-of-the-art vibrational temperatures.

Action RTSP-4 to Raymond Armante and Jerome Vidot

Communicate to the group results of the 4A-RTTOV comparison.

Recommendation RTSP-9 to developers

The group recommends the development of cloudy RT model validation datasets

Recommendation RTSP-10

The group recommends IR support for follow on from CLARREO.

Action RTSP-5 to Ben Johnson

Find prior traceability recommendation, possibly from other meeting.

Recommendation RTSP-11 to developers

Physical consistency should be sought where possible. The use of a single comprehensive database and the development of unified solvers for fast RT model should be pursued.

Recommendation RTSP-12 to developers

An accurate valuation of UV/Vis/near-IR errors/issues should be carried out.

Recommendation RTSP-13 to developers

Include new fast models in the itercomparisons, possibly adding scenes that include clouds and aerosols.

Recommendation RTSP-14 to developers

Add validation component (e.g., soundings, field experiment data), GNSSRO

Recommendation RTSP-15 to users

Exploitation of PC based data requires PC based fast models. In particular, reconstructed radiance observations and reconstructed radiance simulations should be based on the same eigenvector basis.

Recommendation RTSP-16 to community

Coordinate efforts for LS Emissivity modeling to cover spectral and physical requirements, development of modeling framework.

Recommendation RTSP-17 to community

New SST / SSE measurements across all spectral ranges highly encouraged, in coordination with RT model developers / researchers with particular emphasis on temperature dependence.

Action RTSP-6 to Ben Johnson

LSWG coordination of recommendations.

CLIMATE

Recommendation Climate-1 to satellite agencies

The separation of instrument variability from the often subtle, long-term variations in climate related processes requires careful calibration and validation of the sensor and its derived data products. The Climate WG encourages satellite agencies to intercalibrate time series from overlapping satellites in order to allow a continuation of climate time series (including trend analysis) when transitioning from older to newer satellites.

Recommendation Climate-2 to satellite agencies

Satellite agencies should ensure a frequency continuity for all instruments in future sensor designs for developing credible climate data records.

Recommendation Climate-3 to space agencies

Consider climate requirements in terms of stability and length of life cycle when designing small satellite sensors.

Action Climate-1 on Bill Bell

Bill Bell to report at the next meeting (Climate WG meeting at ITSC-24) about the plans at ECMWF and progress to-date concerning impact studies on losing different satellite sensors for assimilation in a reanalysis.

Recommendation Climate-4 to WMO

WMO to collect information on available FCDRs from data providers and include it in OSCAR.

Recommendation Climate-5 to data record providers

CDRs should be citable by e.g. having Digital Object Identifier (DOI) reference and being accessible to users. All data records should be accompanied by metadata that follows WIGOS standards.

Recommendation Climate-6 to data developers

CDR development and stewardship shall follow guidance similar to [NCEI Data stewardship maturity matrix](#) or the [Copernicus Climate Change \(C3S\) convention](#) (including recommendations for metadata)

Action Climate-2 to Climate WG co-chairs

Add information on NCEI Data stewardship maturity matrix and C3S convention to Climate WG webpage.

Recommendation Climate-7 to EUMETSAT

The Climate WG recommends that EUMETSAT consider funding its own dedicated radiosonde program to match MetOp observations with (European) radiosonde observations for satellite validation.

Recommendation Climate-8 to satellite agencies

Satellite agencies shall establish programs to conduct absolute calibration or inter-calibration for hyperspectral IR sounders during their life cycles and document and publish the results.

Recommendation Climate-9 to CGMS

WG recommends that CGMS emphasize the need to establish an improved global climate benchmark with multiple standards as soon as possible for verifying international progress toward dealing with the threat of climate change.

Recommendation Climate-10 to US satellite agencies

WG recommends that the US satellite agencies proceed with the Infrared Pathfinder defined by the CLARREO program.

Recommendation Climate-11 to satellite data products developer

Report statistical uncertainties of the CDR trends together with the calibration uncertainties.

Recommendation Climate-12 to space agencies

Support the further development of ECVs and GHG CDRs to enrich the ECV inventory for climate change monitoring.

DATA ASSIMILATION AND NUMERICAL WEATHER PREDICTION

Action DA/NWP-1 on NWP WG members

Send any evidence of RFI in the observations and results investigating the effects of RFI on forecast skill to the co-chairs of the RFI Technical Subgroup Stephen English (stephen.english@ecmwf.int), Richard Kelley (barometer@verizon.net), Nancy Baker (nancy.baker@nrlmry.navy.mil) and Jean Pla (jean.pla@cnes.fr).

Action DA/NWP-2 on WG Members

Please review the software design documents for ISPP and MWIPP/AAPP on the NWPSAF website and provide feedback to Nigel Atkinson by the end of July 2021 (nigel.atkinson@metoffice.gov.uk).

Action DA/NWP-3 on WG Members

Contact Nigel Atkinson by the end of July 2021 (nigel.atkinson@metoffice.gov.uk) to beta test IRSPP.

Action DA/NWP-4 on Sreerekha TR

Circulate EUMETSAT's data distribution plan to the DA/NWP WG when it is released.

Action DA/NWP-5 on WG members

Email Fiona and Brett if they are interested to be part of SAT feedback discussion group.

Action DA/NWP-6 on WG chairs and Will McCarty

Organise an online meeting to discuss feedback to the SAT on the questions discussed during the WG meeting.

Action DA/NWP-7 on WG members

Review SAT recommendation documents and provide any feedback to Will McCarty (will.mccarty@nasa.gov) by the end of July 2021.

Action DA/NWP-8 on WG members

Contact Lihang Zhou (lihang.zhou@noaa.gov) by the end of June 2021 to be invited to the LEO Constellation Architecture Study workshop on future Microwave Sounders.

Action DA/NWP-9 on WG members

Forward any results of studies for the use of MW-only or MW+SW channels to the working group.

Action DA/NWP-10 on WG co-chairs

Follow progress on implementation of CrIS sub-pixel heterogeneity information at NOAA and report back to WG members bi-annually.

Recommendation DA/NWP-1 to NOAA

Continue to produce POES L1 sounding products for near-real time dissemination.

Action DA/NWP-11 on WG members

Send results of forecast studies that indicate the continuing impact on NWP of POES satellites to Mitch Goldberg (mitch.goldberg@noaa.gov).

Action DA/NWP-12 on Chris Burrows

Provide Working Group with the draft GIIRS BUFR sequence and invite comment.

Action DA/NWP-13 on WG Members

Provide feedback to Chris Burrows (chris.burrows@ecmwf.int) on the draft GIIRS BUFR sequence by the end of July 2021.

Recommendation DA/NWP-2 on the RT WG

Outline what support they require from NWP community regarding CGMS HLPP Item 4.6.3.

Action DA/NWP-14 on WG members

Contact Roger Randriamampianina (rogerr@met.no) to join a group that will discuss bias correction in LAMs.

Action DA/NWP-15 WG members

Contact WG cochairs by the end of July 2021 with topics for a science meeting (already proposed are assimilation in LAMs and how to deal with instruments on small satellites)

Action DA/NWP-16 on WG Co-chairs

Arrange another meeting in a few months to discuss the science issues.

Action DA/NWP-17 on WG members

To review Space Agency contacts page on the website.

Action DA/NWP-18 on WG members

Provide impact recent LAM study references to WG co-chairs for inclusion on the website.

Recommendation DA/NWP-3 to NASA

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

Recommendation DA/NWP-4 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-5 to Space Agencies

Following the successful use of the SAPHIR instrument, future MW missions operating on a similar low inclination orbit are recommended.

Standing Actions and Recommendations

Standing Action DA/NWP-1 on ITWG Co-chairs

To bring relevant recommendations to the attention of CGMS.

Standing Action DA/NWP-2 on DA/NWP WG members

Send any evidence of RFI to co-chairs of the RFI Technical SubGroup - Jean Pla (jean.pla@cnes.fr), Richard Kelley (richard.kelley@noaa.gov), Stephen English (stephen.english@ecmwf.int) and Nancy Baker (nancy.baker@nrlmry.navy.mil)

Standing Action DA/NWP-3 on DA/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 chairs (Benjamin.T.Johnson@noaa.gov & Marco.Matricardi@ecmwf.int).

Standing Action DA/NWP-4 on NWP centres

Continue to provide information on instrument channels assimilated and their observation errors via the working group survey spreadsheet in advance of each conference.

Standing Action DA/NWP-5 on DA/NWP WG Members

Make suggestions and corrections to the DA/NWP Working Group website.

Standing Recommendation DA/NWP-1 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.

Standing Recommendation DA/NWP-2 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.

Standing Recommendation DA/NWP-3 to Data providers

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

Standing Recommendation DA/NWP-4 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.

Standing Recommendation DA/NWP-5 to Data Providers

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

[HLPP: 4.2.6 Establish together with the user community a commonly agreed approach for retrieval of Principal Component scores and associated parameters from hyperspectral infrared data, minimising information loss including the mutually acceptable update strategy for the principal component basis and to implement such an approach in a coordinated manner.]

Standing Recommendation DA/NWP-6 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.

[HLPP: 3.17 Develop best practices for operational user notifications]

Standing Recommendation DA/NWP-7 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.

Standing Recommendation DA/NWP-8 to Data Providers

Provide NedT estimates for inclusion within BUFR for microwave data.

[HLPP 4.4.2 Agree on standardised procedures to derive NedT estimates for microwave sounders, and include such estimates in the disseminated BUFR data.]

Standing Recommendation DA/NWP-9 to Data Providers

Make NedT estimates from microwave instruments available as time series on publicly available websites to enable monitoring of instrument health in near real time.

Standing Recommendation DA/NWP-10 to Instrument Developers

Pre-launch calculation of NedT should use the same algorithm as will be used in-orbit using warm target counts variability divided by the instrument gain.

Standing Recommendation DA/NWP-11 to Data Providers

Develop and maintain public instrument status monitoring web pages similar to the Integrated Calibration and Validation System (ICVS) from NOAA/NESDIS.

ADVANCED SOUNDERS

Recommendation AS-1 to Space Agencies

To develop a methodology to include the imager clusters in the hyperspectral IR sounders field of view and to study different clustering technics and compare them.

Action AS-1 to Mitch Goldberg

To investigate why the VIIRS/CrIS software developed by EUMETSAT Via NWP/SAF is not used.

Recommendation AS-2 to Space Agencies (CMA)

To analyse the need of having the MERSI cloud amount and MERSI radiances coregistered with HIRAS pixels and possibly to develop the new products accordingly.

Action AS-2 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.

Action AS-3 to ITWG Co-chairs

To follow the data release date, 2 or 3 months after the launch of Meteor-M N2-2 (January 2020?) and circulate the information at ASWG.

Recommendation AS-3 to space agencies

To consider LEO constellations of small satellites to improve the temporal refresh. However, the backbone of high quality stable measurements of visible, infrared, microwave, UV, established by NASA (AQUA), NOAA (JPSS), and EUMETSAT (Metop) measurements are still needed. With an observatory of at least microwave, infrared, imagery and ozone to allow continuation of climate data records in fixed stable orbits with two satellites in each orbit for intercalibration enabling continuation of climate data records, and for intercalibration of smallsats in extended orbits, as well as stable long-term observations for NWP.

Recommendation AS-4 to space agencies

To continue to employ the traditional longwave infrared spectral radiance measurement band on all future hyperspectral IR satellite sensors.

Recommendation AS-5 to NOAA

To more quickly develop the plan for its Next-Gen LEO mission/payloads.

Recommendation AS-6 to NOAA

To expedite the implementation of an advanced IR imaging infrared sounder for GEO-XO to assure on-orbit operations by 2030 with a goal of the mid-2020s for better coordination with other international efforts to achieve a more effective global ring.

Recommendation AS-7 to space agencies

To ensure the ICI readiness.

INTERNATIONAL ISSUES AND FUTURE SYSTEMS

Recommendation IIFS-1 to Roshydromet

To share information on products from Arktika-M N1 with ITWG when available.

Recommendation IIFS-2 to CGMS

To explicitly consider instrument capabilities and data quality as well as data provision in future updates of the CGMS baseline, particularly for the 3-orbit backbone system of LEO passive sounders which plays an important role as a reference-style system.

Recommendation IIFS-3 to CGMS and the NWP community

To advance the implementation of the WIGOS Vision 2040 for passive sounding with agency commitments beyond the established 3-orbit baseline in future updates of the CGMS baseline, and to gather requirements and perform trade-offs for such additional systems.

Recommendation IIFS-4 to NWP centres and other organisations involved in the evaluation of existing data from smaller satellites

To report on experiences with passive sounding instruments from smaller satellites at future ITSCs, including evaluations of data quality and stability, with a view towards potential future operationalization of such systems.

Action IIFS-1 on Niels Bormann

To compile a list of existing and planned small-satellite/cubesat initiatives with passive sounding instruments and circulate among IIFS members.

Recommendation IIFS-5 to providers of data from constellations of smaller satellites

To work towards a standardisation of downlink equipment and data protocols to ease provision of NRT capabilities.

Recommendation IIFS-6 to providers of data from constellations of smaller satellites

To work towards a common data outlay in a WMO-recognised data format to ease swift ingestion into NWP systems.

Recommendation IIFS-7 to NWP centres

To conduct impact studies highlighting the benefit of good timeliness of observations, and to report on these at future meetings.

Action IIFS-2 on IIFS members

To provide further feedback on the latest version of the HLPP to IIFS co-chairs.

Recommendation IIFS-8 to CGMS members

To provide ICVS-style instrument performance monitoring for operational instruments.

Recommendation IIFS-9 to CGMS

To include an item on establishing requirements for MW sounding capabilities beyond the CGMS baseline for NWP in the relevant section of the HLPP.

Recommendation IIFS23-R10 to CGMS

To reinstate an item in the HLPP on conducting trade-off studies regarding the benefits of spectral, radiometric, and spatial resolution of infrared sounders, taking into account aspects such as scene inhomogeneity and uncertainties in spectroscopy.

Action IIFS-3 on Peng Zhang

To circulate the workshop report to IIFS members once available.

Standing Recommendations

Standing Recommendation IIFS-1 (IIFS22-5) to WMO and space agencies via CGMS

To coordinate an update of the timeliness requirements and continue to explore innovative methods, such as used by GPM, to provide global data with a timeliness that meets the new requirements, for next generation satellite programmes.

Standing Recommendation IIFS-2 (IIFS22-4) to WMO

WMO to continue to work with 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.

Standing Recommendation IIFS-3 (IIFS22-8) to CGMS

If a mission expects engagement from application areas with an NRT data requirement, budget should be allocated from the start to provide the required technical infrastructure.

Standing Recommendation IIFS-4 (IIFS21-8) 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.

Standing Recommendation IIFS-5 (IIFS22-11) to space agencies 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. Therefore to include as many centres, in particular NWP centres, in the early evaluation phase, will bring benefits both to the Space Agency and to the users, and is therefore highly desirable.

Standing Recommendation IIFS-6 (IIFS22-14) to ITWG Co-Chairs

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

PRODUCTS AND SOFTWARE

Action PSWG-1 on PSWG co-chairs

To liaise with the ASWG and NWPWG co-chairs with the aim of agreeing a coordinated approach to the cluster analysis of VIIRS radiances on the CrIS footprint.

Action PSWG-2 on PSWG co-chairs

To monitor developments in PC representation, liaising with the ASWG, and report back to PSWG at the next ITSC.

Action PSWG-3 on Nathalie Selbach, and others in PSWG who are able to do so

To test new NOAA/CLASS access options, including cloud access, and report back to PSWG.

Recommendation PSWG-1 to NOAA, JAXA and the CSPP team

To continue exploring ways in which the AMSR-2 level 1 software and direct broadcast transmission availability could be shared with DB users.

Recommendation PSWG-2 to software providers

Where possible, offer their software with a choice of either pre-built binaries or source code.

Recommendation PSWG-3 to software providers

For software that will be built from source by the user, list recommended versions of required external (COTS) libraries.

Recommendation PSWG-4 to agencies

Costs to users should be considered when migrating software and data distribution to the cloud.

Recommendation PSWG-5 to agencies

Users should continue to have free access to satellite data.

Recommendation PSWG-6 to software providers

To provide and test software in a cloud-ready format.

Action PSWG-4 on CSPP and IMAPP teams

To share UW/SSEC/CIMSS experiences on working with containers (Docker, Podman, Singularity), including lessons learnt, via the PSWG web site.

Action PSWG-5 on CSPP and IMAPP teams

To provide information on running Linux packages in Windows, via the PSWG web site.

Action PSWG-6 on PSWG co-chairs

To provide feedback on the High Level Priority Plan and CGMS Best Practices document to ITWG co-chairs by end 2021.

Action PSWG-7 on Paul Menzel and Tony Reale

To send a few sentences summarising their validation studies to the PSWG co-chairs, for inclusion in High Level Priority Plan feedback.

RADIO FREQUENCY INTERFERENCE

Action RFITSG-1 on Stephen English

To contact IPWG and IESWG co-chairs to discuss possible coordination on spectrum matters.

Action RFITSG-2 on Rich Kelley

To discuss with potential webpage manager and inform TSG of outcome.

Action RFITSG-3 on Mikael Rattenborg

To provide CGMS document and all TSG members to comment.

Action RFITSG-4 on Stephen English

To ask Markus Dreis (EUMETSAT) to provide information to the TSG.

Action RFITSG-5 on all TSG members

To share information via the mailing list on plans for enhanced RFI monitoring and detection.

Action RFITSG-6 on all TSG members

To share information published and where possible unpublished, via the mailing list, on recorded RFI of relevance to ITWG.

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), Akira Ando (JMA), Raymond Armante (LMD, CNRS), Eva Borbas (UW-Madison/CIMSS), Ming Chen (CISESS), Nico Cimini (CNR-IMAA), Cheng Dang (JCSDA, UCAR), Thibault Delahaye (LMD/CNRS), Prateek Kumar Dongre (Cardiff University), Stephen English (ECMWF), Evan Fishbein (JPL), Victoria Galligani (CIMA-UBA-CONICET), Donatello Gallucci (CNR-IMAA), Stephanie Guedj (Met Norway), Vincent Guidard (CNRM, Météo-France, CNRS), Liam Gumley (CIMSS/SSEC UW-Madison), Wei Han (JCSDA), Ishida Haruma (JMA), Sylvain Heilliette (Environment Canada), James Hocking (Met Office), James Jung (UW-Madison), Norio Kamekawa (JMA), Jeon-Ho Kang (KIAPS), Masahiro Kazumori (JMA), Rich Kelley (Alion Science), Bob Knuteson (UW-Madison SSEC/CIMSS), Keiichi Kondo (JMA), Christina Köpken-Watts (DWD), Naoto Kusano (JMA), Bjorn Lambriksen (JPL), Ahreum Lee (KIAPS), Sang-Moo Lee (University of Colorado), Emily Liu (NOAA/NCEP/EMC), Cristina Lupu (ECMWF), Sergio Machado (UMBC), Miguel-Angel Martinez (AEMET), Silke May (DWD), Jana Mendrok (DWD), Scott Mindock (SSEC/CIMSS), Hidehiko Murata (JMA), Nick Nalli (IMSG Inc. at NOAA/NESDIS/STAR), Kozo Okamoto (JMA), Yoshifumi Ota (JMA), Indira Rani S (NCMRWF), Hank Revercomb (UW-Madison SSEC), Filomena Romano (IMAA/CNR), Leonhard Scheck (LMU Munich), Noelle A. Scott (LMD/IPSL/Ecole Polytechnique), A.K. Sharma (NOAA/NESDIS), Patrick Stegmann (JCSDA), Christina Stumpf (DWD), Emma Turner (Met Office), Tiger Yang (UMD), Zhiyu Yang (SITP/CAS), Yanqiu Zhu (GMAO)

2.1.1 Line by Line Modeling

The RTSP-WG discussed the improvement of LBL calculations using an enhanced formulation of CO₂ line mixing effects (e.g. full line mixing) and the introduction of a speed dependent formulation of the Voigt line shape. It was noted that full line mixing is worth pursuing at 15 μm whereas first-order line mixing is sufficient at 4.3 μm . At shorter wavelengths, first-order line mixing is still sufficient but requires speed dependent Voigt and Dicke effects to be included. The full impact of Voigt line shape is yet to be studied in the thermal infrared. It was also noted that in the MW, speed dependent effects and second-order line mixing have a not negligible impact.

Recommendation RTSP-1 to LBL model developers

Include full line mixing and speed dependent Voigt line shape when relevant.

Action RTSP-1 to Sergio DeSouza-Machado

Report on the development of the Harvard CO₂ line mixing model especially with regard to possible issues related to full line mixing calculations around $\sim 730\text{ cm}^{-1}$ and negative optical depths in first-order line mixing calculations.

The group discussed the status of CLBLM and noted that the model has not yet been officially released. Doubts were raised regarding the funding of the project. University of Colorado is developing a new LBL model mainly for radiation scheme applications. It was also noted that there is a need for the characterization of LBL model error covariances which could be useful for use in NWP applications.

Recommendation RTSP-2 to LBL model users

To share LBLRTM input file (TAPE5) generation processors (perhaps having a discussion group online for sharing).

Action RTSP-2 to the group

Report on the development/availability of LBL model error covariance datasets, especially those including high water vapour loading situations. Need to review the work of Cimini et al., LBL error covariance and spectroscopic parameter perturbation in the MW available in several publications.

2.1.2 Spectroscopy

The group discussed the need of a spectroscopic characterization of the impact on TOA radiances. This should be based on the use of known uncertainties in spectroscopic parameters such as the line shapes, line strengths, and half widths. Uncertainties in line shapes should also include line mixing. It was also noted that the possibility exists for using spectroscopic parameters that allow computing line broadening effects due to specific species.

Recommendation RTSP-3 to the group

Report and/or suggest specific studies/methodologies used for spectroscopic error propagation.

Recommendation RTSP-4 to LBL model users

For terrestrial applications, when available, include in the LBL calculations the effect of CO₂ line broadening by water vapour.

Action RTSP-3 to Sergio DeSouza-Machado

Communicate to the group results of the study on spectroscopic parameter perturbation effects on radiances.

2.1.3 Fast RT models in the near IR, Visible and UV. NLTE effects in the near

The group discussed the development of fast RT models in the near IR, visible and UV. In the visible, LUT based models are well established (e.g., MFASIS) but it was noted that physically based models (e.g., FLOATSAM) are also available. Recent MFASIS developments based on the use of a NN approach for LUTs were discussed. Alternative approaches including a fully based AI/ML model and a Principal Component based model were noted. An issue was raised regarding the accuracy of Jacobians computed by AI/ML based models.

Recommendation RTSP-5 to the group

Support an ISSI proposal to do visible RTM intercomparisons and developments (due January 2022).

Recommendation RTSP-6 to developers

Ensure that AI/ML Jacobians are properly evaluated and possibly corrected using, for instance, regularization techniques.

The group discussed the development of fast RT models in the UV. It was noted that there are plans in place for CRTM 3.0 and perhaps for RTTOV 13.1 possibly using a LUT based

approach in RTTOV 13.2. An issue was raised regarding the minimum version of LBLRTM/Line Parameter database for UV support. It was agreed that LBLRTM v12.8 should be suitable. The status of fast NLTE models was discussed. Proposed upgrades include the extension of the training to larger solar angles and the inclusion of ozone variability as well as the use of state-of-the-art vibrational temperatures.

Recommendation RTSP-7 to developers

The group encourages the development of fast models in the UV.

Recommendation RTSP-8 to developers

Improve the training of NLTE fast models by including larger solar angles, ozone variability and state-of-the-art vibrational temperatures.

The group discussed the development of fast RT models in the IR and far IR and the use of ML techniques. It was noted that within the framework of CRTM, ML techniques have been applied to computations used for transmittance coefficient generation in clear sky. This resulted in higher accuracy and possibly speed increase. However, there are issues with adjoint computations. An AI version of CRTM (CRTM-AI) has been noted.

RTTOV has been extended to the simulation of far IR radiances (e.g. FORUM). CRTM has plans but there is no explicit testing yet. Upcoming sensors might include PREFIRE. The status of spectroscopy and continuum modeling in the far IR has been discussed. A comparison is planned between 4A and LBLRTM/RTTOV to study the impact of different spectroscopic databases.

Action RTSP-4 to Raymond Armante and Jerome Vidot

Communicate to the group results of the 4A-RTTOV comparison.

2.1.4 RT model validation

The group discussed the validation of RT models putting a special emphasis on validation data sets for cloudy cases. The RT subgroup has a profiles datasets webpage, but these are focused on clear sky radiative transfer calculations. Although there have been cloudy RT model intercomparisons, atmospheric datasets to assess the absolute accuracy/precision of these models are needed. Cloudy RT validation data sets could be coincident with satellite-based radiances but the atmosphere, cloud properties and scene complexity needs to be characterized.

Recommendation RTSP-9 to developers

The group recommends the development of cloudy RT model validation datasets

2.1.5 Reference / on-orbit calibration

The group discussed the Solar Pathfinder follow on from CLARREO, the European mission in UKSA+ESA TRUTHS mission and the FY5-Libra China benchmark mission. The need for traceability from Spectroscopy to RT and validation using SI traceability methodologies was discussed.

Recommendation RTSP-10

The group recommends IR support for follow on from CLARREO.

Action RTSP-5 to Ben Johnson

Find prior traceability recommendation, possibly from other meeting.

2.1.6 Optical and Physical Properties: Aerosols, Clouds, and Precipitation Model Solvers and Approximations

Recommendation RTSP-11 to developers

Physical consistency should be sought where possible. The use of a single comprehensive database and the development of unified solvers for fast RT model should be pursued.

Recommendation RTSP-12 to developers

An accurate valuation of UV/Vis/near-IR errors/issues should be carried out.

2.1.7 Fast model coefficient generation and fast RT model intercomparison

The group discussed the possibility of establishing a reference dataset for AI training possibly using a common approach for RT and DA applications. An intercomparison between CRTM and RTTOV is ongoing through JEDI/UFO (clear sky so far). The planned validation of SARTA/kCarta based on co-located sondes was noted.

Recommendation RTSP-13 to developers

Include new fast models in the intercomparisons, possibly adding scenes that include clouds and aerosols.

Recommendation RTSP-14 to developers

Add validation component (e.g., soundings, field experiment data), GNSSRO

2.1.8 PC based approaches for data assimilation

The availability and the development of PC based fast RT models has been reviewed. The use of PC based fast RT models developed at ECMWF, Met Office and NASA is now well established.

Recommendation RTSP-15 to users

Exploitation of PC based data requires PC based fast models. In particular, reconstructed radiance observations and reconstructed radiance simulations should be based on the same eigenvector basis.

2.1.9 Surface properties

A digitized dataset of refractive indices for sea surfaces was presented. A comparison between CRTM and RTTOV sea surface emissivity models is planned as well as the validation of sea surface emissivity models using AIRS data. The development of the ISSI reference model (primarily in the MW) was noted.

The CAMEL dataset is being updated to version 3 based on MODIS c6.1. The dataset covers the short wave and an extension to the far IR is planned.

The development of a physical model for snow/ice is planned for CRTM. Snowpack modeling at MW frequencies has also been noted. It was observed that models used in broadband radiations schemes should be consistent with models used for data assimilation.

The group discussed BRDF modeling considering the validity of statistical approaches vs. physical modeling. The utility of atlas-based approaches was questioned. The group also discussed the definition of skin temperature noting that this requires precise definitions/assumptions. The need for community defined / agreed standards for “in practice” usage was noted. This requires information exchange.

Recommendation RTSP-16 to community

Coordinate efforts for LS Emissivity modeling to cover spectral and physical requirements, development of modeling framework.

Recommendation RTSP-17 to community

New SST / SSE measurements across all spectral ranges highly encouraged, in coordination with RT model developers / researchers with particular emphasis on temperature dependence.

Action RTSP-6 to Ben Johnson

LSWG coordination of recommendations.

2.1.10 Future developments

- Fast RT models used in NWP operational systems
 - CRTM v3, RTTOV v14 with full polarization support and UV support
 - ARMS model (some feedback is needed here)
 - New / upcoming fast models with TL/AD support?
 - AI approaches
- Fast RT models used for research/retrievals
 - SARTA: update planned based on new HITRAN data
 - ARTS: (need to touch base with ARTS team for updates)
- Spectroscopy
 - Databases: GEISA 2020, HITRAN 2020
- LBL
 - CLBLM?
- Surface
 - Physical -> Radiance modeling improvements, full polarization / BRDF

2.2 CLIMATE

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

Nathalie Selbach (Co-Chair, DWD), Cheng-Zhi Zou (Co-Chair, NOAA), Younousse Biaye (Université Gaston Berger, UFR SAT), Bill Bell (ECMWF), Yong Chen (NOAA), Domenico Cimini (CNR-IMAA), Evan Fishbein (NASA), Larry Flynn (NOAA), Vincent Guidard (CNRM/MeteoFrance), Liam Gumley (UW-Madison CIMSS), Wei Han (UW-Madison SSEC), Timo Hanschmann (EUMETSAT), Sylvain Heilliette (ECCC), Viju John (EUMETSAT), James Jung (NOAA), Jeon-Ho Kang (KIAPS), Masahiro Kazumori (JMA), Robert Knuteson (UW-Madison SSEC), Salvatore Larosa (CNR-IMAA), Laura Le Barbier (CNES), Rohit Mangla (Meteo-France), Graeme Martin (UW-Madison SSEC), Silke May (DWD), Erica Lynn McGrath-Spangler (NASA), Scott Mindock (UW-Madison SSEC), Kozo Okamoto (JMA/MRI), Joe Predina (Logistikos Engineering), Indira Rani S (NCMRWF, MoES), Hank Revercomb (UW-Madison SSEC), Awdhesh Sharma (NOAA), Peter Steinle (BOM), Chun-Hsu Su (BOM), Hu (Tiger) Yang (Univ. of Maryland), Zhiyu Yang (SITP/CAS), Lihang Zhou (NOAA)

2.2.1 Introduction

The ITSC-23 Working Group on Climate convened on Tuesday, 8 June 2021 (via video conference), and discussed actions and recommendations from earlier meetings and new topics related to satellite climate data products and climate change.

2.2.2 Follow-up on actions from earlier meetings

The status of actions from ITSC-21 and ITSC-22 is summarized below:

- **Action Climate21-1 on WG co-chairs**

Establish how requirements from 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 ITWG-Climate group on definition of climate requirements for new satellite sounding sensors

Status: Closed. Input received from Jörg Schulz (EUMETSAT) for ITSC-22:

“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. “

This topic was further discussed at ITSC-22 and a recommendation (Climate22-4) to satellite agencies has been formulated and was included in the report to CGMS.

- **Action Climate22-1 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.

Status: Ongoing. Development work related to OSCAR/Space is ongoing. WMO is currently implementing a restful API to deliver WIGOS and JSON OSCAR/Space records. The idea is to make OSCAR/Space WIGOS metadata record compatible allowing users to export information from the OSCAR/Space database based on the XML template, for example regarding the relationship between instruments and variables. The Joint Working Group Climate has been involved. WMO is currently implementing this new functionality. A first version of OSCAR/Space with this functionality will be released in August/September 2021. Once the new functionality is available, the respective information will be added to the Climate WG webpage.

- **Action Climate22-2 on Co-Chairs**
Provide information on the CEOS/CGMS Joint Working Group on Climate on the Climate WG webpage (e.g. link to report, etc.)
Status: Closed. Information has been added to WG webpage (<http://cimss.ssec.wisc.edu/itwg/cwsg/>).
- **Action Climate22-3 on Co-Chairs**
Provide information on the GCOS and AOPC gap analysis report to the Climate WG webpage (e.g. link to report, etc.)
Status: Closed. Information has been added to WG webpage.
- **Action Climate22-4 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.
Status: Closed. Discussion between the Climate WG and the GSICS group: Since GSICS is primarily a forward-looking organization, it would be difficult to provide guidance on data stewardship of early satellite datasets. The GSICS Research Working Group progress is mainly attained by the activities of the subgroup members. If the Climate WG could focus on specific instruments, the request may be taken to the GSICS subgroups or satellite climate data record programs (e.g. NOAA/NCEI maintains a set of temperature profile observations from the Vertical Temperature Profile Radiometer (VTPR) during 1972-1979 and MSU and SSU observations during 1978 to 2006).
- **Action Climate22-5 on Climate WG members**
To determine the requirements for uncertainty information from all operational hyperspectral IR instruments and document.
Status: Closed. This topic has been further discussed during the ITWG-23 WG meeting. New recommendations have been added to the ITSC-23 WG on this topic (see Recommendations Climate-8, Climate-9, and Climate-10 below)
- **Action Climate22-6 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.
Status: Closed. Discussions with the GSICS group suggested that this request could be reviewed and discussed at the next GSICS Panel Meeting. In addition, Manik Bali (NOAA, GSICS Coordination Centre) provided lots of input that has been added to the Climate WG webpage.

2.2.3 Discussion during ITSC-23 WG Meeting:

The discussion concentrated on topics related to the [CGMS HLPP \(2021-2025\)](#).

Mitigation of the impact of identified degradation or loss of capabilities of the CGMS baseline and contingency measures

End of life of sensors and impact in climate time series

EUMETSAT Metop-A satellite will be de-orbited in November 2021

(<https://www.eumetsat.int/plans-metop-end-life>). A series pitch-over maneuver tests will be conducted before the end of its life. NOAA legacy satellites NOAA-15 and NOAA-18 have

been operational for more than 20 and 15 years, respectively. Instrument failure or satellite decommission may happen any time (NOAA-16 and NOAA-17 were decommissioned in June 2014 and April 2013 respectively). A potential impact of the loss of capabilities on climate applications is the termination of CDRs developed from these satellites.

Mitigation approaches include developing inter-satellite calibration capabilities to transition climate data records using legacy satellites to those using newer generation of satellite observations. Calibration programs must pay attention to assessing the performance of new sensors, even if they are copies of old sensors. This assessment may mean overlapping the use of old and new sensors so it will be possible to ensure compatibility between data products. Changes in technology will eventually make it impossible to reproduce a given set of instruments as the availability of the specific components and intellectual skills associated with a particular design vanish. In fact, some space instruments have been in production for about two decades, but closer examination would reveal that they have been continually upgraded to surmount some of the parts availability problems. As sensors are replaced over time, it is essential to maintain continuity of the data product despite changes in sensor performance ("dynamic continuity").

One example for such a transition is the layer mean atmospheric temperature time series that transitioned the AMSU-A observations onboard Aqua and MetOp-A to ATMS observations onboard S-NPP and NOAA-20 ([Zou et al., 2021](#)). The transition was made possible by inter-satellite calibration and satellite merging using overlaps between the legacy and newer satellites. In inter-satellite calibration, channel frequency continuity is essential for harmonic transition from the old satellites to newer satellites. Other approaches include simulation of the respective channels onboard the older satellite series with data from newer frequencies. This will require a good overlap in covered frequencies between the two sensor generations.

The Climate WG support the continuity of the different orbits and observations for upcoming new satellite generations in order to provide the baseline for satellite-based climate monitoring.

Recommendation Climate-1 to satellite agencies

The separation of instrument variability from the often subtle, long-term variations in climate related processes requires careful calibration and validation of the sensor and its derived data products. The Climate WG encourages satellite agencies to intercalibrate time series from overlapping satellites in order to allow a continuation of climate time series (including trend analysis) when transitioning from older to newer satellites.

Recommendation Climate-2 to satellite agencies

Satellite agencies should ensure a frequency continuity for all instruments in future sensor designs for developing credible climate data records.

Small satellites

Small satellites are becoming more important in the context of Earth observation and have potential for climate applications. Small satellites allow for an affordable future constellation that can offer measurements with a temporal-spatial resolution that is not accessible to traditional remote-sensing satellites, thus offering new capacity to monitor very dynamic phenomena and helping to fill the gaps in our monitoring of the Earth's vital signs for the future. They typically have a shorter lifetime than the traditional larger satellites and are a

complement to the larger satellites, but not as a replacement for them. As accuracy requirements for climate research needs are much more stringent than the operational needs, a full understanding of their calibration characteristics is needed, particularly if absolute calibration is required.

Recommendation Climate-3 to space agencies

Consider climate requirements in terms of stability and length of life cycle when designing small satellite sensors.

Impact on reanalysis

Observations from many different satellites are assimilated in reanalysis. The observation system changes during the period covered in the reanalysis (e.g., number of satellites, available channels from different sensors, etc.). Studies would be needed to understand the impact of losing different sensors and assess the possible loss of performance. ECMWF is currently planning to perform such studies in preparation of the next generation of their reanalysis (ERA-6).

Action Climate-1 on Bill Bell

Bill Bell to report at the next meeting (Climate WG meeting at ITSC-24) about the plans at ECMWF and progress to-date concerning impact studies on losing different satellite sensors for assimilation in a reanalysis.

Long-term continuity of OSCAR/Space

The long-term continuity of OSCAR/Space as a primary tool to support the CGMS Risk assessment and the WMO Rolling Review of Requirements including gap analysis against observing system requirements for satellite data are one of the tasks in the CGMS HLPP. This includes making OSCAR/Space the primary repository for WIGOS satellite metadata records generated by CGMS operators. The Climate WG supports this activity.

Development work is ongoing at WMO to implement a restful API to deliver WIGOS and JSON OSCAR/Space records. The aim is to make OSCAR/Space WIGOS metadata record compatible allowing users to export information from the OSCAR/Space database based on the XML template, for example regarding the relationship between instruments and variables. The Joint Working Group Climate has been involved. WMO is currently implementing this new functionality and a first version of OSCAR/Space with this functionality will be released in August/September 2021.

Recommendation Climate-4 to WMO

WMO to collect information on available FCDRs from data providers and include it in OSCAR.

Radio Frequency (RF) Protection

The protection of frequencies to observation of Essential Climate Variables (ECVs) is considered very important by the Climate WG. Depending on specific frequency, a loss of radio frequency may result in termination of a CDR or difficulties to merge CDRs from observations with old frequencies with observations with replaced new frequencies. Frequency interference may result in time series not being suitable for e.g. trend analysis or other climate applications. The group recognizes that the ITWG Technical Sub-group on Radio Frequency Interference has been re-started at ITSC-23 (focusing on frequency

protection for the microwave region of the electromagnetic spectrum used for scientific and operational applications of passive remote sensing), which is highly appreciated.

Coordination of data access and end-user support

This section of the HLPP focuses on NRT and NPW applications, it would be beneficial if the tasks could be broadened to also reflect the requirements of the climate community.

References to data records

Similar to publications, data records should obtain a Digital Object Identifier (DOI). This allows for clear citation and transparency. This applies to Fundamental Climate Data Records (FCDRs) as well as climate data records (CDRs) of ECVs.

Metadata and data format

Observations without metadata are of very limited use: it is only when accompanied by adequate metadata (data describing the data) that the full potential of the observations can be utilized. Data compatibility will also be supported by the use of standardized data representation and formats. Adding metadata and use of standardized data representation and formats improve the interoperability and compatibility through the application of internationally accepted standards and best practices. The [WIGOS metadata standards](#) lists requirements for metadata, which should describe the observed variable, the conditions under which it was observed, how it was measured or classified, and how the data have been processed, in order to provide users with confidence that the data are appropriate for their application. In more specific, metadata shall contain the details and history of local conditions, instruments, operating procedures; data-processing algorithms and other factors pertinent to interpreting data should be documented and treated with the same care as the data themselves.

Recommendation Climate-5 to data record providers

CDRs should be citable by e.g. having Digital Object Identifier (DOI) reference and being accessible to users. All data records should be accompanied by metadata that follows WIGOS standards.

Recommendation Climate-6 to data developers

CDR development and stewardship shall follow guidance similar to [NCEI Data stewardship maturity matrix](#) or the [Copernicus Climate Change \(C3S\) convention](#) (including recommendations for metadata).

Action Climate-2 to Climate WG co-chairs

Add information on NCEI Data stewardship maturity matrix and C3S convention to Climate WG webpage.

Establish a fully consistent calibration of relevant satellite instruments across CGMS agencies, recognizing the importance of collaboration between operational and research CGMS agencies

GSICS activities were broken up in different sub-groups for different spectral ranges, covering a full spectrum in satellite instrument inter-calibrations. (see e.g., the list of GSICS Processing and Research Centres (GPRCs) at <https://gsics.wmo.int/en/product-services-and-technical-information>). Inter-calibrations for hyperspectral IR instruments and microwave sounders are active elements in GSICS activities with good results achieved. The Climate

WG has active communications with GSICS community to get information on instrument calibration status and uncertainties.

The Climate WG supports the current and continued activities at GSICS in calibration/inter-calibration/recalibration of current satellites. The Climate WG encourages climate groups at different agencies to look into calibration/intercalibration of time series of older satellites for generation of FCDR and CDRs of ECVs.

Bias monitoring

The NOAA Product Validation System (NPROVS) currently store collocated radiosonde (high-density) and hyper-infrared/advanced microwave instrument measurements for every GRUAN radiosonde that falls within 2 hours of a MetOp or NOAA (SNPP/JPSS) overpass. These include radiosondes from the JPSS dedicated radiosonde program targeting NOAA satellites. The Climate WG supports these activities.

Recommendation Climate-7 to EUMETSAT

The Climate WG recommends that EUMETSAT consider funding its own dedicated radiosonde program to match MetOp observations with (European) radiosonde observations for satellite validation.

Hyperspectral instruments

Satellite agencies have extensive calibration and validation programs before and after satellite launches to determine the uncertainty information of operational hyperspectral IR instruments (AIRS, IASI, CrIS, etc.). This information can be found in instrument calibration documents and relevant publications generated by satellite agencies. GSICS also provides instrument uncertainty information by comparing different hyperspectral IR instruments onboard different satellites operated by different agencies. Uncertainty information can be found in many relevant presentations and publications on inter-comparisons of hyperspectral IR sounders on GSICS website (<https://gsics.wmo.int>). Most of this uncertainty information such as instrument noise and systematic calibration biases are for NWP applications. For climate applications, uncertainty information shall be focused on long-term instrument radiometric stability and bias drift. Such uncertainty estimates could be made possible by comparing hyperspectral IR instruments to an on-board reference for absolute calibration for its entire observation period or by inter-comparisons for the entire life cycles of overlapping instruments.

The group emphasized the importance of improving the accuracy and information content of spaceborne observations for detecting climate trends and quantifying feedback mechanisms using on-orbit SI standards for the absolute calibration of spectrally resolved radiances and adequate global sampling (as defined for the US CLARREO benchmarking mission, [Wielicki et al., 2013](#)). The WG recognizes and endorses the significant progress expected for the solar part of the spectrum via the US CLARREO Reflected Solar Pathfinder (2023), ESA TRUTHS mission (2026-28), and Chinese LIBRA mission (2025-2032); and future plans for new Earth emission observations by the ESA FORUM mission (2026) and the Chinese LIBRA mission as defined at the workshop “An SI-Traceable Space-based Climate Observing System” held by CEOS WGCV and WMO-CGMS GSICS at NPL, UK on Sept, 2019 and associated publications.

However, given the importance of these observations for verifying international progress toward dealing with the threat of climate change, the WG recommends that CGMS

emphasize the need to establish an improved global climate benchmark with multiple standards as soon as possible. Therefore, specifically, the WG recommends that the US proceed with the Infrared Pathfinder defined by the CLARREO program, which by making use of the expected international fleet of sounding instruments and FORUM, would enable an 0.1 K k=2 global benchmark to be established within five years of launch ([Taylor et al. 2020](#)). Such accuracy proven on orbit represents about an order of magnitude improvement and allows contributions relevant to quantifying the global radiative imbalance to be observed. Other solar missions to address global sampling issues are also strongly encouraged. In addition, future launches are needed to establish decadal trends and must be built into plans.

Recommendation Climate-8 to satellite agencies

Satellite agencies shall establish programs to conduct absolute calibration or inter-calibration for hyperspectral IR sounders during their life cycles and document and publish the results.

Recommendation Climate-9 to CGMS

WG recommends that CGMS emphasize the need to establish an improved global climate benchmark with multiple standards as soon as possible for verifying international progress toward dealing with the threat of climate change.

Recommendation Climate-10 to US satellite agencies

WG recommends that the US satellite agencies proceed with the Infrared Pathfinder defined by the CLARREO program.

Error characteristics of satellite data and products

Establishing a common vocabulary and methodology with appropriate error propagation to include the errors associated with validation data (e.g. radiosonde temperature, water vapor, precipitation and winds) is important to better understand and trace uncertainties when interpreting long time series of e.g., ECVs.

When reporting climate trends, the climate community addresses statistical uncertainties in trends associated with the lengths of observations and magnitudes of variability in time series. On the other hand, the satellite CDR community addresses calibration uncertainty, or stability, of time series in trend detection.

Recommendation Climate-11 to satellite data products developer

Report statistical uncertainties of the CDR trends together with the calibration uncertainties.

Research regarding enhanced radiative transfer capabilities

The Climate WG group recognizes the paramount importance of radiative transfer developments for satellite products and supports the continued development and refines of radiative transfer capabilities, as they are an important tool in inter-satellite calibrations with double difference approaches.

