Recent development of satellite data assimilation at JMA

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1. Outline of NWP systems at JMA

Specification of JMA's forecast model and data assimilation system

Model	Global Model & Analysis (GSM,GANL)	Meso-scale Model & Analysis (MSM,MANL)
Horizontal res.	TL959 (20km)	5km
Vertical res. (model top)	60 (0.1hPa)	50 (21.8km)
Forecast range (Initial time)	84h (00,06,18UTC) 216h (12UTC)	15h (00,06,12,18UTC) 33h (03,09,15,21UTC
Frequency	4/day	8/day
Target	One-week forecast Short-range forecast Aeronautical forecast	Disaster prevention information
Data Assimilation (outer/inner loop)	4D-Var (TL959/T159 or 20km/80km)	4D-Var (5km/15km)
Assimilation window	6h (-3 to +3 hours of analysis time)	3h (-3 hours to analysis time)
Radiance assimilation	RTTOV9.3, VarBC	X
Cut off time	Early Analysis : 2h25m Cycle Analysis: 11h15m(00,12), 5h15m(06,18)	50m

Satellite (to be) used in the operational global and meso-scale NWP system
() is under development. Items in red have been implemented operational system since ITSC16

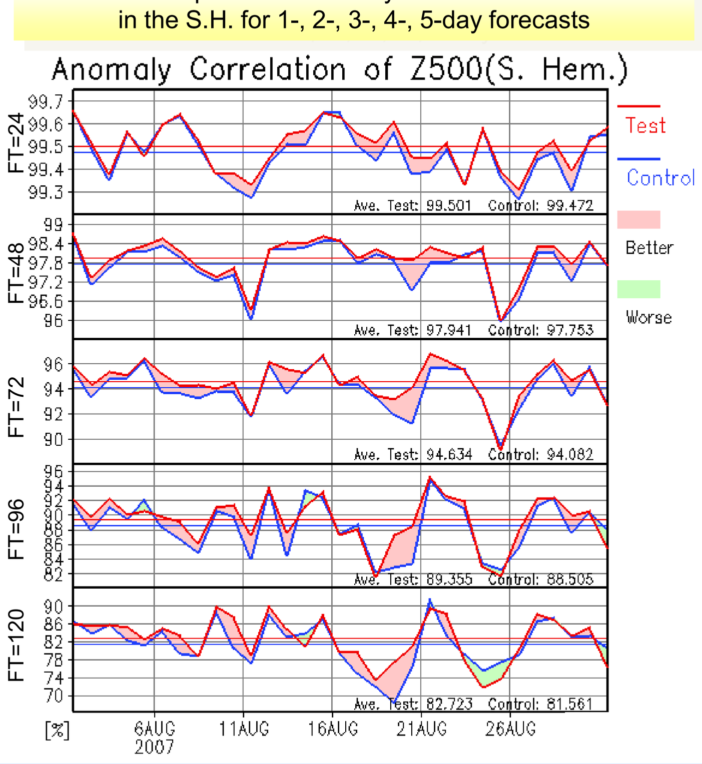
Satellite/Instrument		GANL	MANL
1. Sounder	NOAA15,16,18,19/AMSU-A	Radiance	Temperature , (→Radiance)
	NOAA15,17,18,19/AMSU-B,MHS	Radiance	Temperature , (→Radiance)
	Aqua/AMSU-A	Radiance	(Radiance)
	Metop/AMSU-A,MHS	Radiance	Temperature , (→Radiance)
	DMSP16/SSMIS	Radiance	(Radiance)
	(Aqua/AIRS, Metop/IASI)	(Radiance)	(Radiance)
2. MW Imager	TRMM/TMI	Radiance	TCWV(→Radiance) , Rain Rate
	Aqua/AMSR-E	Radiance	TCWV(→Radiance), Rain Rate
	DMSP16,17/SSMIS	Radiance	(TCWV(→Radiance), Rain Rate)
3. VIS/IR Imager	MTSAT-1R, Meteosat-7,9, GOES-11,12	Radiance	(Radiance)
		AMV	AMV
	Aqua,Terra/MODIS	AMV	X
4. Scatterometer	Metop/ASCAT	Ocean surface wind	(Ocean surface wind)
5. GPS-RO	GRACE	Refractivity	(Under development)
	Metop/GRAS	Refractivity	(Under development)
6. Ground-based GPS		(ZTD)	TCWV (→ZTD)