Advancing the architecture for space-based monitoring of climate, including greenhouse gas monitoring

The CEOS/CGMS [ECV Inventory Questionnaire Guide](#) identified about 30 ECVs, consisting of nearly 100 individual physical variables covering the atmosphere, ocean, and terrestrial for

a complete monitoring and understanding of climate change. Current CEOS/CGMS [ECV inventory](#) includes nearly 800 CDRs, in many cases with multiple CDRs describing a same physical variable. [Gap analysis](#) of the existing ECV Inventory indicated that some key ECVs, particularly GHG, are still under-represented in the current ECV inventory.

Programs that archive GHG include the [ESA Climate Change Initiative \(CCI\)](#), EUMETSAT's [Satellite Application Facility on Atmospheric Composition \(AC SAF\)](#) and [Copernicus Climate Change Service \(C3S\)](#). CCI supports merging data from different sensors, on missions flown by different space agencies, to generate climate data records with the longest possible time spans. The [CCI GHG project](#) performs research and development needed to generate new satellite-derived carbon dioxide (CO₂) and methane (CH₄) products. The AC SAF products include total ozone, trace gas total columns (NO₂, SO₂, BrO, HCHO, H₂O, OCIO, CO), tropospheric O₃ and NO₂, coarse and high-resolution ozone profiles. Products are available for atmospheric monitoring as NRT products and archived for offline ordering. The AC SAF also has a number of longer data records available (from 2007 onwards). The C3S also archives carbon dioxide and methane products from 2002 to present retrieved from multiple satellite observations. In addition, NOAA [CLASS](#) archives long-term greenhouse gases (GHG) data products including ozone (O₃), methane (CH₄), carbon monoxide (CO), carbon dioxide (CO₂), SO₂, N₂O, and HNO₃. These are retrieved products based on CrIS and ATMS observations using the NOAA Unique Combined Atmospheric Processing System (NUCAPS). These products may contain bias jumps due to improvements over time in retrieval algorithms as well as calibration algorithm improvement over time in generating the input sensor data records. Reprocessing is needed to produce consistent GHG products based on NUCAPS. In addition to GHG retrievals, the [JAXA Greenhouse gases Observing SATellite \(GOSAT\)](#) has been providing CO₂ and CH₄ observations for over ten years and the datasets are archived in the ESA [Earth Online](#) Program. The Chinese [TanSat](#) (Carbon Satellite) has been monitoring the global change of CO₂ since 2016.

Recommendation Climate-12 to space agencies

Support the further development of ECVs and GHG CDRs to enrich the ECV inventory for climate change monitoring.

Training

The Climate WG supports the continued training activities organized by different satellite agencies, including EUMETSAT and NOAA, Copernicus, as well as COMET Training program, to use satellite data for climate applications. These trainings allow users to get familiar with and understand the format, uncertainties, and the differences of satellite data from ground based conventional data. The Climate WG also supports efforts to make data easy to use for non-expert users.

2.3 DATA ASSIMILATION AND NUMERICAL WEATHER PREDICTION

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

Working group members: Brett Candy (Co-Chair, Met Office), Fiona Smith (Co-Chair, Bureau of Meteorology), Mathieu Asseray (Météo-France), Nigel Atkinson (Met Office), Olivier Audouin (Météo-France), Maziar Bani Shahabadi (ECCC), Marylis Barreyat (Météo-France), Kristen Bathman (IMSG@NOAA/NCEP/EMC), Alain Beaulne (ECCC), Bill Bell (ECMWF), Camille Birman (CNRM, Météo-France & CNRS), Mary Borderies (Météo-France/ DESR/ CNRM), Niels Bormann (ECMWF), Sid Boukabara (NOAA), Chris Burrows (ECMWF), William Campbell (NRL), Fabien Carminati (Met Office), Philippe Chambon (Météo-France), Hao Chen (Jiangsu Meteorological Observatory), Yong Chen (NOAA/NESDIS/STAR), Hui Christophersen (NRL), Hyoung-Wook Chun (KMA), Olivier Coopmann (CNRM, Université de Toulouse, Météo-France & CNRS), Dorothee Coppens (EUMETSAT), Mohamed Dahoui (ECMWF), Yu (Judy) Deng (Alion Science), Di Di (Nanjing University of Information, Science & Technology), David Duncan (ECMWF), Stephen English (ECMWF), Reima Eresmaa (Finnish Meteorological Institute), Robin Faulwetter (DWD), Evan Fishbein (JPL), Larry Flynn (NOAA), Nadia Fourrie (CNRM Météo-France and CNRS), Normand Gagnon (ECCC), Donatello Gallucci (CNR-IMAA), Sabrina Gentile (CNR-IMAA), Stephanie Guedj (Met Norway), Vincent Guidard (CNRM, Météo-France, CNRS), Liam Gumley (CIMSS/SSEC UW-Madison), Chawn Harlow (Met Office), Wei Han (JCSDA), Wang Hao, Sylvain Heilliette (ECCC), James Hocking (Met Office), Tim Hultberg (EUMETSAT), Kayo Ide (University of Maryland), Flavio Iturbide-Sanchez (NOAA), Jianjun Jin (NASA GMAO), Erin Jones (CISESS @ NOAA/NESDIS/STAR), Satya Kalluri (NOAA), Norio Kamekawa (JMA), Jeon-Ho Kang (KIAPS), Bryan Karpowicz (CISESS @ NOAA/NESDIS/STAR), Aya Kasai (JMA), Masahiro Kazumori (JMA), Rich Kelley (Alion Science), Toshiyuki Kitajima (JMA), Robert Knuteson (UW-Madison SSEC/CIMSS), Christina Koepken-Watts (DWD), Keiichi Kondo (JMA/MRI), Naoto Kusano (JMA), In-Hyuk Kwon (KIAPS), Jean-Marie Lalande (Météo-France), Bjorn Lambrigtsen (JPL), Agnes Lane (Bureau of Meteorology), Salvatore Larosa (CNR-IMAA), Katie Lean (ECMWF), Eunhee Lee (KMA, NASA), Jin Lee (Bureau of Meteorology), Joshua Lee (National Environment Agency, Singapore), Seungwoo Lee (KMA), Sihye Lee (KIAPS), Zhenglong Li (UW-Madison SSEC), Agnes Lim (CIMSS/SSEC), Emily Liu (NOAA/NCEP/EMC), Haixia Liu (IMSG@NOAA/NCEP/EMC), Qifeng Lu (NSMC/CMA), Cristina Lupu (ECMWF), Erin Lynch (GST, Inc.), Yufen Ma (Institute of Desert Meteorology, CMA), Rohit Mangla (Météo-France), Graeme Martin (UW-Madison SSEC/CIMSS), Mashuo, Iriola Mati (ECCC), Marco Matricardi (ECMWF), Silke May (DWD), William McCarty (NASA GMAO), Tony McNally (ECMWF), Stefano Migliorini (Met Office), Mate Mile (Met Norway), Alessandra Monerri (Bureau of Meteorology), Emily Morgan (FNMOC – U.S. Navy), Masami Moriya (JMA), Mahdiyeh Mousavi (DWD), Hidehiko Murata (JMA), Kozo Okamoto (JMA/MRI), Joe Predina (Logistikos Engineering LLC), Chengli Qi (CMA), Samuel Quesada-Ruiz (ECMWF), Roger Randriamampianina (Norwegian Meteorological Institute), Indira Rani S (NCMRWF), Mikael Rattenborg (WMO), Filomena Romano (IMAA/CNR), Kirsti Salonen (ECMWF), Leonhard Scheck (LMU Munich), David Schonach (Finnish Meteorological Institute), Awdhesh Sharma (NOAA/NESDIS), Hiroyuki Shimizu (JMA), Bill Smith (CIMSS/SSEC), Fiona Smith (Bureau of Meteorology), Peter Steinle (Bureau of Meteorology), Olaf Stiller (DWD), Chun-Hsu Su (Bureau of Meteorology), Ruth Taylor (Met Office), Sreerexha Thonipparambil (EUMETSAT), Chris Tingwell (Bureau of Meteorology), David Tobin (SSEC), Ricardo Todling (NASA), Robert (Bob) Tubbs (Met Office), Emma Turner (Met Office), Jerome Vidot (CNRM), Zheng Qi Wang (McGill University), Simon Wood (NIWA New Zealand), Hejun Xie (Zhejiang University), Xishuang (CMA), Tiger Yang (UMD), Zhiyu

Yang, Ruoying Yin (Numerical Weather Prediction Center), Biaye Younoussse (Université Gaston Berger), Xiaoyan Zhang (NOAA/NCEP/EMC & IMSG), Lihang Zhou (NOAA), Yanqiu Zhu (GMAO)

The Working Group was held in the form of a remote (online) meeting on 7th June 2021.

2.3.1 Actions from the previous meeting

The status of the actions from the previous conference can be found on the DA/NWP website: https://groups.ssec.wisc.edu/groups/itwg/nwp/action_status_tracker
Most actions were completed and standing actions can be seen in Appendix 1.

The only action remaining open that is not captured in the report below is:

- **Action DA/NWP 22-13 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 for support of the early morning orbit.

Status: Open. FY3E is to be launched imminently and we look forward to progress on this action at the next conference.

2.3.2 Radio Frequency Interference

Radio Frequency Interference (RFI) has the potential to seriously impact the usefulness of microwave data used for NWP. At the last World Radiation Conference conf (WRC-19) Spectrum was allocated to 5G in an adjacent band to our 24GHz channels where the level of protection is lower than ITU had recommended. The 183 GHz band has also potentially been opened up for new applications.

Steve English, Nancy Baker, Rich Kelley and Jean Pla have proposed, with the support of working group co-chairs, to reactivate the RFI Technical Subgroup. This Subgroup will collect inputs, acting as a single point of contact for collating evidence; have more detailed discussions; and prepare arguments for the World Radiance Conference (WRC) every 4 years. The intention will be to hold the RFI Subgroup meeting ahead of ITSC to identify issues of concern for discussion within particular Working Groups.

The NWP Community needs to work together to identify Instances of RFI to provide evidence to spectrum managers regarding the need to safeguard the passive bands that NWP relies on.

DA/NWP Working Group members were encouraged to support the activities of the RFI Technical Subgroup and to attend their first meeting on Friday 19th June. From this point, evidence of RFI should be sent to the Subgroup Co-chairs.

Action DA/NWP-1 on NWP WG members

Send any evidence of RFI in the observations and results investigating the effects of RFI on forecast skill to the co-chairs of the RFI Technical Subgroup Stephen English (stephen.english@ecmwf.int), Richard Kelley (barometer@verizon.net), Nancy Baker (nancy.baker@nrlmry.navy.mil) and Jean Pla (jean.pla@cnes.fr).

2.3.3 WMO activities in support of satellite data for NWP

The WMO has a new [Expert Team for Space Systems and Utilization](#) (ET-SSU). This group sits under the Infrastructure Commission (INFCOM), and the Standing Committee on Earth

Observing Systems and Monitoring Networks (SC-ON), is chaired by Stephen English (ECMWF) with Ken Holmlund being the primary interface to the WMO Secretariat. The first task of the team was to write a Position Paper on Satellite Data Requirements for Global Numerical Weather Prediction. The paper was recently presented to CGMS and was subsequently formally accepted by WMO's INFCOM-1 meeting. The WG members were encouraged to read the Position Paper.

2.3.4 NWP-SAF support for EUMETSAT's future missions

EUMETSAT's next generation satellites, Metop-SG A and B and MTG-S will be supported by software from the NWP-SAF for their MW and IR sounders. Nigel Atkinson (Met Office, NWPSAF) presented the status of this software, and seeks feedback from NWP users to ensure the software meets users' needs.

The future data standard format is netCDF, not traditionally used by many NWP systems. Direct Broadcast processors will be available for generating standard netCDF products. The SAF advocate that users generate their own BUFR according to local requirements and are requesting feedback for this approach.

MTG-IRS L1 data will be available as full spectra (but not in NRT) and as PC scores, however this product is expected to be too large for the GTS. The SAF IRSPP package will allow various steps of processing to generate BUFR radiances from PC scores. The software design document is available [on the NWPSAF website](#). A software release is planned in late 2021 and beta testers are requested.

EPS-SG's MWS and IASI-NG will be supported via an add-on to AAPP. The baseline is netCDF input for locally-generated direct broadcast data and netCDF and/or BUFR for global reception (e.g. EUMETCast), depending on the instrument, with PC Scores for IASI-NG. Various tools are planned e.g., spatial filtering, radiance reconstruction, microwave to IR mapping, and conversion of IASI-NG to IASI spectral resolution. MWI and ICI have considerable geolocation complexity. They will be supported via the [MWIPP](#) package which will provide tools for spatial averaging, mapping, coregistration, thinning, BUFR encoding etc.

There was discussion about the fact that netCDF is not optimised for data transmission. Sreerekha TR (EUMETSAT) said that EUMETSAT's data distribution is being reviewed with respect to new data services and the plan will be released in Q3 2021.

Action DA/NWP-2 on WG Members

Please review the software design documents for ISPP and MWIPP/AAPP on the NWPSAF website and provide feedback to Nigel Atkinson by the end of July 2021 (nigel.atkinson@metoffice.gov.uk).

Action DA/NWP-3 on WG Members

Contact Nigel Atkinson by the end of July 2021 (nigel.atkinson@metoffice.gov.uk) to beta test IRSPP.

Action DA/NWP-4 on Sreerekha TR

Circulate EUMETSAT's data distribution plan to the DA/NWP WG when it is released.

2.3.5 NOAA Future Architecture

Sid Boukabara (NOAA) and Will McCarty (NASA) introduced the System Performance Assessment Team (SAT), a science team set up to provide regular feedback to NOAA on next generation space architecture from a science and user expectation perspective and discuss cost/performance trade-offs. Members cover all applications including NWP, nowcasting, ocean, land and hydrology. The team meet bi-weekly, and agenda varies including technology, requirements, impact of legacy sensors etc.

The SAT have produced various recommendation documents which are available on the website <https://www.star.nesdis.noaa.gov/sat/index.php>. These include tables with product priorities (e.g., temperature and humidity sounding performance, ice and precipitation retrieval performance, spatial resolution, swath width etc.) and various levels of desired performance for each priority (for example number of channels and spectral ranges).

Items that raised particular controversy at the previous ITSC include:

- The spectral coverage of the infrared sounding instrument. SAT have currently made a recommendation that IR sounders should have a long-term objective to cover LW+MW+SW for long-term objective, but SW+MW should be considered for a pathfinder.
- Instrument collocation. NWP has stated that this is not a strong requirement for IR+MW to be collocated, but the retrieval product community do consider this to be important. Both options are considered for future systems. IR sounder/imager collocation has not been discussed to such a great extent. WG members expressed the view that perhaps for NWP heterogeneity information from an imager is more important than collocated MW.

Questions that the SAT would like the NWP community to contribute to include:

1. For a sounder constellation what is the best combination of sensor quality and constellation-driven temporal refresh and spatial coverage?
2. In a budget constrained environment, what is the best balance of quality vs quantity?
3. What is the role of GEO sounders and how should we seek to fill gaps between GEO coverage and the poles where there are frequent LEO overpasses?
4. To what extent is the community ready to embrace new sensors vs skeptical of proposed changes. What mechanisms need to be in place to help the user community be ready?

Discussion during the WG covered the following aspects (for brevity, the term “Small Satellites” will be used to cover SmallSat, CubeSat and MicroSat type missions that are typically of short duration and considerably smaller than traditional LEO satellites):

1. The extent to which RFI has been considered for small satellites.
2. Lack of clarity around the role of these small satellite missions - are they complementary to a JPSS follow-on, or are they intended to be the follow-on?
3. A more ambitious trade-off envelope could be recommended as the high-end of the requirements range in the SAT memos seem to be not very demanding in comparison with, for example, specifications of the EPS-SG missions.
4. Are requirements for improved footprint size adequately captured?
5. Regarding coincident MW/IR and IR/Imager, do the recommendations adequately reflect future more advanced DA techniques we can envisage?
6. Do small satellite instruments benefit from intercalibration with large longer-term and stable platforms and has this been planned for?

Other points to note:

1. Under the JPSS/LEO-Sounder Project there is a LEO Constellation Architecture Study with a workshop on future Microwave sounders tentatively scheduled in July/Aug time.
2. ESA also has a project to look at future microwave sounder constellations. See poster by Katie Lean at this conference.

It was proposed to hold a meeting of interested WG members to collate feedback on the SAT's questions listed above.

Action DA/NWP-5 on WG members

Email Fiona and Brett if they are interested to be part of SAT feedback discussion group.

Action DA/NWP-6 on WG chairs and Will McCarty

Organise an online meeting to discuss feedback to the SAT on the questions discussed during the WG meeting.

All members are encouraged to review the SAT documents and to provide feedback, regardless of whether they join the discussion group.

Action DA/NWP-7 on WG members

Review SAT recommendation documents and provide any feedback to Will McCarty (will.mccarty@nasa.gov) by the end of July 2021.

Action DA/NWP-8 on WG members

Contact Lihang Zhou (lihang.zhou@noaa.gov) by the end of June 2021 to be invited to the LEO Constellation Architecture Study workshop on future Microwave Sounders.

2.3.6 CrIS Status

S-NPP Bands

The DA/NWP working group recently provided feedback to NOAA by email on their preferences for the future configuration of the S-NPP CrIS instrument (LW+SW or MW+SW). The WG thank NOAA for their efforts to collect user feedback before making a final decision, and to support the majority view that LW+SW is the preferred option.

The majority of NWP users are not able to use the SW to mitigate the loss of the LW band at the present time. Centres are not able to use the MW without the LW to assist with cloud screening. The WG note that work at NOAA STAR and JPL are showing promising results for MW+SW assimilation (see poster by Erin Jones at this conference). Continued research into the use of MW+SW is encouraged.

Action DA/NWP-9 on WG members

Forward any results of studies for the use of MW-only or MW+SW channels to the working group.

Sub-pixel heterogeneity

The previous conference had the following action:

- **Action DA/NWP 22-11 on Andrew Collard:**
Check with NESDIS-STAR on plans to implement the VIIRS cluster algorithm for global CrIS data dissemination.

Advice received from Tom King is that NOAA are normally unwilling to implement external code or algorithms, such as the clustering algorithm from AAPP, without their science team extracting the code and supporting it scientifically. Furthermore the AAPP code uses a different geolocation process from the operational NOAA procedure and the clustering algorithm would need to be adapted prior to implementation.

Working group members continue to have a requirement for sub-pixel heterogeneity information for CrIS but it was felt that mean and sd of VIIRS radiances within each footprint would suffice if NOAA would be more willing to implement this. The current CrIS BUFR sequence accommodates mean and standard deviation of VIIRS radiances.

Progress on this item, having been slow for many years, is now progressing rapidly and NESDIS are examining the AAPP code and comparing algorithms.

Action DA/NWP-10 on WG co-chairs

Follow progress on implementation of CrIS sub-pixel heterogeneity information at NOAA and report back to WG members bi-annually.

2.3.7 POES continuation

There was discussion on the important contribution to the observing network from the POES series of satellites (NOAA-15, 18 & 19). Orbital drift since launch has meant that these satellites help to improve data coverage for AMSU-A and MHS (NOAA-19). Several NWP centres have already sent evidence (FSOI and data denial studies) to help support the case for continuing the data dissemination from these satellites and there will be further discussions on this as part of the group meeting to discuss the SAT questions above. The orbital drift will continue and so these results provide a current snapshot of impact. It was noted that several of the POES AMSU instruments continue to have excellent noise performance for critical sounding channels.

Recommendation DA/NWP-1 to NOAA

Continue to produce POES L1 sounding products for near-real time dissemination.

Action DA/NWP-11 on WG members

Send results of forecast studies that indicate the continuing impact on NWP of POES satellites to Mitch Goldberg (mitch.goldberg@noaa.gov).

2.3.8 GIIRS BUFR Sequence

GIIRS data is available via CMA/EUMETCast Terrestrial in HDF-5. For NWP applications Nigel Atkinson and Chris Burrows have developed a draft BUFR sequence. The sequence has been derived from first principles; it is not based on CrIS and IASI. This is because some characteristics of the data stream are specific to the GIIRS instrument. For example, the geolocation of the medium wave and long wave bands are different. Chris and Nigel are seeking feedback on the sequence within the next month; in particular the choice of metadata

and also whether there is enough flexibility to handle future developments of the GIIRS instrument.

Action DA/NWP-12 on Chris Burrows

Provide Working Group with the draft GIIRS BUFR sequence and invite comment.

Action DA/NWP-13 on WG Members

Provide feedback to Chris Burrows (chris.burrows@ecmwf.int) on the draft GIIRS BUFR sequence by the end of July 2021.

2.3.9 CGMS HLPP

Relevant parts of the CGMS High Level Priority Plan (HLPP) were reviewed and discussed.

4.2.7 Establish together with the user community a commonly agreed approach for retrieval of Principal Component scores and associated parameters from hyperspectral infrared data, minimizing information loss including the mutually acceptable update strategy for the principal component basis and to implement such an approach in a coordinated manner.

The hybrid methodology developed at EUMETSAT has been discussed at previous ITSC meetings. The WG thank EUMETSAT for their continued work in this promising area. EUMETSAT will disseminate IASI PC scores via the hybrid methodology from Nov/Dec 2021. All NWP centres are encouraged to investigate use of the hybrid PC score dataset. In particular this is an important activity for readiness for MTG-IRS. The following recommendation is retained.

- **Recommendation DA/NWP 22-14 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.

It was also noted that the hybrid approach is also being developed for PC representation of CrIS data and may become an official product.

A ECMWF/EUMETSAT study is underway to investigate the effects on radiance reconstruction if the eigenvectors are changed. This study aims to address concerns that long lead times would be required if a change of eigenvector basis is proposed. See poster at this conference presented by Cristina Lupu.

4.4.2 Agree on standardized procedures to derive NedT estimates for microwave sounders and include such estimates in the disseminated BUFR data.

There was a general feeling in the WG that the timeseries of NedT estimates is very useful, as it allows users to identify when changes to the instrument occur. In particular websites showing the time series can be very helpful in making decisions on instrument/channel rejection. This is not just a requirement for short-range NWP; timeseries spanning the lifetime of instruments can be useful to reanalysis applications.

With regards to consistency in the method used to estimate NedT, it was pointed out that it is not always possible to perform the calculation in the same way for all instrument types.

Consequently it was felt that we modify the recommendation previously DA/NWP 22-8 to reflect this. The following two new standing recommendations were made.

Standing Recommendation DA/NWP-13 to data providers

Provide NedT estimates for inclusion within BUFR for microwave data.

Standing Recommendation DA/NWP-14 to data providers

Make NedT estimates from microwave instruments available as time series on publicly available websites to enable monitoring of instrument health in near real time.

Joerg Ackermann who was unable to attend the meeting requested that the WG make the following additional recommendation, to aid instrument characterisation:

Standing Recommendation DA/NWP-15 to instrument developers

Pre-launch calculation of NEdT should use the same algorithm as will be used in-orbit using warm target counts variability divided by the instrument gain.

4.6.3 Through coordination between IPWG, ITWG and ICWG, continue to improve microwave radiative transfer models to include complex surfaces (e.g., snow, desert, etc.) and scattering atmospheres (e.g., frozen hydrometeors) to support improved algorithm development for current and future sensors.

Discussion focused on how this working group can support this effort, for example by coordinated effort to test new scattering tables or other improvements to the RT modelling. It was noted that RTTOV version 13 includes a major upgrade of RTTOVSCATT (for instance, allowing for the first time an arbitrary number of hydrometeor types, and improved hydrometeor tables of scattering properties). The group proposes to seek advice from the RT Working Group.

Recommendation DA/NWP-2 on RTWG

Outline what support they require from NWP community regarding CGMS HLPP Item 4.6.3.

Also the question was raised whether the new instruments MWI and ICI on Metop-SG (that have channels sensitive to scattering) are also included in the remit of this working group. This was agreed.

2.3.10 Science topics for discussion

Satellite data in convective scales, and challenges of increasing volumes of radiances

The group discussed the challenges of assimilating radiance data as global NWP model resolutions are moving towards the convective scale. One area of ongoing research is how to move towards a higher density of data in the assimilation, which means potentially dealing with temporal and spatial error correlations. Technical aspects can be difficult to deal with, especially in a multi-processor environment. The Desroziers method can help estimate correlations and several centres have attempted assimilating geostationary imagery at higher density, but the temporal error correlations appear to be different for different centres. Another approach investigated at ECCC as presented at the previous conference is to reduce

spatial thinning and inflate observation errors, this appears to favour channels sensitive to the lower troposphere. There are plenty of open questions with regards to improving data density.

As NWP models move to smaller spatial scales the correct treatment of the observation operator is important (satellite footprint vastly greater than the NWP grid scale). This may also influence the spatial resolution of future sounders.

As the volume of sounder data increases, there may be a lack of sufficient anchor observations for bias correction.

Bias handling in LAMs

This is still an active area of research and there may be common issues between LAMs and global bias correction, as the global grids approach convective scale. VarBC with normal cycling in LAMs has been shown to work less well than 24-hour cycling. FMI are investigating the following approach: for each satellite, identify one cycle per day to update the bias coefficients with a relatively good satellite coverage, in conjunction with radiosonde launches to act as an anchor. This VarBC update cycle will differ depending on instrument overpass time.

Action DA/NWP-14 on WG members

Contact Roger Randriamampianina (rogerr@met.no) to join a group that will discuss bias correction in LAMs.

There was insufficient time to sufficiently discuss the topics proposed at this meeting. It was suggested to hold a science meeting for the WG in Q3 2021.

Action DA/NWP-15 on WG members

Contact WG co-chairs by the end of July 2021 with topics for a science meeting (already proposed are assimilation in LAMs and how to deal with instruments on small satellites).

Action DA/NWP-16 on WG Co-chairs

Arrange another meeting in a few months to discuss the science issues.

2.3.11 Web Site

<https://groups.ssec.wisc.edu/groups/itwg/nwp>

The WG Co-chairs reviewed the web site prior to the meeting and removed some pages and information that are now out of date. This was done in consultation with the Working Group via email. The SSMIS page will be regularly updated with a chart showing the health of each instrument, courtesy of Steve Swadley (NRL). This is very useful as this information is not easily found on other sites.

Space Agency contacts are likely to be out of date and Working Group members are encouraged to review this page and let WG Co-Chairs know of any updates.

Action DA/NWP-17 on WG members

To review Space Agency contacts page on the website.

The regional model page is still considered to be an important resource; a useful first step for someone starting to use radiances in a LAM. It should ideally comprise of a set of references

and guidance for things that need consideration. In particular a missing topic is guidance on which metrics are useful in determining improvements to a convective scale model.

Action DA/NWP 23-18 on WG members

Provide impact recent LAM study references to WG co-chairs for inclusion on the website.

2.3.12 Recommendations from the previous conference

The DA/NWP Working Group has a long list of recommendations, many of which have been retained across conferences, which were previously embedded in the working group report. The WG co-chairs have decided to take standing recommendations out into an appendix to be quickly reviewed at future meetings. The standing recommendations can be found in Appendix 2.

This conference, the majority were retained, with several discussed as described below. Post-conference, the WG co-chairs discussed with conference co-chairs and those leading WMO activities the removal of recommendations that have already been taken up by CGMS. Such recommendations have thus been removed. For recommendations where CGMS has a related action, the HLPP text is provided in Appendix 2 in italics.

Standing Recommendation DA/NWP-4 (previously 22-5) to Space Agencies

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

As part of the discussion of this recommendation it was noted that FY-3E will be launched in July 2021. It is anticipated that there will be 3 months of on-orbit tests and for the instruments that are more mature, such as the MW sounders, data will hopefully be released within the testing period. Newer instrument types, such as the scatterometer will be made available later.

~~**Recommendation DA/NWP 22-17 to DBNet providers:** Switch on the production of VIIRS cluster information for DBNet for IASI and CrIS.~~

This recommendation seemed inappropriate given that the cluster analysis is not present in the global data product. The feedback from users for DBNet data is always that it should be the same as the global data product where possible. Therefore this recommendation is dropped for now.

~~**Recommendation DA/NWP 22-22 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.~~

It is noted that NESDIS have already stopped the supply of AIRS data, so we will modify the recommendation to be to NASA only (now renumbered).

Recommendation DA/NWP-3 to NASA

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

The following recommendation has been made for several meetings in a row but has not generated any response. It is proposed to retain it for one more conference and to encourage presentation of results at the next conference:

Recommendation DA/NWP-4 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.

The following recommendation was made at the last meeting but has not generated any response. It is proposed to retain it for one more conference and to encourage presentation of results at the next conference:

- **Recommendation DA/NWP22-18 to NWP Centres:**
Evaluate IKFS-2 data.

2.3.13 AOB

Benefit of low inclination MW sounder

Forecast benefits have been reported by many NWP centres through assimilation of observations from the SAPHIR MW humidity sounder. This operates in a low inclination orbit which allows improved temporal sampling of the moisture and cloud field in the Tropics. Consequently the WG recommends continual use of a MW sounder in this orbit.

Recommendation DA/NWP-5 to Space Agencies

Following the successful use of the SAPHIR instrument, future MW missions operating on a similar low inclination orbit are recommended.

Instrument monitoring by data providers

The real-time monitoring of instrument status (ICVS, from NESDIS, for example) is invaluable for operational centres.

Standing Recommendation DA/NWP-11 to Data Providers

Develop and maintain public instrument status monitoring web pages similar to ICVS from NOAA/NESDIS.

Appendix 1: DA/NWP Working Group Standing Actions

Standing Action DA/NWP-1 on ITWG Co-chairs: To bring relevant recommendations to the attention of CGMS.

Standing Action DA/NWP-2 on DA/NWP WG members: Send any evidence of RFI to co-chairs of the RFI Technical SubGroup - Jean Pla (jean.pla@cnes.fr), Richard Kelley (richard.kelley@noaa.gov), Stephen English (stephen.english@ecmwf.int) and Nancy Baker (nancy.baker@nrlmry.navy.mil).

Standing Action DA/NWP-3 on DA/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 chairs (Benjamin.T.Johnson@noaa.gov & Marco.Matricardi@ecmwf.int).

Standing Action DA/NWP-4 on NWP centres: Continue to provide information on instrument channels assimilated and their observation errors via the working group survey spreadsheet in advance of each conference.

Standing Action DA/NWP-5 on DA/NWP WG Members: Make suggestions and corrections to the DA/NWP Working Group website.

Appendix 2: DA/NWP Working Group Standing Recommendations

Standing Recommendation DA/NWP-1 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.

Standing Recommendation DA/NWP-2 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.

Standing Recommendation DA/NWP-3 to Data Providers: Include azimuthal viewing and solar angles as appropriate in BUFR for present and future instruments.

Standing Recommendation DA/NWP-4 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.

Standing Recommendation DA/NWP-5 to Data Providers: When using PC compression, noise normalisation should be performed using the full noise covariance matrix.

[HLPP: 4.2.6 Establish together with the user community a commonly agreed approach for retrieval of Principal Component scores and associated parameters from hyperspectral infrared data, minimising information loss including the mutually acceptable update strategy for the principal component basis and to implement such an approach in a coordinated manner.]

Standing Recommendation DA/NWP-6 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.

[HLPP: 3.17 Develop best practices for operational user notifications]

Standing Recommendation DA/NWP-7 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.

Standing Recommendation DA/NWP-8 to Data Providers: Provide NedT estimates for inclusion within BUFR for microwave data.

[HLPP 4.4.2 Agree on standardised procedures to derive NedT estimates for microwave sounders, and include such estimates in the disseminated BUFR data.]

Standing Recommendation DA/NWP-9 to Data Providers: Make NedT estimates from microwave instruments available as time series on publicly available websites to enable monitoring of instrument health in near real time.

Standing Recommendation DA/NWP-10 to Instrument Developers: Pre-launch calculation of NEdT should use the same algorithm as will be used in-orbit using warm target counts variability divided by the instrument gain.

Standing Recommendation DA/NWP-11 to Data Providers: Develop and maintain public instrument status monitoring web pages similar to the Integrated Calibration and Validation System (ICVS) from NOAA/NESDIS.

2.4 ADVANCED SOUNDERS

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

Working Group members: Dorothee Coppens (Co-Chair, EUMETSAT), David Tobin (Co-Chair, SSEC/UW-Madison), Tom Atkins (NOAA), Nigel Atkinson (Met Office), Kristen Bathman (MSG@NOAA/NCEP/EMC), Alain Beaulne (ECCC), Peter Beierle (UMD), Lei Bi (Zhejiang University), Niels Bormann (ECMWF), Chris Burrows (ECMWF), Xavier Calbet (AEMET), William Campbell (NRL), Fabien Carminati (Met Office), Yong Chen (NOAA/NESDIS/STAR), Olivier Coopmann (CNRM, Université de Toulouse, Météo-France & CNRS), Stephen English (ECMWF), Reima Eresmaa (Finnish Meteorological Institute), Eric Fetzer (JPL), Evan Fishbein (JPL), Alan Geer (ECMWF), Mitch Goldberg (NOAA), Vincent Guidard (CNRM, Météo-France, CNRS), Liam Gumley (CIMSS/SSEC UW-Madison), Wei Han (JCSDA), Chawn Harlow (Met Office), Ishida Haruma (JMA), Sylvain Heilliette (ECCC), Tim Hultberg (EUMETSAT), Flavio Iturbide (NOAA), Benjamin Johnson (UCAR @ JCSDA), Jianjun Jin (NASA GMAO), James Jung (UW-Madison), Norio Kamekawa (JMA), Jeon-Ho Kang (KIAPS), Aya Kasai (JMA), Masahiro Kazumori (JMA), Rich Kelley (Alion Science), Toshiyuki Kitajima (JMA), Dieter Klaes (EUMETSAT, retired), Robert Knuteson (UW-Madison SSEC/CIMSS), Keiichi Kondo (MRI/JMA), Christina Köpken-Watts (DWD), Naoto Kusano (JMA), Bjorn Lambrigtsen (JPL), Katie Lean (ECMWF), Zhenglong Li (UW-Madison/SSEC), Agnes Lim (CIMSS/SSEC), Emily Liu (NOAA/NCEP/EMC), Haixia Liu (MSG@NOAA/NCEP/EMC), Cristina Lupu (ECMWF), Erin Lynch (GST, Inc.), Graeme Martin (UW-Madison SSEC/CIMSS), Miguel-Angel Martinez (AERMET), Vinia Mattioli (EUMETSAT), Silke May (DWD), William McCarty (NASA GMAO), Paul Menzel (UW/SSEC/CIMSS), Scott Mindock (SSEC/CIMSS), Masami Moriya (JMA), Hidehiko Murata (JMA), Nick Nalli (MSG Inc. at NOAA/NESDIS/STAR), Kozo Okamoto (JMA/MRI), Yoshifumi Ota (JMA), Luca Palchetti (CNR-IMAA), Heikki Pohjola (WMO), Joe Predina (Logistikos Engineering LLC), Chengli Qi (CMA), Indira Rani S (NCMRWF, MoES), Hank Revercomb (UW-Madison SSEC), Filomena Romano (IMAA/CNR), Kirsti Salonen (ECMWF), Noelle Scott (LMD/IPSL/ Ecole Polytechnique), Awdhesh Sharma (NOAA/NESDIS), Hiroyuki Shimizu (JMA), Bill Smith (CIMSS/SSEC), Fiona Smith (Bureau of Meteorology), Patrick Stegmann (JCSDA), Olaf Stiller (DWD), Ninghai Sun (GST), Joe Taylor (SSEC, UW-Madison), Robert (Bob) Tubbs (Met Office), Zhipeng Ben Wang (NOAA), Hejun Xie (Zhejiang University), Zhiyu Yang

2.4.1 Working Group meeting agenda: 16 June 2021

The ASWG held its working group meeting on 16 June 2021. The meeting agenda is shown below, and each of the presentations are available online at:

http://cimss.ssec.wisc.edu/itwg/itsc/itsc23/working_groups.html

ITSC-23 ASWG Meeting Agenda		
ASWG Introduction / Goals / Review of the Agenda	5 min	Co-chairs
Review of progress of action items and recommendations from the last meeting	20 min	Co-chairs/all
WMO Coordination Group for Meteorological Satellites (CGMS) High Level Priority Plan Items	5 min	Co-chairs/all
Hybrid PC approach for the hyperspectral sounder radiances Current status at EUMETSAT (dissemination and ongoing studies) Current status for CrIS	20 min	Tim Hultberg D.Tobin
Latest status of FY-3D/3E and FY-4A/4B	20 min	Chengli Qi
Presentation of the FORUM mission	20 min	Luca Palchetti
User readiness for ICI	15 min	Alan Geer
Information on NOAA future missions	30 min	Mitch Goldberg
Coming End Of Life activities IASI EOL AIRS EOL	20 min (if time permits)	Dorothee Coppens D.Tobin for S.Broberg
Open discussion, Candidate recommendations/actions	20-30 min	All
ASWG Website	5 min	
AOB		

The ASWG email list has been updated, and all ASWG participants may be reached via email with the following address: itwg_aswg@g-groups.wisc.edu

2.4.2 Planned Sensors and Data

Cloud and Sub-Pixel Information within Sounder Footprints

The meeting included a review of progress of action items and recommendations from the last meeting and discussion of needs regarding planned sensors and related data. This included a discussion on having IR+MW sensors on the same platform like it was recommended at the last ITSC, instead of having IR+imager to get the cloud information. Cloud information from collocated imager/sounder data are used by NWP centres among other methodologies, as well as other users like atmospheric composition community.

The meeting included discussion on the methodology to include cluster information from the imager in the IR FOV. The methodology of the Nuees dynamiques for the AVHRR/IASI could be used by other instruments. EUMETSAT NWP/SAF has applied that methodology to VIIRS/CrIS. The following recommendations and action were made:

Recommendation AS-1 to Space Agencies

To develop a methodology to include the imager clusters in the hyperspectral IR sounders field of view and to study different clustering technics and compare them.

Action AS-1 to Mitch Goldberg

To investigate why the VIIRS/CrIS software developed by EUMETSAT Via NWP/SAF is not used.

Recommendation AS-2 to Space Agencies (CMA)

To analyse the need of having the MERSI cloud amount and MERSI radiances coregistered with HIRAS pixels and possibly to develop the new products accordingly.

PC Reconstructed Radiances

The meeting also included a review of Recommendations and Actions regarding the availability and use of PC reconstructed radiances. Those included:

- **Recommendation AS22-10 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 AS22-8**
EUMETSAT hybrid method should be taken as the best practice to establish PC for IRS on MTG.
- **Action AS22-4 to ASWG co-chairs**
To circulate to ASWG the information to the bandwidth for the MTG IRS L1 PC dissemination as soon as it is available.
- **From CGMS**
To establish together with the user community a commonly agreed approach for retrieval of Principal Component scores and associated parameters from hyperspectral infrared data, minimizing information loss including the mutually acceptable update strategy for the principal component basis and to implement such an approach in a coordinated manner.

At the Working Group meeting, EUMETSAT presented the status of the hybrid approach development and the activities related to the use of reconstructed radiances in NWP and Atmospheric Composition (AC) user communities. The hybrid methodology is being refined at the very moment to capture all atmospheric signal to answer the AC user needs. CIMSS/SSEC reported that the hybrid approach is currently being implemented by NOAA for the CrIS products.

The action AS22-4 has been closed during the meeting.

No new actions nor recommendations have been identified. The recommendation AS22-10 should be re-conducted and becomes:

Action AS-2 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.

Updates on Chinese Satellites

Relevant recommendations from ITSC-22 included:

- **Recommendation AS22-1 to Space Agencies (CMA)**
Disseminate the HIRAS and GIIRS data 6 months after launch if possible, and not only via EUMETCAST but also to the Global User Community.
- **Recommendation AS22-2 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 AS22-3 to Space Agencies (CMA)**

FY-4B 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-4B GIIRS spectra to ~680 1/cm.

At the Working Group meeting an updated presentation from CMA was given on the status of upcoming FY-3D/FY-3E and F-4A/FY-4B. Lots of new information given, including the following points to answer the recommendations of the ITSC-22:

- HIRAS/FY-3E spectra will be available at full spectral resolution for all bands;
- HIRAS/FY-3E will continuous like the IASI spectra;
- Data of FY3E/HIRAS and FY4B/GIIRS will be disseminated 6 months after launch: in December 2021 for FY4B/GIIRS and January 2022 for FY3E/HIRAS; and
- LWIR of FY4B/GIIRS is 680-1130 cm^{-1} .

Updates on Russian Satellites

EUMETSAT provided an update that MTVZA-GY (Conical scanning imaging/sounding microwave radiometer with 21 frequencies and 29 channels) data from Roshydromet Meteor-M N2-2 satellite will be available on EUMETCast from 6 May 2021.

No information on IKFS-2 was available at the meeting.

The Action from ITSC-22 is retained:

Action AS-3 to ITWG Co-chairs

To follow the data release date, 2 or 3 months after the launch of Meteor-M N2-2 (January 2020?) and circulate the information at ASWG.

2.4.3 Next Generation Sensors and Data

NOAA Next-Generation Systems

An action from ITSC-22 was for NOAA to update the ASWG on efforts to define their Next-Gen systems, to be in place following JPSS and the GOES-R series:

- **Action AS22- 5 to Karen St Germain**
To provide information on the new NOAA trade study mission.

At the WG meeting, NOAA provided a detailed presentation on this status of this effort. For GEO, the preliminary recommended GEO-XO Architecture is:



And for the LEO plans, the presentation material indicates that the plan for the Next-Gen LEO system should be in place in a couple of years from now. Emphasis is on continuing the backbone observations in the 13:30 orbit and other application driven assets for higher temporal coverage.



Regarding these next-gen systems, the WG created the following new recommendations:

Recommendation AS-3 to space agencies

To consider LEO constellations of small satellites to improve the temporal refresh. However, the backbone of high quality stable measurements of visible, infrared, microwave, UV, established by NASA (AQUA), NOAA (JPSS), and EUMETSAT (Metop) measurements are still needed. With an observatory of at least microwave, infrared, imagery and ozone to allow continuation of climate data records in fixed stable orbits with two satellites in each orbit for intercalibration enabling continuation of climate data records, and for intercalibration of smallsats in extended orbits, as well as stable long-term observations for NWP.

Recommendation AS-4 to Space Agencies

To continue to employ the traditional longwave infrared spectral radiance measurement band on all future hyperspectral IR satellite sensors.

Recommendation AS-5 to NOAA

To more quickly develop the plan for its Next-Gen LEO mission/payloads.

Recommendation AS-6 to NOAA

To expedite the implementation of an advanced IR imaging infrared sounder for GEO-XO to assure on-orbit operations by 2030 with a goal of the mid-2020s for better coordination with other international efforts to achieve a more effective global ring

The Ice Cloud Imager (ICI) Mission

The WG meeting included an overview of the upcoming ICI mission with the following summary points and recommendation.

- ICI –to be launched 2024
 - Operational radiance measurements at 183 GHz –664 GHz on Metop-SG
 - Co-flown with Microwave Imager (MWI) and scatterometer on B-satellite
- Test data in NetCDF available now
 - **BUFR format still in preparation** (aim: this year)
- Radiative transfer modelling (e.g. RTTOV-SCATT, CRTM?):
 - Sub-mm spectroscopy, error characterisation (**ongoing EUMETSAT / Met Office study**)
 - Ice hydrometeors (**shape, orientation, polarisation, PSD**)
 - Surface emissivity (ocean, **sea-ice, snow, land**)
- Data processing:
 - Possible ECMWF approach: **Assimilate L1B radiances with superobbing (e.g. 40 by 40 km) and combine into one super-sensor with MWI**
 - Alternative possibility: **Optimal convolution onto a single FOV**; to be part of L2 processing

Recommendation AS-7 to Space Agencies

To ensure the ICI readiness.

2.4.4 Re-iterating previous high priority ASWG recommendations:

The WG also re-iterates several previous high priority recommendations:

- **Recommendation 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 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 to Satellite Agencies**

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

- **Recommendation to Satellite Agencies**
To develop, test, and implement an Infrared SI-traceable radiometric standard in space as soon as feasible.
- **Action to ITWG Co-chairs**
To re-iterate these recommendations to Space Agencies via CGMS.

2.5 INTERNATIONAL ISSUES AND FUTURE SYSTEMS

Working Group members: Peng Zhang (CMA, China, Co-chair), Niels Bormann (ECMWF, Co-chair), Mathieu Asseray (Météo France), Nancy Baker (NRL), Marylis Barreyat (Météo France), Alain Beaulne (ECCC), Brett Candy (Met Office), Xavier Calbet (AeMET), Fabien Carminati (Met Office), Olivier Coopmann (Météo France), Dorothee Coppens (EUMETSAT), Yu Deng (Alion Science and Technology), David Duncan (ECMWF), Stephen English (ECMWF), Reima Eresmaa (FMI), Evan Fishbein (NASA), Vincent Guidard (Météo France), Liam Gumley (SSEC), Dieter Klaes, Kenneth Holmlund (WMO), Jianjun Jin (NASA), Richard Kelley (NOAA), Agnes Lane (BoM), Katie Lean (ECMWF), Jin Lee (BoM), Erin Lynch (NOAA), Rohit Mangla, Jeon-Ho Kang (KIAPS), Masahiro Kazumori (JMA), Robert Knuteson (UW), Christina Köpken-Watts (DWD), Paul Menzel (SSEC), Hidehiko Murata (JMA), Roger Randriamampianina (Met No), Indira Rani (NCMRWF), Mikael Rattenborg (CGMS Secretariat), Hank Revercomb (SSEC), Fiona Smith (BoM), Hu (Tiger) Yang (UMD), Zhiyu Yang (UCAS), Biaye Younoussé (Université Gaston Berger)

2.5.1 Introduction

The ITSC-23 Working Group on International Issues and Future Systems (IIFS) met on-line on Friday 11th June 2021 to discuss actions and recommendations from ITSC-22 and new topics benefitting from coordination between agencies. The group started off by thanking Stephen English for expertly guiding the IIFS WG as co-chair during the past four meetings. Stephen English stepped down at the last meeting, and Niels Bormann is now co-chairing the group together with Peng Zhang (CMA) who remains co-chair.

Due to the on-line nature of the meeting, the IIFS had a much larger than usual attendance, with useful discussion on a range of topics regarding the evolution of the global observing system and other aspects of international coordination. The on-line nature of the meeting as well as holding the meeting before the conference nevertheless also brought about its challenges, and the usual physical WG format is considered preferable when possible.

The discussions resulted in ten new recommendations and three actions, alongside six standing recommendations.

2.5.2 Status of actions and recommendations from ITSC-22

All actions from ITSC-22 are now closed or superseded by new actions. More details on responses to previous actions can be found in slides shown at the meeting (see [meeting slides](#)). A number of past recommendations were identified as remaining valid, and these are included at the end of this report as “standing recommendations.” These will be reviewed again at upcoming meetings.

Spectrum management aspects were this time transferred to the newly revived technical sub-group on this aspect. It is expected that this sub-group will take leadership in spectrum management and Radio Frequency Interference (RFI) aspects, fielding specific topics to relevant other WGs of ITWG as required.

2.5.3 Evolution of the global observing system

Noting a number of recent and up-coming milestone launches, the group congratulated the respective agencies for these achievements, in particular:

- FY-4B (launched 3 June 2021 by CMA): First operational geostationary satellite with hyperspectral sounding capabilities. It also features the AGRI imager, a new Geostationary High-speed Imager (GHI), and other instruments.
- FY-3E (launch 5 July by CMA): First CMA LEO satellite to cover the early morning orbit.
- Arktika-M N1 (launched 28 Feb 2021 by Roshydromet): First meteorological satellite in highly elliptic orbit, carrying an IR/VIS imager, which includes water vapour channels.

FY-4B and FY-3E are of particularly strong interest to ITWG, and early evaluation and sharing of findings is encouraged. Data are expected to be available to users approximately 6 months after launch. Centres are encouraged to register [here](#) for the FY-Pioneer programme for early access to data.

For Arktika-M N1, a list of products is being defined by Roshydromet during the commissioning phase, and this will be of high interest to relevant users.

Recommendation IIFS-1 to Roshydromet

To share information on products from Arktika-M N1 with ITWG when available.

2.5.4 Review and evolution of the CGMS baseline

The CGMS baseline for passive IR and MW sounding instruments currently specifies three sun-synchronous orbits with MW sounding and hyperspectral IR, as well as slots of geostationary satellites with hyperspectral IR instruments.

Peng Zhang (CMA) summarised outcomes relating to passive sounding instruments from a recent overall assessment of the continuity of provision against the CGMS baseline (see [here](#) for the slides). In subsequent discussions it was established that with respect to the 3-orbit system resilient coverage of the morning and early afternoon orbits is well ensured by EUMETSAT and NOAA in this time-frame. CMA planning to ensure early-morning coverage beyond FY-3E is well advanced, though a moderate risk of losing coverage remains. The group highly appreciates and supports CMA's efforts towards continued coverage of the early morning orbit.

The WG considered the current CGMS baseline in the context of potential future moves towards disaggregated systems and the use of smaller satellites. For the back-bone 3-orbit constellation, high-end, high quality observations are usually assumed by users, continuing and improving on established capabilities. This 3-orbit constellation plays an important role as "reference" system for a range of applications, and it is considered important that this is maintained. The CGMS baseline is, however, not explicit regarding the expected capabilities. Hence the WG expressed the following:

Recommendation IIFS-2 to CGMS

To explicitly consider instrument capabilities and data quality as well as data provision in future updates of the CGMS baseline, particularly for the 3-orbit backbone system of LEO passive sounders which plays an important role as a reference-style system.

The WG noted that benefit has been demonstrated in NWP from passive sounding data beyond the 3-orbit CGMS baseline system. This has been recognised, for instance, in the WIGOS Vision 2040 where such systems are mentioned as additional observations.

Recommendation IIFS-3 to CGMS and the NWP community

To advance the implementation of the WIGOS Vision 2040 for passive sounding with agency commitments beyond the established 3-orbit baseline in future updates of the CGMS baseline, and to gather requirements and perform trade-offs for such additional systems.

2.5.5 Small satellites/cubesats

Constellations of small satellites/cubesats offer the potential to provide higher temporal sampling from LEO, beyond the 3-orbit CGMS baseline. In line with the previous recommendation, the WG welcomes and encourages efforts to make use of these complementary opportunities and to establish relevant requirements (incl. orbits, instrument capabilities etc.).

The WG notes, however, that experience within ITWG about such systems is very limited, particularly for operational applications, and there are concerns about achievable capabilities, calibration accuracy or stability, geolocation, lifetime, etc. Given the great potential of such systems, it is important to establish what is possible with such system. Some NWP centres are planning to assess data quality of selected upcoming missions (e.g., NRL, Météo France, ECMWF).

Recommendation IIFS-4 to NWP centres and other organisations involved in the evaluation of existing data from smaller satellites

To report on experiences with passive sounding instruments from smaller satellites at future ITSCs, including evaluations of data quality and stability, with a view towards potential future operationalization of such systems.

As there was some uncertainty about which missions exist or are planned, it was considered useful to compile a list of these with relevance to ITWG.

Action IIFS-1 on Niels Bormann

To compile a list of existing and planned small-satellite/cubesat initiatives with passive sounding instruments and circulate among IIFS members.

It was noted that near-real-time (NRT) data downlink has been an issue for some current cubesats, but this is not a limitation for cubesats in general. Agencies should be forward-looking and include NRT capabilities from the start (see Standing Recommendation IIFS-3). Available bandwidth for downlinks could be an issue, a topic to be discussed in the spectrum management sub-group.

Given shorter life-times of these satellites (especially of cubesats), efforts to accelerate data usage will be needed. It was suggested that the NWP WG consider this in an upcoming additional WG meeting after ITSC targeted at science and development questions. Commonality in the provided data could greatly help with the acceleration of efforts, hence the group formulated:

Recommendation IIFS-5 to providers of data from constellations of smaller satellites
To work towards a standardisation of downlink equipment and data protocols to ease provision of NRT capabilities.

Recommendation IIFS-6 to providers of data from constellations of smaller satellites
To work towards a common data outlay in a WMO-recognised data format to ease swift ingestion into NWP systems.

2.5.6 WMO activities and timeliness aspects

The WG noted with appreciation that the paper on “[Satellite Data Requirements for Global Numerical Weather Prediction](#)” has now been approved as a position paper by WMO, and a specific presentation by Ken Holmlund on data policy activities is included in the conference. IIFS members are encouraged to read the paper at the address provided.

The group emphasised the importance of good data timeliness for operational applications, and fully supports WMO efforts in this area (Standing Recommendation IIFS-1). The WG also welcomed the WMO plan to include information on timeliness in the OSCAR database. The group was reminded that best practices for DBNet operators can be found [here](#).

To support timeliness activities, dedicated impact studies are very useful. Such studies have been conducted in the past by JMA and will be reported at ITSC-23, but it was felt more would be useful.

Recommendation IIFS-7 to NWP centres

To conduct impact studies highlighting the benefit of good timeliness of observations, and to report on these at future meetings.

2.5.7 Review of the CGMS High-Level Priority Plan

The latest version of the CGMS High Level Priority Plan (HLPP) is now available, see [here](#).

Action IIFS-2 on IIFS members

To provide further feedback on the latest version of the HLPP to IIFS co-chairs.

The WG discussed items assigned to ITWG with relevance to the WG. On item 4.4.1 (on error propagation vocabulary and methodology), there was no further feedback beyond what was discussed at previous IIFS meetings. On item 4.4.2 (on NEdT estimates for MW sounders), it was noted that a recent paper by Yang and Yang is currently under review, and this includes comparisons of different NedT algorithms (Yang and Yang, 2021, “A New Algorithm for Determining the Noise Equivalent Delta Temperature of In-orbit Microwave Radiometers,” IEEE Transaction on Geoscience and Remote Sensing).

The group reiterated that websites with timeseries of instrument performance indicators such as the [NOAA/NESDIS ICVS \(Integrated Calibration/Validation System\)](#) monitoring are an invaluable resource for data users, including for NWP and reanalysis applications. The group would greatly appreciate such monitoring to be available from other space agencies.

Recommendation IIFS-8 to CGMS members

To provide ICVS-style instrument performance monitoring for operational instruments.

The group also reviewed other aspects of relevance to ITWG in the HLPP and suggested new items for the HLPP, reflecting areas of importance with relevant activity in the community. Regarding the HLPP section “Advance the response to the Vision for WIGOS (WMO Integrated Global Observing System) in 2040, by the implementation of new capabilities beyond the CGMS baseline,” various activities are mentioned relating to increased temporal sampling for IR sounders are mentioned, but an item on advancing MW sounding capabilities for NWP beyond the CGMS baseline is missing (see also link to Recommendation IIFS-3).

Recommendation IIFS-9 to CGMS

To include an item on establishing requirements for MW sounding capabilities beyond the CGMS baseline for NWP in the relevant section of the HLPP.

Regarding the HLPP section “Stimulate trade-off analyses for the development of future passive sounding instruments”: A previous item on trade-off studies that includes FOV-sizes for IR sounders has been closed. The group noted that such trade-off activities are still relevant and important to guide future evolution.

Recommendation IIFS-10 to CGMS

To reinstate an item in the HLPP on conducting trade-off studies regarding the benefits of spectral, radiometric, and spatial resolution of infrared sounders, taking into account aspects such as scene inhomogeneity and uncertainties in spectroscopy.

The WG acknowledged the value of CGMS best practices and welcomed the review of best practices for achieving user readiness mentioned in the HLPP. Engagement with NWP centres and other users via the CGMS SWGs (e.g., ITWG) will be important, and the CGMS secretariat confirmed that this is indeed planned.

2.5.8 Calibration aspects

The group reiterated the importance of reliable calibration for a wide range of application areas, including NWP and reanalysis. It discussed efforts to establish an in-orbit SI-traceable reference (see also Standing Recommendation IIFS-SR4), noting several planned or proposed concepts (LIBRA, CLARREO, TRUTHS, etc.).

A workshop ‘An SI-Traceable Space-based Climate Observing System’ was held by CEOS WGCV and WMO-CGMS GSICS at NPL, UK in September 2019. One outcome of the workshop is a special issue in Remote Sensing “[The Needs and Path Toward an SI-Traceable Space-based Climate Observing System](#)” which has now been published.

A whitepaper ‘SI-Traceable Space-based Climate Observing System’ is being drafted, led by Hewison, Fox, Wielicki and Kopp.

Action IIFS-3 on Peng Zhang

To circulate the workshop report to IIFS members once available.

2.5.9 Standing recommendations

The following recommendations from the previous WG meeting have been adopted as standing recommendations and remain valid:

Standing Recommendation IIFS-1 (IIFS22-5) to WMO and space agencies via CGMS

To coordinate an update of the timeliness requirements and continue to explore innovative methods, such as used by GPM, to provide global data with a timeliness that meets the new requirements, for next generation satellite programmes.

Standing Recommendation IIFS-2 (IIFS22-4) to WMO

WMO to continue to work with 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.

Standing Recommendation IIFS-3 (IIFS22-8) to CGMS

If a mission expects engagement from application areas with an NRT data requirement, budget should be allocated from the start to provide the required technical infrastructure.

Standing Recommendation IIFS-4 (IIFS21-8) 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.

Standing Recommendation IIFS-5 (IIFS22-11) to space agencies 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. Therefore to include as many centres, in particular NWP centres, in the early evaluation phase, will bring benefits both to the Space Agency and to the users, and is therefore highly desirable.

Standing Recommendation IIFS-6 (IIFS22-14) to ITWG Co-Chairs

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

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), Mathieu Asseray (Météo-France), Olivier Audouin (Météo-France), Nick Bearson (UW-Madison SSEC/CIMSS), Alessandra Moneris Belda (Bureau of Meteorology), Younouss Biaye (Université Gaston Berger), Dorothee Coppens (EUMETSAT), Geoffrey Cureton (CIMSS, UW-Madison), James Davies (SSEC, UW-Madison), Yu (Judy) Deng (Alion Science), Vincent Guidard (CNRM, Météo-France, CNRS), Liam Gumley (CIMSS/SSEC UW-Madison), Ken Holmlund (WMO), James Jung (UW-Madison), Robert Knuteson (UW-Madison SSEC/CIMSS), Agnes Lane (Bureau of Meteorology), Salvatore Larosa (CNR-IMAA), Rohit Mangla (Météo-France), Miguel-Angel Martinez (AEMET), Silke May (DWD), Paul Menzel (UW/SSEC/CIMSS), Scott Mindock (SSEC/CIMSS), Masami Moriya (JMA), Hidehiko Murata (JMA), Heikki Pohjola (WMO), Anthony L Reale (NOAA NESDIS STAR), Hank Revercomb (UW-Madison SSEC), Pascale Roquet (Météo-France), Nathalie Selbach (DWD), AK Sharma (NOAA/NESDIS), Kathy Strabala (UW-Madison/SSEC/CIMSS), Tiger Yang (UMD), Lihang Zhou (NOAA)

2.6.1 Introduction

The group was reminded of the scope of the Products and Software Working Group:

- 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.

The agenda included the following topics:

- Review of open actions and recommendations from ITSC-22;
- Status of existing software packages;
- New and future sensors and plans for supporting software;
- DBNet status and plans;
- Cloud services and cloud data distribution;
- CGMS High Level Priority Plan; and
- PSWG web site.

2.6.2 Review of open actions and recommendations from ITSC-21 and ITSC-22

- **Action PSWG21-2:** KMA and SSEC to come up with a plan to make the GK-2A software available to DB users.

It was confirmed that Hee-Jung Kang is still the contact at KMA for any enquiries about the GK-2A software. There are no plans for SSEC to be involved with software support or distribution. Because this action is now several years old, and no changes are anticipated in the near future, it was agreed to close it.

Action closed.

- **Action PSWG22-1:** Nigel Atkinson to provide Lihang Zhou with information on the VIIRS to CrIS clustering in AAPP.

VIIRS to CrIS clustering is implemented as an option in AAPP v8. The information was provided to Lihang Zhou.

Action closed.

However, the issue is not settled, as NOAA are not yet producing VIIRS radiances on the CrIS footprint as part of the operational product (even though the BUFR format has slots allocated). There does appear to be a desire from users to have this information but there are various reasons why NOAA cannot use the AAPP code. This issue has also been discussed at the NWP and Advanced Sounder working groups. A new action has been proposed:

Action PSWG-1 on PSWG co-chairs

To liaise with the ASWG and NWPWG co-chairs with the aim of agreeing a coordinated approach to the cluster analysis of VIIRS radiances on the CrIS footprint.

- **Action PSWG21-4:** Nigel Atkinson to look at the CrIS PC product and compare the implementation with that used for IASI.
Lihang Zhou reported that CrIS PC products are not being generated operationally due to lack of users' requests. PC score monitoring files are being produced. Points of contact at NOAA are A K Sharma or Murty Divakarla. It was agreed to close the action.

Action closed.

There is, however, interest in PC representation for IASI, CrIS, IASI-NG and MTG-IRS, particularly the hybrid approach being introduced by EUMETSAT. This was the subject of a discussion at the Advanced Sounders Working Group. A new action has been proposed:

Action PSWG-2 on PSWG co-chairs

To monitor developments in PC representation, liaising with the ASWG, and report back to PSWG at the next ITSC.

- **Action PSWG22-2:** SSEC (Scott Mindock) to work with NOAA to obtain and make available historical LUTs for VIIRS, ATMS, CrIS.
Scott Mindock reported that the CSPP team has worked with NOAA to improve the FTS LUT site. This site provides access to current and historical LUTs in the format that they were originally produced. The site does not provide historical LUTs compatible with the most recent version of project software. Some groups have successfully processed older datasets by modifying the effectivity dates of the current LUTs.

Liam Gumley suggested that anybody who is having issues with LUTs for historical data should contact the CSPP team, who would be happy to try to help.

Action closed.

- **Action PSWG22-3:** 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.

Lihang Zhou reported that discussions have been held with CLASS. Here is the response from Axel Graumann (NOAA CLASS): I have heard of users scripting access to CLASS data holdings in a roundabout way using the web interface in an automated fashion. However, users should be aware that there are limitations to the size of each order and number of daily orders one can place. Also, users must consider bandwidth capability to download large volumes of data within a 96-day lifespan of ordered files delivered to its ftp server. **Action closed.**

It was noted that CLASS is planning to move to the Cloud. The following web site describes its Big Data Program datasets:

<https://www.noaa.gov/organization/information-technology/list-of-big-data-program-datasets>

Nathalie Selbach reported that the CM-SAF has some experience at retrieving large amounts of data from CLASS and agreed to test the new functionality:

**Action PSWG-3 on Nathalie Selbach, and others in PSWG who are able to do so
To test new NOAA/CLASS access options, including cloud access, and report back to PSWG.**

- **Action PSWG22-4:** Lihang Zhou to circulate a link to the NOAA 90-day rolling archive.
The archive is here: <ftp://ftp-jpss.avl.class.noaa.gov>. It contains a 90-day archive of a selection of Suomi-NPP and NOAA20 products. Note also that there is a tutorial linked from the CLASS home page that gives further details on data access.
Action closed.
- **Action PSWG22-5:** PSWG co-chairs to ask EUMETSAT for an update on the feasibility of providing ASCAT processing software to DB users.
An update was received from Stefanie Linow who is in charge of ASCAT processing at EUMETSAT: “I’m aware of occasional requests to release the ASCAT L1 processor. In principle I would support this, but we have some licensing issues which prevent the distribution. For this reason, we are not planning to release the L1 ASCAT processor. I can confirm that there are plans to provide software for the local DB users for the EPS-SG instruments.”
Action closed.
- **Action PSWG22-6:** PSWG co-chairs to update the group web page by next ITSC, assuming Wordpress is implemented by CIMSS as planned.
The implementation of Wordpress at CIMSS has been delayed.
Action remains open. See agenda item 8.

The group then reviewed the recommendations from ITSC-22. Many of these concern best practices and do not need to be repeated in this report. Several of them are now reflected in the new document *CGMS Agency Best Practices in support to Local and Regional Processing of LEO Direct Broadcast data* which is available from the Publications tab at <https://www.cgms-info.org/>.

Updates were provided on the following recommendations from ITSC-22:

- **Recommendation PSWG22-5** concerning test data for EPS-SG and MTG. Test data are now available from the EUMETSAT web site. We expect that more datasets will be added as the programmes progress.
- **Recommendation PSWG22-6** “when designing software, keep DB users in mind from the outset in order to minimise costs at the user end.” This has been followed in ESA’s Arctic Weather Satellite mission planning, see details in section 4.
- **Recommendation PSWG22-7** concerning coverage and latency of CrIS. Liam Gumley explained that CSPP SDR software requires 9 CrIS granules in order to process the central granule. Tests have been done on fewer granules (3, 5, 7) but some differences in the radiances were found with respect to global data. Therefore it has been decided not to proceed with a change until NOAA have checked the impact on products.
- **Recommendation PSWG22-8** concerning AMSR-2 L1 software for the DB community. The software is only available to NOAA partners. It was also pointed out that the DB transmission from GCOM-W1 is only switched on over certain parts of the world. Nevertheless, Kathy Strabala reported that the IMAPP team does still get requests for the AMSR-2 software. A new recommendation was proposed:

Recommendation PSWG-1 to NOAA, JAXA and the CSPP team

To continue exploring ways in which the AMSR-2 level 1 software and direct broadcast transmission availability could be shared with DB users.

- **Recommendation PSWG22-10** concerning protection of frequencies used in DB reception. Richard Kelley confirmed that downlink frequencies are in the scope of the newly reconstituted Technical Subgroup on frequency protection. This is currently particularly relevant to planning of SmallSat missions.

2.6.3 Status of existing software packages

CSPP LEO

Recent developments:

- GCOM-W1 AMSR-2 GAASP Microwave Retrieval Software.
- The NOAA Unique Combined Atmospheric Processing System (NUCAPS) Hyperspectral Sounding Retrieval Software is now the *Hyper-Spectral Enterprise Algorithm Package (HEAP)*.

The next version of CSPP SDR software will include support for OMPS and also preliminary support for JPSS-2 (NOAA-21). Full support for JPSS-2 will be in the second half of 2022.

All new versions will be built on 64-bit CentOS 7.

AAPP and MWIPP

These packages are being extended to support EPS-SG. More detail will be in the talk 3.01 by Nigel Atkinson.

FY-3 processors

No update from CMA, but it is expected that software will be made available to support FY-3E (due for launch in July 2021).

CSPP GEO

Information is available at <https://cimss.ssec.wisc.edu/csppgeo/>.

The US still does not have a hyperspectral sounder in GEO orbit, but there are proposals to include one in the next generation NOAA system.

GOES-18 is due for launch in December 2021 and will be supported in CSPP Geo software as soon as possible, anticipating an accelerated commissioning and transition to the operational GOES-West satellite.

Graeme Martin advertised the CSPP Geosphere web site: <https://geosphere.ssec.wisc.edu> which is running in real-time at SSEC.

IMAPP

Kathy Strabala reported that the IMAPP project has once again received funding: see <https://cimss.ssec.wisc.edu/imapp/>. The website and several of the software packages have been updated. The Aqua and Terra spacecraft have the potential to operate until at least 2025.

There is a new version of the IDEA-I software to produce trajectories of ozone and carbon monoxide. This now includes facilities to create animations.

MODIS level 1 software will be packaged inside a Singularity wrapper.

2.6.4 New and future sensors and plans for supporting software

NOAA-21

CSPP has been funded to support NOAA-21.

FY-3E and FY-4B

The FY-4B satellite was launched on 2nd June 2021 and it is hoped that data will be available before the end of 2021. Ken Holmlund informed the group that interested users can register to receive early access to data for FY-3E and FY-4B, at <http://www.nsmc.org.cn/NSMC/project/pioneer/index.html>.

EPS-SG software

Nigel Atkinson reported that software packages to process MWS, METimage, IASI-NG, MWI, ICI and SCA are being procured by EUMETSAT. They will be distributed by the NWP SAF.

We understand that source code will be available, but it is not known yet whether users will have to compile the software themselves or whether binaries will be provided. This was the subject of some discussion. Some users would like the software to be “ready to run” binaries. But other users prefer the option to build from source. Scott Mindock pointed out that distribution of only binaries constrains the processor architecture: this will not necessarily be x86 in the future. In general, any developments that make it easier for non-experts to install the software are to be commended.

Recommendation PSWG-2 to software providers

Where possible, offer their software with a choice of either pre-built binaries or source code.

Recommendation PSWG-3 to software providers

For software that will be built from source by the user, list recommended versions of required external (COTS) libraries.

Arctic Weather Satellite (AWS)

AWS is an ESA SmallSat mission containing a microwave sounder (50 to 325 GHz). A prototype satellite is due to be launched around 2024, with a future constellation being considered. Direct broadcast planned to be available at L-band. ESA have agreed to include DB software in its mission specifications. The NWP SAF have included support for AWS software in their proposal for the next phase of the NWP SAF (CDOP-4).

GEO-XO

See <https://www.nesdis.noaa.gov/GeoXO>. The project is still in a planning phase and no decisions have yet been made about whether there will be direct broadcast at full resolution. Cloud distribution is being actively discussed.

2.6.5 DBNet status and plans

DBNet continues to evolve as a means of providing low-latency sounder data for NWP. Since the last ITSC, four stations have started to be set up in Africa (Kenya, Niger, Gabon, South Africa). This is an initiative of the South African Weather Service, supported by EUMETSAT. Test data are flowing from South Africa to the NWP SAF, for monitoring.

There is a move to include microwave imagers in DBNet. EUMETSAT are already distributing EARS-MWRI operationally and are planning a regional service for EPS-SG. These are rather large datasets if transmitted at full resolution; it is important to ensure that data volumes are manageable for DBNet.

It can be challenging to upgrade station hardware to support future missions. It is known that JPSS requirements are unlikely to change much in the near future, but EPS-SG is a major change from EPS and will require new hardware (e.g., demodulators). Funding can be a major issue. It is felt that technical requirements are generally understood by the system vendors, so the vendor should be the first point of call if specific information is needed (e.g., dish sizes). CGMS are well aware of these issues, so no particular recommendation is needed from PSWG at this time.

Some DBNet regions are planning a move to centralised processing in the Cloud. This was discussed further in item 6.

2.6.6 Cloud services and cloud data distribution

The costs of cloud services were discussed. Charging is generally based on server footprints, with different cloud providers having different charging structures. When considering hosted processing, users should look for efficiencies and make use of tools to analyse metrics such as disk usage. Software should not, in general, be tailored to suit a single cloud provider.

Downloading data from the cloud does incur costs, but agreements are being drawn up by e.g., NOAA and NASA to ensure that end users would not have to pay. It is important that end users continue to have free access to essential meteorological data.

EUMETSAT are setting up a pilot service in which processing is being moved to virtual machines in the same location as the data.

Recommendation PSWG-4 to agencies

Costs to users should be considered when migrating software and data distribution to the cloud.

Recommendation PSWG-5 to agencies

Users should continue to have free access to satellite data.

Recommendation PSWG-6 to software providers

To provide and test software in a cloud-ready format.

Related to this is the issue of making use of containers, to ensure consistency of operating systems, libraries, etc., and as a first step toward running software in the cloud. This is not necessarily straightforward and there can be a steep learning curve to develop the expertise to set up containers. For some centres (e.g. Met Office) the developers do not have access to an Admin account, which limits what can be done: Singularity requires Admin privilege to create containers but not to run them, while Podman has no Admin requirement. Jim Davies reported that the CSPP team has experience of working with containers and is actively working in the area. Scott Mindock has packaged the SDR in several containers.

Action PSWG-4 on CSPP and IMAPP teams

To share UW/SSEC/CIMSS experiences on working with containers (Docker, Podman, Singularity), including lessons learnt, via the PSWG web site.

The question was raised as to whether any users are reliant on Windows. Kathy Strabala confirmed that there are indeed some users who rely on Windows for processing, analysis and visualisation. The “DB Virtual Machine” is not currently working, but SSEC/UW/CIMSS plan to reinstate it soon. Jim Davies has run IDEA-I as a container inside a VM on Windows.

Action PSWG-5 on CSPP and IMAPP teams

To provide information on running Linux packages in Windows, via the PSWG web site.

2.6.7 CGMS High Level Priority Plan (HLPP)

The CGMS 4-year rolling priority plan is available from the About tab at <https://www.cgms-info.org/>.

The items in the current CGMS HLPP that are most relevant to the PSWG were shared with the meeting. The ITWG co-chairs would like to gather information on progress against these items, as well as suggestions for new recommendations.

It was pointed out the *CGMS Agency Best Practices in support to Local and Regional Processing of LEO Direct Broadcast data* document referred to in Section 2 is particularly relevant to this group, and to the HLPP.

Action PSWG-6 on PSWG co-chairs

To provide feedback on the High Level Priority Plan and CGMS Best Practices document to ITWG co-chairs by end 2021.

Progress was noted against the following items:

1. *2.3.2 Facilitate the transition to new LEO direct broadcast systems (JPSS, FY-3, Meteor-M, Metop-SG):* Information related to JPSS and Metop-SG has been shared with the direct broadcast community by NOAA and EUMETSAT. Plans for software have been shared, and further presentations will be made during the course of ITSC-23.
2. *2.3.3 Advance the implementation of the CGMS Agency Best Practices in support to Local and Regional Processing of LEO Direct Broadcast data for operational satellites:* the Best Practices document referred to in Section 2 is particularly relevant to this group, and to the HLPP.
3. *4.3 Foster the continuous improvement of products through validation and inter-comparison through international working groups and SCOPE-type mechanisms, and 4.3.3 Conduct an intercomparison study between the different methods to derive level 2 data from infrared hyperspectral sounders, recognising that there are several software packages available that utilize AIRS/IASI/CrIS data.* Tony Reale reported on the NPROVS intercomparisons, and a presentation will be made in Session 3 of the conference. Paul Menzel advertised the poster by Eva Borbas that includes the results of HIRS and MODIS comparisons from 2003 to 2013.

Action PSWG-7 on Paul Menzel and Tony Reale

To send a few sentences summarising their validation studies to the PSWG co-chairs, for inclusion in High Level Priority Plan feedback.

Action PSWG-7 was completed during the conference, with input from Paul and Tony being received, see *PSWG Appendix*.

2.6.8 PSWG web site

After a delay of several years, SSEC are now in a position to look at getting Wordpress implemented for ITWG working groups. Leanne Avila is setting this up.

There is already an html document on the site related to software packages, and it was agreed that this document should be transferred to the new format and updated. The suggestion was made to include a contact for each package, where appropriate. Another important document will be the “best practices” document on cloud processing and containers (see section 6).

Action PSWG22-6 remains open, and covers the porting activity that should now be feasible between ITSC-23 and ITSC-24.

PSWG Appendix: Input received in fulfilment of action PSWG-7

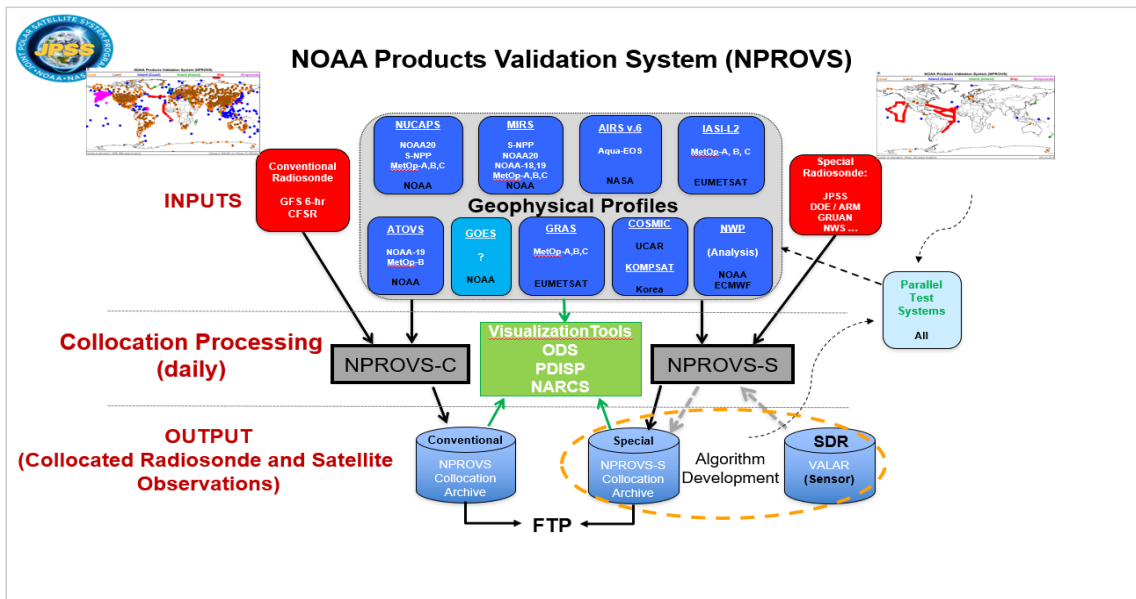
From Paul Menzel

Tropospheric moisture records from HIRS, MODIS, and VIIRS plus CrIS are being compared at UW/SSEC in an ongoing effort. These include total column precipitable water vapor (TPW) as well as integrated high (UTH), mid, and low layer tropospheric precipitable water vapor that are derived using infrared spectral bands in CO₂ and H₂O absorption bands (fusion with CrIS has recently added these bands to VIIRS) plus IR window bands. A statistical regression has been developed from an atmospheric profile database that consists of geographically and seasonally distributed radiosonde, ozonesonde, and ECMWF reanalysis data. TPW and UTH are determined for clear sky radiances (and brightness temperatures, BTs) over land and ocean both day and night at 1 deg spatial resolution with monthly average values for one of four possible time periods daily (night before and after midnight and day before and after noon), compiled for the operational months of each satellite. The regression coefficients are generated using calculated synthetic radiances and the matching atmospheric profile. The regression seeks a “best-fit” atmospheric profile that is computed using least squares methods applied to actual measurements; integration over the total column yields the TPW water and integration from 400 to 10 hPa gives the UTH. The Aqua MODIS and S-NPP VIIRS equator crossing time have been maintained at 13:30 Local Time (LT); HIRS on NOAA-16, -18, and -19 cross from 14:00 to 15:00 LT during their operational lifetimes. In a poster presented by Borbas et al. at ITSC23, VIIRS plus CrIS fusion products are compared to MODIS for one year in 2017 and HIRS and MODIS are compared from 2003 to 2013.

From Tony Reale

The NOAA Products Validation System (NPROVS) has been operating at NESDIS Office of Satellite Applications and Research (STAR) since 2008. The objective was to provide a common interface for assessing operational sounding products developed at STAR (ATOVS, DMSP, MiRS) against global conventional radiosonde (and dropsonde) observations serving as a common baseline; previously each product suite included a separate system for collocation with radiosondes creating artificial (perceived) differences. NPROVS also included EUMETSAT operational soundings from IASI (MetOp-A) and GNSS Radio Occultation (RO) observations (COSMIC-1) from UCAR. In 2012, NPROVS was expanded to include hyperspectral sounding products from Aqua-AIRS (v6.1) and experimental NOAA Unique Combined Atmospheric Processing System (NUCAPS) product suites. In 2013, a major expansion to access Special Radiosondes, typically not available conventionally, including JPSS funded dedicated radiosondes (at 3 ARM sites) and “fully characterized” observations from the GCOS Reference Upper Air Network (GRUAN); referred to as NPROVS Special. An agreement between STAR and GRUAN to “reference-process” the JPSS dedicated radiosonde created the sweetest fruit for assessment, namely, the dedicated and fully characterized reference radiosonde observation. Further expansions of the product suites including Metop-B, Metop-C and COSMIC-2 followed and GNSS-RO from KOMPSAT (Korea) were integrated by 2019. Currently, over 20 product (and Test) suites are accessed across NPROVS providing “one-stop shopping” for consistent, reliable inter-comparisons of national (US) and international sounding product suites. NPROVS also includes graphical/analytical applications (JAVA) for inter-comparing and assessing (including enterprise assessment) across the multiple (user selected) satellite product suites. Graphical applications and collocation datasets (back to 2008) are available to users (binary

and netCDF), please visit our web site at <https://www.star.nesdis.noaa.gov/smcd/opdb/nprovs/>.



3. TECHNICAL SUB-GROUP REPORTS

3.1 RADIO FREQUENCY INTERFERENCE

Web site: <http://cimss.ssec.wisc.edu/itwg/groups/frequency/>

Working group members: Rich Kelley (Co-Chair,), Nancy Baker (Co-Chair, NRL), Stephen English (Co-Chair, ECMWF), Jean Pla (Co-Chair,), Tom Atkins, Roger Oliva Balague, Mike Banks, Niels Bormann, Nico Cimini, Judy Deng, Vincent Guidard, Liam Gumley, Erin Jones, James Jung, Norio Kamekawa, Jeon-Ho Kang, Masahiro Kazumori, Keiichi Kondo, Christina Köpken-Watts, Paul Menzel, Hidehiko Murata, Indira Rani, Mikael Rattenborg, Hiroyuki Shimizu, Ninghai Sun, Emma Turner, Tiger Yang, Mohammed Zomorodi

3.1.1 Introduction

Liam Gumley welcomed all participants to the ITSC23 Radio Frequency Interference Technical Subgroup Meeting. Stephen English introduced the agenda, which was agreed upon, with no AOB proposed. Participants were invited to introduce themselves in the chat, along with their motivation for participating. Motivations included:

- To ensure the links between this group and the CGMS activities on Frequency Coordination.
- What we can do to monitor occurrence of RFI and its impact on applications such as NWP and climate, as well as remote sensing applications in general.
- How RFI impacts relate to spectral response functions.
- Discuss what this group can do in general to address spectrum issues for operational and research satellite sounding missions.
- The impact of RFI on the reliable downlink of real-time satellite data in X-band and L-band.

As this meeting was re-launching the TSG there was not time to address all these issues, but they will be addressed in future TSGs.

3.1.2 Report to the group of relevant outputs from WRC and Plenipotentiary ITU Conferences

Jean Pla summarized key outcomes of WRC-19, which was happening close to the same time as ITSC-22, and ITU conference.

3.1.3 Identify ITWG RFI TSG POCs in key international and regional groups

Jean Pla and Nancy Baker presented lists of key relevant groups. For many, ITWG has clear contacts: Jean Pla and Judy Deng for 7B, 7C and 7D; Jean Pla for CEPT and WP5D, Mike Banks for ET-RFC and EUMETFREQ; Mohammed Zomorodi for APT; Nancy Baker for NAS/CORF, FCC and US WP7C; Mikael Rattenborg for CGMS. However, other organizations such as CITELE were not covered. It was agreed that it would be useful to have a list of key groups, along with their purpose/mission, identify ITWG members responsible for that link, and a diagram showing the interrelationship between all of these groups, and the flow of decision-making processes. In addition to those groups listed above, this list includes, IPWG, ISWG and indeed all CGMS Science Working Groups, as well as spectrum activities as space agencies and NMHSs. All TSG members are encouraged to consider potential Points of Contact. Stephen English agreed to identify contacts within the IPWG and IESWG and to assess to what extent the CGMS science WGs would wish to coordinate in this area.

Action RFITSG-1 on Stephen English

To contact IPWG and IESWG co-chairs to discuss possible coordination on spectrum matters.

3.1.4 Appoint ITWG RFI web coordinator to coordinate RFI-related material with WG

It was noted that the RFI material on the ITWG has not been updated for many years, especially on the TSG pages. Some material is still of value, but some is out of date and superseded by newer documents. The TSG agreed it would be best to have a named individual responsible for reviewing and updating information provided by TSG members, working closely with the UW/SSEC team. Rich Kelley reported he was aware of a possible volunteer, and as no other names were suggested, Rich agreed to find out if this person is willing to serve ITWG/TSG in this role.

Action RFITSG-2 on Rich Kelley

To discuss with potential webpage manager and inform TSG of outcome.

It was agreed the webpage should have these elements:

- Clear description of the process for ITWG members to follow if concerned or RFI suspected, including points of contact in ITWG, and how to find points of contact in their country.
- Clarity on the consultation process for WRC and non-WRC issues, and how ITWG can support Spectrum Managers. This will provide a guide for ITWG members.
- List of issues currently under discussion relevant to ITWG (see agenda item 5 below)
- Up to date information
 - List of key groups, what they are for, who is linking to them within ITWG, if anyone
 - Links to key documents in force now (e.g. Radio Regulations, WRC outcomes, ITU-R documents).
 - Links to key consultation workshops and fora – issues and outcomes
 - Links to studies / talks / papers from ITWG members
 - Links to studies / talks / papers from the wider community

3.1.5 Identify WRC-23 and future WRC items in WMO / USA position papers of interest to ITWG and identify ITWG WGs that may have an interest in each

Rich Kelley briefly introduced the major agenda items for WRC-23, noting that he would provide an update on ITU-R Resolutions Pertaining to EESS (passive). The key passive frequencies of concern appear to be the bands at 18.7 and 36.5 GHz. It was agreed it would be valuable for the TSG webpage to have an issues list (both WRC (see web item above)).

Mikael Rattenborg noted that the CGMS has produced a list of key items and encouraged the ITWG TSG to review and comment.

Action RFITSG-3 on Mikael Rattenborg

To provide CGMS document and all TSG members to comment.

3.1.6 Identify non-WRC issues of interest to ITWG, and identify ITWG WGs that may have an interest in each

Jean Pla introduced non-WRC items. There was a discussion about small satellites, including downlink and command and control spectrum requirements. It was agreed this is an area of serious concern for ITWG in addition to the concern over passive bands. It was agreed ITWG needs better information on the level of threat here, and the potential solutions. It is understood the space agencies are already considering this carefully (e.g., EUMETSAT), and it was agreed to ask EUMETSAT for information that may guide ITWG to support Space Agencies more effectively regarding these concerns.

Action RFITSG-4 on Stephen English

To ask Markus Dreis (EUMETSAT) to provide information to the TSG.

3.1.7 New IEEE Standard from IEEE SA just starting, and chaired by Roger Oliva

Roger Oliva presented an important new initiative under his leadership for a standard on RFI under the IEEE Standards Association. This will improve reporting and sharing of information about RFI. The group has only just been formed and had its first meeting, which was mainly procedural. Roger will continue to provide information directly to ITWG, or via Stephen English who is a member of the IEEE group. The group agreed this is a very valuable and important development.

3.1.8 Discussion on status of development of detection for low levels of RFI in bands of interest to ITWG, with possible reports/recommendation on CGMS HLPP (High Level Priority Plan) item for this, esp. at 24 GHz or for the band 86-92 GHz

This was briefly discussed. Roger Oliva informed the group of the work being done by his company for ECMWF and ESA for L-band, where a potential extension to higher frequencies (e.g. 24 GHz) has been identified. This approach would allow enhanced detection by looking at aspects such as the spatial coherence and has the advantage of being NWP independent, so it could be used in the ground segment of a space agency, and provide additional protection to monitoring and detection by users (e.g., at NWP centers). Additionally, Stephen English informed the group that ECMWF are talking to ESA about bespoke NWP-based monitoring and detection, but these discussions are at a very early stage. Stephen English noted that false alarms will be minimized and confidence of detection will be higher if multiple groups are monitoring and sharing monitoring results. There is therefore a strong case to be made to coordinate efforts for RFI monitoring, to ensure ease of sharing information. He asked if any other centres are considering bespoke RFI monitoring and detection. No centre reported that they are, but an action remains open to share information.

Action RFITSG-5 on all TSG members

To share information via the mailing list on plans for enhanced RFI monitoring and detection.

Stephen English also advertised the RFI workshop that will be held at ECMWF in February 2022, as it will be an excellent opportunity to share plans, as well as learn from other communities (Radio Astronomy, Land Surface). The details of this workshop will be confirmed soon and shared with the ITWG TSG mailing list (itwg_rfi_tsg@g-groups.wisc.edu).

There was a discussion on what reports already exist on RFI, in addition to the Draper paper already available on the NWP WG RFI pages. Nico Cimini helpfully provided a number of links:

- Mohammed et al 2019, <https://doi.org/10.1109/TGRS.2019.2911290>
- Draper and de Matthaëis 2019, <https://doi.org/10.1109/IGARSS.2019.8898054>
- de Matthaëis et al 2019, <https://doi.org/10.23919/RFI48793.2019.9111824>
- Johnson et al 2020, <https://doi.org/10.1109/JSTARS.2020.2978016>

The TSG members agreed to share information on published and unpublished RFI information via the mailing list (itwg_rfi_tsg@g-groups.wisc.edu).

Action RFITSG-6 on all TSG members

To share information published and where possible unpublished, via the mailing list, on recorded RFI of relevance to ITWG.

3.1.9 Summarise key issues for each WG (NWP, AS, Climate, Products, RT, International)

The issues related to RFI have the potential to affect applications within all ITWG working groups. Passive microwave observations are particularly vulnerable to RFI, due to the intrinsically weak nature of the signal being observed. As the accuracy of Earth System Modeling and Prediction (NWP/Climate) increases, we increasingly seek to minimize the errors in the various components, including (but not limited to) atmosphere (up through mesosphere), ocean, sea-ice (cryosphere) and land.

These Earth System Prediction improvements are supported and complemented by simultaneous improvements in satellites (Advanced Sounders), observations (Products) and radiative transfer models (RT).

The radio regulations are both international and domestic, and are ultimately governed by international treaty (International Issues). There are ever increasing commercial demands for radio frequency usage, with increasing pressure on the higher frequencies for increased bandwidth.

These mutual concerns among all ITWG working groups motivate the increased need for spectral sharing and coordination. It is difficult to reverse regulations and recover spectrum when passive services are negatively impacted.