AMV : Atmospheric Motion Vector, TCWV : Total Column Water Vapor, RO : Radio Occultation, ZTD : Zenith Total Delay

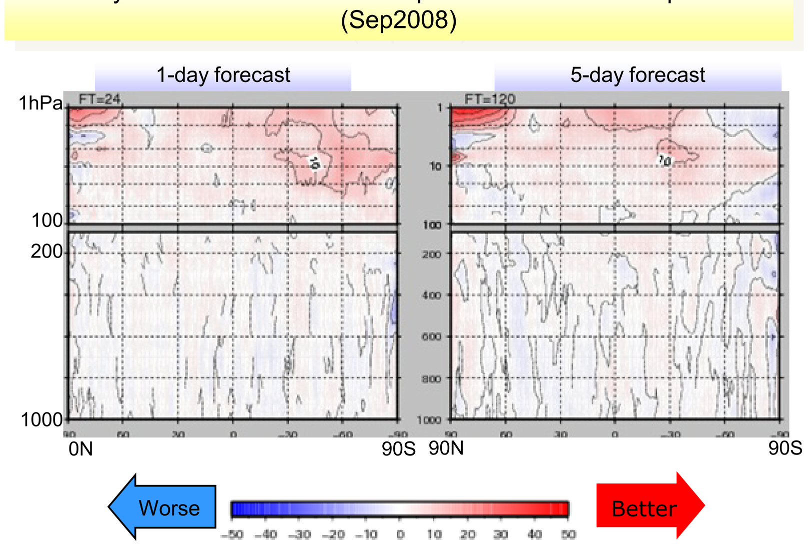
2.1 Unify and improve pre-processings of radiance assimilation

- Unify and reorganize pre-processings for radiance assimilation except QC procedures, BC predictors and data interface
  - ATOVS, MW imagers and geo.sat imagers (CSRs)
  - Increase the maintainability of the codes and extensibility to other instruments
- Improve pre-processings
  - Tighten cloud screening for MW imagers
    - Stricter criteria of cloud liquid water (CLW, 100g/m2), and add CLW to VarBC predictors to remove cloud effect
  - Use pixels at both edges of scan for ATOVS
- Upgrade RT model: RTTOV7 -> RTTOV8.7 -> RTTOV9.3
  - Improve MW ocean emissivity model
  - Improve Jacobian mapping of a new interpolation algorithm and discontinue invalid Zeeman effect
- Forecast Impacts
  - Improve tropospheric humidity field by reducing dry bias
  - Improve tropospheric temperature and geopotential height especially over the ocean in the Tropics and S.H.
  - RTTOV9.3 significantly improves stratospheric temperature in the winter hemisphere

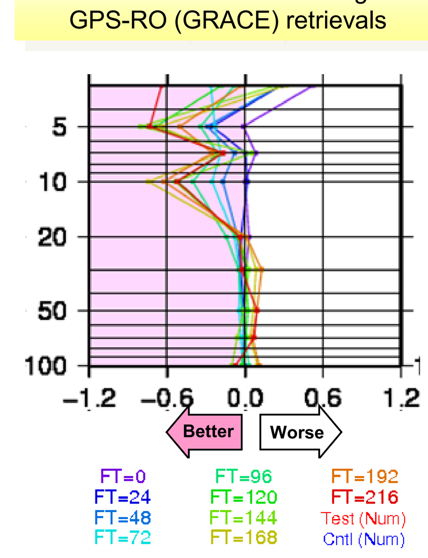
Time sequence of anomaly correlation of Z500 in the S.H. for 1-, 2-, 3-, 4-, 5-day forecasts



Monthly zonal mean of forecast Improvement rate for temperature (Sep2008)