Note Key documents can be posted on the ITWG website at http://cimss.ssec.wisc.edu/itwg/itsc/itsc23/working_groups.html

3.1.10 Summary of issues to communicate to CGMS and to WMO/ET-RFC

Low level rfi

- ITSC members should develop and publish detection techniques. Discussion on status of development of detection for low levels of RFI in bands of interest to ITWG, with possible reports/recommendation on HLPP item for this, esp. at 24 GHz or for the band 86-92 GHz
- This was briefly discussed. Roger Oliva informed the group of the work being done by his company, ECMWF and ESA for L-band, where a potential extension to higher frequencies (e.g. 24 GHz) has been identified. This is to allow enhanced detection by

looking at aspects such as the spatial coherence and is NWP independent, so that it could run in the ground segment of a space agency and provide additional protection to monitoring and detection by users (e.g., at NWP centers). Also Stephen English informed the group ECMWF are talking to ESA about bespoke NWP based monitoring and detection, but these discussions are at a very early stage. Stephen English noted that false alarms and confidence of detection will be higher if multiple groups are monitoring and sharing monitoring results. There is therefore a strong case to coordinate efforts for RFI monitoring, to ensure ease of sharing. He asked if any other centres are considering bespoke RFI monitoring and detection. No centre reported that they are, but an action remains open to share information.

Smallsats (Nanosats, Cubesats and other small to moderate sized platforms)

- It was agreed this is an area of serious concern for ITWG in addition to the concern over passive bands. It was agreed ITWG needs better information on the level of threat here, and the potential solutions. It is understood the space agencies are already considering this carefully, e.g., EUMETSAT, and it was agreed to ask EUMETSAT for information that may guide ITWG to support Space Agencies more effectively on this question.
- Current passive microwave satellites are effective but expensive and take a long lead time to be brought into operations. Smallsats have quick launch windows but is the ground system robust enough to handle the data?

3.1.11 Discussion of frequency of TSG meetings; should they be held with each ITSC or more frequently?

It was agreed that the key dates for spectrum matters do not always align with the timeframe of ITSCs, so it would be useful for the TSG to meet independently and more often than just at ITSCs. It was agreed that December 2021 would be the ideal timeframe for a short update meeting. It was noted that the next ITSC is probably to be held very late in 2022.

Further information is included in the presentation from Rich Kelly on WRC-23 issues (<http://cimss.ssec.wisc.edu/itwg/itsc/itsc23/presentations/oral.1.01.kelley.pdf>) and TSG issues (<http://cimss.ssec.wisc.edu/itwg/itsc/itsc23/presentations/ITWG%20RFI%20TSG%2018%20June%202021.pdf>).

3.2 RTTOV/CRTM

Working group members: James Hocking (Co-Chair, ?), Benjamin Johnson (Co-Chair, ?), Mathieu Asseray, Marylis Barreyat, Eva Borbas, Chris Burrows, Philippe Chambon, Ming Chen, Nico Cimini, Hui Christophersen, Cheng Dang, Yu (Judy) Deng, Di Di, Stephen English, Evan Fishbein, Larry Flynn, Victoria Galligani, Donatello Gallucci, Stephanie Guedj, Vincent Guidard, Liam Gumley, Wei Han, Ishida Haruma, Sylvain Heilliette, Jianjun Jin, James Jung, Bryan Karpowicz, Rich Kelley, Robert Knuteson, Keiichi Kondo, Christina Köpken-Watts, Hari Prasad Kottu, Jean-Marie Lalonde, Bjorn Lambrigtsen, Salvatore Larosa, Emily Liu, Cristina Lupu, Erin Lynch, Rohit Mangla, Miguel-Angel Martinez, Silke May, Jana Mendrok, Stefano Migliorini, Scott Mindock, Kozo Okamoto, Indira Rani S, Hank Revercomb, Filomena Romano, Pascale Roquet, Benjamin Ruston, Roger Saunders, Mathias Schreier, Noelle Scott, Patrick Stegmann, Olaf Stiller, Christina Stumpf, Stephen Tjemkes, David Tobin, Emma Turner, Jerome Vidot, Zheng Qi Wang, Tiger Yang, Zhiyu Yang

James presented an overview of planned RTTOV developments. The latest major update, v13.0, was released in autumn 2020, and minor version updates (v13.1, v13.2) will follow in autumn 2021, and autumn 2022. The next major update, v14.0, is planned for spring 2024.

Basic RTTOV support for UV sensors will be introduced in v13.1 with a view to improving this capability in future releases. It is expected that the new v13 optical depth prediction will work well, but updates to the predictors and support for additional variable gases will be considered for v13.2 if necessary. The existing Rayleigh single-scattering treatment is likely to prove inadequate, so a parameterisation for Rayleigh multiple-scattering is a candidate for v13.2. Sea surface reflectance in the UV is already supported and extending the land surface BRDF atlas will be considered for v13.2 or v14. The existing cloud optical properties provided with RTTOV can be extended to the UV. Aerosol properties will not be supplied initially, but this will be reviewed for a future release, and users can generate their own Mie properties using the tool supplied with RTTOV. Initially only the slower DOM solver will be supported in the UV (optionally including full Rayleigh multiple scattering), but fast cloud simulations will be supported by MFASIS in v13.2.

The MFASIS fast visible cloud solver is being developed to improve the treatment of mixed phase clouds and to support near-IR channels at 1.6 microns in v13.1. A neural-network-based version is in development for v13.2. This offers benefits over the existing look-up table approach by allowing additional input parameters while maintaining accuracy and speeding up the model by an order of magnitude. In addition, the NN coefficient files are far smaller than the look-up table files.

RTTOV supports Hamming apodised MTG-IRS radiances based on the latest channel specifications. EUMETSAT are currently assuming NWP users will want Hamming apodised radiances, so anyone who requires “lightly” apodised MTG-IRS radiances should raise this (for example through the NWP SAF).

RTTOV also has coefficients for the proposed far-IR FORUM mission, and work is planned to improve treatment of cloud scattering and surface emissivity in the far-IR in future releases.

James went on to describe some of the plans for RTTOV v14, which will be a very significant update to the RTTOV model. This includes unifying RTTOV with RTTOV-

SCATT, the associated microwave scattering model. Part of this unification implies changes to the way RTTOV interprets input profiles to be more consistent with the representation of the fields in NWP models. This leads to changes in simulated radiances, and RTTOV v14 will not be able to replicate v13 radiances. RTTOV will no longer allow an arbitrary surface pressure: this will always be assumed to lie on the bottom input pressure level. RTTOV v14 will fully integrate the microwave scattering within RTTOV in the same way that IR scattering is already supported. Ultimately this will improve spectral consistency in terms of solvers and optical properties.

Numerous other updates are planned for v14 including support for fully polarised simulations, updates to the Python/C++ wrapper, improved performance on vector architectures (e.g., NEC), and various technical improvements in the code (better subroutine and variable naming, improved consistency, code cleaning). It is also planned to remove the solar single-scattering solver.

Ben presented on recent and planned developments in CRTM. These included: CRTM version 2.4.0, which supersedes the never released v2.3.1. CRTM v2.4.0 was released October 28, 2020. It supports the following new features:

- Support for netCDF4 file format reading: CloudCoeff.nc4 and AerosolCoeff.nc4;
- OpenMP optimization (vs. profiles);
- Experimental Cloud Coefficient tables (see `fix/CloudCoeff`) in binary and netcdf4 formats;
- Added 81 regression and 4 unit tests, see `README.md`;
- Updated: CMAQ-based (v4.x) Aerosols and Radiance/AOD simulation; and
- Improved loop-level performance: 4 to 5 times native improvement by optimizing loops.

Additionally, multiple bug fixes vs. v2.3.x have been implemented; see the release notes for a detailed list of bug fixes.

Support for multiple new sensors added: –EON MW, Sentinel3a SLSTR, Meteosat-11 Seviri. GOES-17 ABI 81K fix, Metop-C: AVHRR, IASI, SMAP/SMOS, TEMPEST-D, MLCOMS.v2, JPSS-2 VIIRS, GEOKOMPSAT-2a AMI, Metop-SG-A1 MWS, FY4a-GIIRS.

Plans for CRTM version 2.4.1 were presented as well. It is expected to be released in Fall 2021.

CRTM v2.4.1 is a minor release with the following new features and bug fixes vs. v2.4.0:

- OpenMP extended, now supports both channel and profile loops (D. Abdi);
- Fix: Snow cover emissivity when bad/missing observation data present (M. Chen);
- Updates to compiler-specific configuration files;
- Updated support for Aerosol Coefficient files: CMAQ, GOCART, NAAPS (C. Dang);
- Implemented two new aerosol coefficient look-up tables based on GOCART-GEOS5 and NAAPS aerosol specifications (New aerosol species: nitrate and smoke) (C. Dang);
- Binary files / netCDF files hosted via git-LFS, gzipped for storage / speed; and
- Test codes updated to reflect/test new coefficient files.

Sensors added in v2.4.1:

1. Corrections to internal sensor naming issues of abi_g17-81K;
2. IASI-NG (testing), TROPICS_sv1_srf_v1, OMS GEMS-1/2;
3. v2 ACCoeff and SpcCoeff for Metop-C / AMSU-A / MHS;
4. ATMS-NG (in progress); and
5. GOES-T ABI (testing/STAR).

CRTM v2.4.1 serves as the baseline for CRTM v3.0, which expands the scalar radiance capability to full stokes polarization support. CRTM v3 is a long-term development of the CRTM, requiring many changes to the code architecture, supporting tables, testing framework, and user interfaces.

The first areas of focus are the core solver implementation and evaluation beyond what's already been tested. Optimization will follow after the initial evaluations are completed. In the meantime, the CRTM community has been focusing on updating cloud and precipitation tables to enable consistency with microphysical model assumptions and to provide full support for polarized radiance interactions (via the optical properties and scattering phase matrix). Furthermore, the CRTM has been extended by Mark Liu (NOAA STAR) to support UV capabilities as part of a joint proposal with JCSDA and NESDIS. Initially the OMPS instrument is supported, but this will be extended to other UV-based instruments as we develop capabilities and evaluate the model.

Another key area of development is the surface models and associated radiance simulations. To fully support polarized radiance calculations, new BRDF models are developed over both land and ocean in coordination with STAR researchers Ming Chen (IR/MW emissivity) and Nick Nalli (IR Sea Surface Emissivity). These efforts will require months of development, integration, and testing. The final fully developed CRTM v3.x is not expected for a couple of years, but we will release versions that are functional along the way, with the first release expected by April 2022.

Additional topics covered for CRTM were the comparisons between v2.3.0 and v2.4.0. The upshot is that v2.4.0 is superior in accuracy compared to v2.3.0 according to initial tests in a data assimilation system. The speed of v2.4.0 is also substantially improved in operational frameworks that utilize openMP.

There was also a brief discussion of the ongoing efforts to improve the NLTE simulation capabilities in the CRTM, work is ongoing presently within the Team. Also, the CRTM team has been expanding the aerosol simulation capabilities, to include CMAQ and NAAPS aerosol specifications.

Finally, an update was provided on the transmittance coefficient generation package, permitting expert users to develop their own transmittance coefficient files. There are ongoing efforts to ensure that developers appropriately identify their created files for publication purposes, to mitigate any issues associated with user-created files negatively impacting the representation of CRTM simulation capabilities.

There was some discussion after the presentations:

1. There was a question about whether variable ozone could be supported for microwave sensors in RTTOV. Investigations by the RTTOV development team have indicated that the impact of ozone variability is rather small for channels below 200 GHz so

variable ozone coefficients have not been produced (noting that a climatological ozone profile is included in the “fixed gas” component of the gas optical depth prediction). New variable ozone coefficients are now available for Metop-SG ICI for which ozone variability does have a significant impact. The NWP SAF can provide variable ozone microwave coefficients on request for other (sub-200 GHz) sensors if required.

2. Members discussed polarisation and/or polarimeters, indicating the need to support not only full BRDF simulation requirements for surface leaving radiances, but also for oriented hydrometeor sensitivities – which impart a polarization difference due to scattering, particularly at 165 GHz as reported by Galligani et al.
3. Members also discussed small sats and the requirements for NWP. There is a worry that the lifetime of these small sat missions is relatively short compared to the time it takes to assimilate data from new satellites into operations leading to diminished benefits. Often the individual sensors in a satellite series have different characteristics that mean essentially the same amount of work is required for each individual instrument. What information should be provided by satellite operators right up front for small sats to be supported by fast RT models pre-launch? Assuming they are similar to existing sensors, then the spectral responses and channel polarisations are the primary data required. New coefficients for fast RT models can then be created that can be used with contemporary versions of the RT models. However, it was noted that the TROPICS mission, for example, involves a novel polarisation that required code changes in the fast RT models. Full support for this is then limited by the release schedules of the RT software.

LIST OF ACRONYMS

AAPP: Advanced ATOVS Processing Package
AC: Atmospheric Composition
AI: Artificial Intelligence
AIRS: Atmospheric InfraRed Sounder
AMSR: Advanced Microwave Scanning Radiometer
AMSU: Advance Microwave Sounding Unit
ARM: Atmospheric Radiation Measurement
ASTER: Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATMS: Advanced Technology Microwave Sounder
ATOVS: Advanced TIROS Operational Vertical Sounders
AVHRR: Advanced Very High Resolution Radiometer
AWS: Arctic Weather Satellite
BUFR: Binary Universal Form for the Representation of meteorological data
C3S: Copernicus Climate Change Service
CAMEL: Combined ASTER and MODIS emissivity over Land
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
CLBLM : Community Line By Line Model
CMA: China Meteorological Administration
CNES: Centre National d'Etudes Spatiales
COTS : Commercial Off The Shelf
CrIS: Cross-track Infrared Sounder
CRTM: Community Radiative Transfer Model
CSPP: Community Satellite Processing Package
DB: Direct Broadcast
DMSP: Defense Meteorological Satellites Program
DOI: Digital Object Identifier
DWD: Deutscher Wetterdienst (German Weather Service)
EARS: EUMETSAT Advanced Retransmission 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
GEO-XO: Geostationary Extended Observations
GHG: Greenhouse Gas
GIIRS: Geostationary Interferometric Infrared Sounder
GMI: Global Precipitation Measurement (GPM) Microwave Imager
GNSSRO: Global Navigation Satellite System Radio Occultation

GOES: Geostationary Operational Environmental Satellite
GOSAT: Greenhouses gases Observing 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
ICVS: Integrated Calibration and Validation System
IKFS: Russian advanced infrared atmospheric sounder
IPWG: International Precipitation Working Group
IR: Infrared
IRC: International Radiation Commission
IRSP: Infrared Sounder Pre-Processor
ITSC: International TOVS Study Conference
ITU: International Telecommunication Union
ITWG: International TOVS Working Group
JAXA: Japan Aerospace Exploration Agency
JEDI: Joint Effort for Data assimilation Integration
JPSS: Joint Polar Satellite System
LAM: Limited Area Model
LBL: Line By Line
LBLRTM: Line By Line Radiative Transfer Model
LEO: Low Earth Orbit
LUT: Lookup Table
MERSI: Medium Resolution Spectral Imager
MetOp: Meteorological Operational
MFASIS: Method for FASt Satellite Image Synthesis
MHS: Microwave Humidity Sounder
ML: Machine Learning
MODIS: Moderate-resolution Imaging Spectroradiometer
MTG-IRS: Meteosat Third Generation - Infrared Radiometric Sounder
MTVZA: Russian Imaging/Sounding Microwave Radiometer
MW: Microwave
MWS: Microwave Humidity Sounder
MWIPP: Microwave Imager Pre-Processor
NASA: National Aeronautics and Space Administration
NCEI: National Centers for Environmental Information
NEdT: Noise Equivalent Delta Temperature
NESDIS: National Environmental Satellites, Data, and Information Service
NLTE: Non Local Thermodynamic Equilibrium
NOAA: National Oceanic and Atmospheric Administration
NPROVS: NOAA PROduct Validation System
NRL: Naval Research Laboratory
NUCAPS: NOAA Unique Combined Atmospheric Processing System

NWP: Numerical Weather Prediction
OMPS: Ozone Mapping and Profiler Suite
OSCAR: Observing Systems Capability Analysis and Review
PC: Principal Component
PREFIRE: Polar Radiant Energy in the Far Infrared Experiment
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
SAPHIR: microwave humidity sounder on French-Indian satellite Megha-Tropiques
SARTA: Stand-alone AIRS Radiative Transfer Algorithm
SAT: System Performance Assessment Team
SDR: Sensor Data Record
SNO: Simultaneous Nadir Overpass
SRF: Spectral Response Function
SSE: Sea Surface Emissivity
SSEC: Space Science and Engineering Center
SSMIS: Special Sensor Microwave Imager/Sounder
SST: Sea Surface Temperature
SSU: Stratospheric Sounding Unit
STAR: Center for Satellite Applications and Research
TOA: Top Of Atmosphere
TOVS: TIROS Operational Vertical Sounder
TROPICS: Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats
TRUTHS: Traceable Radiometry Underpinning Terrestrial- and Helio- Studies
UAS: Upper Atmospheric Sounding
UFO: Unified Forward Operator
UV: Ultraviolet
VIIRS: Visible/Infrared Imager Radiometer Suite
WG: Working Group
WIGOS: WMO Integrated Global Observing System
WMO: World Meteorological Organization

ITSC-23 AGENDA

Virtual Program (Time is in UTC)

Thursday, 24 June 2021

12:15 Virtual Meeting opens

12:30 Welcome Liam Gumley, Vincent Guidard (ITWG Co-chairs)
 Welcome message Florence Rabier (Director-General, ECMWF)

12:45-14:15 Working Group reports (oral presentations - 15 minutes)

Chair-persons: Liam Gumley, Vincent Guidard

- Numerical Weather Prediction
- Radiative Transfer and Surface Properties
- Advanced Sounders
- Products and Software
- Climate
- International Issues and Future Systems

14:15-15:00 Session 1: International (oral presentations - 12 minutes)

Chair-person: Dorothee Coppens

1.01	Richard Kelley <i>Alion Science for DOC/NOAA/NESDIS</i>	Two ITU Items of Interest since ITSC-XXII RFI TSG
1.02	Mitch Goldberg <i>NOAA</i>	Report from CGMS
1.03	Philippe Chambon <i>Météo-France</i>	Report from IPWG

15:00-15:15 Health Break

15:15-16:45 Session 2: Radiative Transfer (oral presentations - 12 minutes)

Chair-person: Christina Stumpf

2.01	Xavier Calbet <i>AEMET</i>	Results on the radiative transfer model effects from the in-homogeneity of water vapor fields in the field of view of infrared and microwave sounders
2.02	Thibault Delahaye <i>LMD/CNRS</i>	CO2 spectroscopy in 4A/OP: new developments and applications to satellite missions
2.03	James Hocking <i>Met Office</i>	RTTOV development status
2.04	Benjamin Johnson <i>UCAR @ JCSDA</i>	Recent advances in the Community Radiative Transfer Model
2.05	Leonhard Scheck <i>Hans Ertel Centre For Weather Research / Lmu Munich</i>	A fast neural network based method for generating synthetic satellite images in the solar spectral range

2.06	Jun Yang <i>Chinese Academy of Meteorological Sciences</i>	Recent developments and applications of advanced radiative transfer modeling system (ARMS)
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16:45 End of Day 1

Friday, 25 June 2021

12:15-12:30 Virtual Meeting opens**12:30-14:00 Session 3: Products, Retrievals and Software** (oral presentations - 12 minutes)

Chair-person: Kathleen Strabala

3.01	Nigel Atkinson <i>Met Office</i>	NWP SAF Processing Packages to support EPS-SG and MTG
3.02	Jérôme Pernin <i>Laboratoire de Météorologie Dynamique</i>	A newly born TIGR data set to meet the requirements of the high spectral resolution instruments: the TIGR-2020
3.03	Graeme Martin <i>UW-Madison SSEC/CIMSS</i>	Overview of the NASA CrIS Level 1B Version 3 Data Product and Product Assessment
3.04	Hao Hu <i>Chinese Academy of Meteorological Sciences</i>	GSDART: A Global Scene-Dependent Atmospheric Retrieval Testbed for Passive Microwave Sounding Instruments
3.05	Tim Hultberg <i>EUMETSAT</i>	Hyperspectral Infrared Machine Learning (HSIR ML)
3.06	Anthony L. Reale <i>NOAA NESDIS STAR</i>	Enterprise Comparison of Atmospheric Profiles Derived from Polar Satellite and GNSS Constellations

14:00-14:15 Information on how poster sessions will run

14:15-14:30 Health break**14:30-16:00 Poster session 1**

1p.01	Olivier Audouin <i>Météo-France</i>	Assimilation of GOES16 ABI radiances in ARPEGE model
1p.02	Younousse Biaye <i>Université Gaston Berger</i>	Study of the evolution of the Sahelian climate based on satellite observation and ATOVS data
1p.03	Brett Candy <i>Met Office</i>	Impact of satellite sounder data on global forecasts, including the benefit of using the direct broadcast network (DBNet)
1p.04	Ming Chen <i>Cooperative Institute for Satellite Earth System Studies</i>	Machine Learning Applications in Community Surface Emissivity Modeling (CSEM) System
1p.05	Cheng Dang <i>JCSDA, UCAR</i>	Recent developments in CRTM aerosol simulations

1p.06	Peiming Dong <i>Chinese Academy of Meteorological Sciences</i>	Impacts of Combined FY-3D MWTS and MWHS Data Stream on Typhoon Forecasts
1p.07	Victoria Galligani <i>CIMA-UBA-CONICET</i>	On the accuracy of RTTOV-SCATT for radiative transfer in all-sky conditions
1p.08	Xueyan Hou <i>Chinese Academy of Meteorological Sciences</i>	Evaluation of the In-Orbit Performance of the Microwave Temperature Sounder Onboard the FY-3D Satellite Using GPS Radio Occultation Data
1p.09	Jisoo Kim <i>Ewha Womans University</i>	Impact of assimilation of the Advanced Technology Microwave Sounder data over sea-ice in the Korean Integrated Model
1p.10	B R R Hari Prasa Kottu <i>NCMRWF</i>	Impacts of assimilating ABI and AHI Water Vapor channel radiances in GFS-T1534 with GSI
1p.11	Michelle Loveless <i>UW-Madison SSEC</i>	Hyperspectral Sounder Radiance Comparisons of SNPP/NOAA-20 CrIS, METOP-A/B/C IASI, and Aqua AIRS: Refined Analysis Techniques and Updated Results
1p.12	Yufen Ma <i>Institute of Desert Meteorology, China Meteorological Administration, Urumq</i>	Evaluation of Infrared Land Surface Emissivity over the Taklimakan Desert
1p.13	Nicholas Nalli <i>IMSG Inc. at NOAA/NESDIS/STAR</i>	Addressing the temperature dependence of water within the CRTM IR sea surface emissivity (IRSSE) model
1p.14	Chengli Qi <i>National Satellite Satellite Center, China Meteorological Administration</i>	FY3E HIRAS-II and its pre-launch performance evaluation
1p.15	Yi-ning Shi <i>China Meteorological Administration</i>	Discrete Ordinate Adding Method (DOAM), a new solver for Advanced Radiative transfer Modeling System (ARMS)
1p.16	Olaf Stiller <i>Deutscher Wetterdienst</i>	Newly developed impact diagnostics for cross-validating satellite radiances with conventional observations
1p.17	Joe Taylor <i>SSEC, University of Wisconsin-Madison</i>	Doppler Shift Correction of the Cross-track Infrared Sounder (CrIS) Observed Radiances
1p.18	Robert Tubbs <i>Met Office</i>	Results from OSEs for satellite observation types in the Met Office UKV 4D-Var regional NWP system
1p.19	Ruoying Yin <i>Numerical Weather Prediction Center</i>	The Impact of Geostationary Interferometric Infrared Sounder (GIIRS) Cloud Cleared Radiances on Typhoon forecasts: Maria (2018)

1p.20	Yang Zhiyu <i>The Shanghai Institute of Technical Physics of the Chinese Academy of Sciences</i>	A Model of Polarization Correction for the High-spectral Infrared Atmospheric Sounder (HIRAS-II) of FY-3E
1p.21	Scott Mindock <i>SSEC/CIMSS</i>	CSPP SDR 3.3, ASCI 1.1 - ATMS,CrIS,VIIRS plus OMPS and LSE

16:00-16:50 Session 4: Space agency reports (oral presentations - 8 minutes)

Chair-person: Nadia Fourrié

4.01	Dorothee Coppens <i>EUMETSAT</i>	EUMETSAT
4.02	Kozo Okamoto <i>JMA/MRI</i>	JMA and JAXA
4.03	Mitch Goldberg <i>NOAA</i>	NOAA
4.04	Peng Zhang <i>National Satellite Meteorological Center</i>	CMA
4.05	Sergey Uspensky <i>SRC Planeta</i>	ROSHYDROMET
4.06	Kenneth Holmlund <i>WMO</i>	WMO

16:50 End of Day 2

Monday, 28 June 2021

12:15-12:30 Virtual Meeting opens

12:30-13:45 Session 5: Calibration - Validation (oral presentations - 12 minutes)

Chair-person: Michelle Loveless

5.01	Hu Yang <i>University of Maryland</i>	Current Status and Future Improvements for JPSS ATMS On-orbit Absolute Calibration
5.02	Fei Tang <i>Nanjing Joint Institute for Atmospheric Sciences</i>	Bias characterization of FengYun-4A/AGRI infrared channels using Advanced Radiative Transfer Modeling System (ARMS)
5.03	Peng Zhang <i>National Satellite Meteorological Center</i>	The Progress on Retrospective Calibration of Historical Chinese Fengyun Satellite Data
5.04	Jaap Onderwaater (for Timo Hanschmann) <i>EUMETSAT</i>	A consistently calibrated data record of the High-Resolution Infrared Radiation Sounder (HIRS) radiances
5.05	Cheng-Zhi Zou <i>NOAA</i>	The Reprocessed Suomi NPP Satellite Observations

13:45-14:00 Session 1: International (Continued) (oral presentations - 12 minutes)

Chair-person: Michelle Loveless

1.04	Gianpaolo Balsamo ECMWF	The new International Earth Surface Working Group
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14:00-14:15 Health break

14:15-15:45 Poster Session 2

2p.01	Liselotte Bach <i>Deutscher Wetterdienst</i>	Assimilating visible reflectances of SEVIRI in a convective-scale ensemble Kalman Filter
2p.02	Eva Borbas <i>UW-Madison/CIMSS</i>	Tropospheric Moisture Retrievals from HIRS, MODIS, and VIIRS plus CrIS
2p.03	Fabien Carminati <i>Met Office</i>	A channel selection for the assimilation of CrIS and HIRAS instruments at full spectral resolution
2p.04	Olivier Coopmann <i>CNRM, Université de Toulouse, Météo-France & CNRS</i>	First steps in the preparation for the assimilation of the future IRS sounder in NWP models
2p.05	James Davies <i>SSEC/UW-Madison</i>	IMAPP IDEA-I: An Air Quality Forecast Software Package for Aerosols, Ozone and Carbon Monoxide from Polar Orbiting Satellites using Global Forecast System (GFS) Winds
2p.06	David Duncan <i>ECMWF</i>	The impact of background error specification on microwave sounder OSEs
2p.07	Vincent Guidard <i>CNRM, Météo-France, CNRS</i>	Estimation of the error covariance matrix for IASI radiances and its impact on ozone analyses
2p.08	Jianbing Jin <i>Nanjing University of Information Science & Technology</i>	Dust emission inversion through assimilating satellite measurements
2p.09	Toshiyuki Kitajima <i>Japan Meteorological Agency</i>	Current Status and Future Plan on direct readout activity in MSC/JMA
2p.10	Katie Lean <i>ECMWF</i>	Investigating the optimal design for a future constellation of microwave sounding instruments on small satellites using the Ensemble of Data Assimilations method
2p.11	Yu Lu <i>Nanjing Joint Institute for Atmospheric Sciences</i>	Microwave land surface emissivity over Tibetan Plateau retrieved from FY-3D Microwave Radiation Imager
2p.12	Miguel-Angel Martinez <i>AEMET</i>	Preparation of MTG era: developing of nowcasting tools for GEO imagers and sounders
2p.13	Zhuoya Ni <i>National Satellite Meteorological Centre</i>	Introduction of FY4B GIIRS and its application prospect
2p.14	Moved to oral presentation	

2p.15	Hiroyuki Shimizu <i>Japan Meteorological Agency</i>	Addition of microwave humidity sounder radiance data to all-sky assimilation in the JMA global NWP system
2p.16	Kathleen Strabala <i>UW-Madison/SSEC/CIMSS</i>	Features and Advancements in Polar2Grid and Geo2Grid Image Creation Software
2p.17	Joao Teixeira <i>Jet Propulsion Laboratory</i>	Toward a Global Planetary Boundary Layer Observing System: The NASA PBL Incubation Study Team Report
2p.18	Jerome Vidot <i>CNRM/CNRS</i>	Evaluation of the RTTOV IR/MW underlying spectroscopy in the frame of the C3S project on early satellites
2p.19	Feng Zhang <i>Fudan University</i>	An efficient radiative transfer model for thermal infrared brightness temperature simulation in cloudy atmospheres
2p.20	Yanqiu Zhu <i>GMAO</i>	Improving the use of surface-sensitive radiances in the GMAO GEOS system

15:45-16:45 Session 6: Climate (oral presentations - 12 minutes)

Chair-person: Nathalie Selbach

6.01	William Bell <i>ECMWF</i>	Preparations for Assimilating Sounding Observations in the Next Generation Global Atmospheric Reanalysis at ECMWF - ERA6
6.02	Indira S. Rani <i>NCMRWF</i>	An overview of the satellite sounding radiance assimilation in the IMDAA regional reanalysis
6.03	Henry Revercomb <i>UW-Madison, Space Science and Engineering Center</i>	Rationale for Flight of an Infrared SI Reference Sensor for Climate Data Uncertainty Quantification
6.04	Yoann Tellier <i>Laboratoire de Météorologie Dynamique, CNRS, IPSL</i>	Clear-Sky Estimation of Earth Outgoing Longwave Radiation and Atmospheric Heating Rate with IASI

16:50 End of Day 3

Tuesday, 29 June 2021

12:15-12:30 Virtual meeting opens

12:30-14:20 Session 7: NWP centre reports (oral presentations - 10 minutes)

Chair-person: Agnes Lane

7.01	Indira S. Rani <i>NCMRWF</i>	NCMRWF
7.02	Chris Tingwell <i>Bureau of Meteorology</i>	Bureau of Meteorology
7.03	Ruoying Yin <i>Numerical Weather Prediction Center</i>	CMA

7.04	Hidehiko Murata <i>Japan Meteorological Agency</i>	JMA
7.05	Emily Liu <i>NOAA/NCEP/EMC</i>	NCEP
7.06	Philippe Chambon <i>Météo-France</i>	Météo-France
7.07	Christina Köpken-Watts <i>DWD</i>	DWD
7.08	Alain Beaulne <i>ECCC</i>	ECCC
7.09	Chawn Harlow <i>Met Office</i>	Met Office
7.10	Mohammed Dahoui <i>ECMWF</i>	ECMWF
7.11	Benjamin Ruston <i>U.S. Naval Research Laboratory</i>	NRL

14:20-14:30 Health break

14:30-15:45 Poster Session 3

3p.01	Nancy Baker <i>Naval Research Lab</i>	Update on Activities of the U.S. National Academies' Committee on Radio Frequencies
3p.02	Niels Bormann <i>ECMWF</i>	The Arctic Weather Satellite - a small satellite concept to improve Arctic and global weather forecasts through millimetre and sub-millimetre microwave sounding
3p.03	Hao Chen <i>Jiangsu Meteorological Observatory</i>	Why and how does the actual spectral response matter for microwave radiance assimilation?
3p.04	Paola Corrales <i>UBA-CIMA-CONICET</i>	A first attempt to assimilate satellite radiance observations in a deep convection case during RELAMPAGO using the WRF-GSI-LETKF system
3p.05	James Davies <i>SSEC/UW-Madison</i>	CSPP (Community Satellite Processing Package) Software for Satellite Sounders in Direct Broadcast
3p.06	Stephen English <i>ECMWF</i>	A reference ocean surface emission and backscatter model
3p.07	Moved to oral presentation	
3p.08	Erin Jones <i>CISESS @ NOAA/NESDIS/STAR</i>	Evaluating CrIS Shortwave Infrared Observations in the NOAA Global Data Assimilation System: Impacts and Recommendations

3p.09	Robert Knuteson <i>University of Wisconsin-Madison SSEC/CIMSS</i>	Quality Assessment of the Radiometric and Spectral Calibration of the FY4A Geostationary Interferometric Infrared Sounder (GIIRS) using NOAA-20 CrIS and METOP-B IASI as On-Orbit Reference Sensors
3p.10	Emily Liu <i>NOAA/NCEP/EMC</i>	Progress and Plans for Satellite Data Assimilation in the NCEP Global and Regional Data Assimilation Systems
3p.11	Cristina Lupu <i>ECMWF</i>	Evaluation of the radiative transfer model RTTOV-13.0 at ECMWF
3p.12	Erica McGrath-Spangler <i>USRA/GESTAR and NASA GSFC/GMAO</i>	Assimilation of hyperspectral infrared radiances from the cloud-clearing methodology: Results from the 2017 Atlantic Tropical Cyclone season
3p.13	Ester Nikolla <i>University of Wisconsin-Madison SSEC/CIMSS</i>	Hyperspectral Infrared Near Surface Observations of Arctic Snow, Sea Ice, and Non-Frozen Ocean from the RV PolarStern during the MOSAiC Expedition October 2019 to September 2020
3p.14	Noelle A. Scott <i>LMD/IPSL/ Ecole Polytechnique</i>	At the confluence of forward and inverse remote sensing, IA and calval studies : The 2021 overview of the LMD (GEISA, ARSA, TIGR, ICO) databases
3p.15	Patrick Stegmann <i>Joint Center for Satellite Data Assimilation</i>	The 2021 Iteration of the TAMU Aerosol Refractive Index Database
3p.16	Christina Stumpf <i>DWD</i>	Evaluation of ICON's model cloud fields using simulated and observed visible satellite images
3p.17	Sreerekha Thonipparambil <i>EUMETSAT</i>	EUMETSAT user preparation towards Meteosat Third Generation (MTG) and European Polar System - Second Generation (EPS-SG)
3p.18	Francesca Vittorioso <i>CNRM</i>	An Infrared Atmospheric Sounding Interferometer – New Generation (IASI-NG) channel selection for Numerical Weather Prediction
3p.19	Peng Zhang <i>National Satellite Meteorological Center</i>	Development of the Chinese Space-Based Radiometric Benchmark Mission LIBRA

15:45-16:45 Session 8: NWP Advances (oral presentations - 12 minutes)

Chair-person: Nancy Baker

8.01	Roger Randriamampianina <i>Norwegian Meteorological Institute</i>	Improving the use of satellite radiances in high latitude regional NWP
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8.02	Fiona Smith <i>Bureau of Meteorology</i>	Operational Hyperspectral Sounder Error Correlations
8.03	Hongyi Xiao <i>China Meteorological Administration</i>	Impact of FY-3D MWRI Radiance Assimilation in GRAPES 4D-Var on Typhoon Shanshan Forecasts
8.04	Wei Han <i>JCSDA</i>	Assimilation of Geostationary Hyperspectral InfraRed Sounders (GeoHIS): progresses, challenges and perspectives

16:45 End of Day 4

Wednesday, 30 June 2021

12:15-12:30 Virtual meeting opens

12:30-13:30 Session 9: All-sky assimilation (oral presentations - 12 minutes)

Chair-person: Christina Köpken-Watts

9.01	Maziar Bani Shahabadi <i>Environment and Climate Change Canada</i>	Recent Progress for All-Sky Microwave Radiance Assimilation in Environment Canada's Global Deterministic Weather Prediction System
9.02	Philippe Chambon (on behalf of Mary Borderies) <i>Météo-France/ DESR/ CNRM</i>	Status of the assimilation of cloudy and rainy microwave observations in the Météo-France global NWP model ARPEGE
9.03	David Duncan <i>ECMWF</i>	Moving AMSU-A to all-sky assimilation at ECMWF
9.04	Kozo Okamoto <i>JMA/MRI</i>	Preliminary assimilation of all-sky IR radiances of Himawari-8 in the global data assimilation system at JMA

13:30-14:45 Poster Session 4

4p.01	Nick Bearson <i>UW-Madison SSEC/CIMSS</i>	CSPP Geo Gridded GLM
4p.02	Chris Burrows <i>ECMWF</i>	Progress in the assimilation of GIIRS data
4p.03	Ke Chen <i>Huazhong University of Science and Technology</i>	A Remapping technique of FY-3D MWRI using deep learning for better use in data assimilation
4p.04	Geoff Cureton <i>CIMSS, University of Wisconsin - Madison</i>	Near Real Time Active Fires and GAASP Level-2 Products Via Direct Broadcast Using the Community Satellite Processing Package
4p.05	Di Di <i>Nanjing University of Information, Science & Technology</i>	Geostationary hyperspectral infrared sounder channel selection for capturing fast-changing atmospheric information
4p.06	Stephen English <i>ECMWF</i>	An overview of current EESS Spectrum issues relevant to ATOVS-heritage systems

4p.07	Sylvain Heilliette <i>Environment Canada</i>	Impact of various ozone profile sources on the simulation of hyperspectral Infrared radiances by RTTOV. Towards the assimilation of ozone sensitive IR radiances in Environment Canada NWP analysis system
4p.08	Bryan Karpowicz <i>GESTAR/USRA/NASA GMAO</i>	Assimilation of CrIS Shortwave Infrared Channels into the GEOS Atmospheric Data Assimilation System
4p.09	Keiichi Kondo <i>Meteorological Research Institute</i>	Impact of microwave radiance assimilation over land using dynamic emissivity in the global NWP system of JMA
4p.10	David Loveless University of Wisconsin-Madison	Supplementing Space-based Sounding with the Ground-based Atmospheric Emitted Radiance Interferometer (AERI) to Improve Thermodynamic Sounding of the Planetary Boundary Layer
4p.11	Cristina Lupu <i>ECMWF</i>	The assimilation of EUMETSAT reconstructed radiances for IASI data compression
4p.12	Moved to 1p.21	
4p.13	Alexander Polyakov <i>Saint-Petersburg State University</i>	Observation of the total ozone columns using the IKFS-2 instrument aboard the Meteor-M N2 satellite in 2015-2020
4p.14	Nathalie Selbach (on behalf of CM SAF team) <i>Deutscher Wetterdienst</i>	Climate Data Records of the EUMETSAT Satellite Application Facility on Climate Monitoring
4p.15	Patrick Stegmann <i>Joint Center for Satellite Data Assimilation</i>	Version 1.0 of the CRTM Transmittance Coefficient Generation Package
4p.16	Bomin Sun <i>IMSG at NOAA/STAR</i>	Accuracy of newly emerging Vaisala radiosonde humidity measurements in comparison with satellite hyperspectral infrared measurements
4p.17	David Tobin <i>SSEC</i>	The Curious Case of the Hottest (and Coldest) FOVs
4p.18	Withdrawn	
4p.19	Xiaoyan Zhang <i>NOAA/NCEP/EMC & IMSG</i>	Assimilating all-sky microwave radiance within NOAA's prototype Rapid Refresh Forecast System

14:45-15:00 Health break

15:00-15:30 Session 10: NWP Surface (oral presentations - 12 minutes)

Chair-person: Cristina Lupu

10.01	Niels Bormann <i>ECMWF</i>	Advances in the assimilation of MW sounding data over snow and sea-ice
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10.02	Camille Birman <i>CNRM-UMR3589, Météo-France & CNRS</i>	Assimilation of SEVIRI retrieved land surface temperature in AROME NWP model
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15:30-16:30 Session 11: NWP Future (oral presentations - 12 minutes)

Chair-person: Kirsti Salonen

11.01	Will McCarty <i>NASA Global Modeling and Assimilation Office</i>	Investigating the Impacts of Hyperspectral Infrared Sounders in Geostationary Orbits Using Observing System Simulation Experiments
11.02	Chris Burrows <i>ECMWF</i>	Initial assimilation tests of CrIS short-wave channels at ECMWF
11.03	William Smith <i>CIMSS/SSEC</i>	Hyperspectral Radiance Sounding Information Content
11.04	Bjorn Lambrigtsen <i>Jet Propulsion Laboratory</i>	Is a Geostationary Microwave Sounder Now Feasible?

16:30-16:45 Closing Session

Co-chairs: Vincent Guidard, Liam Gumley

16:45 End of Day 5 – End of ITSC-23

ITSC-23 ABSTRACTS

Session 1: International (oral presentations)

1.01 Two ITU Items of Interest Since ITSC-XXII

Richard Kelley¹, Fred Mistichelli²

¹*Alion Science for DOC/NOAA/NESDIS, Annapolis Junction, United States,* ²*NESDIS Spectrum Manager, Silver Spring, United States*

ITU-R Resolutions give instructions on the organization, methods or programmes of the Radiocommunication Assembly or Study Group work.

Some items of ITSC interest are within Study Group 7, specifically Working party 7C which is responsible for “remote sensing applications in the Earth exploration-satellite service (EESS), both active and passive, systems of MetAids service, as well as space research sensors, including planetary sensors.”

The talk will examine two ITU-R resolutions, a new one, RES. 731; and a modified one, RES. 750.

RES. 731 opens discussion of sharing passive bands above 71 GHz. Since many ITWG members rely on data at these higher frequencies, this should be of interest.

The modified resolution is of interest primarily because it changes rfi protection around 24 GHz.

1.03 Research Highlights from the International Precipitation Working Group (IPWG)

Philippe Chambon¹, Viviana Maggioni², Vincenzo Levizzani³, Ralph Ferraro⁴

¹*Météo-France, Toulouse, France,* ²*George Mason University, Fairfax, USA,* ³*CNR-ISAC, Bologna, Italy,* ⁴*NOAA STAR, College Park, USA*

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, workshops, and 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 (i) some of the latest research findings from the IPWG working groups, (ii) outcomes from recent virtual sessions on the status of the global precipitation satellite constellation, (iii) as well as recent efforts to review the different applications of space-borne precipitation radars within the community in support of the development of future active sensors.

Session 2: Radiative Transfer (oral presentations)

2.01 Results on the radiative transfer model effects from the in-homogeneity of water vapor fields in the field of view of infrared and microwave sounders

Xavier Calbet¹, Cintia Carbajal-Henken, Bomin Sun, Tony Reale, Sergio DeSouza-Machado
¹*AEMET, Madrid, Spain*

Results on the effects in the radiation transfer from infrared and microwave sounders from the water vapor in-homogeneities within the field of view will be presented.

Random Gaussian field structure of the atmospheric water vapor and temperature fields will be presented as measured by various instruments.

The effect of this structure in the radiative transfer will be shown. Highlighting the cases when these effects can be important. This phenomena seems to imply an underestimation of the water vapor concentration for infrared hyperspectral sounders in some cases.

2.02 CO₂ spectroscopy in 4A/OP: new developments and applications to satellite missions

Dr. Thibault Delahaye¹, Dr. Raymond Armante¹, Matthieu Dogniaux¹, Dr. Cyril Crevoisier¹
¹Laboratoire de Météorologie Dynamique, Ecole Polytechnique, CNRS, Palaiseau, France

During the past decades, substantial efforts have been made to monitor CO₂ sources and sinks. Several satellite missions have been designed in order to retrieve its atmospheric concentration (i.e. IASI, Microcarb, OCO-2), mainly by inverting infrared spectra products using radiative transfer-based algorithms to interpret measured atmospheric absorptions in terms of column-averaged dry-air mole fraction of CO₂ (XCO₂). As a consequence, this method fundamentally relies on the precision of CO₂ molecular spectroscopy knowledge. In this work, we present a status of the CO₂ spectroscopy, as well as the most recent developments towards a better modelling of CO₂ in the radiative transfer software 4A/OP. A particular attention is devoted to the implementation of line-mixing effects, considering the well-known W 'full relaxation matrix' approach, as well as its first and second order approximations, and their impact and limits on atmospheric spectra modelling in TIR and NIR spectral regions. The CO₂ spectroscopic parameters improvement reported in GEISA-2020 database and the effect of speed-dependent line-profile consideration are also presented. These developments are highlighted by comparisons between calculated spectra computed with 4A/OP and observations from different sources. We first show how they reduce 'calculated - observed' spectral residuals computed for measurements made by the ground-based Total Carbon Column Observing Network (TCCON) in the NIR and by the IASI instrument in the TIR. In such studies, the knowledge of the greenhouse gases (GHG) concentration profile is crucial. For this reason, we also considered in this study, as input of 4A/OP, vertical CO₂ concentration profiles acquired during the 2019 Monitoring of Atmospheric composition and Greenhouse gases through multi-Instruments Campaign (MAGIC) in collocation with instruments such as IASI and OCO-2.

2.03 RTTOV development status

James Hocking¹, Pascal Brune¹, Philippe Chambon², Alan Geer³, Stephan Havemann¹, Christina Köpken-Watts⁴, Cristina Lupu³, Marco Matricardi³, Pascale Roquet², Roger Saunders¹, Leonhard Scheck⁴, Christina Stumpf⁴, Emma Turner¹, Jérôme Vidot²

¹Met Office, Exeter, United Kingdom, ²Météo-France, ³ECMWF, ⁴DWD

A new major release of RTTOV, v13.0, was made available to users in November 2020. The new package includes various developments. A new predictor scheme for gas absorption optical depths has been implemented that shows promising results in testing across the spectrum. New visible/infrared optical depth coefficients have been generated based on LBLRTM v12.8. Extinction due to molecular Rayleigh scattering is now separable from the gas absorption for visible channels. This enables Rayleigh multiple scattering to be included when using the Discrete Ordinates Method (DOM) solver yielding more accurate radiances for visible channels. This in turn benefits the MFASIS fast visible cloud parameterisation which is trained on the DOM calculations. The visible/infrared cloud liquid water optical properties have been updated using a more recent refractive index dataset, and a parameterisation for cloud liquid water particle size has been implemented. The microwave scattering model RTTOV-SCATT has undergone numerous improvements. Simulations may now use an arbitrary number of hydrometeor types (determined by the optical property "hydrotable" file provided by the user), optionally with separate cloud fraction profiles per hydrometeor. RTTOV-SCATT includes a new approximate treatment of polarised scattering by frozen hydrometeors, and a new radar reflectivity simulation capability. The optical property hydrotables supplied by the NWP SAF have been updated with improved microphysical representation of cloud ice, snow and graupel properties. An overview of the new capabilities will be presented along with a look ahead to planned developments for future versions.

2.04 Recent advances in the Community Radiative Transfer Model

Benjamin Johnson¹, Dr. Patrick Stegmann¹, Dr. Cheng Dang¹, Dr. Quanhua Liu², Dr. Ming Chen², Dr. Yingtao Ma², Mr. James Rosinski¹, Dr. Daniel Abdi³

¹UCAR @ JCSDA, Boulder, ²NOAA STAR, College Park, ³NOAA GSL, Boulder

The JCSDA Community Radiative Transfer Model (CRTM) is a fast operational radiative transfer model used in numerical weather prediction, satellite simulation, and calibration / validation applications spanning multiple research and operational organizations.

In October 2020, the CRTM team released version 2.4.0 of the CRTM, marking a substantial improvement in performance and flexibility over v2.3.0. Version 2.4.0 employs OpenMP modifications to the profile loop, enabling substantial improvements in wall-clock time, on the order of 5x for demanding applications. This enables calling models that utilize MPI to better load balance as well, leading to a substantial synergistic performance improvement.

CRTM v2.4 is developed using modern software engineering practices. For collaboration and version control, we have adopted the Github platform, enabling unrestricted access to the model and allowing for developers to work, collaborate, design, develop, test, and release from a distributed platform. Users now have complete flexibility in selecting the elements they'd like to use.

CRTM v2.4 was released under a public domain license (CC0), removing any restrictions for use that were present in previous versions.

The aerosol model in the CRTM has been substantially improved as well, now supporting updated GOCART, CMAQ, and NAAPS specifications. CRTM supports native netCDFv4 reading/writing of aerosol and cloud coefficient files, permitting greater ease of use and collaboration with developers.

The transmittance coefficient generation process has been re-developed, with the TROPICS, IASI-NG, and several other sensor coefficient files developed and delivered.

A new cloud coefficient dataset has been provided as well, demonstrating the ability to expand the CRTM to support future microwave sensors, such as the Ice Cloud Imager, with frequencies supported up to 664 GHz. In coordination with Penn State University researchers, we have implemented their microphysics-model matched cloud coefficient tables within the CRTM. Specifically the GFDL, WSM-6, and Thompson microphysics schemes are supported. The CRTM team is also busy working on the version 3 release of CRTM, which builds on the success of the v2.4 series, enabling the capability of simulating the full Stokes polarization state, rather than the scalar intensity. This required substantial changes to the solver and lookup tables, the initial codes were modified by Dr. Quanhua Liu (NOAA/STAR) and delivered to the

CRTM team for integration, further development, and testing.

CRTM v3 features OpenMP optimization over both profiles and channels, enabling a more flexible use case for stakeholders, particularly relevant to modern hyperspectral sensor support. It has a selectable polarization capability, reverting to scalar simulation with a single option change. This permits a more seamless integration into operational systems that may not immediately require full polarization support.

CRTM v3 extends the spectral simulation support to the ultraviolet region, with an initial support for the OMPS instrument. This work was developed under a grant from NOAA, lead by Dr. Cao and Dr. Liu.

The presentation will highlight the new capabilities of the CRTM in v2.4.x and v3.0 status, along with developments in the aerosol, clouds, and surface properties. We will discuss the future work remaining for a full release of version 3, and discuss a 5 year outlook for fast RT modeling requirements.

2.05 A fast neural network based method for generating synthetic satellite images in the solar spectral range

Leonhard Scheck^{1,2}, Florian Baur^{1,2}, Christina Stumpf¹, Christina Köpken-Watts¹

¹Hans Ertel Centre For Weather Research / LMU Munich, Munich, Germany, ²DWD Deutscher Wetterdienst, Offenbach, Germany

Visible and near-infrared satellite images provide high-resolution information on clouds and aerosols. To use this information for data assimilation and for the evaluation of numerical weather prediction models, sufficiently fast and accurate forward operators are required, which compute synthetic satellite images from the output of numerical weather prediction models. In the solar spectral range, multiple scattering is important, which makes radiative transfer methods complicated and computationally expensive. Only recently, a fast method for visible images has become available, which is based on a compressed eight-dimensional reflectance look-up table computed with a much slower standard radiative transfer method. While this operator has been successfully used for model evaluation and data assimilation, it is restricted to clouds and non-absorbing channels. Taking aerosols and additional effects like absorption by trace gases into account with the same approach is not very practical, as it

would require additional dimensions and thus a strongly increased table size. Here we report on using feed-forward neural networks as an alternative to the look-up table and demonstrate that this approach allows for reducing the computational effort and increasing the accuracy. Best results are achieved with between 4 and 8 hidden layers in the network. Both the amount of training data and the memory required by the operator can be reduced by three orders of magnitude, which makes additional input dimensions feasible. Moreover, the neural-network approach has an advantage for variational or hybrid data assimilation systems: Tangent-linear and adjoint versions of the neural network inference code can easily be derived for arbitrary network structures and do not have to be changed when the network is trained with different data.

2.06 Recent developments and applications of advanced radiative transfer modeling system (ARMS)

Jun Yang¹, Fuzhong Weng¹, Yang Han², Yining Shi¹, Peiming Dong¹, Hao Hu¹

¹Chinese Academy of Meteorological Sciences, Beijing, China, ²National Satellite Meteorological Center, Beijing, China

An advanced radiative transfer modeling system (ARMS) has been developed in CMA for satellite data assimilation and remote sensing applications. ARMS inherits many capabilities of RTTOV and CRTM but has more advanced components such as polarimetric two-stream approximation (P2S), vector doubling adding (VDA), discrete ordinate adding method (DOAM) and advanced doubling adding (ADA). Of these solvers, P2S and DOAM are recommended as the preferred solvers to simulate the Stokes vector and scalar intensity, respectively. The ARMS forward operator includes a fast transmittance module, a new particle absorption and scattering look-up table, surface emissivity and four radiative transfer solvers. Unlike the scalar solvers used in CRTM and RTTOV, the vector solvers need to accurately calculate the Legendre expansion coefficients of six elements in the scattering phase matrix when dealing with multiple scattering of particles. The particle optical properties of aerosols and ice clouds are calculated based on a super-spheroidal T-matrix model. Currently, ARMS fast transmittance absorption coefficients are developed for the infrared and microwave sensors (e.g. AGRI, GIIRS, MWTS, MWHS, MWRI) carried onboard the Fengyun satellites in addition to those coefficients for NOAA and METOP instruments. In this study, the simulations of ARMS are compared with those of other models and observations of Fengyun

satellites, respectively. It is shown that ARMS results agree well with other existing fast radiative transfer models. Considering the computational accuracy and efficiency of P2S and VDA, ARMS is developing two new vector solvers: vector discrete ordinate adding method (VDOAM) and vector discrete ordinate radiative transfer (VDISORT), which will be the preferred vector solvers in the next version of ARMS.

Session 3: Products, Retrievals, and Software (oral presentations)

3.01 NWP SAF Processing Packages to support EPS-SG and MTG

Nigel Atkinson¹, Samantha Pullen¹, Fabien Carminati¹

¹Met Office, Exeter, United Kingdom

In the time frame 2024 onwards, several new EUMETSAT satellites will be launched that will carry instruments that are of major importance for NWP: Metop-SG-A1, Metop-SG-B1 and MTG-S1. The NWP SAF, funded by member states through EUMETSAT, is developing software to facilitate the exploitation of the data from these satellites. The presentation will give an overview of the software packages that are dedicated to pre-processing and the planned developments.

For EPS-SG direct broadcast applications, EUMETSAT are procuring software to perform level 1 processing. On the “A” satellite, the following instruments will be included: MWS, IASI-NG and METImage. On the “B” satellite, MWI, ICI and SCA. Initially, several options were considered for procuring the packages, but it is now known that they will be based mainly on EUMETSAT’s in-house prototypes, refined and packaged by industry. The IASI-NG software will be developed by CNES (i.e. not based on a EUMETSAT prototype). The responsibility of the NWP SAF will be for testing each software package, for distributing them to users, for providing user support and for liaising with EUMETSAT on any issues that may arise.

The NWP SAF is also developing pre-processing software for several instruments, in order to facilitate use of the data in NWP systems. This applies to both direct broadcast and global data streams. Such pre-processing steps include: (i) format conversion, e.g. from netCDF to BUFR, (ii) spatial filtering, (iii) spectral filtering and handling of Principal Components scores (for IASI-NG and MTG-IRS), (iv) re-mapping of one instrument to

another, e.g. MWS onto IASI-NG grid and ICI to MWI. The software will be released as extensions to the existing AAPP and MWIPP deliverables, and there will also be a new deliverable IRSP for processing data from MTG-IRS. Information on these packages, including design and specification documents, can be found on the NWP SAF web pages <https://nwp-saf.eumetsat.int/site/>.

The presentation will provide the development status of the various software packages, together with some technical details and timescales for release of pre-launch and post-launch versions of each package. We will also be requesting feedback from ITWG in order to ensure that these packages meet the needs of the user community.

3.02 A newly born TIGR data set to meet the requirements of the high spectral resolution instruments: the TIGR-2020

Jérôme Pernin¹, Alain Chédin¹, Cyril Crevoisier¹, Virginie Capelle¹, Raymond Armante¹, Laurent Crépeau¹, Noëlle Scott¹, Mathieu Vrac²
¹Laboratoire de Météorologie Dynamique, Palaiseau, France, ²Laboratoire des Sciences du Climat et de l'Environnement, Gif sur Yvette, France

The successive Thermodynamic Initial Guess Retrieval (TIGR) databases (<https://ara.lmd.polytechnique.fr/index.php?page=tigr>) designed at LMD are collections of representative atmospheric thermodynamic states described by temperature, specific humidity and ozone mixing ratio vertical profiles as well as surface temperature and pressure. Associated with these atmospheric profiles are the Radiances, Transmittances and Jacobians TIGR datasets specifying the situations a satellite-based instrument (e.g. TOVS, ATOVS, AIRS, IASI, Modis, Sevir, IIR) would have observed under various in-flight conditions (satellite zenith angle, surface characteristics, ...). These databases are generally used as relevant a priori information in inverse radiative transfer problems (e.g., Bayesian approach, NN training) as well as in the definition of space mission (selection of channels, sensitivity studies, ...). The current version, TIGR-2000, is widely used by our scientific community (300 versions distributed worldwide, a monthly mean of 4 requests these latter months).

The limited number of these states – so far 2311 in the current TIGR-2000 – results from adequate sampling methods applied on larger datasets, mainly based on radiosounding data, and are

classified into 5 air masses homogenous in terms of temperature and humidity.

However, this current version has shown some limits regarding: (i) the thermodynamic state sampling, (ii) the thermodynamic profile vertical resolution, (iii) the air mass classification, when faced with the high vertical and spectral resolutions as well as the low noise levels of the more recent sounding instruments. Here, we propose an improved version of TIGR, TIGR-2020 with a higher number of states (3335 vs 2311) and the following improvements: (i) a classification into 8 air masses based on a probabilistic approach through the use of a multivariate Gaussian mixture model applied to temperature and humidity cumulative distribution functions (J. Pernin et al, 2016); (ii) a 70-level hybrid sigma-pressure vertical grid with finer resolution near the surface and around the tropopause; (iii) a similar multivariate sampling approach applied on some up-to-date source databases, that is the Analyzed RadioSoundings Archive (ARSA) database at LMD and ERA-Interim reanalyses from ECMWF as ancillary data to fill the few missing thermodynamic states.

The description and impact studies of this new TIGR-2020 version of 3335 states will be presented at the time of the conference. We intend to open the distribution of the new 2020 version in the coming Summer 2021.

References

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3.03 Overview of the NASA CrIS Level 1B Version 3 Data Product and Product Assessment

Graeme Martin¹, Joe Taylor¹, Larrabee Strow², Hank Revercomb¹, Michelle Feltz¹, Dave Tobin¹, Bob Knuteson¹, Ray Garcia¹, Howard Motteler², Greg Quinn¹, Jessica Braun¹, Dan Deslover¹, Will Roberts¹

¹University of Wisconsin - Madison, SSEC/CIMSS, Madison, ²University of Maryland Baltimore County, Atmospheric Spectroscopy Laboratory

NASA has supported creation of a climate-quality Cross Track Infrared Sounder (CrIS) Level 1B dataset consisting of calibrated and navigated radiances that span the current SNPP and NOAA-20 missions, and that are expected to continue over the full JPSS mission timeframe. The processing software is written and maintained by the CrIS Level 1B Science Team, located at the University of Wisconsin-Madison and University of Maryland-Baltimore County. The algorithm theoretical basis is similar to the NOAA SDR product, but because the products are intended for use in climate applications, an emphasis is put on consistency in processing over the length of the mission, and on transparent and well-documented code. The latest software, Version 3, was put into production in January 2021, and the full SNPP and NOAA-20 mission products to date are now available for download from the NASA GES DISC web site.

Major improvements in the Version 3 product include polarization correction, correction for Doppler shift arising from Earth rotation, fringe count error detection and correction, improved calibration robustness and quality, and various other upgrades affecting data quality. Radiometric uncertainty can now be calculated for each observation using added outputs. Data quality checks and associated thresholds were improved. Improvements were made to geolocation.

Assessment of the Version 3 product included comparisons among detectors on each instrument (inter-FOV), as well as comparisons among CrIS instruments (SNPP / NOAA-20), with other instruments in the same platform (VIIRS), with other sounders (AIRS / IASI), and comparisons with model data.

This presentation will provide an overview of the CrIS Level 1B product, discuss the improvements in Version 3, and describe the results of the Version 3 product assessment. Future plans will also be discussed.

3.04 GSDART: A Global Scene-Dependent Atmospheric Retrieval Testbed for Passive Microwave Sounding Instruments

Hao HU¹, Fuzhong WENG¹, Jun YANG¹, Yang HAN², Yining SHI¹

¹Chinese Academy of Meteorological Sciences, China Meteorological Administration, Beijing, China, ²National Satellite Meteorological Center, China Meteorological Administration, Beijing, China

Microwave radiometers onboard satellites received the scattering and emitting radiation from clouds and precipitation and provided the data for detecting the atmospheric vertical thermal structures. Two microwave sounding instruments onboard the FengYun-3D satellite include the Microwave Temperature Sounder (MWTS) and the Microwave Humidity Sounder (MWHs). Their observation frequencies cover the low-frequency oxygen absorption bands near 50-60 GHz, the high-frequency oxygen absorption bands at 118 GHz, and high-frequency water vapor absorption bands at 183 GHz. With the observations from these absorption bands, the atmospheric temperature, humidity and hydrometers profiles, as well as surface parameters such as the surface temperature, surface pressure, etc., could be retrieved.

With a core one-dimensional variational (1DVAR) algorithm, this study developed a Global Scene-Dependent Atmospheric Retrieval Testbed (GSDART), which could retrieve the three-dimensional atmospheric temperature and water vapor. In GSDART, the scene information including geography, surface type and weather conditions of a field-of-view (FOV) could be automatically identified according to the observations, and then the specific atmospheric background field, background covariance matrix and error matrix are matched with the scene in the 1DVAR algorithm. Also, the newly developed Advanced Radiative Transfer Modeling System (ARMS) is utilized as a forward model in the variational algorithm and makes it possible to retrieve the atmospheric profiles under various weather conditions.

The assessment results show that the RMSE (Root Mean Squared Error) of the retrieved temperature profile is maintained within 2 K in low latitude areas (latitude less than 30°) for all weather conditions over land and ocean surfaces. But the RMSE increases to about 2.5 K in mid to high latitudes (latitude greater than 30°). Meanwhile, the RMSE of water vapor profile is under 20% for all latitudes and weather conditions. However, over snow and ice surface, the RMSE of temperature and water vapor become poor and can be as large as 4 K and 35%. With the retrieved surface pressure field, the location and intensity of tropical cyclones could be estimated. Compared with the best-track dataset for two-year tropical cyclones over the Western-North Pacific Ocean, the RMSE of location and intensity estimation is 28.79 km and 8.5 hPa, respectively. Further study will focus on the assessment of hydrometer profiles. And the improvements on retrieval

accuracy will be more focused on specific areas such as the Tibet Plateau, the third pole of the world.

3.05 Hyperspectral Infrared Machine Learning (HSIR ML)

Tim Hultberg¹, Thomas August

¹EUMETSAT, Darmstadt, Germany

Supervised learning has proven its potential for satellite retrieval and is an important first step in the operational IASI L2 processors of both EUMETSAT and NOAA. Nevertheless, in clear sky cases, these first retrievals are subsequently improved by variational (optimal estimation like) retrievals. This raises the question whether the precision of ML retrieval can be improved, such that it can fully replace optimal estimation for HSIR temperature and water vapour retrieval. We discuss different options for improving the ML retrieval precision and report on their overall success.

But good retrieval precision alone is not enough. We also need reliable error characterisation and the possibility to exploit a-priori knowledge to guide the retrieval of fine scale structures, which can't be determined by the measurements. That ML retrieval serves both these needs very well, will be demonstrated in detail. The optimal estimation error characterisation, which depends on the configured observation and a-priori error covariance matrices, is often considered to be more "rigorous" than the error estimates associated with ML retrievals. Such a claim is unjustified as the main error source of retrievals is the null space error (aka "smoothing" error), which is determined by the averaging kernel and the statistical distribution of the profiles - both of which can be well characterised by the ML retrieval. Likewise, there is no problem of characterising the impact of the instrument noise on the ML retrievals (which is typically a much smaller component of the total retrieval error). Extensive validation confirms the good quality of the error estimates of the ML piecewise linear regression IASI retrievals. The incorporation of prior knowledge, typically from NWP forecasts, is achieved simply by adding the additional knowledge to the list of predictors. We show that this enables us to retain the fine scale structures of the forecasts while still correcting the broad scale features when they are not compatible with the measurements. As a by-product, for each retrieved quantity, we obtain a weight, which describes how big a fraction of the retrieval is taken from the a-priori.

3.06 Enterprise Comparison of Atmospheric Profiles Derived from Polar Satellite and GNSS Constellations

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Comparisons of derived temperature and moisture profiles from selected NOAA, EUMETSAT and GNSS atmospheric product suites are compared. Baseline for comparisons are the conventional and reference radiosonde observations that are routinely collocated with the respective product suites using the NOAA Products Validation System; reference radiosondes are from the GCOS Reference Upper Air Network (GRUAN). Comparisons are enterprise meaning that the sets of radiosondes for comparing respective product suites are identical. Global and regional comparisons are provided including against specific radiosonde instrument types.

Session 4: Space Agency Reports (oral presentations)

4.01 EUMETSAT current plans

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This paper will summarize EUMETSAT's current status and plans of the future programmes. This will include the current and future mandatory programmes in Low Earth Orbit (LEO) and Geostationary (GEO) orbits: The EUMETSAT Polar System (EPS), Meteosat Second Generation (MSG) as well as EPS-Second Generation (EPS-SG) and Meteosat Third Generation (MTG). Third party missions and international cooperation will be also addressed.

4.02 Status report of space agency: JMA and JAXA

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JMA has been discussing the follow-on satellites of Himawari-8/9, scheduled to start the operation in 2029. It sees the hyperspectral infrared sounder as a potential payload and is making feasibility study from the scientific, social, and financial point of view.

JAXA operates the GCOM-W/AMSR2, GCOM-C/SGLI, GPM-core/DPR, GOSAT and GOSAT-2

missions, and prepares the EarthCARE/CPR and GOSAT-GW/AMSR3 missions for future launch. Their status and recent achievement will be presented in the conference.

Session 5: Calibration - Validation (oral presentations)

5.01 Current Status and Future Improvements for JPSS ATMS On-orbit Absolute Calibration

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The Advanced Technology Microwave Sounder (ATMS) is a passive microwave radiometer for the current generation of polar-orbiting meteorological satellites operated by NOAA. The first two ATMS instruments are manifested onboard the Suomi National Polar-orbiting Partnership (S-NPP) and NOAA-20 satellites. The ATMS will remain as the only microwave sounding instrument to fly on the subsequent JPSS satellites (JPSS-2 to JPSS-4), and all ATMS have a similar design. ATMS is a cross-track scanning microwave sounding instrument observing in 22 channels with frequencies ranging from 23 to 183 GHz. The ATMS raw Earth scene radiometric count measurements are converted into antenna brightness temperatures by first applying a two-point linear calibration equation, and a correction is made for the ATMS non-linear response. In general, all critical instrument performance specifications have been met. Several critical changes have been made to ATMS operational calibration algorithm since March 2017. The calibration processing has been revised from a Raleigh-Jeans approximated algorithm to a full radiance algorithm in order to reduce the error introduced by the approximation over cold radiances in the higher frequency channels. In addition, based on the lessons learned from S-NPP and NOAA-20 post-launch calibration/validation tests, some major improvements have been made in the updated operational algorithm. These include reflector emission and antenna pattern corrections. Based our most recent studies, temperature gradient in TVAC calibration targets and near-field stray-light contamination may have unignorable impacts on accuracy of on-orbit calibration, which will be addressed in future calibration algorithm.

5.02 Bias characterization of FengYun-4A/AGRI infrared channels using Advanced Radiative Transfer Modeling System (ARMS)

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The Advanced Radiative Transfer Modeling System (ARMS) has been developed to accelerate uses of FengYun satellite data in weather, climate and environmental applications in China. Currently, ARMS can simulate radiances observed by various spaceborne instruments in infrared and microwave spectrum. This work applies the ARMS of version 1.0 to characterize the bias of seven infrared channels of the Advanced Geosynchronous Radiation Imager (AGRI) onboard Chinese geostationary meteorological satellite, FengYun-4A. Since AGRI channel 8 (3.75- μ m) is found to be contaminated by stray light in the mid-night from 1600 to 1800 UTC during the spring and autumn seasons, relevant data were excluded in the statistics. The biases are then estimated by the differences between AGRI infrared observations and ARMS simulations with either the European Center for Medium-Range Weather Forecasts Reanalysis-5 (ERA5) or National Center for Environmental Prediction Final reanalysis (NCEP_FNL) data as input. The mean biases are within -0.7~1 K for all seven infrared channels over ocean and three absorption channels over land under clear-sky conditions, while -0.7~1.3 K are found for four surface-sensitive channels over land. Discrepancies in biases are found by using ERA5 and NCEP_FNL. The biases for the water vapor sounding channels 9 and 10 estimated by ERA5 over ocean are about 0.4 K, while those estimated by NCEP_FNL are within 1 K and 0.7 K, respectively. Such discrepancies arise from the fact that the NCEP_FNL data are colder (wetter) than the ERA5 in the mid-troposphere (upper-troposphere). The AGRI biases calculated by the ARMS are also compared with those by the Radiative Transfer for TIROS Operational Vertical Sounder (RTTOV). It is shown that the ARMS simulates the infrared radiances and estimating the observation biases with a skill similar to RTTOV.

5.03 The Progress on Retrospective Calibration of Historical Chinese Fengyun Satellite Data

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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 and 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, the latest progress of the re-calibration activities will be reported in this paper.

5.04 A consistently calibrated data record of the High-Resolution Infrared Radiation Sounder (HIRS) radiances

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High Resolution Infrared Radiation Sounder (HIRS) measurements, continuously available since the late 1970s, have been widely used in a climate context, e.g., to derive tropospheric temperature and water vapour profiles, climatologies of high clouds, total ozone content, and estimates of outgoing longwave radiation. In addition, the radiances have been assimilated into various global reanalyses.

EUMETSAT has produced a new HIRS radiance data record by reprocessing all available data from three generations of the HIRS instrument on-board

sixteen satellites, TIROS-N (HIRS/2), NOAA-6—14 (HIRS/2), NOAA-15—17 (HIRS/3), and NOAA-18—19 and Metop A/B (HIRS/4) applying a consistent state-of-the-art calibration to the whole time series. The latest HIRS calibration algorithm (version 4) contained in the ATOVS and AVHRR Processing Package (AAPP) software was adapted for application to the HIRS/2 instrument data. The modified version of AAPP calibration algorithm takes into account the self-emission characteristics of the HIRS instruments, which was not considered in the HIRS/2 original calibration procedure. For the HIRS/2 instruments, a discontinuity in the middle of two calibration cycles was found in the original data of up to 0.5K, but this has been mitigated in the new data record by considering multiple calibration cycles. For HIRS/3 instruments, original data were calibrated assuming static instrument gain over a period of 24 h. This can cause a significant bias of up to 0.6K, while the new calibration considers more dynamic instrument gain, which removes this bias. These enhancements to the AAPP software might be part of a future AAPP release.

The resulting data record provides quality controlled and recalibrated brightness temperatures, cold and warm noise equivalent differential temperatures (NEDT), and quality control flags. As the procedure does not involve any cross-calibration of the different satellites or inclusion of uncertainty estimates apart from time dependent instrument noise, it does not yet meet the requirements for a Fundamental Climate Data Record (FCDR), but represents a good baseline to develop it. For all instruments, our results show that the inclusion of NEDT information in the product allows easy identification of times and satellites when the instrumental performance was below specifications. This will help users of this HIRS data record to make informed decisions in their applications.

This presentation will provide details of the calibration algorithm and a quality evaluation of the data record. We have used time series analysis and comparisons against simulated radiances based on reanalysis profiles to evaluate the quality improvements compared to the original data. The overall result for the new data record is a higher quality compared to the operational data. Improvements consist of better Quality Control filtering and the removal of biases in the brightness temperature due to shortcomings in the original calibration algorithms. In addition, we will demonstrate that the new HIRS data record produces more stable calibration coefficients for

the MVIRI water vapour and infrared channel measurements, compared to previous HIRS data sets.

5.05 The Reprocessed Suomi NPP Satellite Observations

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The launch of the NOAA/NASA Suomi National Polar-orbiting Partnership (S-NPP) and its follow-on NOAA Joint Polar Satellite Systems (JPSS) satellites marks the beginning of a new era of operational satellite observations of the Earth and atmosphere for environmental applications with high spatial resolution and sampling rate. The S-NPP and JPSS are equipped with five instruments, each with advanced design in Earth sampling, including the Advanced Technology Microwave Sounder (ATMS), the Cross-track Infrared Sounder (CrIS), the Ozone Mapping and Profiler Suite (OMPS), the Visible Infrared Imaging Radiometer Suite (VIIRS), and the Clouds and the Earth's Radiant Energy System (CERES). Presently, observations from several instruments on S-NPP and JPSS-1 (re-named NOAA-20 after launch) provide near real-time monitoring of the environmental changes and improve weather forecasting by assimilation into numerical weather prediction models. Envisioning the need for consistencies in satellite retrievals, improving climate reanalyses, and development of climate data records, the NOAA/Center for Satellite Applications and Research (STAR) has been reprocessing the S-NPP observations for ATMS, CrIS, OMPS, and VIIRS through their life cycle. The reprocessing generates consistent Level-1 sensor data records (SDRs) using unified and consistent calibration algorithms for each instrument that removes artificial jumps in data owing to operational changes, instrument anomalies, contaminations by anomaly views of the environment or spacecraft, and other causes. The reprocessed SDRs were compared with and validated against other observations for consistency check whenever such data are available. The reprocessed data are being archived in the NOAA data center with the same format as the operational data and technical support for data requests. Such a reprocessing is expected to improve the efficiency of the use of the Suomi NPP and JPSS satellite data and the accuracy of the observed essential environmental variables through either consistent satellite retrievals or use of the reprocessed data in numerical data assimilations.

This presentation will provide preliminary results on the validation of the reprocessed S-NPP SDR datasets. Three approaches are used in the validation: 1) comparisons with operational products for consistency check; 2) comparisons with similar instrument channels but onboard other satellites for radiometric stability assessment; 3) checking the long-term instrument performance through the STAR Integrated Calibration and Validation System (ICVS) to investigate the root causes in the radiometric stability assessment. We will provide examples on the validation results for each sensor of the reprocessed S-NPP SDR products.

Session 6: Climate (oral presentations)

6.01 Preparations for Assimilating Sounding Observations in the Next Generation Global Atmospheric Reanalysis at ECMWF - ERA6

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An extension of the fifth generation atmospheric reanalysis at ECMWF, ERA5, back to 1950 has recently been completed. In addition to assimilating a comprehensive set of satellite sounding data starting from the TOVS suite of instruments from 1979 onwards, ERA5 makes use of early infrared sounding data from VTPR, carried on NOAA-2 through-5 from 1973-1979, as initially reported at ITSC-22 (Bell et al). Preparations are now underway for the next generation of reanalysis, ERA6, due to start in early 2024. These preparations aim to address some aspects, reviewed here, in the assimilation of sounding data evident in ERA5, including: drifting biases for the advanced IR sounding data due to the handling of evolving CO₂ concentrations; large inter-satellite biases in MSU data; and discontinuities in analysed stratospheric temperatures as a result of discontinuities and inter-satellite biases in SSU data.

In addition, ERA6 will make use of several reprocessed radiance datasets produced by EUMETSAT as part of the first (2015-2021) and second (2021-2028) phases of the EU's Copernicus Climate Change (C3S) programme. Plans currently include the assimilation of FCDRs for ATMS, MHS, MWHS-2, HIRS, SSM/T, SSMIS and Japanese geostationary satellite radiances. This element of C3S also aims to produce FIDUCEO-type uncertainty analyses for MSU, AMSU-A and ATMS.

ERA6 will also make use of several recently rescued early (1970s) satellite datasets, including radiances from SI-1, SMMR, SSH, IRIS, SIRS, PMR, MRIR, NEMS, SCAMS, ESMR and SCR. Preparations to date have included the generation of new RTTOV coefficients and evaluation of the quality of these radiances relative to ERA5 using analysis departures computed off-line. These evaluations have uncovered several biases in these datasets which are under investigation.

6.02 An overview of the satellite sounding radiance assimilation in the IMDAA regional reanalysis

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Reanalysis produced by the Indian Monsoon Data Assimilation and Analysis (IMDAA) project is currently the highest resolution (~12 km), long-term (1979 -2018, now extended to 2020), satellite-era regional reanalysis for the south Asian monsoon region where the world's most extensive annual monsoon occurs. Satellite radiance data was the crucial input to the IMDAA reanalysis. Radiances from various infrared (multispectral and hyperspectral) and microwave sounders were assimilated in the IMDAA system after proper quality control and bias correction. Satellite radiances from almost 25 instruments on board more than 40 different satellites have been assimilated in the IMDAA. A noticeable feature of the IMDAA assimilation system is the use of variational bias correction (VarBC) for satellite radiances. The VarBC adjusts observation bias parameters for satellite radiance observations based on other assimilated observations. Four different types of quality control (QC) procedures applied to the satellite radiance assimilation in IMDAA are: (i) initial QC: rejects observations with missing values, flagged as bad by the data producer, duplicates, outside the normal physical range, inconsistent in terms of location/track and too large departures from the hydrostatic equilibrium; (ii) blacklist QC: rejects cloud

contaminated and surface affected radiances, unusable channels, data when instruments have known problems; (iii) background QC: rejects radiances with large background departures, does thin to eliminate the observation cross-correlation errors, and (iv) VarBC: rejects observations those are too far from analysis after successive minimization. The introduction of various satellite radiances in the IMDAA reanalysis, as and when it was available, produced noticeable changes in the assimilation system which is evident in the analysis increment of different model variables. Spatial, spectral, and temporal coverage of the observations from various instruments, are presented in this paper. This paper also discusses the variational bias correction, background and analysis fit of different radiances assimilated in the IMDAA system, and their impact on the reanalysis in detail.

6.03 Rationale for Flight of an Infrared SI Reference Sensor for Climate Data Uncertainty Quantification

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The rationale for flying an infrared SI reference sensor as soon as possible is presented. The short answer is that the higher accuracy provided by an SI reference system will allow significant climate changes to be defined and assessed much sooner. The flight of a single, high quality, reference sensor of the type defined for the NASA Climate Absolute Radiance and Reflectivity Observatory (CLARREO) program would allow the international observing system to be used to establish an initial climate benchmark for future mission comparisons.

For perspective, the CLARREO program in the US is currently only committed to a Solar Pathfinder, the TRUTHS mission from the UK would also be solar, and the LIBRA mission in China that would include the IR is currently envisioned for the 2035 time frame. The highest practical accuracy is needed soon for monitoring international progress towards achieving the purpose of the Paris Agreement and other long-term goals.

CLARREO IR spectrometer requirements for the emission spectrum (3.7-50 microns) have been met by the UW-SSEC Absolute Radiance Interferometer (ARI) Engineering Model, demonstrating better than 0.1 K 3-sigma brightness temperature measurement accuracy

(Taylor et al., Remote Sens. 2020, 12, 1915; doi:10.3390/rs12121915). A key aspect of the ARI instrument is the On-orbit Verification and Test System (OVTS) for verifying its accuracy by reference to International Standards (SI). The OVTS includes an On-orbit Absolute Radiance Standard (OARS), a high emissivity cavity blackbody that can be operated over a wide range of temperatures to directly verify ARI calibration. The OARS uses 3 small phase change cells to establish its fundamental temperature scale to better than 10 mK, real time, on orbit. A broadband heated-halo source is also provided for monitoring its cavity spectral emissivity. Further, a Quantum Cascade Laser (QCL) is used by the OVTS to monitor the ARI spectral lineshape and the emissivity of its calibration blackbody relative to that of the OARS.

After intercalibration with a single ARI flown in a pure polar or 50 degree precessing orbit, like ISS, the near-term international fleet of operational temperature and water vapor sounders in sun-synchronous orbit (0930, 1330, 1730) will provide the global coverage required for establishing a climate benchmark. We expect that ARI will serve as the ultimate reference sought for future Global Space-based Inter-Calibration System (GSICS) activities.

6.04 Clear-Sky Estimation of Earth Outgoing Longwave Radiation and Atmospheric Heating Rate with IASI

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The Earth radiation budget is the main driver of the climate system as it encompasses the balance between the incoming solar radiation and the Outgoing Longwave Radiation (OLR) from the Earth and its atmosphere. This Essential Climate Variable can only be measured from space. In addition to the OLR, longwave atmospheric heating rate measurements allow a deeper understanding of climate dynamics as they describe the vertical distribution of sources and sinks of radiative energy and captures the temperature response of the atmosphere to heating imbalances.

By covering an important proportion of the longwave spectrum (642-2760 cm⁻¹) with a high spectral resolution, the Infrared Atmospheric Sounding Interferometer (IASI), developed by the CNES and onboard EUMETSAT's polar orbiting satellites Metop-A (2006), Metop-B (2012) and Metop-C (2018) will provide 20 years of radiance spectra measurement at the top of Earth atmosphere. Combining a high spectral and radiometric stability, IASI is well suited to study OLR and heating rates, in addition to allowing the retrieval of vertical atmospheric parameters such as temperature profiles or concentration of main constituents and to study their variability on climatic timescales.

Here, we present a fast and accurate machine learning method to estimate the clear-sky OLR on several spectral bands and longwave atmospheric heating rate profiles directly from IASI brightness temperature spectra (L1c products). This method is based on a set of multilayer perceptrons (MLPs) that are specialized for various types of air masses and measurement angles. The learning and evaluation databases rely on the forward computation of 4A/OP to which a module, called 4A-Flux, dedicated to the computation of OLR and heating rates has been implemented. This new capability of 4A/OP has been evaluated in the international inter-comparison exercise RFMIP that has shown very good agreement between participating models (inter-model agreement on forcing estimates are within 0.025 W.m⁻²). The learning database of the MLPs has been generated from the Thermodynamic Initial Guess Retrieval (TIGR) database, and the evaluation of the MLPs is performed on the Analyzed RadioSoundings Archive (ARSA) containing radiosonde measurements coupled with both simulated and observed brightness temperatures of IASI. The comparison of the retrieved OLR with direct computation of these quantities with 4A/OP using IASI thermodynamic retrieved data (operational EUMETSAT L2 products) yields a small bias of 0.52 ± 0.31 W.m⁻² (0.19% ± 0.11%) over the tropical oceans with a computation time 10'000 times faster than direct computation. Our approach thus allows estimations of the OLR and the vertical heating rate that are both accurate and faster than the complete line-by-line computation as implemented in 4A/OP allowing the computation on the long series of IASI observations. We will present OLR time-series derived from the 13 years of IASI measurements and show that it is possible to extract from this time series well-known climatic signatures such as El Niño Southern Oscillation (ENSO). Finally, a comparison between

OLR retrieved from IASI and collocated OLR measured by ScaRaB onboard Megha-Tropiques satellite and CERES onboard Terra will be presented to evaluate the retrieval and shows that IASI is well suited to study OLR over a long time period.

Session 7: NWP Centre Reports (oral presentations)

7.01 Recent updates in the satellite data assimilation in the NCMRWF NWP systems

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NCMRWF operationally runs global deterministic and ensemble models based on both NGFS and NCUM. Apart from these, regional systems like a 4D-Var assimilation system and an ensemble system centered over India and surrounding Oceanic regions based on the NCUM are also operating routinely. This presentation gives an overview of the changes and updates in the radiance usage and data assimilation system, and new instruments activated in the NCMRWF NWP systems since ITSC-22.

7.02 Satellite radiance assimilation at the Bureau of Meteorology

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The Bureau of Meteorology operates a global model, seven regional convection-allowing models, and a relocatable tropical cyclone model, based on the Met Office Unified Model. Since 2020, all of these NWP systems have included 4D-Var data assimilation incorporating satellite radiance data. This presentation will provide an update on these systems relative to the last conference.

Satellite radiance data continue to provide significant forecast impact in our forecast system. Our global configuration assimilates brightness temperatures from ATOVS, IASI, ATMS, CrIS, AIRS (until Dec 2020), AMSR2 and Himawari-8. In a recent upgrade, we have added brightness temperatures from MetOp-C and NOAA-20 instruments.

Our next upgrade will likely include the addition of the Met Office scheme for all-sky microwave data

assimilation, and increase the use of microwave channels over land.

The seven regional convective-scale model configurations and the new TC model use data from ATOVS, IASI, ATMS, CrIS and (until recently) AIRS, from both global and direct readout sources. In the near future we hope to add brightness temperatures and 'GeoCloud' retrievals from Himawari-8/9 to the regional systems.

A 2.2 km National Analysis System (NAS) is also being developed which includes rapid update 3D-Var assimilation in conjunction with a 4D-Var assimilation cycle which will make similar use of brightness temperature data as the regional systems.

7.03 Recent progresses and ongoing developments on satellite data assimilation in GRAPES

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Satellite observations are assimilated in both the global model GRAPES-GFS and meso-scale model GRAPES-meso operationally at CMA. This presentation gives an overview of the recent progresses and ongoing developments of satellite data assimilation, and highlights some recent studies on the use of current FengYun satellite measurements and OSSEs for future FengYun satellites.

Improvements in the assimilation of satellite observations have led to significant performance gains in the GRAPES global model over the last two years. Upgrades in the treatment of satellite observations include the following:

- Assimilation of FY-4A GIIRS temperature sounding channels operationally since December 2018 and updates in January 2020

- Assimilation of water vapor sounding channels of FY-4A AGRI and FY-2H VISSR since April 2020
- Assimilation sounding instruments onboard FY-3D since April 2020

Ongoing developments include:

1. FOV independent observation errors of FY-4A
2. The impact of considering actual spectral response of FY-3D MWTS in radiance assimilation
3. The ascending and descending dependent biases of FY-3D MWTS
4. Assimilation of surface sensitive microwave channels
5. Assimilation of FY-4A GIIRS water vapor sounding channels
6. Assimilation of HY-2B scatwinds
7. Fast non-spherical scattering calculation for all-sky radiance assimilation
8. Hybrid OSSEs for future geostationary microwave sounder
9. Developing adaptive channel selection method for infrared hyperspectral data

7.04 Recent upgrades and progresses of satellite radiance data assimilation at JMA

Mr. Hidehiko Murata¹, Mr. Hiroyuki Shimizu¹, Mr. Norio Kamekawa¹, Mr. Naoto Kusano¹, Ms. Izumi Okabe², Dr. Keiichi Kondo²

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JMA operates three major data assimilation systems (global, meso-scale and local analysis). This presentation overviews recent upgrades of satellite radiance data assimilation into the systems since the last ITSC-22 in November 2019, as well as ongoing developments.

The recent upgrades are highlighted as follows:

- Introduction of all-sky microwave radiance assimilation scheme into the global system for microwave imagers (GCOM-W/AMSR2, GPM/GMI, DMSP-F17,F18/SSMIS, Coriolis/WindSat, FY-3C/MWRI) and water-vapor sounders (GPM/GMI, NOAA-19/MHS, Metop-A,B/MHS) with incorporation of outer-loop iterations and Hybrid 4D-Var/LETKF data assimilation. (December 2019)

- Assimilation of new instruments Metop-C/AMSU-A and MHS into the global system. (September 2020)
- Assimilation of Himawari-8 surface-sensitive bands 9 and 10 clear-sky radiance (CSR) data into the local system in addition to band 8 using the same radiative transfer calculation method as the global and meso-scale systems. (July 2020)

Progresses on major development are the following:

- Application of the all-sky radiance assimilation scheme to additional microwave humidity sounders (Suomi-NPP, NOAA-20/ATMS, DMSP-F17,F18/SSMIS, Megha-Tropiques/SAPHIR, FY-3C/MWHS-2) to the global system.
- Assimilation of GOES-17/CSR into the global system.
- Switch of channel-selected IASI radiance dataset (616 to 500 ch).
- Assimilation of Metop-C/AMSU-A and MHS into the meso-scale system.
- Assimilation of surface-sensitive microwave radiance using dynamically estimated emissivity.

7.05 Current Status, Planned Upgrade, and Challenges in the Use of Sounder Data in NCEP Global Data Assimilation System

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The NCEP Global Data Assimilation System (GDAS) is a hybrid 4D ensemble-variational analysis system, in which it combines numerous types of observations, including satellite radiances, with a short-range forecast to produce an optimal estimate of the atmospheric state for using as an initial condition in a forecast model. Satellite observations are vital to numerical weather prediction (NWP) systems as they provide nearly global and vertical (channel) coverage of high-quality data. Four types of radiance data are currently assimilated in GDAS: infrared imagers, hyperspectral infrared sounders, microwave imagers, and microwave sounders. The microwave sounders such as AMSU-A and ATMS

are assimilated in all-sky conditions whereas the other types are used in clear-sky conditions. Inter-channel error correlations are considered in GDAS for hyperspectral infrared sensors such as IASI and CrIS, over land and sea surface, respectively as they have different error characteristics. A set of selected moisture channels are assimilated in addition to channels in the 15-micron CO₂ band and surface channels. Microwave sounders are assimilated in all-sky conditions in which the observations affected by non-precipitating clouds over the ocean are used in the analysis. In the current operational system, the model top had raised to 80 km with 127 layers. Therefore, the highest-peaking channels from microwave sounders are assimilated to constraint the analysis in the upper atmosphere near the top. These highest-peaking channels are assimilated without bias correction to prevent aliasing model bias into the bias correction estimate. Both IR and MW sounder data are also used in constraint the near sea surface temperature (NSST). In this presentation, the challenges in the use of sounder data in GDAS described above as well as the planned upgrade will be discussed in detail.

7.07 Current status and developments of satellite radiance assimilation at DWD

Christina Köpken-Watts¹, Robin Faulwetter, Olaf Stiller, Anne Walter, Michael Bender, Silke May, Christina Stumpf, Annika Schomburg, Liselotte Bach

¹DWD, Offenbach, Germany

This talk presents an overview of the current status of satellite radiance data assimilation at DWD as well as of ongoing developments both for the global ICON system and the convection-resolving ICON-D2.

The global system has seen updates including the addition of further humidity sensitive radiances from SAPHIR, higher peaking SSMIS channels over land surfaces as well as tuning updates for IASI covariances. This has been complemented by other new satellite data like Aeolus HLOS winds and a number of RO platforms as well as additional conventional data from radiosonde descents. Also, a successful migration of the operational model and analysis systems to the new NEC vector supercomputer with corresponding updates and optimization have taken place. Experiments testing upgrades of the cloud and aerosol detection for the hyperspectral IR sounder data to the most recent CADS version as well as implementing RTTOV-13 along with predictors based on the most recent spectroscopy are

ongoing. This work is now continuing using the most recent ICON version for which the change of the radiation scheme (to ecRad) as well as new surface emissivities and snow albedo have a direct impact on satellite sounder use. A challenge in this respect is transitioning the bias correction to changes in the model climate for which dedicated assimilation runs using a reduced set of satellite radiances are being carried out.