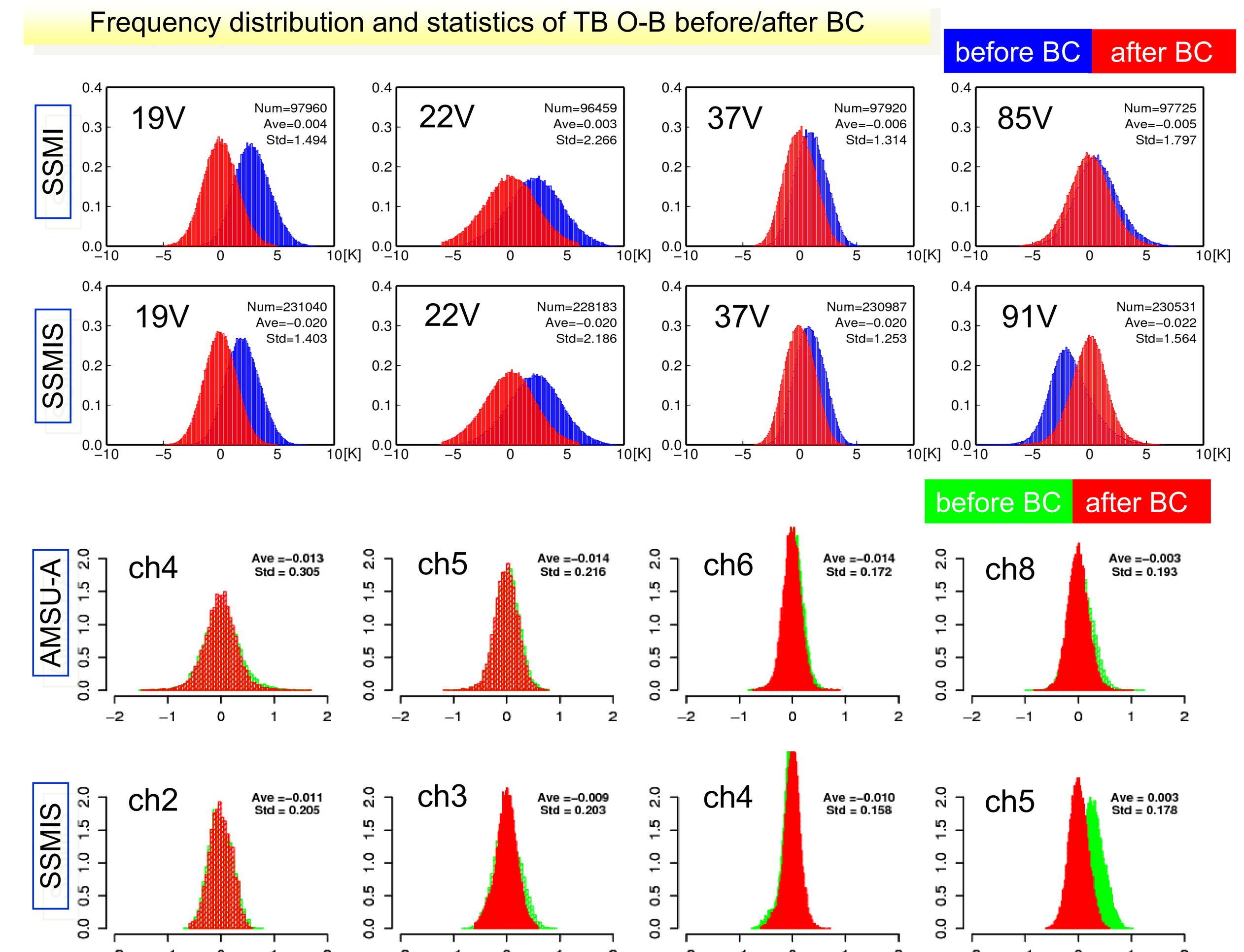
Difference of STD for temperature forecast in the N.H. verified against GPS-RO (GRACE) retrievals



2.2 SSMIS radiance assimilation

- Assimilate clear radiances of DMSP-F16 & -17/SSMIS imaging channels of 13, 14, 16 and 17 (19V,22V,37V and 92V)
  - SSMIS and SSMI after BC are similar in quality
  - Apply the same QC, thinning (200km) and BC procedures as other MW imagers (SSMI, TMI and AMSR-E)
  - Slightly positive impacts on analysis of T850 and TCWV
- Assimilate clear radiances of DMSP-F16/SSMIS temperature sounding channels of 2, 3, 4 and 5
  - Use the data pre-processed by UKMO
    - Discriminate and correct data contaminated by calibration anomalies
  - Channels 6, 7 and 24 are not used due to large bias inconsistency on ascending/descending orbits
  - Channels 21, 22 and 23 are not used due to their sensitivity beyond the model top
  - Apply cloud-QC, scan line QC and gross-error QC
  - Assign larger observation error values than AMSU-A (1.0K vs 0.4K)
  - Positive impacts on short range forecasts of Z500 in the S.H.