For the convection-resolving model, the focus has been on the operationalisation of the assimilation of visible reflectances. This is prepared in the context of the new very short-range forecasting system SINFONY as well as for the new operational limited area ICON-D2 model and assimilation system that is also operationally using 3D radar reflectances.

Both for the global as well as for the convection-resolving NWP systems, the implementation of all-sky assimilation for IR and MW parts of the spectrum is ongoing.

7.08 Recent Updates and Challenges in the Use of Sounder Data at ECCC

Alain Beaulne¹, Maziar Bani Shahabadi¹, Patrice Beaudoin¹, Joël Bédard¹, Mark Buehner¹, Martin Deshaies-Jacques¹, Jose Garcia¹, Ping Du¹, Sylvain Heilliette¹, Pieter Houtekamer¹, Ervig Lapalme¹, Stéphane Laroche¹, David Lobon¹, Stephen Macpherson¹, Emmanuel Poan¹, Nicholas Soulard¹, Judy St-James¹

¹ECCC, Dorval, Canada

Since the ITSC-XXII meeting held in Canada in Fall 2019, Environment and Climate Change Canada (ECCC) weather forecasts have benefited from the operational implementation of new sounder data in its Global and Regional Deterministic (GDPS and RDPS) and Global Ensemble (GEPS) Prediction Systems, whereas scientific improvements for the optimal use of sounder data have been tested and approved for implementation in the coming months.

In the GDPS and RDPS 4DVar algorithm, the AMSUA, MHS and IASI data from Metop-C, CrIS-FSR from Suomi-NPP, MWHS-2 from FY-3C, and the CSR from GOES-17 have been added to the assimilation, while IASI from Metop-A was removed. In the GEPS EnKF algorithm, only the replacement of IASI satellite data was accomplished.

Regarding scientific improvements, better use of sounder data have been tested and accepted for

the GDPS and RDPS, namely slant-path radiative transfer calculations for all satellite radiances, RTTOV computations on model levels, a better detection of cloud contamination in the quality control of CrIS-FSR, a consolidated processing in a unified data assimilation framework and, for the GPDS only, the assimilation of cloud-affected temperature sensitive radiances from AMSUA channels 4 and 5.

In addition to mentioning challenges encountered with the previous innovations, current plans to increase and improve radiance data use in ECCO systems will be discussed.

7.09 Recent upgrades in the use of satellite radiance observations within the Met Office global NWP system

Chawn Harlow¹, Brett Candy¹, Nigel Atkinson¹, Fabien Carminati¹, Michael Cooke¹, James Hocking¹, Byung-Il Lee², Stefano Migliorini¹, Stuart Newman¹, Ed Pavelin¹, David Rundle¹, Ruth Taylor¹, Michael Thurlow¹, Simon Thompson¹, Warren Tennant¹, Emma Turner¹
¹Met Office, Exeter, United Kingdom, ²Korean Meteorological Administration, Seoul, Korea

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 in Dec 2019 and in Dec 2020. Highlights of these upgrades include the following.

We introduced several new radiance instruments in this period including ABI on GOES-16, MWRI on FY-3C (until instrument turn-off in Feb 2020), ATOVS and IASI on Metop-C, and MWHS-2, MWTS-2 and MWRI on FY-3D. ATOVS and IASI on MetOp-C were introduced as a replacement for the instruments on MetOp-A which is approaching end of life later this year. We did this swap of instruments instead of adding the new sounding data from MetOp-C on top of that from MetOp-A and MetOp-B because trials adding the additional data performed poorly in comparison those with data only from two MetOps. The reason for this poor performance will be briefly discussed in the talk.

We incorporated two major updates to radiative transfer during this period. We went from doing RTTOV calculations using coefficients on 43 levels to those on 54 levels. At the same time, we switched from doing radiative transfer calculations for the hyperspectral IR sounders on coefficient

levels to model levels within OPS for the purpose of quality control and retrieval of parameters (such as *tskin* and emissivity) used in VAR. These RT changes led to the largest impact on forecast accuracy of any changes during this period.

We also improved our radiance observation processing during this period. At the last ITSC, we reported on the change from the assimilation of clear-sky only to the assimilation of all-sky radiances of AMSU-A. In this period, in addition to assimilating clear-sky MHS data, we began assimilating cloudy MHS data for scenes without precipitation. This improvement was also reliant on improvements in radiative transfer through the treatment of scattering within RTTOV-SCATT. In addition to this all-sky work, improvements were made to the quality control of 183 GHz humidity sounding data over land and the quality control for cloud screening applied to microwave imagers.

This presentation will focus on the above improvements to our satellite radiance data processing and assimilation during this period.

7.10 Recent changes in the operational use of passive sounding data in the ECMWF NWP system

Mohamed Dahoui¹, Niels Bormann, Stephen English, Massimo Bonavita, Chris Burrows, Reima Eresmaa, Alan Geer, Patrick Laloyaux, Katrin Lonitz, Cristina Lupu, Tony McNally, Marco Matricardi, Peter Weston, Kirsti Salonen
¹ECMWF, Reading, United Kingdom

This presentation gives an overview of the status of the operational assimilation of passive sounding data at ECMWF and highlights recent relevant changes in the ECMWF NWP system. At the time of writing, ECMWF assimilate radiance observations from 19 MW instruments, 6 hyperspectral IR sounders, and 5 geostationary satellites. The main additions of passive microwave or infrared radiances since ITSC-22 have been instruments from FY-3D (MWHS-2 and MWRI) and GOES-17. The year 2020 also saw the active assimilation of wind profiles from the Doppler Wind Lidar Aeolus, as well as a substantial increase in the use of GPS radio occultation observations.

There has been one major upgrade of the ECMWF system since ITSC-22, cycle 47r1, implemented on 3 July 2020 and introducing an number of changes in model physics, assimilation methodology and observation usage. Key innovations for the use of passive sounding data were channel-specific aerosol detection for the hyperspectral IR

sounders, accounting for observation error correlations for NOAA-20 ATMS, and a revision of the skin-temperature background errors used for many sounding instruments, introducing a situation-dependence in the assigned values. There has also been a revision of model error covariances used in weak-constraint 4D-Var for the stratosphere, enabling a better separation between observational biases and model biases, particularly relevant for the top-most MW or IR temperature-sounding channels.

Preparations are also currently underway for a future cycle (47r3), tentatively planned for implementation later in 2021. This is expected to include the extension of the assimilation of AMSU-A data to all-sky, a major upgrade of the radiative transfer coefficients for hyperspectral instruments, and taking into account inter-channel error correlations for the AIRS instrument.

7.11 Recent Earth Observation Developments at the U.S. Naval Research Laboratory

Benjamin Ruston¹, Nancy Baker, Steve Swadley, Hui Christophersen, Dan Tyndall, Sarah King, Pat Pauley

¹*U.S. Naval Research Laboratory, Monterey, United States*

The U.S. Naval Research Laboratory continues to develop and advance the use of Earth observations for Navy systems, including the mesoscale COAMPS[®], global NAVGEM and coupled Navy ESPC environmental prediction models. The mesoscale system continues to use the 3D-Var NRL Atmospheric Variational Data Assimilation System (NAVDAS), while the global and couple models use the hybrid 4D-Var NAVDAS-AR (accelerated representer). The hybrid component uses an 80-member ensemble to develop the ensemble component of the background error, and a single outer loop is used. Finally, the Navy's next generation unified model NEPTUNE is currently under development, with plans to deliver the code to FNMOC in 2023. The data assimilation capabilities for NEPTUNE are being developed using the JCSDA JEDI infrastructure. The initial demonstrations of the NEPTUNE-JEDI 3D-Var and 4D-Var systems are ongoing, and plans are to deliver a Hybrid 4D-Var in 2023. Regarding the Earth observation suite, the global pandemic showed a shift in the observation availability, particularly for conventional observations. In particular, the decrease in the amount aircraft data corresponded with shift to greater reliance on satellite observations. Also of note, GNSS-RO data were provided by NOAA's Commercial Data

Program under its first operational weather data contract for commercial radio occultation data. The impact from this data was seen through the reduction of standard deviation of the fit-to-observations for both radiosonde temperature and microwave sounders showing a benefit of this data. The recent and rapidly evolving landscape of small satellites, with shorter design lifetimes, and containing constellations of disaggregated platforms will likely become the new reality. Emerging missions such as COWVR, TEMPEST, TROPICS, and GEMS-2 will be beneficial in developing new strategies for rapid prototyping and implementation where tools need to be developed to quickly evaluate, monitor and integrate technologies of future systems.

JCSDA: Joint Center for Satellite Data Assimilation

JEDI: Joint Effort for Data assimilation Infrastructure

NEPTUNE: Navy Environmental Prediction system Utilizing the NUMA core

NUMA: Nonhydrostatic Unified Model for the Atmosphere

Session 8: NWP Advances (oral presentations)

8.01 Improving the use of satellite radiances in high latitude regional NWP

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In the framework of the Alertness project, observing system experiments were conducted to qualify the role of observations, including satellite radiances, in the AROME-Arctic. In this study, on top of the classical regional impact study, impacts of Arctic and mid-latitude observations through the lateral boundary conditions were also studied. Apart of this study, efforts are dedicated in implementing more satellite radiances into our operational systems, e.g. adding data from ATMS, MWHS2 and CrIS instruments. Further, we aim at revisiting the updating procedure of the variational bias correction coefficients taking into account the largest availability of the different instruments inside the model domain. Furthermore, implementation of all-sky approach and considering the footprint of each instrument in assimilation process are also ongoing. Moreover, improved use of the surface data assimilation through a weak coupling in the upper-air data assimilation is also under investigation.

If the presentation time permits, we would like to give short report about the above mentioned research and development topics.

8.02 Operational Hyperspectral Sounder Error Correlations

Fiona Smith¹, Kristen Bathmann³, Bill Campbell⁶, Fabien Carminati⁷, Nadia Fourrie², Alan Geer⁵, Toshiyuki Ishibashi⁴, Marco Matricardi⁵, Kozo Okamoto⁴, Kirsti Salonen⁵

¹*Bureau of Meteorology, Docklands, Australia,*

²*Meteo-France, ³NCEP, ⁴JMA, ⁵ECMWF, ⁶NRL, ⁷Met Office*

In 2009, the ECMWF/NWP-SAF Workshop on the assimilation of IASI called for research into better estimates of inter-channel error correlation. This presentation will summarise the methods that have been put into use since then by operational NWP centres to estimate the error covariance matrices. Despite some flurries of activity to investigate alternatives, most centres have settled on the Desroziers et al. (2005) diagnostic method to deliver a pragmatic solution to the estimation of observation errors, for both raw and reconstructed radiances. One aspect that remains somewhat unsatisfactory is the need to inflate observation error variance, or to manipulate the correlation terms, to deliver a matrix that works within the assimilation system. Sometimes the correlations may be under-determined and the covariance matrix rank deficient for mathematical reasons, but in many cases it seems likely that the inflation is related to aspects of the errors that are not resolved by the Desroziers diagnostic. What is striking is that the patterns of errors are remarkably similar between centres and between instruments. Although most NWP centres apply some approach to regularise or inflate the error terms, there is little attempt to ascribe a reason for the requirement. This is an area where the community could probably benefit from some further discussion to direct future work.

8.03 Impact of FY-3D MWRI Radiance Assimilation in GRAPES 4D-Var on Typhoon Shanshan Forecasts

Dr. Hongyi Xiao^{1,2}, Dr. Wei Han^{1,2}, Mr. Hao Wang^{1,2}, Dr. Jincheng Wang^{1,2}, Mrs. Guiqing Liu^{1,2}, Mr. Changshan Xu³

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In this study, Fengyun-3D (FY-3D) MicroWave Radiation Imager (MWRI) radiance data were directly assimilated into the Global/Regional Assimilation and Prediction System (GRAPES) four-dimensional variational (4DVar) system. Quality control procedures were developed for MWRI applications by using algorithms from similar microwave instruments. Compared with the FY-3C MWRI, the bias of FY-3D MWRI observations did not show a clear node-dependent difference from the numerical weather prediction background simulation. A conventional bias correction approach can therefore be used to remove systematic biases before the assimilation of data. After assimilating the MWRI radiance data into GRAPES, the geopotential height and humidity analysis fields were improved relative to the control experiment. There was a positive impact on the location of the subtropical high, which led to improvements in forecasts of the track of Typhoon Shanshan. This study is supported by the National Natural Science Foundation of China (41675108, 42075155), National Key Research and Development Program (2018YFC1506700), and Second Tibetan Plateau Scientific Expedition and Research Program (2019QZKK0105).

8.04 Assimilation of Geostationary Hyperspectral InfraRed Sounders (GeoHIS): progresses, challenges and perspectives

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Hyperspectral infrared (IR) sounders feature thousands of channels, which collectively provide high vertical resolution and the capability to accurately measure atmospheric temperature and humidity vertical structure information. The assimilation of high spectral resolution infrared sounder observations from polar orbit satellites has been widely used in global and regional numerical weather prediction (NWP) models and has large positive impact on NWP. However, Polar hyperspectral IR sounders have inadequate temporal coverage which limits their capability on rapid evolving weather systems analyses and forecasts. High temporal geostationary (Geo) hyperspectral IR sounder (GeoHIS) radiance measurements enable continuous sounding of the atmospheric temperature and moisture, and thus capture the temporal and spatial variability for high impact weather or rapid changing weather events.

On 10 December 2016, the successful launch of China's Fengyung FY-4A satellite into

geostationary orbit initiated a new era in Earth observation by providing the first time-continuous observations of the upwelling thermal infrared at high spectral resolution with the Geostationary Interferometric Infrared Sounder (GIIRS). GIIRS is a Michelson interferometer that measures the atmospheric infrared radiation in a spectral range 700-2250cm⁻¹ at a spectral resolution of 0.625cm⁻¹. It has 1650 spectral channels covering longwave infrared (LWIR) (700-1130cm⁻¹, 689channels) and middle-wave infrared (MWIR) (1650-2250cm⁻¹, 961channels) bands. A subset of GIIRS longwave temperature sounding channels has been assimilated in China's global NWP system GRAPES (Global/Regional Assimilation and PrEdiction System) since December 2018 and improve the forecast over East Asia, especially for high impact weather forecasting, such as Typhoons. The European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) is developing an operational advanced GEO hyperspectral IR sounder (IRS) as a part of Meteosat Third Generation (MTG-3) in the mid 2020's. The Japan Meteorological Agency (JMA) also has started discussions of a follow-on program for the operational geostationary satellites Himawari-8 and -9, which are scheduled to operate until 2029. NOAA recently has evaluated a range of space architecture options to select one that will provide the highest priority observations effectively and efficiently for a future Geosynchronous and Extended Orbit (GEO-XO) program considering infrared hyperspectral sounder onboard two spacecraft near the current GOES-East and GOES-West positions.

Based on the evaluation and assimilation of GIIRS, this study will discuss the recent progresses, current major challenges and future perspectives of GeoHIS assimilation. The opportunities include targeted observing for high impact weather, and improvement in convective storm forecasts, including tornadoes and hurricanes. The challenges include accurate spectral and radiometric calibration, considering the possible diurnal variation, fast radiative transfer model for large satellite zenith angles, and continuous data assimilation for application to high temporal observations.

Session 9: All-sky Assimilation (oral presentations)

9.01 Recent Progress for All-Sky Microwave Radiance Assimilation in Environment Canada's Global Deterministic Weather Prediction System.

Maziar Bani Shahabadi¹, Mark Buehner¹, Sylvain Heilliette¹

¹Environment and Climate Change Canada, Dorval, Canada

Assimilation of non-precipitating ocean scenes of cloud-affected channels 4-5 AMSUA observations with the all-sky approach was recently accepted for operational implementation in the Environment and Climate Change Canada (ECCC) 4D-EnVar for the Global Deterministic Weather Prediction system (GDPS). The symmetric model for the innovation standard deviation (stddev), proposed by Geer and Bauer (2011) is used for the quality control and for defining the observation error stddev of cloud-affected observations. The assimilation experiments without including cloud in the control vector produce similar results to the experiments when cloud is analyzed. This indicates the all-sky assimilation impact is mainly due to using clouds for computing the innovations combined with the cloud-dependent observation error stddev. Overall the results showed statistically significant reductions in error stddev by 1-4% for the temperature, specific humidity, and horizontal wind forecasts up to a lead time of 4 days in the lower troposphere.

Currently, the all-sky assimilation approach is being extended to channels 5-6 ATMS observations. The results from assimilation experiments show neutral impact on the forecast skills.

The background state clouds are largely overestimated in the GDPS. To compensate for this, a multiplicative scale factor is applied to the vertical cloud profile before its use in the observation operator. A cloud pre-processing step is essential to reduce the dependency on the background state cloud and the application of ad-hoc cloud scale factor for all-sky assimilation. Towards this goal, we are investigating adding an outer-loop for computing the analysis increment and using the updated cloud fields to relinearize the non-linear observation operators.

Reference: Geer, A. J., and P. Bauer (2011) Observation errors in all-sky data assimilation. *Quart. J. Roy. Meteor. Soc.*, 137, 2024-2037.

9.02 Status of the assimilation of cloudy and rainy microwave observations in the Météo-France global NWP model ARPEGE

Mary Borderies¹, Philippe Chambon¹, Jean-François Mahfouf¹, Marylis Barreyat¹, Maud Martet¹

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The positive impacts which can be derived from the assimilation of cloudy and rainy radiances of microwave humidity sounders have already been demonstrated by several NWP centres. At Météo-France, the utilization of these cloudy and rainy observations has been the subject of investigations, first with the SAPHIR sounder (Guerbette et al., 2016; Duruisseau et al., 2019) and then with sounders with similar channels around the 183 GHz water vapour absorption band.

In the 2021 parallel suite of the ARPEGE global model, the assimilation of cloudy and rainy observations from 3 MHS and 2 ATMS instruments will be activated. The method used for assimilating those observations is called the '1D-Bay+4D-Var' (Duruiseau et al., 2019). Profiles of relative humidity are first derived via a 1-D Bayesian retrieval, and then used as relative-humidity pseudo-observations in the 4DVar assimilation system of ARPEGE.

In this presentation, the assimilation results which conducted to the activation of this modification in the parallel suite will be summarized; the results of the sensitivity experiments to several parameters including, the observation errors, the quality control as well as the vertical sampling of retrieved profiles will also be shown. Two ongoing developments which could be considered for further improvements of the current method will also be discussed: (i) a dynamic method based on weighting function calculations to better localize the impacts, (ii) a dynamic method to adapt radiative properties of hydrometeors to the current meteorological conditions.

9.03 Moving AMSU-A to all-sky assimilation at ECMWF

David Duncan¹, Niels Bormann¹, Alan Geer¹, Peter Weston¹

¹ECMWF, Reading, United Kingdom

Microwave temperature sounders have been a primary driver of forecast skill at ECMWF for two decades but used in clear-sky conditions only. Expanding the usage of AMSU-A channels 5-7 into clouds and precipitation has been a challenging technical and scientific problem, spanning years of development. Recent enhancements to the treatment of all-sky AMSU-A are described, including changes to data thinning and variational quality control, as well as technical changes that bring all-sky more in line with the clear-sky data stream. In new results, these incremental changes result in all-sky AMSU-A now replicating and, in

some cases, exceeding the overall forecast impact of clear-sky. Used channel 5 and 6 observations increase by about 14% and 6%, respectively, providing greater sampling over storm track and stratocumulus regions in particular. The benefit of all-sky assimilation for AMSU-A is apparent in the improved background fits of surface pressure measurements and various humidity-sensitive observations. Channel 5 now shows a much larger impact on short-range forecasts, as measured by FSOI. Forecasts of tropical cyclones are improved for central pressure and track, with Hurricane Humberto providing a case study. On the strength of these results, AMSU-A will move to all-sky assimilation in the next operational upgrade.

9.04 Preliminary assimilation of all-sky IR radiances of Himawari-8 in the global data assimilation system at JMA

Kozo Okamoto¹, Mr. Masahiro Hayashi¹, Dr. Tempei Hashino², Mr. Masayuki Nakagawa¹, Mr. Arata Okuyama³, Ms. Izumi Okabe¹, Dr. Toshiyuki Ishibashi¹

¹JMA/MRI, Tsukuba, Japan, ²Kochi University of Technology, Kami, Japan, ³JMA/MSC, Kiyose, Japan

All-sky infrared radiance (ASR) assimilation has been developed for Himawari-8 in the global data assimilation system of JMA. The representation of ASR simulations from the global forecast model and radiative transfer model were carefully examined. The poor representation of simulations was found especially for thick high-altitude clouds. The systematic differences between observations and simulations were caused by considerable deficit of high cloud in the forecast model and overestimated absorption of thin ice cloud in radiative transfer calculation. This examination results helped to develop quality control (QC) procedures and bias correction (BC).

We assessed impacts of Himawari-8 ASR through data assimilation cycle experiments in comparison with the operational clear-sky radiances assimilation. The assimilation experiments without BC showed positive impacts in temperature but negative in water vapor with respect to first-guess departure fit, and overall neutral or negative impacts on medium range forecasts. We speculate that the negative impacts were associated with the significant model biases. Several different BC predictors and sampling conditions to compute BC coefficients in the VarBC scheme are being tested. The preliminary results for these assimilation experiments with BC will be presented.

Session 10: NWP Surface (oral presentations)

10.01 Advances in the assimilation of MW sounding data over snow and sea-ice

Niels Bormann¹

¹ECMWF, Reading, United Kingdom

Surface-sensitive observations from MW sounders are currently under-used over snow and sea-ice in ECMWF's assimilation system. Comparisons between observations and background-equivalents exhibit considerable biases in these regions. This presentation will explore two aspects that contribute to these biases seen in channels in the 50 and 183 GHz bands: Firstly, the treatment of snow and sea-ice as Lambertian (or semi-Lambertian) rather than specular surfaces, and secondly, the description of the effective skin temperature used in the radiative transfer.

Comparisons between observations and background equivalents show that accounting for Lambertian surface effects in the radiative transfer calculations significantly reduces viewing-angle-dependent biases for cross-track sounders. This is particularly the case for 183 GHz channels, whereas the situation for 50-GHz temperature sounding channels is more complex. Taking these effects into account leads to more data being assimilated, with some small benefits in terms of forecast impact at higher latitudes.

Experiments also suggest that the presently used description of skin temperature is another considerable source of bias over snow and sea-ice for MW observations, most likely due to neglected penetration effects. An augmented control-variable framework has been developed, that allows the retrieval of a time-varying effective skin temperature field during the assimilation, constrained simultaneously by a range of sensors. The framework points to persistent biases in the presently used skin temperature over snow and sea-ice for MW frequencies, and opens possibilities to address these biases, thereby allowing further increases in the number of assimilated observations.

10.02 Assimilation of SEVIRI retrieved land surface temperature in AROME NWP model

Zied Sassi², Camille Birman¹, Nadia Fourrié¹, Vincent Guidard¹

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Modeling the fluxes between surface and atmosphere is crucial for accurate forecast of near surface fields. Satellite observations sensitive to

lower atmospheric layers are informative for these regions and they are assimilated in the upper air assimilation but are not used to analyse surface variables. The assimilation of satellite radiances requires realistic surface states to accurately simulate observed radiances with model variables. The adopted approach at Météo France to assimilate these radiances consists in using a channel in an atmospheric window to retrieve surface temperature (for infrared sensors) or surface emissivity (for microwave instruments). However these retrieved variables are not directly assimilated in the surface model. The goal of this study is to study the impact of assimilating surface temperatures retrieved from SEVIRI instrument into the surface assimilation system of AROME-France model. In the first part of the study the assimilation of SEVIRI retrieved land surface temperature is implemented in the surface analysis using a 2D optimal interpolation and the parameters of the assimilation (associated observation and background errors, correlation lengths) are diagnosed. Then the impact of the assimilation is evaluated on the assimilation of in-situ and satellite variables, and on 48h forecasts using Synop and radiosonde observations, using a 2 month experiment assimilating SEVIRI land surface temperatures by nighttime only. The results show an improvement of forecasts of near surface variables by nighttime up to 48h and of atmospheric variables up to 36h. The assimilation of microwave radiances is also impacted in a positive way as the retrieval of surface emissivity benefits from a more accurate surface temperature.

Session 11: NWP Future (oral presentations)

11.01 Investigating the Impacts of Hyperspectral Infrared Sounders in Geostationary Orbits Using Observing System Simulation Experiments

Will McCarty¹, Erica McGrath-Spangler, Nikki Prive, Isaac Moradi, Joel McCorkel

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The Global Modeling and Assimilation Office (GMAO) has been investigating the impact of geostationary hyperspectral infrared sounders sensitive to temperature and moisture bands in the context of the current observing system. This effort has been performed leveraging the GMAO Observing System Simulation Experiment (OSSE) framework, with the goal of qualifying and quantifying potential impacts from a projected geostationary infrared constellation. This work

has investigated analysis and forecast impacts both by standard data assimilation validation metrics as well as by leveraging the known underlying truth – the nature run - which is possible within the OSSE framework.

Experiments have been designed in coordination with the NOAA Geostationary and Extended Observations (GEO-XO) program. This study will present both perturbations and results from these experiments as well as a status update on the effort. Furthermore, assumptions and shortcomings made to form fit the OSSE framework will be presented to capture the potential disconnects between the simulated environment versus how the data would perform in the future.

11.02 Initial assimilation tests of CrIS short-wave channels at ECMWF

Chris Burrows¹, Marco Matricardi¹, Tony McNally¹
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Following work performed at NOAA/NESDIS, the ECMWF system has been prepared to assimilate short-wave radiances from CrIS. This has involved the implementation of NLTE (non local thermodynamic equilibrium) and scene-dependent observation errors. The short range forecast impact has been assessed for a depleted observing system baseline. Initial indications are that the impact of the short-wave channels do not match that of the long-wave channels, but the reasons for this may be related to the suboptimal specification of observation errors in the ECMWF system.

11.03 Hyperspectral Radiance Sounding Information Content

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Hyperspectral sounding radiance information content depends on spectral resolution, spectral fidelity, and the number of spectral channel measurements, as well as detector noise. Theoretical physics-based radiance Information Content (IC) studies using Rodger's Optimal Estimation Theory (OE) and empirical analyses of current polar satellite hyperspectral radiance measurements are used to demonstrate the dependency of IC on the measurement spectral characteristics. It is shown that the Longwave infrared (9-15 μm) radiance observations are critical for capturing the temperature and water vapor IC contained within the full spectrum (4-15

μm) of infrared radiance observations being observed with current satellite atmospheric sounding instruments.

11.04 Is a Geostationary Microwave Sounder Now Feasible?

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During the latter half of 2020 a detailed study of a geostationary microwave sounder concept and its projected performance was undertaken as one of several such studies commissioned by NOAA for the purpose of configuring NOAA's next generation of earth environmental satellite systems. Based on the Geostationary Synthetic Thinned Aperture Radiometer (GeoSTAR) concept developed at JPL, essentially an "AMSU in GEO", such a sounder is now feasible and will provide similar measurements as are now obtained with the current low-earth-orbiting microwave sounders, AMSU and ATMS, but every 15 minutes instead of every 12 hours and covering a large fraction of a hemisphere instead of a narrow swath. GEO orbits are almost 50 times higher than the LEO orbits that current microwave sounders operate from, and the corresponding scaling of aperture size required to maintain spatial resolution had stymied the development of such a sensor for many decades in spite of an expectation in the atmospheric science community that a geostationary microwave sounder would revolutionize the field. The aperture synthesis approach implemented with GeoSTAR finally overcomes that obstacle, and the large number of microwave receivers and associated electronics required is made possible with the new technology that has now been developed and fully tested. The study determined that performance of such a system will match, and in some areas exceed, the performance of AMSU and ATMS and will lead to significant improvements in both regional and global weather prediction, particularly for tropical cyclones. It will also provide vertical profiles of atmospheric wind vector under almost any weather condition. We present a summary of our findings, including instrument characteristics, measurement accuracy and precision, and expected impact on weather prediction and applications.

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Poster Session 1

1p.01 Assimilation of GOES16 ABI radiances in ARPEGE model

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A large part of assimilated observations in the global ARPEGE model of Météo-France comes from infrared radiances. Even if the majority of these data are provided by hyperspectral instruments such as IASI, CrIS and AIRS, geostationary imagers provide in clear sky conditions frequent data over the same area. Up to now, observations from geostationary infrared sounders were assimilated in the global model as Clear Sky Radiances which represent an average of clear radiances present over a spatial grid. This is different of what is done in the convective scale model AROME where SEVIRI radiances are directly used in the 3D-Var. Here the proposed poster presents a study on the assimilation of GOES-16 ABI radiances in the global model ARPEGE. The experiment setting will be presented. To begin, only 3 channels sensitive to upper-tropospheric water vapour and temperature (2, 3 and 4) have been considered for the assimilation. In this case inter-channel observation error correlations were considered. The impact in terms of analysis and forecast scores will be also shown.

1p.02 Study of the evolution of the Sahelian climate based on satellite observation and ATOVS data

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The Sahelian zone which is the framework of this study is now known to the world because of the drought. Since 1968, this area has experienced a real climate crisis, characterized by a persistent rainfall deficit. Meteorological and/or climatological studies require diverse, important and independent data from satellite and/or in-situ observations.

The distribution of in-situ stations in the Sahelian zone is less dense, which decreases the accuracy of the global models in this zone.

It is these contexts and problems that justify our research to be oriented to the evolution of the Sahelian climate based on satellite observation and ATOVS data.

In this work, a main component analysis of monthly infrared and microwave data was used to study the monthly distributions of spectral signatures of ATOVS channels. We returned the amount of water, the temperature and the relative humidity. For this purpose, the radio sounding data and the brightness temperature data measured by the AMSU-A and MHS microwave radiometers, as well as the HIRS infrared sensors on board the NOAA and MetOp satellites were used.

Keywords: Sahelian zone, satellite, TOVS, AMSU, MHS, Infrared.

1p.03 Impact of satellite sounder data on global forecasts, including the benefit of using the direct broadcast network (DBNet)

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A recent study at the Met Office into the relative impact of all the main observing types will be presented. This made use of a series of data denial experiments. We will show that the sounding data from both the infrared and microwave parts of the electromagnetic spectrum are still very important. GNSS radio occultation and observations from radiosondes are also very beneficial.

In addition to these results, we will also investigate the forecast impact of using observations obtained via the Direct Broadcast Network (DBNet). This network supplements the global datasets for a variety of sounding instruments, improving the timeliness of the data. With the increased use of multiple outer loops in the data assimilation step (either planned or in operations), the timeliness of observations still remains critical for global models. We will examine the impact when the DBNet datastream supplements the global data for AMSU, MHS and ATMS instruments.

1p.04 Machine Learning Applications in Community Surface Emissivity Modeling (CSEM) System

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Satellite observations have been extensively utilized in numerical weather predictions (NWP) to improve the analysis of atmospheric state variables (e.g., vertical temperature and water

vapor profiles) and the overall forecasting skills of the NWP system. The Community Surface Emissivity Modeling (CSEM) system developed at NOAA/NESDIS/STAR will be used in the next major release of the Community Radiative Transfer Model (CRTM) to support the direct radiance assimilation of satellite surface sensitive channels and to provide accurate surface emissivity condition in support of the quality-control processes of data assimilation. Both model accuracy and model computing efficiency are essential for data assimilation. Very few observations of surface sensitive channels are directly assimilated in the past for lack of fully functional surface emissivity models. Machine learning techniques have been applied in developing the accurate and fast CSEM models from physically sound but computationally expensive physics models and from vast observation data.

We will present our latest work on the CSEM improvements by utilizing the machine learning (ML) techniques. In particular, we will show how ML is used to reconstruct computationally efficient fast surface emissivity and BRDF forward, tangent linear and adjoint models from a complex physics-based model. The reconstruction is successively performed at sub-physical spaces, which retains the model physics while significantly reducing the requirement of the computing resources in the original physical space.

The ML technique may be also utilized to derive highly accurate surface emissivity models from satellite observations. We will introduce the latest MW land surface model improvements together with the machine learning techniques applied.

1p.05 Recent developments in CRTM aerosol simulations

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The Community Radiative Transfer Model (CRTM) is operationally used for aerosol radiative-property

(such as AOD) data assimilation. CRTM simulates the aerosol light absorption and scattering based on offline aerosol coefficient lookup tables (LUTs); the accuracy of computed radiative quantities is therefore largely constrained by the a priori knowledge of aerosol optical properties stored in LUTs.

Over a decade ago, CRTM implemented an aerosol LUT for five species following the then Goddard Chemistry Aerosol Radiation and Transport (GOCART) model; this LUT has been used as the default LUT for CRTM simulations since then. However, with the recent theoretical and observational advancements on aerosol properties and the growing interest in modeling more species, a more flexible CRTM aerosol interface is desirable. In this work, we introduce the recent developments concerning the CRTM aerosol simulations, including (1) the expansion and updates on aerosol species and their optical properties, (2) the evaluation of the corresponding radiative transfer simulations, and (3) a new and flexible CRTM aerosol interface.

1p.06 Impacts of Combined FY-3D MWTS and MWHS Data Stream on Typhoon Forecasts

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FY-3D satellite was launched with microwave temperature sounder (MWTS) and microwave humidity sounder (MWHS) on board. Typically, two data streams from both instruments are assimilated in numerical weather prediction models. Unlike ATMS and AMSU, MWTS does not two low frequencies at 23.8 and 31.4 GHz and thus it is difficult for those users who are customized with the quality control of ATMS data in NWP models. In this study, we presented a combined microwave sounding data sets (CMWS) generated from MWTS and MWHS with a total of 30 channels. Two synthetic channels at 23.8 GHz and 31.4 GHz are also produced through a machine learning training against ATMS data. In addition, MWTS and MWHS are also matched to the same field of view size similar to ATMS temperature sounding channels. It is shown that the cloud liquid water (CLW) retrieved from CMWS data has a similar quality to ATMS one and can be used for quality control (QC), a key procedure in satellite data assimilation. After removing the scan-angle dependent bias, CMWS is now successfully

assimilated in the typhoon prediction model and produced a forecast impact comparable to ATMS. The CMWS data is now also being used as a proxy data for the upcoming FY-3E MWTS and MWHS data that have the same number channels of CMWS.

1p.07 On the accuracy of RTTOV-SCATT for radiative transfer in all-sky conditions

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With the emergence of a new generation of microwave instruments and, especially, the Ice Cloud Imager (ICI) covering frequencies between 183 and 664 GHz, it is necessary to evaluate the performance of the fast scattering solver of Radiative Transfer for TOVS (RTTOV-SCATT). Thus, we compare RTTOV-SCATT with the reference quality model ARTS (Atmospheric Radiative Transfer Simulator), with a special emphasis on ICI. Results are also presented on the basis of the Advanced Microwave Sounding Unit A (AMSUA) and the Microwave Humidity Sounder (MHS). Simulations are conducted for (a) simple yet realistic cloudy conditions and (b) idealized scenarios that are designed to identify the limitations of RTTOV-SCATT. Under typical cloudy conditions, a rather good agreement is found between the two models for all sensors, with RTTOV-SCATT producing brightness temperatures that can differ by about ± 4 -10 K, strongly depending on the channel's frequency and the level of extinction. However, the comparison reveals that, for large viewing angles (above 55°), high values of the optical thickness (deep convective systems), and strongly peaked phase functions (linked to high frequencies), the two-stream solution of RTTOV-SCATT is less accurate; the disagreement between the models exceeds 20 K.

1p.08 Evaluation of the In-Orbit Performance of the Microwave Temperature Sounder Onboard the FY-3D Satellite Using GPS Radio Occultation Data

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The Microwave Temperature Sounder (MWTS) onboard the Fengyun-3D (FY-3D) satellite can profile the vertical structure of the atmospheric temperature from the surface to 1 hPa under nearly all-weather conditions. It is important to assess its in-orbit performance and calibration accuracy prior to the data applications. In this study, the atmospheric profiles obtained from Global Positioning System (GPS) radio occultation (RO) data, which are both stable and accurate, are used for assessing the performance of microwave sounders in orbit, as demonstrated by many previous studies. In addition, ERA-Interim analysis data was also used to assess the performance of the MWTS. To understand the sources of error, three fast models including Advanced Radiative Transfer modeling System (ARMS), Community Radiative Transfer Model (CRTM) and the Radiative Transfer for the Television Infrared Observation Satellite (TIROS) Operational Vertical Sounder (RTTOV) model were used to simulate the brightness temperature of MWTS. The radio-occultation data are quality controlled and the collocation criterion between the radio-occultation data and the MWTS measurements is defined such that the spatial and temporal difference is < 50 km and < 3 h, respectively. The results show that the biases of MWTS channels 5–10 produced by three models agree well over the oceans under clear sky conditions between 60° S and 60° N from July to December 2018. The mean biases simulated by the radio-occultation and ERA-Interim data are negative and the absolute values of the biases are < 0.8 and < 1.5 K for channels 5–10 of the MWTS, respectively. The biases at channels 4 and 11 between the CRTM and RTTOV simulations are inconsistent and require further investigation. The standard deviation of the biases from the radio-occultation and ERA-Interim data are < 1.8 and < 0.5 K for channels 4–11 of the MWTS. The scan-angle and latitude dependence patterns of the biases are also discussed.

1p.09 Impact of assimilation of the Advanced Technology Microwave Sounder data over sea-ice in the Korean Integrated Model

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In Korean Integrated Model (KIM) which is the operational model at the Korea Meteorological

Administration (KMA), the assimilation of the microwave observations over sea-ice regions is limited due to the difficulties in estimation of surface radiation. In this study, the impact of assimilation of the near-surface Advanced Technology Microwave Sounder (ATMS) observations (53.6 GHz and 54.4 GHz) over sea-ice in KIM system is evaluated. For accurate simulation of surface radiation, dynamically estimated emissivity and constant emissivity (0.92) are tested over sea-ice. The Radiative Transfer for TOVS (RTTOV) version 10 is used for radiance simulations. The dynamic emissivity is calculated in real-time using the ATMS observations and the model background fields. The simulated brightness temperatures at 54.4 GHz show negligible sensitivity to the surface emissivity. Whereas the first guess departures at 53.6 GHz are smaller with the dynamic emissivity (less than 1 K) than with the constant emissivity. Therefore, applying the dynamic emissivity allows more observations over sea-ice to be assimilated with higher quality. As more information about the polar regions is given to the assimilation system, it is expected to reduce the cold bias of temperature fields in the Arctic regions of the KIM. The impact on the analysis and forecast fields is evaluated against the European Centre for Medium-Range Weather Forecasts Integrated Forecasting System (ECMWF IFS). Further results and analysis will be presented in the conference.

1p.10 Impacts of assimilating ABI and AHI Water Vapor channel radiances in GFS-T1534 with GSI

Dr. B R R Hari Prasad Kottu¹, Dr V.S Prasad¹, Dr C.J Johnny¹

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NCMRWF is routinely carrying out GFS-T1534 model analysis, which IMD uses for operational forecasts. The present GFS-T1534 model with hybrid 4D EnsVar assimilation system at NCMRWF is a robust system that monitors the quality of satellite radiances and based on assimilation statistics decisions are taken as to which channels have to be assimilated. Recently with the availability of Advanced Baseline Imager (ABI) and Advanced Himawari Imager (AHI) radiances from GOES-16 and GOES-17 satellites, the current assimilation system has been upgraded to include the ABI and AHI clear-sky radiances. This study emphasizes the added benefit of assimilating the ABI and AHI radiances in the present assimilation system at NCMRWF. The impact of assimilating radiances from ABI and AHI is investigated using

radiances from water vapor channels. The quality of ABI and AHI radiances for each channel is assessed by comparing with the model background. Assimilation experiment shows that assimilation of ABI and AHI water vapor radiance improved the model forecasts in all regions (Northern Hemisphere, Southern Hemisphere, and Tropics) and at different pressure levels in comparison to the control experiment. A significant reduction in RMSE is noticed for variables such as wind vectors, temperature, and geopotential heights at most of the levels. This study reveals that assimilation of ABI and AHI data from water vapor channels show a marginal positive impact on forecast skill in comparison to the Control experiment.

1p.11 Hyperspectral Sounder Radiance Comparisons of SNPP/NOAA-20 CrIS, METOP-A/B/C IASI, and Aqua AIRS: Refined Analysis Techniques and Updated Results

Michelle Loveless¹, Bob Knuteson¹, Dave Tobin¹, Joe Taylor¹, Hank Revercomb¹, Dan Deslover¹, Lori Borg¹, Graeme Martin¹

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Hyperspectral infrared sounders are a key component of the global climate and weather monitoring systems, providing valuable information for numerical weather prediction. The calibration and validation of these instruments is crucial for extracting their full potential. One of the tools of the CrIS cal/val team is the comparison of hyperspectral infrared sounders amongst each other. With this type of analysis, inter-calibration of the instruments is possible. Ideally this would be done with a climate-quality reference instrument such as CLARREO, but inter-comparisons with other current hyperspectral infrared sounders such as AIRS and IASI can also provide valuable information.

This work presents an updated approach and current results from an inter-comparison of the SNPP & NOAA-20 CrIS, Aqua AIRS, and METOP-A/B/C IASI using simultaneous nadir overpasses (SNOs). The comparisons include a spatial sampling error and make use of the CrIS radiometric uncertainty. Comparisons of CrIS and IASI show very good agreement, with radiometric biases that are mostly spectrally flat and mostly within the CrIS radiometric uncertainty. Comparisons of CrIS and AIRS also show good general agreement but have larger biases than seen between CrIS and IASI with spectral features that are indicative of AIRS calibration artifacts as

seen in previous studies. A double difference comparison of NOAA-20 CrIS minus SNPP CrIS using either AIRS or IASI show agreement within about 0.1 K for each of the LW, MW, and SW spectral bands with some isolated exceptions that will be discussed.

1p.12 Evaluation of Infrared Land Surface Emissivity over the Taklimakan Desert

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Infrared (IR) land surface emissivity (LSE) plays a vital role in numerical weather prediction (NWP) models through the satellite radiances assimilation. However, due to the large uncertainties in LSE over the desert, many land-surface sensitive channels of satellite IR sensors cannot be assimilated. This calls for further assessments of the satellite retrieved LSE quality in these desert regions. A set of LSE observation from field experiments was conducted in 26-28, Oct, 2013 along a south/north desert road in the Taklimakan Desert, and the observed LSE are thus used in this study as the reference to validate the quality of Combined ASTER MODIS Emissivity over Land (CAMEL).

The results show that the measured LSE correlates well with CAMEL at the ten observation sites, with the observed LSE slightly smaller than CAMEL in general. The quartz reststrahlen band around 8.6 μm sees largest discrepancy, possibly due to the diurnal variations associated with soil moisture change. In addition, the spectral variation of the observed LSE and CAMEL at the last two observing sites with clay ground surface are smaller than that from sheer desert sites.

Furthermore, from the site 1 at the south edge of the Taklimakan Desert to the site 10 at the north edge, the measured LSE and the corresponding CAMEL in the quartz reststrahlen band firstly decreases, and reach their minimum around sites 4-6 at the hinterland of the Taklimakan Desert. Then the LSE increases gradually and finally get their maximum at site 10 with clay ground surface. For the split window region, the LSE remains almost the same at all 10 observing sites.

1p.13 Addressing the temperature dependence of water within the CRTM IR sea surface emissivity (IRSSE) model

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This presentation will overview recent updates to the Community Radiative Transfer Model (CRTM) IR sea-surface effective-emissivity (IRSSE) model. The model was extended to include temperature dependence (in addition to spectral, view angle and surface windspeed) after recent findings had revealed significant systematic biases (as much as 1 K) on a global scale in cold waters (i.e., the North Atlantic and Southern Oceans). We will present the specific updates and highlight results of the model testing effort, both using ship-based Marine Atmospheric Emitted Radiance Interferometer (MAERI) spectra from cold and warm water ocean campaigns, along with its CRTM implementation within global NCEP Global Data Assimilation System (GDAS) tests. Finally, remaining issues and plans for future improvements will also be discussed.

1p.14 FY3E HIRAS-II and its pre-launch performance evaluation

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FY-3E/HIRAS-II is the second infrared hyperspectral instrument in the FY-3 series of China's polar orbit meteorological satellite system. It will be carried on the early-morning orbit and provide the first infrared vertical sounding data of the early-morning orbit to the numerical prediction centers for global data assimilation application. The data will be used together with morning and afternoon orbit observation and will make new contribution to the accuracy improvement of numerical prediction.

Based on the development of FY-3D satellite, HIRAS-II focuses on improving the detection sensitivity, spectral and radiative accuracy and service life of the instrument. The improvement of performance is conducive to the further improvement of temperature and humidity profile inversion accuracy. Compared with the FY-3D/HIRAS instrument, the observation time of

each scan line of HIRAS-II is changed from 10 to 8 seconds, the view angle is changed from 1.1 to 1 degree and the corresponding nadir spatial resolution improved from 16 to 14 km, and the field of regards (FORs) of earth observation in each scan line are reduced from 29 to 28. In addition, the detector array is changed from 2×2 to 3×3. The observed spectra of the instrument are divided into three infrared bands: long wave (LW), medium wave (MW) and short wave (SW). The maximum optical path difference of the interferometer is 0.8cm, which will produce a basic resolution of 0.625cm-1.

FY-3E HIRAS-II pre-launch test was fulfilled and the instrument performance was evaluated, and the following conclusions are obtained: the sensitivity is significantly improved compared with FY-3D, meet the requirements. The scanning mirror is gold-plated, which greatly reduces the polarization effect. In the MW band, the linearity is obviously improved compared with FY-3D. Spectral calibration accuracy meet the requirement of 7ppm, most of which are better than 5ppm, and spectral resolution and Full Width at Half Maximum(FWHM) of ILS also meet the requirements. FY-3E will be launched at the end of June this year. At present, all the preparations for the satellite instruments and ground processing system have been completed. It is expected that the launch of FY3E will bring more benefits to satellite applications.

1p.15 Discrete Ordinate Adding Method (DOAM), a new solver for Advanced Radiative transfer Modeling System (ARMS)

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Satellite data assimilation requires a computationally fast and accurate radiative transfer model. Currently, three fast models are commonly used in the Numerical Weather Prediction models (NWP) for satellite data assimilation, including Radiative Transfer for TIROS Operational Vertical Sounder (RTTOV), Community Radiative Transfer Model (CRTM), and Advanced Radiative transfer Modeling System (ARMS). ARMS was initiated in 2018 and is now becoming the third pillar supporting many users in NWP and remote sensing fields. Its radiative transfer solvers (e.g. Doubling Adding method) is inherited from CRTM. In this study, we propose a Discrete Ordinate Adding Method (DOAM) to solve the radiative transfer equation including both solar

and thermal source terms. In order to accelerate the DOAM computation, the single scattering approximation is used in the layer with an optical depth less than 10^{-8} or a single scattering albedo less than 10^{-10} . From principles of invariance, the adding method is then applied to link the radiances between the layers. The accuracy of DOAM is evaluated through four benchmark cases. It is shown that the difference between DOAM and DIScrete Ordinate Radiative Transfer (DISORT) decreases with an increase of stream number. The relative bias of the 4-stream DOAM ranges from -5.03% to 5.92% in the triple layers of a visible wavelength case, while the maximum bias of the 8-stream DOAM is only about 1%. The biases can be significantly reduced by the single scattering correction. Comparing to the visible case, the accuracy of the 4-stream DOAM is much higher in the thermal case with a maximum bias -1.69%. Similar results are also shown in two multiple-layer cases. In the MacBook Pro (15-inch, 2018) laptop, the 2-stream DOAM only takes 1.68 seconds for calculating azimuthally independent radiance of 3000 profiles in the hyper-spectral oxygen A-band (wavelength ranges from 0.757 μm to 0.775 μm), while the 4-stream DOAM takes 4.06 seconds and the 16-stream DOAM takes 45.93 seconds. The time of the 2-, 4- and 16- stream DOAM are 0.86 seconds, 1.09 seconds and 4.34 seconds for calculating azimuthally averaged radiance. DISORT with 16 streams takes 1521.56 seconds and 127.64 seconds under the same condition. As a new solver, DOAM has been integrated into ARMS and is used to simulate the brightness temperatures at MicroWave Humidity Sounder (MWHs) as well as MicroWave Radiation Imager (MWRI) frequencies. The simulations by DOAM are compared to those by Doubling Adding method and accuracy of both solvers shows a general agreement. All the results show that the DOAM is accurate and computational efficient for applications in NWP data assimilation and satellite remote sensing.

1p.16 Newly developed impact diagnostics for cross-validating satellite radiances with conventional observations

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Exploiting satellite radiances in an NWP system generally requires great efforts and error mitigation measures to exclude or reduce the weight of some data which otherwise could have a detrimental impact on the forecast skill. Assessing whether the impact of a data type is beneficial is,

however, far from trivial. Here, some guidance may be obtained from cross-validating a considered group of observations with more established (i.e., less problematic) observation.

This poster presents cross-validation diagnostics which were derived by further partitioning the established impact diagnostic originally introduced by Langland and Baker (2004). This gave rise to consistency relations, the most prominent of which indicates whether the first guess departures (o-fg) of a given observation type pull the model state into the direction of the verifying data (when processed with the employed model error covariances). This is a fundamental condition for getting a beneficial impact from these observations. In this work, the verifying data are well established observations as, e.g., radiosonde measurements, and the new diagnostic relationship is exploited to quantify the extent at which an individual satellite channel is consistent with such verifying observations in different locations (e.g., at different latitudes or altitudes) or under some otherwise specified conditions. To obtain a sensitive statistical tool, a normalization is provided which renders results largely independent from the total number of observations and the closeness of their collocation and, also, an indicator of statistical significance (which reflects both, the magnitude and the number of the different contributions in a bin). While the model error covariances employed in this work are estimated from the DWD's localized transform ensemble Kalman filter, we expect results to be highly relevant also to our hybrid EnVar system which also makes use of the ensemble estimated covariances.

As the quality of the assessment strongly depends on the suitability of the ensemble covariances, in a first step the method is applied to the cross-validation of two well established types of in situ observations whose results give some indication of the quality (and some limitations) of these covariances and can be taken as a benchmark when applying the method to more complex observations (like, e.g., satellite radiances). In the first applications to satellite radiances, it was found that the vertical pressure level assigned to many satellite channels (i.e., the localization height) was strongly sub-optimal. Therefore, in order use the method for revealing other possible issues with this observation type, a more appropriate determination of this height had to be developed. For this a criterion based on the maximum correlation (between a satellite channel and the temperature and moisture measurements

at the respective level) was used. It is shown how the new diagnostic supported the development of the new localization height assignment method.

1p.17 Doppler Shift Correction of the Cross-track Infrared Sounder (CrIS) Observed Radiances

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The Cross-track Infrared Sounder (CrIS) on the Suomi NPP and NOAA-20 satellites is designed to give scientists more refined information about the Earth's atmosphere and improve weather forecasts and our understanding of climate. CrIS is an infrared Fourier transform spectrometer that produces high-resolution, three-dimensional temperature, pressure, and moisture profiles. The highly accurate spectrally resolved infrared calibrated radiances and retrieved temperature and water vapor profiles are used to enhance weather forecasting models and facilitate improvements to both short and long-term weather forecasting. The Doppler shift of spectrally resolved infrared Earth observations due to the Earth's rotation is well known and has been documented as detectable in CrIS observations (Chen 2013).

The Earth velocity and the satellite velocity both contribute to the relative velocity between the Earth observation and the observing instrument, and the Doppler velocity is the dot product of the relative velocity vector and the unit line of sight vector. Since the maximum along-track viewing angle with respect to nadir is typically very small for a cross-track scanning low Earth orbiting satellite, it is typically assumed that the Doppler shift associated with the velocity of the satellite will be negligible. However, the satellite velocity is more than an order of magnitude greater (roughly 16x for CrIS) than the maximum Earth rotation velocity at the equator, and the Doppler shift due to the satellite velocity can be shown to be significant even for very small along-track viewing angles ($\sim 1^\circ$). Furthermore, unlike the Earth rotation velocity, the satellite velocity does not have a strong latitude dependence, and the Doppler shift associated with the satellite velocity

and along-track viewing angle is the dominant source of Doppler shift for high latitudes.

A model of the Doppler shift due to both Earth rotation and satellite velocity for the CrIS sensor will be presented and compared to CrIS observations. Additionally, the effectiveness of the Doppler shift correction will be demonstrated.

1p.18 Results from OSEs for satellite observation types in the Met Office UKV 4D-Var regional NWP system

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Results will be presented from a series of satellite denial trials for two UKV trial periods: one in NH winter (01/12/2018 - 31/01/2019); and one in NH summer (15/07/2018 - 14/09/2018). These results show the impact on the performance of the hourly-cycling UKV 4D-Var regional NWP system of a range of observation types, including microwave radiances, hyperspectral infrared radiances, MSG SEVIRI infrared radiances and GeoCloud pseudo-observations of cloud-top derived from MSG SEVIRI. The denials have helped to identify a number of areas where the UKV satellite data assimilation could be improved.

1p.19 The Impact of Geostationary Interferometric Infrared Sounder (GIIRS) Cloud Cleared Radiances on Typhoon forecasts: Maria (2018)

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Hyperspectral infrared (IR) sounder could provide detailed atmospheric temperature and moisture information with high vertical resolution that is essential for improving the forecast skills of numerical weather prediction. Generally, only clear sky radiances are used in model, because the observations from IR sounder are sensitive to clouds. A cloud-clearing (CC) method, which could remove cloud effect from IR cloudy field of view (FOV) and derive the cloud-cleared radiances (CCRs) or clear sky equivalent radiances, can be an

alternative and effective technique to make full use of thermal information of FOV with partial cloud cover in data assimilation. Previous researchers have applied this technique to polar orbiting weather satellites (such as CrIS) and showed good results. This study focuses on Geostationary Interferometric Infrared Sounder (GIIRS) CCRs calculated from Advanced Geosynchronous Radiation Imager (AGRI) onboard FengYun-4A. The differences between the observation and simulation brightness temperature (O-B) indicate that CC method can effectively obtain the GIIRS CCRs for cloudy FOV, because it has consistent O-B with that from clear sky. To compare the impacts from assimilation of GIIRS original radiances and CCRs, three experiments are carried out on Typhoon Maria (2018) case using Global/Regional Assimilation and Prediction System (GRAPES) 4D-Var. In the assimilation window, more GIIRS observations are used by assimilating GIIRS CCRs than by assimilating GIIRS original radiances. The typhoon track forecast also shows that the assimilation effect of GIIRS CCRs is improved compared with the original observations.

1p.20 A Model of Polarization Correction for the High-spectral Infrared Atmospheric Sounder (HIRAS-II) of FY-3E

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The Hyperspectral Infrared Atmospheric Sounder (HIRAS) is a key payload instrument on-board FY-3 satellites. It is mainly used to retrieve atmospheric temperature and humidity profiles for numerical weather forecast and global climate change assessment etc. Compared with HIRAS, HIRAS-II of FY-3E has improved ground detection coverage (from 2x2 array of Field of Views to 3x3 array), spectrum and radiation calibration accuracy, and radiation detection sensitivity while maintaining the spectral band and spectral resolution unchanged.

The polarization is one of the reasons that affect the accuracy of radiation calibration. As we all know, the reflection on slopes will always cause polarization effects. For HIRAS-II, the polarization of the scan mirror couples with that of the aft optics for spectral separation produces radiometric errors. This paper proposes a

polarization correction model by using the measured data to refine the bias of the radiation calibration. The observation data was obtained by rotating the scan mirror and the sub-stellar black body simultaneously by 1.8 degrees each time in the range of - 46.8° to + 46.8°, and then observing the inner black body and the cold space respectively until all angles were rotated. As a result, the relative brightness temperature bias due to polarization is about 0.1K. We found that this deviation increases as the absolute value of the angle increases. The polarization parameter changes with the wavelength, and its magnitude in the long-wave band (from 650 cm⁻¹ to 1135 cm⁻¹) and the medium-wave 1 band (1210 cm⁻¹ to 1750 cm⁻¹) is much larger than the medium-wave 2 band (2155 cm⁻¹ to 2550 cm⁻¹). What's more, our model refined this bias finally. The results suggest that the scan angle-dependent polarization effect gives rise to a radiometric offset. Besides, the polarization effect is different at different scan angles and wavelengths. Future refinements will focus on the impact of the polarization of the aft optics and build some physical models. Also, we will validate these corrections during the in-orbit validation experiment.

Poster Session 2

2p.01 Assimilating visible reflectances of SEVIRI in a convective-scale ensemble Kalman Filter

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We present an overview of our newly developed framework for the data assimilation of the visible 0.6 micron channel of SEVIRI (on-board the geostationary MSG) in the convection-resolving ensemble data assimilation system ICON-D2 KENDA of Deutscher Wetterdienst (DWD). Major motivation for our work is the improvement of cloud and precipitation positioning, needed for the seamless transition of nowcasting to NWP (SINFONY system) that will start its pre-operational test phase at Deutscher Wetterdienst in spring 2021. Our second goal is a better analysis of cloud optical depth leading to improved radiation forecasts that benefit e.g. solar power forecasts. The visible channel presents valuable cloud information due to its ability to also detect low level clouds.

We start by discussing the sensitivities of visible reflectances in comparison to infrared imager channels followed by an overview of the steps done in the course of developing the system. This includes quality control, observation error modelling, data reduction and bias correction of the reflectances. We employ the fast and accurate forward operator MFASIS that undergoes continuous enhancement. A major step to allow for a successful assimilation has been the improvement of microphysical consistency between our NWP model and MFASIS to reduce the bias of first-guess departures. To further stabilize the agreement of observations and model climatologies in the course of the year and changing weather regimes, an innovative histogram-based bias correction is being developed.

To demonstrate the benefits of assimilating the visible SEVIRI channel, the results of case studies as well as comprehensive data assimilation experiments in different cloud situations are discussed – showing the reduction of forecast error of cloud and precipitation system positions including boundary layer clouds, precipitation intensity, global radiation forecasts and screen-level variables.

2p.02 Tropospheric Moisture Retrievals from HIRS, MODIS, and VIIRS plus CrIS

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Tropospheric moisture data records derived from HIRS and MODIS are compared from 2003 to 2013 and from VIIRS plus CrIS fusion and MODIS for one year 2017. Total Precipitable Water (TPW) and Upper Tropospheric Precipitable Water (UTPW or UTH) are derived using infrared spectral bands in CO₂ and H₂O absorption bands (fusion with CrIS has recently added these bands to VIIRS) plus IR window bands. Retrieval of TPW and UTPW uses a statistical regression algorithm performed using clear sky radiances (and brightness temperatures) measured over land and ocean for both day and night. TPW and UTH seasonal cycles of all three observing systems are found to be in synchronization with zonal mean values in good agreement. Combining HIRS, MODIS, and VIIRS+CrIS offers a moisture record that will eventually span more than sixty years.

2p.03 A channel selection for the assimilation of CrIS and HIRAS instruments at full spectral resolution

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A new channel selection is proposed for the processing of observations at full spectral resolution (FSR) from the Cross-track Infrared Sounder (CrIS) and Hyperspectral Infrared Atmospheric Sounder (HIRAS) instruments in the Met Office numerical weather prediction (NWP) global system. The new selection has been derived in order to minimise the error in NWP analysis and has been compared to an existing selection developed at the National Oceanic and Atmospheric Administration (NOAA). Both selections have been tested in the Met Office global NWP system to investigate the use of FSR CrIS over the current normal spectral resolution (NSR) setup employed in operation. Improvements are obtained for most forecast variables up to seven days lead times, with change in root mean square error (RMSE) ranging from 0.13 to 0.54%, although degradation of tropical temperatures are noted for the NOAA selection. The background fit to observations from independent sounders improves by up to 0.8% with the new selection, outperforming the NOAA selection which results in degradations across most instruments. The assimilation of HIRAS observations do not however benefit the system.

2p.04 First steps in the preparation for the assimilation of the future IRS sounder in NWP models

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IRS (InfraRed Sounder) is an infrared Fourier transform spectrometer that will be on board the Meteosat Third Generation series of the future EUMETSAT geostationary satellites. After its launch planned in 2023, it will be able of measuring the radiance emitted by the Earth at the top of the atmosphere using 1960 channels in two spectral bands between 680 – 1210 cm⁻¹ (long-wave infrared) and 1600 – 2250 cm⁻¹ (mid-wave infrared). It will perform measurements over the full Earth disk with a particular spatial and temporal resolution of 4 km at nadir and 30 minutes over Europe respectively.

The assimilation of these new observations represents a great challenge for the improvement of numerical weather prediction models, especially

for convective-scale area model such as AROME-France. IRS will indeed provide frequent information which is required especially over the sea. In this first year of study, we have carried out a selection of IRS channels useful for all kind of representative atmospheric profiles in order to address the challenge of processing the very important amount of information that IRS will generate. A specific study of the information content shows that a selection of 300 channels spread across the absorption bands of CO₂, O₃, water vapour and the atmospheric window is a good compromise between the data amount and the quality of information.

The final objective will be to evaluate the impact of IRS observations in the regional AROME model. To carry out this work, we are building the OSSE (Observing System Simulation Experiments) method. Thus, we will describe here the first step which consists in setting up a realistic atmospheric state (Nature Run) for the global ARPEGE and regional AROME model, which will be used for the simulation of the observing system including IRS radiances and radars for the first time. Two Nature Run ARPEGE, which consisted in an uninterrupted forecasts were built for the summer (JJA) and winter (DJF) periods, each lasting 3 months, including one month of spin-up. The spin-up time represents the time needed for the simulation model to approach its own climatology after being launched from other initial conditions. For a NWP model, this can be relatively fast achieved (about a month) because the atmosphere has a short memory. Then two Nature Run AROME were built coupled with the Nature Run ARPEGE and starting one month after the spin-up. This NR AROME is used to accurately simulate all the observations assimilated in this model (conventional observations, satellite data and radars). It is important to as close as possible to the operational assimilation system with simulated one in order to reproduce the real impact of the different types of observations. We will compare the weight of the OSSE observations compared to the operational one and we will evaluate the contribution of the different observations by adjusting their errors. The IRS observations will be also simulated from this atmospheric forecast.

Initially, we assessed the quality of the different Nature Runs in order to validate their robustness and to verify that there are no temporal drifts or unrealistic regional effects. Finally, we started to set up the AROME observation system in order to simulate all the assimilated observations that could include IRS.

2p.05 IMAPP IDEA-I: An Air Quality Forecast Software Package for Aerosols, Ozone and Carbon Monoxide from Polar Orbiting Satellites using Global Forecast System (GFS) Winds

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From 2000 to 2017 the International MODIS/AIRS Processing Package (IMAPP) [Huang, et al., 2004] successfully provided global receiving stations the ability to support environmental observations for decision makers using Aqua and Terra MODIS, AIRS, AMSU, and S-NPP VIIRS and CrIS instruments. In 2020 SSEC allocated internal funding to rehabilitate and enhance IMAPP through prioritizing software upgrades based upon their utility and on the effort required to update them. One of those packages was IDEA-I, an open source, portable, international version of Infusing satellite Data into Environmental air quality Applications (IDEA) [Al-Saadi, et al., 2005].

IDEA-I is a real-time system for trajectory-based forecasts of atmospheric transport of air parcels identified in Level-2 products from polar orbiting satellites. Specifically these are air parcels anomalously high in aerosol, carbon monoxide or ozone whose predicted trajectories may have them remain near, or descend down to, the Earth's surface. We have updated IDEA-I to support MODIS and VIIRS aerosol optical depth products, ozone retrievals from HSRTV (UW Hyperspectral Retrieval Package) and carbon monoxide retrievals from HEAP (Hyper-Spectral Enterprise Algorithm Package, the follow-on to NUCAPS), each driven by GFS winds for global applicability. Improved HTML5 web delivery has been achieved by leveraging HAnIS, a tool developed at SSEC that provides animated sequences of images on web pages with user-selectable overlays. We have focussed on delivering IDEA-I in a VM so that it is available to the broadest range of potential users on Linux, Windows and Mac. For native Linux users, it is provided in a Singularity container to minimize system requirements.

We show how to install and configure IDEA-I for any geographical domain and demonstrate the capabilities of the new web interface that provides a simple way to disseminate the graphical outputs of IDEA-I.

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2p.06 The impact of background error specification on microwave sounder OSEs

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A series of OSEs were conducted to assess the NWP benefit of additional microwave sounders to the global observing system. To probe the importance of how background errors (B) are specified in OSEs such as these, two ensemble of data assimilations (EDA) experiments were run to calculate consistent Bs for the depleted system with no sounders and the fuller one with 7 sounders active. These B matrices were then used in 4D-Var experiments with the converse observing system to gauge changes in skill from over- and under-estimating background errors. Combinations of these experiments thus simulate data denial and data addition OSEs as traditionally practiced. The loss of all microwave sounder data increases global mean EDA spread by about 3-10% in the stratosphere and 2-4% in the troposphere. Specification of B is found to be a secondary effect on forecast skill when compared to the shift wrought by the observing system change itself. Only upper stratospheric scores are significantly different, notably where the EDA spread changed the most. The impact of using an inconsistent B is estimated at about 10% of the observing system change's own effect on scores. These results provide useful context for other OSEs and indicate that the EDA spread could be used as a tool to inform OSE-type studies in the future.

2p.07 Estimation of the error covariance matrix for IASI radiances and its impact on ozone analyses

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In atmospheric chemistry retrievals and data assimilation systems, observation errors associated with satellite radiances are chosen

empirically and generally treated as uncorrelated. In this work, we estimate inter-channel error covariances for the Infrared Atmospheric Sounding Interferometer (IASI) and evaluate their impact on ozone assimilation with the chemical transport model MOCAGE.

The results show significant differences between using the estimated error covariance matrix with respect to the empirical diagonal matrix employed in previous studies. The validation of the analyses against independent data reports a significant improvement, especially in the tropical stratosphere. The computational cost has also been reduced when the estimated covariance is employed in the assimilation system.

2p.08 Dust emission inversion through assimilating satellite measurements

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The 2021 spring has seen the most severe dust storm/storms over East Asia in the past two decades. Dust aerosols present great threats to the environment, property and human health over the areas in the downwind of arid regions. Several dynamical dust models have been developed to predict the dust concentrations in the atmosphere. Currently, the accuracy of these models is limited mainly due to the imperfect modeling of dust emissions. Along with the progress in the dust and aerosol modeling, the advances in sensor technologies have made large-scale aerosol measurements feasible. The rich measurements, especially satellite observations, provide opportunities to estimate uncertain emission fields, and subsequently, to improve the forecast skill. Such process of emission optimization conditioned on measurements is referred as emission inversion. Dust emission inversion is usually challenging due to the huge computational costs of the assimilation algorithm, biases in the assimilated observations, observation-simulation inconsistency, and the difficulties in quantifying the intrinsic emission uncertainty. In this work, these challenges are explored for real severe dust storms occurred in East Asia. The most important progress made in our research is the design of a dust emission inversion system which has a high computational efficiency, bias correction of measurements, data selection of satellite properties (AODs) as preprocessing before the assimilation, as well as an adjoint method for emission error detection.

2p.09 Current Status and Future Plan on direct readout activity in MSC/JMA

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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. 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 going to be processed soon. 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/MS LEO activities.

2p.10 Investigating the optimal design for a future constellation of microwave sounding instruments on small satellites using the Ensemble of Data Assimilations method

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Recent advances in technology have allowed the possibility of launching microwave (MW) sounding instruments on small satellites with a performance that is expected to be satisfactory for Numerical Weather Prediction (NWP). In this study, which is carried out in collaboration with ESA, we aim to investigate different potential future constellations of small satellites carrying MW sounding instruments. How much further benefit could be achieved with even better temporal sampling from additional instruments will be established while considering practicalities such as

instrument limitations and cost in order to determine an optimal design for global NWP. The impact of these possible constellations will be evaluated by the Ensemble of Data Assimilations (EDA) method. The EDA consists of running a finite number of independent cycling assimilation systems, in which observations and the forecast model are perturbed to generate different inputs for each member. The small satellite data and accompanying observation errors will be simulated. Benefit from adding the data to the observing system is measured by reducing the spread of the ensemble members which reflects improvement to the uncertainties in analyses and forecasts.

Here we present the EDA methodology and preparatory work which includes relating the changes in ensemble spread to the change in forecast error computed using more common Observing System Experiments (OSEs). The short-range forecast error is calculated using both operational analyses and radiosonde observations as a reference. Results show overall good qualitative similarity and that the EDA method provides a good basis to investigate the relative impacts from the future simulated small satellite data. We will also discuss the adaptation of the all sky observation error model arising from the potential loss of lower frequency wavelengths (below 50GHz) due to the compact instrument. An alternative cloud indicator based on the 52.8GHz channel was developed using AMSU-A data. Assimilation experiments confirmed that while some small degradations are present in short-range forecasts, overall the impact of changing the observation error model is relatively small. We can therefore expect good impact from the available channels from a small satellite provided channel characteristics are comparable to those of AMSU-A. Key aspects for the constellation design that motivate the final list of scenarios to be subsequently tested will also be presented. This comprises factors such as the number of orbits and the trade-off between humidity sounding channels only or having additional temperature sounding channels.

2p.11 Microwave land surface emissivity over Tibetan Plateau retrieved from FY-3D Microwave Radiation Imager

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Land surface emissivity is an important parameter used in satellite remote sensing and NWP data assimilation. Its physical properties are affected by surface type, surface roughness, surface temperature, dielectric constant, and water content, as well as frequency and zenith angle. The current emissivity products from various sources show some significant discrepancies, especially in some areas such as the third pole—the Tibetan Plateau (TP).

Different from station observation, satellite remote sensing observations have advantages in terms of spatial and time coverages and are becoming one of the most effective methods to understand the global land surface information. Using microwave radiation imager (MWRI) onboard FY-3D satellite has five frequencies at 10.65 GHz, 18.7 GHz, 23.8 GHz, 36.5 GHz and 89 GHz, respectively. Each frequency has two measurements at horizontal and vertical polarization. Since 2018, FY-3D MWRI has provided a good quality of data for remote sensing of surface parameters.

In this study, we first used ERA5 reanalysis data, MODIS cloud products, combined with ARMS radiation transfer model to calculate the microwave land emissivity under clear sky over the TP. MWRI land emissivity over the TP is also retrieved by the 1D-Var algorithm. The emissivity from different databases is then compared and a long-time series of microwave land emissivity dataset over the TP based will be established in connecting FY-3D MWRI data with other emissivity datasets.

2p.12 Preparation of MTG era: developing of nowcasting tools for GEO imagers and sounders

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The NWC SAF AEMET team has proposed the development in CDOP-3 and CDOP-4 of various products and services for MTG-I/FCI and MTG-S/IRS with the aim of maximizing synergies between all MTG instruments.

To prepare MTG era, the AEMET PGE00 programs has been used to calculate synthetic FCI and IRS data in clear and cloudy conditions. It has been generated the first scientifically correct 24 hours MTG synthetic dataset on a mean user region of interest. PGE00 programs use RTTOV-13.0 and 4D interpolation (vertical, temporal and spatial interpolation) of ECMWF profiles at hybrid levels to calculate high degree of realism synthetic data

on the future FCI projection grid. These synthetic data are being used as an important basis for a full preparation of MTG era and several examples will be shown.

The NWCSAF GEO products and services for the future MTG-S/IRS will be also briefly presented. As example of the quick-IRS service, examples of synthetic IRS RGB images and the use of IRS images for top to down view of the atmosphere will be presented.

For GEO imager instruments, iSHAI (imager Satellite Humidity and Instability) is the clear air product of the NWCSAF/GEO software that allows the monitoring in clear pixels of several key ingredients in pre-convection phase. In next versions, iSHAI product will can be generated from MSGs, Himawari and GOES-R class satellites and from the future MTG-I/FCI. Ideas to improve iSHAI in combination with the MTG-S/IRS L1 and L2 will be also briefly presented.

Thus, the combined use of iSHAI from FCI, sSHAI products from IRS and NWP will allow users to develop their own local 4D data cubes.

2p.13 Introduction of FY4B GIIRS and its application prospect

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GIIRS is the precise instrument which is carried in Geostationary orbit to measure the vertical profile of temperature and humidity of the atmosphere with improved detection accuracy and vertical resolution. FY-4B GIIRS is the operational satellite and will be launched between May and June. It includes two infrared bands with the 0.625 cm⁻¹ spectral resolution and one VIS band, respectively LWIR (680-1130cm⁻¹), S/MIR (1650-2250 cm⁻¹), and VIS (0.55-0.75 μm). Compared with FY-4A GIIRS, the focal array for FY-4B GIIRS is arranged with 16*8. The sensitivity is improved significantly, such as less than 0.5 mW/m² sr m⁻¹ for LWIR, and less than 0.1 mW/m² sr m⁻¹ for MWIR. In the same time, the radiation calibration accuracy is improved from 1.5K to 0.7K, and the spectral calibration accuracy improved from 10ppm to less than 10ppm. Besides, the spatial resolution is improved from 16 km to 12 km for infrared bands and from 2 km to 1 km for VIS. The calibration experiment in thermal vacuum (TVAC) test showed that the main performance indicators satisfied the instrument design requirements. GIIRS can provide the rich information about the three-dimensional

vertical distribution structure of atmospheric temperature and humidity profile and atmospheric composition (ozone, trace gas), etc. Its observational data and products are mainly used in fields such as numerical weather forecasting, air quality monitoring, climate change monitoring, global radiation energy budget, and atmospheric trace gas changes, etc.

2p.15 Addition of microwave humidity sounder radiance data to all-sky assimilation in the JMA global NWP system

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Microwave radiance data from space-based observation contain a variety of information on geophysical parameters relating to the atmosphere and the earth's surface (e.g., atmospheric temperature and water vapor profiles, cloud, precipitation, surface wind and surface temperature). In this context, microwave radiance over ocean areas in clear-sky conditions has been assimilated in JMA's global numerical weather prediction (NWP) system. By properly considering microwave radiance data relating to cloud and precipitation, assimilation of all-sky (including clear-sky, cloud and precipitation) microwave radiance contributes to better forecasting of atmospheric phenomena associated with severe weather conditions. JMA developed an all-sky microwave radiance assimilation scheme for microwave imagers and microwave humidity sounders. It was introduced into JMA's operational global NWP system in December 2019. Currently, the all-sky assimilation scheme is applied to several microwave humidity sounders (GMI/GPM, MHS/NOAA-19, Metop-A, -B) and microwave imagers (AMSR2/GCOM-W, GMI/GPM, SSMIS/DMSP F-17, F-18, WindSat/Coriolis, MWRI/FY-3C).

To apply the all-sky microwave assimilation scheme to the other microwave humidity sounders (e.g., ATMS/Suomi-NPP, NOAA-20, SSMIS/DMSP F-17, F18, SAPHIR/Megha-Tropiques, MWHS-2/FY-3C), several evaluations of the data quality and data assimilation experiments were carried out. The results showed better fit of first guess to radiosonde observations and clear-sky infrared radiance observations. The details of the experiment results are presented in the conference.

2p.16 Features and Advancements in Polar2Grid and Geo2Grid Image Creation Software

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An important part of facilitating the use of any meteorological environmental satellite data is the creation of high quality images. Creating 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 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 software packages. These toolkits provide an easy interface for reprojecting and converting calibrated radiance data and some higher level science products from supported imagers and sounders into a variety of output formats including GeoTIFF, the US National Weather Service (NWS) AWIPS NetCDF format, Binary and KMZ. Commands are carried out through simple bash shell scripts that wrap underlying python code. 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.

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 for parallel processing. Polar2Grid is the toolkit currently used at direct broadcast receiving stations to provide Polar Orbiter imagery from VIIRS, MODIS and AVHRR imagers, and ATMS, and GCOM-W1 AMSR2 microwave sounders 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 1.0.2 software supports GOES-16 and GOES-17 ABI

and Himawari-8 AHI. 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.

CSPP software is used globally by a large contingent of operational environmental decision makers, scientists and students. Polar2Grid and Geo2Grid application examples will be provided including uses by local US NWS forecasters and other global public service and private sector organizations. In addition, future enhancements will be highlighted.

2p.17 Toward a Global Planetary Boundary Layer Observing System: The NASA PBL Incubation Study Team Report

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A global Planetary Boundary Layer (PBL) observing system is urgently needed to address fundamental PBL science questions and societal applications related to weather, climate and air quality. This observing system should optimally combine new space-based observations of the PBL thermodynamic structure with complementary surface-based and suborbital assets, while taking advantage of, and helping improve, modeling and data assimilation systems. The Earth science community has expressed great interest in improving the characterization of the atmospheric PBL in the recent National Academies of Sciences, Engineering and Medicine (NASEM) 2017-2027 decadal survey for Earth Science and Applications from Space (ESAS 2017). Better observations of PBL temperature and water vapor profiles, and of PBL height were selected as priorities by ESAS 2017.

The NASA PBL Study Team identified (i) the most critical PBL science questions and applications topics; (ii) specific PBL needs from a data assimilation, modeling and prediction perspectives; (iii) the critical geophysical

observables and their associated spatial and temporal measurement requirements; (iv) the observational gaps from the current program of record; and (v) practical yet effective emerging measurement approaches to address these requirements from space. Several key science aspects require a global space-based PBL observing system, including measuring PBL thermodynamic structure from a global perspective, and being able to appropriately measure the interactions between PBL thermodynamics and the mesoscale.

Following the NASA PBL Study Team report, the essential components of a future global PBL observing system include: 1) Differential absorption lidar (DIAL) and differential absorption radar (DAR) in low Earth orbit (LEO) to provide high vertical resolution (approximately 200 m) water vapor profiles in clear and cloudy conditions; 2) High horizontal resolution hyperspectral infrared (IR) (1 km) and microwave (MW) (5 km) sounders in LEO to provide 3D temperature and water vapor structure context to DIAL+DAR observations, potentially on SmallSat or CubeSat constellations; 3) Radio Occultation (RO) using larger constellations of Global Navigation Satellite System (GNSS-RO) receivers and/or novel orbital configurations and signal frequencies; and 4) Geostationary hyperspectral IR sounding, taking advantage of future operational GEO sounders, to dramatically increase temporal sampling of temperature and water vapor profiles.

2p.18 Evaluation of the RTTOV IR/MW underlying spectroscopy in the frame of the C3S project on early satellites

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The present study is a part of the Copernicus Climate Change Service (C3S) project on early satellite data rescue (311c Lot 1). This project aimed to evaluate the possibility to use the observations from infrared and microwave instruments, which flew in space in the 70s and 80s, in the next ECMWF ERA-6 reanalysis. The project focused in many sensors from Nimbus, TIROS and DMSP eras such as the IRIS-D, MRIR, THIR, SIRS, HRIR, SMMR, SSM/T-2, MSU, SSM/I and SSMIS. The evaluation have four objectives. The first one is to provide the RTTOV clear-sky coefficients for all instruments including improvement from LBL models and latest knowledge of spectral response functions (SRF).

The second one is to provide a validation of the RTTOV coefficients on a large independent diverse profile dataset (5000 profiles). The third objectives is to provide RTTOV coefficients for a pseudo infrared hyperspectral instrument that cover the full IR range with a spectral resolution of 0.5 cm⁻¹ to study potential spectral shift effect in the knowledge of SRF. The fourth objective is to provide forward model errors based on IR underlying spectroscopy variability by using three versions LBLRTM (v11.2, v12.2 and v12.8). The results and conclusion will be shown.

2p.19 An efficient radiative transfer model for thermal infrared brightness temperature simulation in cloudy atmospheres

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An efficient radiative transfer model (ERTM) is developed to simulate thermal infrared brightness temperatures observed by the Advanced Himawari Imager (AHI) in this study. The ERTM contains an alternate mapping correlated k-distribution method (AMCKD), a parameterization for cloud optical property, and a rapid infrared radiative transfer scheme. The AMCKD is employed to calculate the gaseous absorption in the inhomogeneous thermodynamic atmosphere. The optical properties of clouds are parameterized by the effective length for ice clouds based on the Voronoi model, and by the effective radius for water clouds based on the Lorenz-Mie theory. The adding method of four-stream discrete ordinates method (4DDA) is used as the infrared radiative transfer scheme in ERTM. The discrete ordinate radiative transfer (DISORT) is inserted into line-by-line radiative transfer model (LBLRTM) as a benchmark model. A series of comparisons between ERTM and benchmark model under various cloud conditions are discussed to assess the performance of ERTM. Under the standard atmospheric profiles, the RMSEs of simulated BTs reach a maximum of 0.21K at the B16 channel, while the minimum RMSE is only 0.04K at the B13 channel. Moreover, the computational efficiency of ERTM is approximately five orders of magnitude

higher than that of the benchmark model. Finally, Typhoon Mujigae on 3 October 2015 at 6:00 UTC is used as a practical case to validate the ERTM. The simulated brightness temperatures by ERTM are highly consistent with the rigorous results and observations from AHI, which verifies the excellent performance of ERTM for the realistic atmosphere.

Reference

Wenwen Li, Feng Zhang, Yi-Ning Shi, Hironobu Iwabuchi, Mingwei Zhu, Jiangnan Li, Wei Han, Husi Letu, and Hiroshi Ishimoto, 2020: Efficient radiative transfer model for thermal infrared brightness temperature simulation in cloudy atmospheres, *Optics Express*, 28, 25730-25749.

2p.20 Improving the use of surface-sensitive radiances in the GMAO GEOS system

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The planetary boundary layer (PBL) was designated as an incubation-class targeted observable in the 2018 Decadal Survey. For this purpose, it is important to enhance existing and develop new data assimilation techniques to support existing and next-generation observations that are important to the PBL and coupled systems. GMAO has put in efforts to enhance surface-sensitive radiance assimilation. In this talk, the study to improve the usage of surface-sensitive microwave radiances in the GMAO GEOS data assimilation system will be presented. Although a vast number of microwave radiance observations are used in the GEOS, very few surface-sensitive microwave radiances are currently used over land due to the large uncertainty of land surface emissivity in the CRTM as well as cloud detection issue. Dynamically varying emissivity can be retrieved from observations of window channels in the GEOS for non-scattering FOVs and applied to sounding channel assimilation. Moreover, bias correction scheme needs to be modified as bias drifting is observed with the original predictors, and quality control procedure is adapted accordingly as well. Experiment results will be presented and future plan will be discussed at the conference.

Poster Session 3

3p.01 Update on Activities of the U.S. National Academies' Committee on Radio Frequencies

Nancy L. Baker¹, Mahta Moghaddam², Liese van Zee³, Nathaniel Livesey⁴, Tomas Gergely⁵, Darrel Emerson⁶, William Emery⁷, Dara Entekhabi⁸, Phillip J. Erickson⁹, Kelsey Johnson¹⁰, Karen Masters¹¹, Scott Paine¹², Frank Schinzel¹³, Gail Skofronick-Jackson¹⁴

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The Committee on Radio Frequencies (CORF) is an independent committee of experts convened by the U.S. National Academies of Sciences, Engineering, and Medicine to consider the use of radio frequency spectrum for scientific applications and how such use may be protected amidst rising needs for the use of spectrum for numerous other purposes. CORF is charged with considering new or modified uses of the spectrum that are proposed or implemented and how they affect the interests of the U.S. science community for both passive and active observing systems. This presentation will provide an overview of a range of CORF activities with focus on the work of the committee in the past year.

With the proliferation of the use of the radio frequency (RF) spectrum for commercial and operational applications, the possible consequential limitations imposed on its use for scientific applications may be significant. Passive observations are particularly vulnerable to RFI given the intrinsically weak nature of the signals being observed – signals that active users of the spectrum would consider the “noise floor”. The frequencies used are largely dictated by the fundamental properties of nature such as the opacity of Earth’s atmosphere and the location of spectral signatures of molecules.

CORF represents a common interest in the protection of crucial scientific observations from Radio Frequency Interference (RFI) resulting from governmental and commercial uses of the spectrum for communications, radar, etc. CORF works to protect both passive and active use of the spectrum for Earth remote sensing, but does not generally consider issues related to communication with remote-sensing satellites. The radio spectrum range typically considered is

within 3 kHz to 3000 GHz range. Currently, only 1.4% of spectrum below 5 GHz – the frequency range with the most commercial development – is allocated on a primary basis for passive measurements. Some key bands, where particularly weak and/or crucial signals are observed, are protected by U.S. and international rules that dictate that no transmissions be permitted, in order to ensure that the observations are as unaffected by radio frequency interference as possible.

CORF, which is supported by the National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA), conducts its work through monitoring public spectrum-use proceedings of the U.S. Federal Communications Commission (FCC) and filing responses to cases that it considers to have potential impacts on the scientific use of the RF spectrum. CORF also represents the interests of the US science community through its participation in Study Groups and Working Parties within both the USA and the International Telecommunication Union Radio-communications sector (ITU-R). The Radio Regulations (RR), an international treaty that regulates the uses of the radio spectrum, is maintained by the ITU. Every 2 to 5 years, the ITU convenes a World Radiocommunication Conference (WRC) that revises the Radio Regulations. In the period between WRCs, the stakeholders work to develop possible ways to address the various items on the agenda of the WRC. CORF participates in this process by putting together and publicizing the views of the U.S. science community on the agenda items of interest, under the umbrella of the National Academies. The Academies' consensus views on the WRC-23 agenda items, along with views on draft agenda items for the 2027 WRC is expected to be published in early-to-mid 2021.

This presentation will summarize recent CORF filings on multiple FCC proceedings that have the potential to impact scientific use of the spectrum, as well as its views on the Agenda Items for the upcoming 2023 World Radiocommunication Conference, with an emphasis on the Earth Exploration Satellite Service (EESS) applications.

3p.02 The Arctic Weather Satellite - a small satellite concept to improve Arctic and global weather forecasts through millimetre and sub-millimetre microwave sounding

Niels Bormann¹, Joerg Ackermann², Dirk Schuettemeyer³, Christophe Accadia², Nigel

Atkinson⁴, Alessio Canestri², Philippe Chambon⁵, Paolo Colucci², Sabatino Di Michele², Adam Dybbroe⁶, Daniele Gherardi³, Ville Kangas³, Imke Krizek², Roger Randriamampianina⁷, Clemens Simmer⁸

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Preparations are underway at the European Space Agency (ESA) for the Arctic Weather Satellite, a small satellite (120 kg) in sun-synchronous orbit aimed at improving Arctic and global weather forecasts. It features a cross-track scanning 19-channel microwave sounding instrument with temperature and humidity sounding capabilities in the traditional 54 and 183 GHz bands, complemented with a new channel set in the 325 GHz humidity band. The latter channels are expected to significantly enhance the separation of ice-cloud and humidity signals when combined with the traditional 183 GHz channels. The launch of AWS is planned for 2024, and it is expected to be a prototype satellite for a constellation of similar satellites, aimed at significantly improving the temporal sampling available from MW sounders over the polar regions and globally. Requirements and further aspects of this constellation are currently being developed together with EUMETSAT, in dialogue with representatives from the user community.

The poster gives an overview of the characteristics of the AWS and its instrument, including the channel definitions, performance expectations, and sampling characteristics. Data dissemination aspects will also be discussed, as well as expected applications in global and regional Numerical Weather Prediction.

3p.03 Why and how does the actual spectral response matter for microwave radiance assimilation?

*Dr. Hao Chen^{1,2}, Prof. Wei Han³, Hao Wang³, Chen Pan⁴, Dawei An⁴, Songyan Gu⁴, Peng Zhang⁴
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Based on Global/Regional Assimilation and Prediction System-Global Forecast System (GRAPES-GFS) and actual Spectral Response

Functions (SRFs) of three Selected Single-Passband Channels (SSPCs, channel 5, 6 and 7) of FengYun-3D MicroWave Temperature Sounders (FY-3D MWTS), the impact of actual SRFs on Brightness Temperature (TB) simulation were analyzed. Compared with simulating by ideal SRF, mean Observation minus Background (OMB) by actual SRFs decreases about 0.31 K with a root mean square error (RMSE) of 0.29 K, which are 30.2% and 37.3% reductions. The improvements on equatorial regions are more obvious than middle and high latitudes. Five types of deformations were put forward to analyze impacts of deformations on TB simulation by applying multi-layered Radiative Transfer Model (RTM). Attenuation at low and high frequency ends of passband, passband shifting and extending affects simulated TB about 0.1–1 K. Trap deepening or shifting at the center of passband has little impacts with a value of about 0.01–0.1 K.

The main reason caused TB simulating errors of FY3D-MWTS by ideal SRFs is attenuation characteristics losing and passband extending of the actual SRF. The differences between TBs simulated using ideal and actual SRFs don't depend on the magnitude of the difference between ideal and actual SRFs, but on the balances of different types of deformations. Suppressing attenuation and keeping attenuation balance at low and high frequency ends of passband is more important and useful than inhibiting trap appearing on the center of the passband during the design stage. For detail, see <https://doi.org/10.1029/2020GL092306>.

3p.04 A first attempt to assimilate satellite radiance observations in a deep convection case during RELAMPAGO using the WRF-GSI-LETKF system

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We evaluated the impact of assimilating satellite observations over Argentina using the WRF-GSI-LETKF. While this is the first attempt to use the GSI system in Argentina as well as to assimilate

satellite radiances in a regional context, previous work has shown promising results on mesoscale and convective scale data assimilation in the region (Dillon 2019, García Skabar and Nicolini, 2014). We conducted a case study corresponding to a huge mesoscale convective system (MCS) developed over central and north-eastern Argentina during November, 22th, 2018. This MCS developed during an Intense Observing Period (IOP) of the RELAMPAGO field campaign during Nov. 2018.