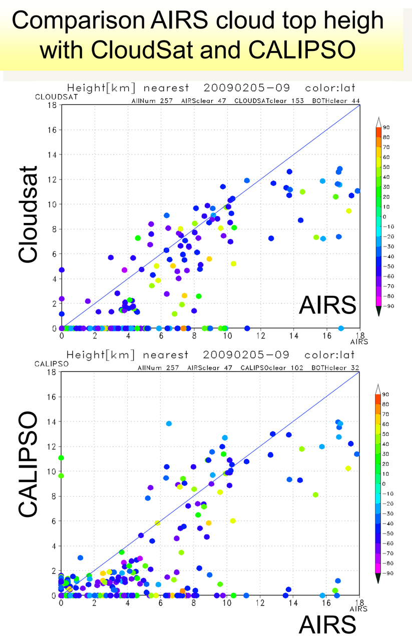
Frequency distribution and statistics of TB O-B before/after BC



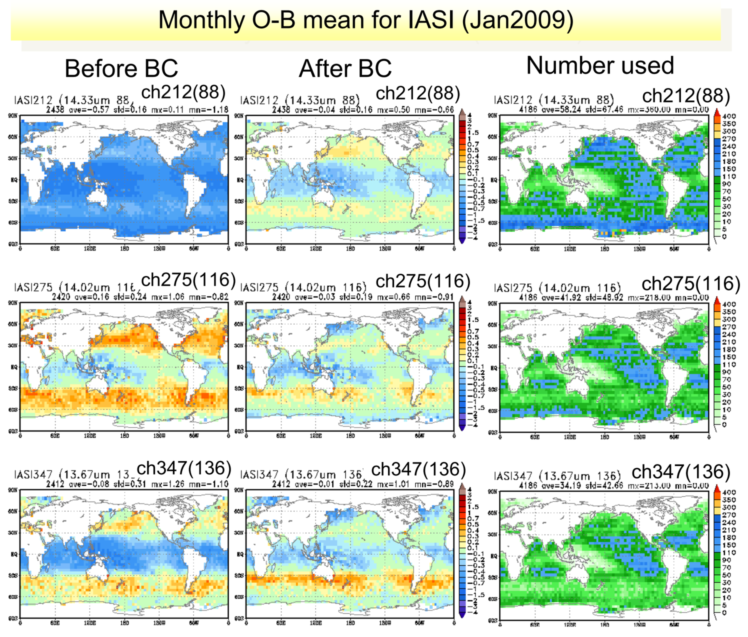
2.3 AIRS & IASI clear radiance assimilation

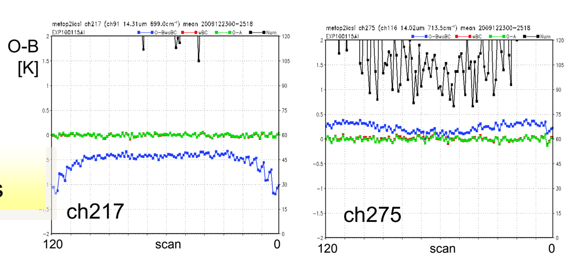
- Assimilate temperature channels over the ocean
  - AIRS 82ch, IASI 74ch (no surface ch)
- Identify cloud-affected channels using a CO2-slicing method
  - Cloud top height seems to be too high for clouds, especially with tiny fraction => may remove more channels than they should be but avoid contamination by cloud-affected channels
- Remove biases using VarBC with predictors of normalized Tb calculated from first-guess, nadir view angle raised to one, two, three and four, and constant.
  - Channels sensitive to the lower troposphere has dependency on the fourth power
- Set observation errors from O-B std and multiply them by four in 4D-Var to balance impacts with other observations
- Successfully reduce positive biases in the upper tropospheric temperature in the low latitude in the analysis and short-range forecast
- However degrade lower tropospheric temperature and upper stratospheric wind forecasts . Possible causes are
  - Reduction of the tropical temperature biases, even in the right direction, may upset the forecast model balance => under investigation of, for example, convection process
  - Still misuse cloud-affected radiances and/or inadequate bias correction => review interaction among QC, BC and cloud detection