Assimilation experiments were conducted using conventional observations and satellite-derived winds along with radiances from different infrared and microwave sensors (i.e. AMSU, HIRS, MHS, ATMS, AIRS and IASI). An online bias-correction approach is applied to reduce systematic errors during the assimilation processes. Analyses with 10-km horizontal grid spacing were produced with the GSI-4DLETKF system assimilating observations every hour from 11/20 18Z to 11/23 12Z. We used a 60-members multiphysics ensemble initialized from the GFS deterministic analysis with random perturbations. The impact of satellite radiances upon different aspects of the regional-scale circulation for this particular event is analyzed in this work.

The comparison of the vertical profiles of the different experiments shows that the radiance observations produce drying and increased temperature and northerly wind at the surface. This generates a convective environment with a maximum cape higher than 4000 Kg/J before the convection develops. The MSC generated as a result produced less precipitation than observed but it was well distributed over the domain.

3p.05 CSPP (Community Satellite Processing Package) Software for Satellite Sounders in Direct Broadcast

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The Community Satellite Processing Package (CSPP) comprises software packages to support the Direct Broadcast (DB) meteorological and environmental satellite community. The timely delivery of Level 2 sounder products can have great impact for those users involved in severe weather warnings and aviation safety. CSPP distributes four sounder retrieval packages; IAPP (International ATOVS Processing Package), HSRTV (UW-Madison HyperSpectral ReTrieVal Software), MiRS (Microwave Integrated Retrieval System) and

HEAP (Hyper-Spectral Enterprise Algorithm Package). Each is provided by CSPP as an executable package for Linux that can be installed, configured and be running within minutes of its download. CSPP also provides a QuickLook package that makes images from a selection of the data products generated to provide rapid feedback through product visualization.

We demonstrate the ease with which these four sounder packages can be installed on modest consumer-level hardware, describe the products that they generate and, between them, the range of satellite missions and instruments now supported. We show also the imagery that can be routinely and automatically generated as visual assurance that valid sounder data products are being produced.

3p.06 A reference ocean surface emission and backscatter model

Stephen English¹, Catherine Prigent², Emmanuel Dinnat³, Magdalena Anguelova⁴, Thomas Meissner⁵, Lise Kilic², Ben Johnson⁶, Jacqueline Boutin², Stuart Newman⁷, Masahiro Kazumori⁸, Fuzhong Weng⁹, Ad Stoffelen¹⁰, Christophe Accadia¹¹, Nick Nalli¹²

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Radiance measurements from TOVS-heritage spaceborne instruments are the most impactful observations used in Numerical Weather Prediction (Eyre, English and Forsythe 2020). Sophisticated data assimilation methods such as 4D-Var have been critical to this success, enabling direct assimilation of raw radiances. However, until recently, different Earth System components such as ocean, land and atmosphere were always handled separately, meaning those radiances which are sensitive to more than one component are still assimilated sub-optimally. The development of coupled data assimilation methodologies enables us to take another big step in the use of radiances, simultaneously and consistently fitting the state in multiple sub-systems to the same observations. This requires improved surface radiative transfer models. For the ocean, it has been noted at past ITSCs that the uncertainty in emissivity models is not well known and often different models are used for

different spectral bands, and for active and passive sensing instruments. For active-instruments empirical Geophysical Model Functions are used, which have an accuracy ~0.1 dB. To date physically-based methods achieve much lower accuracy for active sensors (Fois, 2015). Unifying approaches could benefit both passive and active forward operators. Furthermore, in attempting error budget closure, lack of knowledge of uncertainty in surface emission has been shown to be a limiting factor (GAIA-CLIM: www.gaia-clim.eu/). An International Space Science Institute team was created (English et al. 2020) to address this gap, taking the best available model components, integrating, testing across all spectral bands and characterizing as far as possible the uncertainty. The resulting reference model will then be provided as community software on GitHub.

In this short presentation, the choices made assembling this model will be explained, building on the starting point of the LOCEAN model of Dinnat et al. (2003). Samples of characterization undertaken will also be summarized. This includes comparison to SMAP, AMSR2 and GMI (e.g. Kilic et al. 2019) and early work to evaluate in the infrared and for active sensors. Finally, the plans for making code available will be briefly presented. This model will also be used to generate training data for fast models, e.g. Fastem (English and Hewison 1998), as used in operational data assimilation and climate re-analysis.

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3p.08 Evaluating CrIS Shortwave Infrared Observations in the NOAA Global Data Assimilation System: Impacts and Recommendations

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The Cross-track Infrared Sounder (CrIS) hyperspectral infrared (IR) sensor has three bands that are used for remote sensing: a longwave (LW) band from 650 - 1095 cm⁻¹, a midwave (MW) band from 1210 - 1750 cm⁻¹, and a shortwave (SW) band with wavenumbers covering 2155 - 2550 cm⁻¹. In the NOAA operational Global Data Assimilation System (GDAS), only CrIS LW channels and a small number of CrIS MW channels from a subset of 431 CrIS full spectral resolution (FSR) channels are actively assimilated. Work at NOAA/NESDIS/STAR and University of Maryland CISESS has been aimed at evaluating the use of CrIS SW observations in the GDAS and Finite-Volume Cubed-Sphere Global Forecast System (FV3GFS) from the 431 and full 2211 channel sets in SW-only and LW plus SW configurations. Initial findings suggest that the assimilation of CrIS SW observations, with the implementation of new CrIS SW-specific quality controls and scene-dependent observation errors, can produce a beneficial impact on FV3GFS forecasts when compared to the assimilation of only the CrIS LW and MW channels normally used in operational forecasting.

Additional work has sought to evaluate CrIS MW observations and explore their assimilation in the GDAS. Efforts have also been made to apply lessons learned from the optimization of the assimilation of CrIS observations to the assimilation of observations from other hyperspectral IR sensors. To be discussed here are the analysis and forecast impacts of assimilating CrIS SW observations in the GDAS, an evaluation of the assimilation of other CrIS channels (e.g. CrIS MW channels) not normally assimilated and/or not present in the 431 channel set, and recommendations for how the assimilation of other hyperspectral infrared sensors might be improved based on lessons learned.

3p.09 Quality Assessment of the Radiometric and Spectral Calibration of the FY4A Geostationary Interferometric Infrared Sounder (GIIRS) using NOAA-20 CrIS and METOP-B IASI as On-Orbit Reference Sensors

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The Geostationary Interferometric Infrared Sounder (GIIRS) sensor was launched on the China Meteorological Administration (CMA) Feng-Yun-4A satellite in a geostationary orbit currently centered over the equator near 105 E longitude. The GIIRS has operated since 2017 with data available from the CMA data portal since February 2019. The University of Wisconsin-Madison Space Science and Engineering Center (UW-SSEC) has been supported under a NOAA grant since July 2019 to collaborate with the U.S. Joint Center for Satellite Data Assimilation (JCSDA) in assessing the quality of GIIRS data for the purpose of nowcasting and medium range weather prediction. The GIIRS is the first on-orbit demonstration of an imaging Fourier Transform Spectrometer (FTS) from geostationary orbit. Prior to GIIRS, the UW-SSEC supported a NASA funded development of a U.S. sensor named GIFTS (Geostationary Imaging FTS) which was successfully tested in 2005 but was never launched into space. Experience with the GIFTS sensor has proven invaluable in the quality assessment of observations from the FY4A GIIRS technology demonstration. The CMA calibrated FY4A GIIRS L1 radiances available from the CMA data portal exhibit many characteristics that are expected and normal but also contain numerous artifacts that have proven problematic for data assimilation. These include time dependent variations in channel spectral stability and radiometric bias at scales that vary from minutes to hours to months and to seasons. Since the early phases of the quality assessment, Simultaneous Nadir Overpass (SNO) type coincident observations (matching time, lat/lon, and view angle) were made with the Cross-track InfraRed Sounder (CrIS) on NOAA-20 and with the Infrared Atmospheric Sounding Interferometer (IASI) on METOP-B. CrIS and IASI sensors have been extensively inter-compared to each other using SNOs by several groups including the presentation by M. Loveless in this conference showing agreement of radiometric calibration within 0.5 K brightness temperature for most infrared channels with each exhibiting an absolute spectral accuracy of better than 2 ppm (dv/v) in wavenumber. This presentation will show that FY4A GIIRS exhibits spectral calibration errors of

the order of plus and minus 10 ppm relative to both CrIS and IASI and radiometric bias errors for most channels within 1-2 K. These results are for the CMA L1 calibration version 3, the prior V1 and V2 contained very large spectral shifts which prevented assimilation of the data. However, even in CMA L1 V3 the product exhibits error characteristics that are unexpected, both in terms of radiometric bias and in the stability of radiometric and spectral calibration. The discussion of the details of these errors are too extensive for this abstract but will be summarized on the poster. A preliminary conclusion of the assessment of FY4A GIIRS is that the geostationary hyperspectral infrared sounder concept remains valid but the full potential is not yet realized in FY4A GIIRS. Hopefully in future versions of the GIIRS sensor on the FY4 satellite series CMA will address some of the issues identified through satellite inter-calibration with NOAA-20 and METOP. The community expectation is that the EUMETSAT MTG IRS sounder will avoid the technical problems of the FY4A GIIRS which are mainly related to instrument on-orbit stability and inadequate implementation of the calibration algorithm in the CMA ground data processing.

3p.10 Progress and Plans for Satellite Data Assimilation in the NCEP Global and Regional Data Assimilation Systems

Emily Liu¹, Catherine Thomas¹, Haixia Liu², Kristen Bathmann², Iliana Genkova², Hui Shao³, Xu Li², Louis Kouvaris², Scott Sieron², Daryl Kleist¹
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The operational NCEP Global Data Assimilation System (GDAS) has been upgraded in March 2021 with the following new features which have impacts on the use of satellite data, including the extension to 127 layers with approximately 80km model top, updated physics, modulated-ensemble LETKF (model space localization), 4D-IAU, and spectrally correlated observation error for hyperspectral infrared sensors. New satellite observations implemented include GNSSRO from MetOp-C and Geostationary clear-sky product.

The next observation upgrade to GDAS is under planning with the following improvements and additions to GDAS:

- MetOp-C IASI with correlated observation error
- GOES-17 clear-sky product

- VIIRS and AVHRR radiance for near sea surface temperature analysis
- Precipitation-affected MW and GMI radiances
- Assimilate antenna corrected MW radiances
- Retrieved total column ozone from NOAA-20 OMPS nadir mapper
- NESDIS UV and Visible blended product from KPSS-1 OMPS limb profile
- Leo-Geo AMV winds
- GOES_17 Mitigated AMV winds
- VIIRS winds
- Revised use of ASCAT winds (data thinning and updated observation error)
- Commercial GPSRO

The status regarding the implementation of the Joint Effort for Data assimilation Integration (JEDI) and the Unified Forward Operator (UFO) as GFS v17 will also be presented.

3p.11 Evaluation of the radiative transfer model RTTOV-13.0 at ECMWF

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¹ECMWF, Reading, United Kingdom

The use of satellite radiance observations in NWP depends directly on the accuracy of the radiative transfer model, RTTOV, developed within the context of EUMETSAT NWP-SAF activity. This study summarizes the evaluation in the IFS of the very latest release of the radiative transfer model, RTTOV-13.0 with updated microwave scattering model RTTOV-SCATT and coefficient databases. The latter includes a new v13 predictor scheme for gas absorption optical depths. An overview of the performance of RTTOV-13 in the IFS will be presented along with a look at recent harmonization and upgrades of infrared radiative transfer, spectroscopy and trace gas assumptions via the replacement of all RTTOV coefficients for hyperspectral sounders.

3p.12 Assimilation of hyperspectral infrared radiances from the cloud-clearing methodology: Results from the 2017 Atlantic Tropical Cyclone season

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¹USRA/GESTAR and NASA GSFC/GMAO

Infrared radiance assimilation in partially cloudy regions has previously been shown by this team to

benefit numerical weather prediction (NWP) models. This is particularly true for the representation of tropical cyclones (TCs) in analyses and forecasts. The “cloud-clearing” methodology has been used to generate radiances that, when thinned more aggressively than clear-sky radiances prior to assimilation, have a strong positive impact on the representation of TC structure and behavior. To overcome limitations preventing the operational use of these data, this team has ported the Atmospheric InfraRed Sounder (AIRS) cloud-clearing algorithm to NASA high end computing resources (HEC), deprived it of external dependencies, and parallelized it thus reducing issues of latency. These modifications are customizable, allowing choice of channel selection and use of any given model’s fields as a first guess. The cloud-cleared radiances (CCRs) are then assimilated in NASA’s Goddard Earth Observing System (GEOS) hybrid 4D-EnVar system, focusing on the 2017 Atlantic hurricane season and the impact on three TCs (Harvey, Irma, and Maria) in particular. More recently, this approach has been applied to the Cross-track Infrared Sounder (CrIS) and could potentially be extended to other hyperspectral sounders.

3p. 13 Hyperspectral Infrared Near Surface Observations of Arctic Snow, Sea Ice, and Non-Frozen Ocean from the RV PolarStern during the MOSAiC Expedition October 2019 to September 2020

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The use of IR channels in NWP data assimilation is often limited to non-frozen ocean due to uncertainties in surface emissivity of snow and sea ice. The University of Wisconsin Marine Atmospheric Emitted Radiance Interferometer (MAERI) is a ground based hyperspectral infrared instrument that measures a spectral range similar to the NOAA Cross-track Infrared Sounder (CrIS). The MAERI was deployed on the icebreaker RV PolarStern during the MOSAiC (Multidisciplinary drifting Observatory for the Study of Arctic Climate) expedition as part of the US Department of Energy Atmospheric Radiation Measurement (ARM) mobile facility. Near surface air temperature and elevated air temperature have been derived from the MAERI observations for a variety of atmospheric conditions for a full year in the Arctic. The MAERI made continuous measurements of the upwelling infrared emission from the surface (snow, sea ice, water) and of the

downwelling emission from the atmosphere. Coincident observations were made with radiosondes at 6 hour intervals and from a surface met station. The MAERI infrared observations have been used to determine the change of air temperature with height in the lowest levels of the atmosphere. The upwelling observations of the MAERI provide validation spectra for the evaluation of satellite observations from NOAA-20 CrIS and METOP-IASI.

3p.14 At the confluence of forward and inverse remote sensing, IA and calval studies : The 2021 overview of the LMD (GEISA, ARSA, TIGR, ICO) databases

Dr Raymond ARMANTE¹, Dr Noelle A. SCOTT¹, Jérôme PERNIN¹, Dr Virginie CAPELLE¹, Laurent CREPEAU¹, Dr Cyril CREVOISIER¹, Dr Alain CHEDIN¹
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For years, we have amply verified the interest of maintaining, evolving and sharing our databases (GEISA, TIGR, ARSA, L2 retrievals of atmospheric and surface variables, ... distributed at IPSL or ECMWF).

In this presentation, we review the evolution of these LMD in-house databases, often described and widely distributed in our international community (a few hundred access to GEISA and the same amount of requests already satisfied for TIGR). These evolutions aim to keep these databases relevant to the improvements of ground based or on-board instruments (spectral resolution performance, radiometric stability and noise levels).

We also intend to present a prototype of the ICO (IASI Composite Observatory) LMD database. This prototype groups L1 and L2 data from two years of IASI/MetOp observations as well as other spatio-temporally co-located data ranging from in situ observations to model outputs, etc... . In this way, we attempt to respond to programs such as - among others - GAIA-CLIM (Gap Analysis for Integrated Atmospheric ECV CLimate Monitoring) which propose to i) simplify user access to co-location data between non-satellite measurements and satellite measurements. ii) provide them with a variety of tools for interpreting the comparisons. "

<https://ara.lmd.polytechnique.fr/>
<https://ara.lmd.polytechnique.fr/index.php?page=publications>

3p.15 The 2021 Iteration of the TAMU Aerosol Refractive Index Database

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A central aspect of modeling the optical properties of atmospheric aerosols, such as mineral dust, sea salt, and organic and black carbon particles are the dielectric material properties in terms of the refractive index spectrum. In 2017, a comprehensive aerosol refractive index database was published [1] together with the associated algorithms. This database contains compiled refractive index spectra for most major aerosol types over a broad spectral range and offers the unique advantages of distinguishing between different geographical regions, and particle sizes. This is achieved by collecting a comprehensive dataset using an OCR approach and combining these data on the basis of the Bruggeman effective medium theory. Furthermore, the resulting spectra are guaranteed to be physical by applying a Kramers-Kronig transform to the raw spectral data.

Since the original release of the database, a number of changes have been applied. These changes are primarily aimed at increasing the robustness, ease of use, and computational speed of the library. Additionally, the functionality of the database has been extended by providing methods that allow studying the sensitivity of the aerosol refractive index spectra towards uncertainties in the aerosol particle composition and the component refractive index data.

References:

[1] Stegmann, P., and P. Yang (2017): A regional, size-dependant, and causal effective medium model for Asian and Saharan mineral dust refractive index spectra. *J. Aer. Sci.* 114, 327-341.

3p.16 Evaluation of ICON's model cloud fields using simulated and observed visible satellite images

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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 been implemented into RTTOV since version 12.2. First evaluation and data assimilation experiments using MFASIS in combination with the COSMO and the new ICON-LAM regional models at DWD have demonstrated its value by improving the representation of cloud cover and precipitation as well as short term forecasts of surface variables. As a further step towards using visible satellite images in operational data assimilation, we perform a detailed validation of the accuracy of MFASIS in RTTOV v13 and an evaluation of the representation of clouds in DWD's global NWP system ICON+EnVAR. For evaluating MFASIS, its forward computation results are compared to results of the DISORT implementation in RTTOV (RTTOV-DOM) for a range of model profiles and stratified according to model cloud situations. For evaluating the model clouds, we compare RTTOV-MFASIS forward simulations based on global ICON model fields to visible channel observations of various imagers on board geostationary and polar orbiting satellites. This setup allows for an evaluation of the model equivalents in a large variety of atmospheric situations and at different local times. Additionally, we make use of level-2 cloud products, such as EUMETSAT's Optimal Cloud Analysis product OCA for SEVIRI on Meteosat, to analyse results and systematic errors classified by cloud types. 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 and has a higher sensitivity with respect to some model physics aspects like sub-grid scale cloud representation.

3p.17 EUMETSAT user preparation towards Meteosat Third Generation (MTG) and European Polar System - Second Generation (EPS-SG)

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EUMETSAT is launching its next generation satellites Meteosat Third Generation (MTG) and EUMETSAT Polar System – Second Generation (EPS-SG) as a follow on to its Meteosat Second Generation (MSG) and EPS programmes.

EUMETSAT is committed to support its users in their preparation for the use of data from MTG and EPS-SG through the MTG User Preparation (MTGUP) and EPS-SG User Preparation (EPS-SG UP) projects, which coordinate the user

preparation activities in EUMETSAT and reaching out to the user community.

The main objective of the User Preparations projects (MTG UP and EPS-SG UP) is to ensure an early uptake of data from the heritage instruments of MTG and EPS-SG thus ensuring a smooth transition and continuity of operations for the National Meteorological Services. A second objective of the UP projects is to support the users in their preparation to gain advantage from the enhanced capabilities of the heritage missions and novel missions that are part of MTG and EPS-SG. These projects also provide a platform for the user communities to share their experiences and cross-fertilise their user preparation activities. The User preparation activities are centred around five core themes: Science support, Test data and format support, User information and communication, training and data access support. One main achievement is the provision of format familiarization test data for most observation missions of MTG and EPS-SG. EUMETSAT is also organising webinars on each observation missions aiming at raising scientific awareness among the user community. This paper will cover the achievements of the projects over the last two years and the plans for the period 2021-2025. EUMETSAT joins hands with partners and Member States in the user preparation activities and in close cooperation with the Satellite Application Facilities, in particular the Nowcasting SAF and the NWP SAF.

3p.18 An Infrared Atmospheric Sounding Interferometer – New Generation (IASI-NG) channel selection for Numerical Weather Prediction

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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 radiances at a doubled spectral resolution compared to its predecessor and with a signal-to-noise ratio improved by a factor of 2. The high amount of data arising from IASI-NG will present many challenges for data transmission, storage and assimilation. Moreover, the full set of measured radiances will not be exploitable in an operational Numerical Weather Prediction (NWP) context. For these reasons, an appropriate IASI-NG

channel selection is needed, aiming to select the most informative channels for NWP models.

For such a purpose, the standard iterative channel selection methodology, based on the optimal linear estimation theory and assuming spectrally correlated errors, has been applied to a set of simulated data of the IASI-NG spectrum. The entire simulated IASI-NG spectrum has been first investigated, while finally focusing the channel selection procedure on the most interesting wavelength ranges for the assimilation.

Through this process, a total of 500 channels have been chosen to serve as a basis for the future channel selections to be provided to the NWP centres. It consists of 277 temperature, 23 surface-sensitive and 200 water vapour channels. One-dimensional variational (1D-Var) assimilation experiments show that using this selected set of channels leads to a reduction of the standard deviation of the error in temperature (up to 30%) vapour (up to 50%) profiles with respect to the a priori information.

3p.19 Development of the Chinese Space-Based Radiometric Benchmark Mission LIBRA

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Climate observations and their applications require measurements with high stability and low uncertainty in order to detect and assess climate variability and trends. The difficulty with space-based observations is that it is generally not possible to trace them to standard calibration references when in orbit. In order to overcome this problem, it has been proposed to deploy space-based radiometric reference systems which intercalibrate measurements from multiple satellite platforms. Such reference systems have been strongly recommended by international expert teams. This paper describes the Chinese Space-based Radiometric Benchmark (CSRB) project which has been under development since 2014. The goal of CSRB is to launch a reference-type satellite named LIBRA in around 2025. We present the roadmap for CSRB as well as

requirements and specifications for LIBRA. Key technologies of the system include miniature phase-change cells providing fixed-temperature points, a cryogenic absolute radiometer, and a spontaneous parametric down-conversion detector. LIBRA will offer measurements with SI traceability for the outgoing radiation from the Earth and the incoming radiation from the Sun with high spectral resolution. The system will be realized with four payloads, i.e., the Infrared Spectrometer (IRS), the Earth-Moon Imaging Spectrometer (EMIS), the Total Solar Irradiance (TSI), and the Solar spectral Irradiance Traceable to Quantum benchmark (SITQ). An on-orbit mode for radiometric calibration traceability and a balloon-based demonstration system for LIBRA are introduced as well in the last part of this paper. As a complementary project to the Climate Absolute Radiance and Refractivity Observatory (CLARREO) and the Traceable Radiometry Underpinning Terrestrial- and Helio- Studies (TRUTHS), LIBRA is expected to join the Earth observation satellite constellation and intends to contribute to space-based climate studies via publicly available data.

Poster Session 4

4p.01 CSPP Geo Gridded GLM

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This poster introduces the recently released CSPP Geo Gridded GLM software. It discusses current capabilities and future plans. It also offers users an opportunity to ask questions or give feedback.

The CSPP Geo project serves the direct broadcast community by providing software to generate geophysical products from geostationary satellite data. All CSPP Geo software is free to download and use.

The CSPP Geo Gridded GLM software processes GOES-16 and GOES-17 Geostationary Lightning Mapper (GLM) Level 2+ LCFA products in mission standard format, generating a new set of products which have been gridded to the Advanced Baseline Imager (ABI) 2-km resolution, and are aggregated at one-minute intervals. Spatial extent information that is not readily available in the GLM L2+ data is recovered and used to create the gridded products.

This software package was developed at the University of Wisconsin - Madison, SSEC / CIMSS,

under funding provided by the GOES-R Program and NOAA STAR. It is built on the open source glmtools software developed by Dr. Eric Bruning (Texas Tech University). Ongoing development of operational Gridded GLM products and related research is led by Dr. Scott Rudlosky (NOAA/NESDIS/STAR).

4p.02 Progress in the assimilation of GIIRS data

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The Chinese hyperspectral instrument GIIRS is the first of its kind on a geostationary platform. This presents new challenges for assimilation into global NWP systems, but is an excellent opportunity to prepare implementation methodologies ahead of the launch of future Chinese satellites and the European MTG-IRS. This presentation will describe various aspects of the assimilation methodology which is being developed and tested at ECMWF, including the specification of cloud detection, bias correction (which can potentially interact detrimentally) and observation errors, along with further instrument-specific data selection choices.

4p.03 A Remapping technique of FY-3D MWRI using deep learning for better use in data assimilation

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The assimilation of spaceborne passive microwave measurements is often suffered from the representativeness error due to the mismatch between the observation footprints and the NWP model grids. In this paper, a new brightness temperature remapping technique based on deep convolution neural network (CNN) is proposed to reduce the observation representativeness error of FY-3D MWRI. The remapping technique used an adapted dataset construction method, in which the training dataset is consist of synthetic NWP-model-grid-based MWRI brightness temperature (TB) images and the synthetic MWRI observed antenna temperature (TA) images. The impact of the CNN-based remapped MWRI observation on data assimilation is evaluated through Observation Minus Background (OMB) diagnosis with Global/Regional Assimilation and PrEdiction

System (GRAPES) 4D-Var. The experiment results illustrated that bias and standard deviation of OMB with the CNN-based remapped MWRI observation was quantitatively reduced comparing with the raw measurements in GRAPES 4D-Var.

4p.04 Near Real Time Active Fires and GAASP Level-2 Products Via Direct Broadcast Using the Community Satellite Processing Package

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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).

4p.05 Geostationary hyperspectral infrared sounder channel selection for capturing fast-changing atmospheric information

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Various methodologies have been developed for selecting a subset of channels from a hyperspectral infrared (IR) sounder for assimilation. The information entropy iterative method was considered optimal for channel selection. However, this method only considers the decrease in uncertainty in the atmospheric

state caused by measurements at a single time, without considering the dynamic effect of measurements over a period of time; therefore, it might not be optimal for hyperspectral infrared sounders onboard geosynchronous satellites which mainly aim to observe rapidly changing weather events. An alternative channel selection method is developed through adding an M index which reflects the Jacobian variance over time; the adjusted algorithm is ideal for the Geosynchronous Interferometric Infrared Sounder (GIIRS) which is the first high spectral resolution advanced IR sounder onboard a geostationary weather satellite. Comparisons between the conventional algorithm (information entropy iterative method) and the adjusted algorithm show that the channels selected from GIIRS by the adjusted algorithm will have larger brightness temperature diurnal variations and better information content than the conventional algorithm, based on the same background error covariance matrix, the observational error covariance matrix, and the channel blacklist. The adjusted algorithm is able to select the channels for monitoring atmospheric temporal variation while retaining the information content from the conventional method. The one-dimensional variational (1Dvar) retrieval experiment also verifies the superiority of this adjusted algorithm; it indicates that using the channel selected by the adjusted algorithm could enhance the water vapor profile retrieval accuracy, especially for the lower and middle troposphere atmosphere.

4p.06 An overview of current EESS Spectrum issues relevant to ATOVS-heritage systems

Stephen English¹, Mohamed Dahoui¹, Niels Bormann¹, Alan Geer¹, Emma Turner², Mike Banks², Mike Willis³, Markus Dreis⁴, Christophe Accadia⁴, Yan Soldo⁵, Flavio Jorge⁵, Bruno Espinosa⁶, Philippe Tristant⁷, Nancy Baker⁸
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Spectrum bands allocated to the Earth Exploration-Satellite Service (EESS) enable essential weather, climate and hydrological operational and research services to be provided, underpinned by global Numerical Weather Prediction (NWP). The EESS bands are important in a variety of ways: for radiance observations such as from ATOVS-heritage microwave instruments; for active observations such as ground radar; for

communicating observations (e.g. the 400.15–406 MHz band allocated for MetAids operations) and weather satellite downlinks; and for weather satellite command and control. In the past, most reported interference issues have been for low frequency, e.g. at L-band for the Soil Moisture Active Passive (SMAP) instrument, an Earth satellite mission that provides soil moisture information; for C-band rain radar; and C and X band radiance measurements that provide information on rain and on surface conditions (e.g. sea surface temperature, sea ice, snow). Cases of interference in these bands is well documented.

In this presentation focus will be given to the expansion of new operations (e.g. 5G mobile telecommunications) close to frequencies used by TOVS-heritage instruments e.g. at 24, 50 and 89 GHz, and indeed at frequencies above 100 GHz. Particular focus will be given to preparation in Europe for monitoring of 24 GHz, following the decision at WRC-19 to allow 5G applications to exceed the power levels that studies in the EESS community had concluded were the upper limit to prevent harmful interference. Some regulatory authorities are allowing deregulation and/or licensing of new use of bands above 100 GHz. The potential of this to disrupt services reliant on EESS allocations will also be discussed. The ITWG members will again be encouraged to actively monitor specific bands for evidence of Radio Frequency Interference, to document and share information on the value of bands, particularly where this can be expressed in terms of socio-economic value, and to communicate with spectrum managers (e.g. in NOAA, ESA, EUMETSAT, EUMETNET etc.) and where appropriate also with their countries regulatory authorities on issues of shared concern in the broad ATOVS science and operational community.

4p.07 Impact of various ozone profile sources on the simulation of hyperspectral Infrared radiances by RTTOV. Towards the assimilation of ozone sensitive IR radiances in Environment Canada NWP analysis system

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In the latest operational implementation at Environment Canada, a prognostic stratospheric ozone scheme using linearized chemistry (LINOZ) was introduced in the GEM atmospheric forecast model together with a deterministic chemical data

assimilation system. The impact of the chemical analysis on NWP forecasts is mostly due to the radiative effect of ozone. In this first implementation, the chemical analysis is performed independently of the NWP analysis. In the NWP analysis system, some weakly ozone sensitive hyperspectral IR radiances located in the 15 microns CO₂ band (from the AIRS, IASI and CrIS instruments) were already assimilated using ozone from the Fortuin and Kelder climatology. In this poster, we will present the impact on radiances and meteorological forecasts of using three different ozone sources for IR radiances assimilation, namely the RTTOV reference ozone profile, Fortuin and Kelder climatology and prognostic ozone from LINOZ (without chemical assimilation). In the future, it is planned to couple NWP and chemistry analysis through the use of LINOZ ozone fields in place of the Fortuin and Kelder climatology. It is also intended to test the assimilation of strongly ozone sensitive IR channels. Preliminary results towards these two objectives will be also presented.

4p.08 Assimilation of CrIS Shortwave Infrared Channels into the GEOS Atmospheric Data Assimilation System

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In recent years, there has been a renewed interest in using the 4.3 μm shortwave infrared (SWIR) band for temperature sounding. This is in part brought on by proposed cubesat missions sensing the 4.3 μm band such as MiSTIC (Maschhoff et al., 2019) and CIRAS (Pagano, et al., 2019). Jones et al. (2021) has shown that shortwave infrared channels on CrIS can be used effectively in NOAA's Global Forecast and Data Assimilation System (GDAS). In this work a similar study is presented using the Goddard Earth Observing System - Atmospheric Data Assimilation System (GEOS-ADAS). Results from Observing System Experiments (OSEs) utilizing SWIR CrIS are presented using standard community accepted forecast metrics including Forecast Sensitivity to Observation Impact (FSOI), and an assessment of vertical sensitivity using Jacobians from the Community Radiative Transfer Model (CRTM). The implications and utility within the GEOS-ADAS for future NASA GMAO products are discussed.

Jones et al., "The Evaluation and Impact of CrIS Shortwave Infrared Observations in the NOAA Global Data Assimilation System", American Meteorological Society Annual Meeting, 2021.

Maschhoff et al., "MISTiC winds: a micro-satellite constellation approach to high resolution observations of the atmosphere using infrared sounding and 3D winds measurements: a summary of risk reduction testing", Proc. SPIE 11131, CubeSats and SmallSats for Remote Sensing III, 111310I (30 August 2019); <https://doi.org/10.1117/12.2530810>

Pagano et al., "CubeSat Infrared Atmospheric Sounder technology development status," Journal of Applied Remote Sensing 13(3), 032512 (24 September 2019). <https://doi.org/10.1117/1.JRS.13.032512>

4p.09 Impact of microwave radiance assimilation over land using dynamic emissivity in the global NWP system of JMA

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The Japan meteorological agency/Meteorological research institute (JMA/MRI) is working on applying a dynamic emissivity (DE) method over land to the global NWP system of JMA. The DE gives a good estimation of land surface emissivity which depends on surface conditions, and improves the accuracy of radiative transfer calculation. By applying the DE to surface-sensitive channels of the advanced microwave sounding unit (AMSU-A) and advanced technology microwave sounder (ATMS), the RMSD between brightness temperatures of background and observation became smaller over continents, and the forecast skill improved especially in the northern hemisphere. This poster will include the most recent results up to the time of the ITSC-23.

4p.10 Supplementing Space-based Sounding with the Ground-based Atmospheric Emitted Radiance Interferometer (AERI) to Improve Thermodynamic Sounding of the Planetary Boundary Layer

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Both the National Research Council in 2009 and the 2017 NASA Decadal Survey have highlighted the weaknesses of the space-based observing

system in thermodynamic sounding of the planetary boundary layer (PBL) and the need for better observations. The 2017 NASA Decadal Survey highlighted sounding of the PBL as an area for future investment in the next decade. The National Research Council suggested the development of a nationwide network of ground-based profilers to supplement space-based profilers in order to improve observations of the PBL. One of the instruments that would fulfill the requirements outlined by the National Research Council for this ground-based network would be the Atmospheric Emitted Radiance Interferometer (AERI). AERI has been used extensively in calibration and validation studies of space-based instruments in addition to process studies of the PBL in research settings. AERI also has a long-term data record as part of the Atmospheric Radiation Measurement (ARM) Program.

Should such a network of ground-based sensors be implemented, one of the outstanding questions would be how to integrate it with the existing space-based observing system. This presentation will attempt to shed insight on that question by displaying results of a synthetic information content study of a synergy of space-based and ground-based sounders. Results show that a synergy of AERI with space-based sounders results in greater information content and improved vertical resolution throughout most of the troposphere. The synergy has greater degrees of freedom in the surface to 700 hPa layer than either AERI alone or the space-based instrument alone, suggesting that a synergistic retrieval is the method to extract the most information from these instruments. Preliminary results of a synergistic retrieval will also be presented.

4p.11 Assimilation of Reconstructed Radiances in NWP

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The primary objective of this study is to establish if ECMWF could switch the assimilation system with minimal adaptation to use reconstructed-radiances instead of conventional IASI radiances. This is important for the future use of observations from MTG-IRS as the EUMETSAT baseline dissemination system will only carry reconstructed-radiances data and the full level-1 spectrum of conventional radiances will not be available in near real time.

The reconstructed-radiances were generated locally at ECMWF from L1C radiances and a fixed set of global eigenvectors from IASI principal component data distributed by EUMETSAT. Assimilation trials using reconstructed radiances for the same set of IASI channels currently assimilated in ECMWF operations have been run, in an initial setup treating them similarly to conventional radiances. Their performance is evaluated in a depleted control system containing no active use of any infrared sounder radiances from polar orbiters and running at reduced horizontal resolution.

Preliminary results show that IASI reconstructed radiances have a positive impact on analyses and forecast quality, comparable in magnitude to that obtained when IASI radiances are assimilated. Future developments will explore the practices to determine the observation error for the assimilation of reconstructed radiances and the impact of changing the eigenvector basis on the forecasts skills.

4p.12 CSPP SDR 3.3, ASCI 1.1 - ATMS, CrIS, VIIRS plus OMPS and LSE

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The CSPP (Community Science Processing Package) Team at SSEC/CIMSS has created CSPP SDR 3.3 and CSPP ASCI 1.1 software packages for use by the Direct Broadcast Community. The SDR and ASCI packages work together to provide an extensive set of products from the JPSS Satellite platform. Exciting additions have been made to both packages.

CSPP SDR 3.3 builds on the proven reliability of the SDR codebase with the addition of OMPS processing. OMPS support includes both OMPS Limb and Nadar SDR production. The software also adds enhanced installation capabilities. These capabilities allow users to customize the installation for their unique processing requirements including cloud environments.

The CSPP ASCI package has been updated to include the latest version of NOAA Star's Enterprise Products for VIIRS with the addition of LSE (Land Surface Emissivity) products. The software pairs with CSPP SDR to provide the user with NOAA'S enterprise algorithms and Direct Broadcast data.

This poster illustrates several SDR / ASCII processing installations. It highlights how different

configurations can be tailored for different processing needs.

4p.13 Observation of the total ozone columns using the IKFS-2 instrument aboard the Meteor-M N2 satellite in 2015-2020

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Stratospheric ozone affects the radiative balance and temperature structure of the atmosphere and UV irradiance of the surface. Tropospheric ozone impacts the ecosystem as a pollutant and greenhouse gas. Satellite measurements using various methods and instruments make a significant contribution to the monitoring of ozonosphere. A method based on measurements of outgoing thermal radiation can be used during all days and seasons, including polar nights. At present, this method has been implemented using various equipment (AIRS, TES, IASI, CrIS, and IKFS-2).

Since 2015, the Russian Fourier spectrometer IKFS-2 on board the "Meteor-M N2" satellite has been measuring outgoing radiation in the range of 660-2000 cm⁻¹. Therefore, by the end of 2020 a large amount of measured spectra is accumulated.

Artificial Neural Networks (ANN) of total ozone column estimation were trained based on these spectra and total ozone column (TOC) measurements of the OMI instrument; different sets of predictors were analyzed. We derived the global TOCs distribution fields, including both inaccessible to UV methods areas and periods (more than 1.6×10^8 TOC values) in 2015-2020.

The data obtained was validated by comparison with independent TOCs measurements; it was shown that the bias between different datasets does not exceed 1%; its standard deviation is close to 3.5%. A dependence of differences on the space and time mismatch was analyzed.

IKFS-2 TOC distribution fields in the polar and circumpolar regions are used to analyze the state of the ozonosphere in certain observation periods. Comparison of IKFS-2 data with the results of ECMWF reanalysis (ERA-5) enables the explanation of changes in TOCs distribution fields and the appearance of ozone anomalies.

4p.14 Climate Data Records of the EUMETSAT Satellite Application Facility on Climate Monitoring

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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 CDRs (FCDRs), Thematic CDRs (TCDRs) and Interim CDRs (ICDRs) are being released. They primarily describe properties of atmospheric radiation, clouds, water vapour and precipitation. Thus, users have access to many parameters of the Earth's water and energy cycle based on operational satellite instruments. 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 geostationary satellites. For the majority of the already available FCDR and TCDRs improved and extended versions will become available. Additionally, the range of data records will be extended by TCDRs based on HIRS for cloud properties as well as microwave sounders combined with infrared channels on different geostationary sensors for a global precipitation product during CDOP-3.

The time series of the currently available climate data records range from 8 to about 40 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). All CDRs undergo a thorough validation and review process before their release. While TCDRs are based on inter-calibrated satellite level-1 products, the respective ICDRs, which are based on the same algorithms as the TCDRs, have less stringent requirements on the input data. This allows for a release within a few days after observation in order to serve applications with stronger timeliness requirements. For a number of data records (based on AVHRR and MVIRI/SEVIRI), CM SAF already now covers the new WMO reference period (1991-2020) with a combination of the TCDR and the respective ICDR data. By

2022, these ICDRs will be partly superseded by new versions of the underlying TCDRs with temporal coverage extended to 2020.

4p.15 Version 1.0 of the CRTM Transmittance Coefficient Generation Package

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A core part of the Community Radiative Transfer Model (CRTM) is the fast parameterization of gaseous transmittance for fast and accurate radiative transfer. This is achieved by means of a re-gression approach that fits accurate but expensive line-by-line results for a given instrument. A downside of this process is that a set of regression data in the form of a coefficient file for each new instrument that is to be used in conjunction with the CRTM is required. The purpose of the CRTM Transmittance Coefficient Generation Package is to streamline and automate the combined line-by-line computation and regression process as far as possible and allow a maximum of flexibility when it comes to the specifics of the instrument under investigation. Furthermore, expert CRTM users should be enabled to compute CRTM transmittance coefficients for new instruments themselves. This presentation provides an overview of the current state of the CRTM Transmittance Coefficient Generation Package and showcases a number of instrument examples that were processed using the package.

4p.16 Accuracy of newly emerging Vaisala radiosonde humidity measurements in comparison with satellite hyperspectral infrared measurements

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Radiosondes are important for calibrating satellite sensors and assessing sounding retrievals. Vaisala RS41 radiosondes have replaced RS92 in the Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN) and the conventional network. This study assesses RS41 and RS92 upper tropospheric humidity (UTH) accuracy by comparing with Infrared Atmospheric Sounding Interferometer (IASI) upper tropospheric water vapor absorption spectrum measurements. The assessment is conducted using radiosondes (RS41 and RS92 soundings) at GRUAN and DOE Atmospheric Radiation Measurement (ARM) sites collocated with cloud-free IASI radiances (OBS), and we compute Line-by-Line Radiative Transfer

Model radiances for radiosonde profiles (CAL) in comparison with OBS. In this presentation, we also introduce the NOAA Joint Polar Satellite System (JPSS) dedicated radiosonde database in support of satellite data calibration/validation.

4p.17 The Curious Case of the Hottest (and Coldest) FOVs

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When formed into Field-Of-Regards (FORs) consisting of 3x3 Field-Of-VIEWS (FOVs), various investigations have noted that the warmest (and coldest) AIRS and CrIS radiance observations are not equally likely (~11%) to be found among the nine FOVs, but that the corner FOVs are most likely to observe the extreme values within the FORs (~15%) followed by the side FOVs (~9%), and then center FOV (~5%). This behavior is found to be a feature of images with certain characteristics, not specific to IR Sounding satellite observations, which will be explored in this presentation. Implications for various applications, including the selection of warmest (clearest) data in NWP thinning procedures, and cloud clearing in atmospheric sounding, will also be discussed.

4p.18 Assessment of Uncertainties of Polarimetric Radar Variables Concerning Microphysical Parameters of Hydrometeors by using the Invariant Imbedding T-matrix Method

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Hydrometeors, especially frozen types, are known to have large variations of microphysics parameters related to densities, aspect ratios and orientation preferences existing in various precipitation systems and regions, as observed from field measurements by using particle cameras and disdrometer (e.g., see Refs.[1, 2]). Meanwhile, polarimetric radar variables observed by widely deployed dual-pol weather radars exhibit high sensitivity to those microphysics characteristics, posing great challenges to exploiting the underlying information quantitatively with applications in data assimilation systems. Essentially, a firm grasp of absorption and scattering by frozen hydrometeors with varying microphysical parameters is required.

In this presentation, we report on our recent progress made to address the uncertainties of polarimetric radar variables based on the state-of-the-art particle scattering solver IITM (Invariant-Imbedding T-matrix, [3,4]) and the microphysical data including aspect ratios, orientation preferences, terminal velocities, and size distributions [1,2]. In particular, we will report a new snow model which allows for convenient representation of particle geometry variation. The IITM is employed to compute the single-scattering properties of non-spherical particles with orientation preference. We also compare the results with those of widely used shapes including spheroid, hexagonal prism and dendrite particles [5]. Detailed comparison of polarimetric radar signatures related to particle shapes in our simulations will be discussed. Our preliminary results show that assigning an uncertainty of 5% to each microphysical parameters of orientation preference and aspect ratios for snowflake leads to a probability distribution of intrinsic differential reflectivity factor (ZDR) with a standard deviation as large as 50%, while that of reflectivity factor (ZH) only gives 3%. The present study is expected to be useful for developing well-constrained hydrometeor models for applications in spaceborne radar data assimilations.

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4p.19 Assimilating all-sky microwave radiance within NOAA's prototype Rapid Refresh Forecast System

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At EMC, a unified hourly-updated, storm-scale ensemble data assimilation and forecasting system based on the FV3 dynamic core, which will be called the Rapid Refresh Forecast System (RRFS), is under development. In this system, most of the data is assimilated as in EMC's global system (FV3GFS). But for microwave radiance, only clear-sky radiance have been assimilated. With the recent update of using DBNet radiance data in RRFS, we have seen the assimilation of the DBNet radiance data largely increased the data coverage for the hourly analysis, especially for ATMS. It makes it possible for us to take into account the effect of cloud and precipitation on both AMSU-A and ATMS. The test version of this system utilizes the Thompson microphysics and the MYNN planetary boundary layer schemes, the Noah land surface model and runs over the CONUS (FV3LAM) with 3-km horizontal resolution. In this work the impact of extending the existing clear-sky assimilation of temperature-sounding AMSU-A and ATMS radiances to cloudy areas will be investigated. The current global operational

FV3GFS is assimilating clear and non-precipitating cloudy radiances from AMSU-A and ATMS. Cloudy scenes are assumed to be overcast (no fractional cloud coverage). The capability of assimilating precipitation-affected radiances had been developed for testing in FV3GFS and extended to FV3LAM. The analysis variables are augmented to include precipitation components (rain, snow, and graupel). The observation operator (CRTM) has also been enhanced to simulate cloudy radiances with fractional cloud coverage. The cloudy radiance from AMSUA and ATMS is presently limited over the ocean due to the challenge of the uncertainty in simulating microwave land surface emissivity. This poster will focus on demonstrating the simulated cloudy radiance of the microwave with the high resolution model background; the impact on the analysis from assimilating cloud-affected radiance vs. precipitation-affected radiance; discussing the challenge of quality control and bias correction for assimilating the microwave sounding channel radiance in a limited-area regional model. From the results of trial experiments we will also discuss impacts of the assimilation of microwave cloudy radiance on convective scale weather forecasts.