Comparison AIRS cloud top heigh with CloudSat and CALIPSO



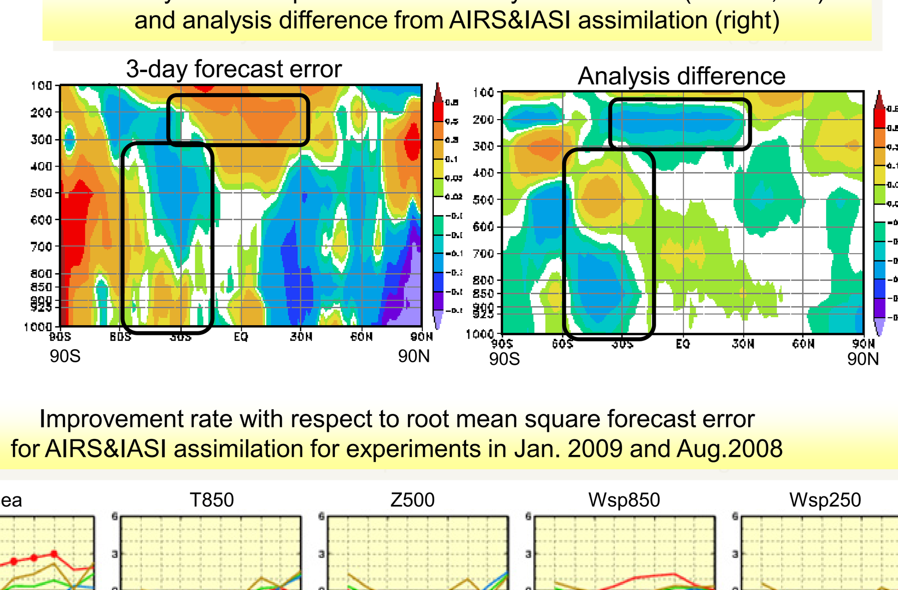
Monthly O-B mean for IASI (Jan2009)



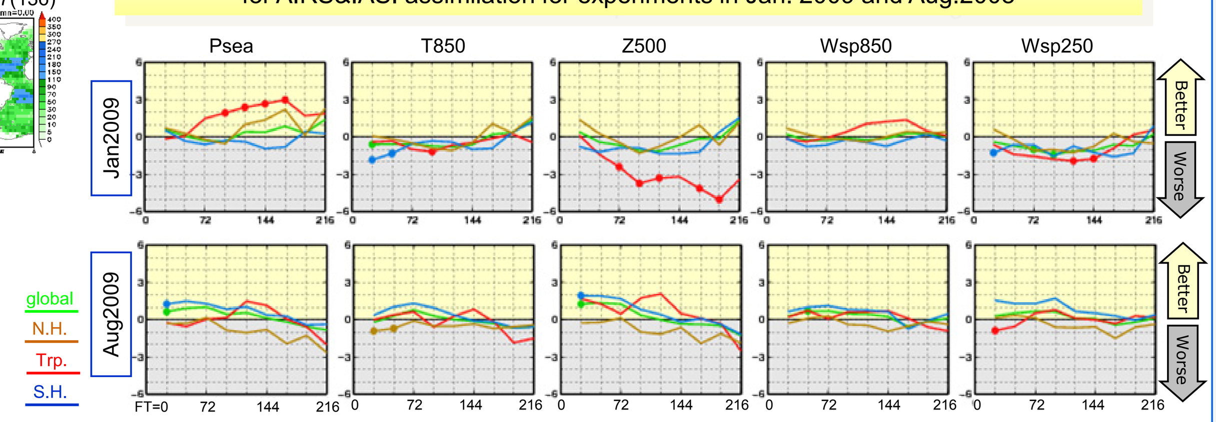


IASI O-B mean before/after BC at each scan position for 3 days

Monthly mean temperature of the 3-day forecast error (fcst-init, left) and analysis difference from AIRS&IASI assimilation (right)



Improvement rate with respect to root mean square forecast error for AIRS&IASI assimilation for experiments in Jan. 2009 and Aug.2008



3. History and Plans

- History
  - 2008.8 : Assimilate clear sky radiances (CSRs) of water-vapor channels from five geo-stationary satellites
  - 2008.10 : Unify and improve pre-processings of radiance assimilation
  - 2009.3 : Upgrade RTTOV to version 9.3
    Assimilate DMSP-F16/SSMIS imaging channel radiances
  - 2009.4 : Upgrade meso-scale 4D-Var analysis system (JNoVA)
  - 2009.7 : Assimilate oceans surface winds from Metop/ASCAT
    Assimilate DMSP-F16/SSMIS temperature sounding channel radiances
  - 2009.10 : Assimilate TCWV from ground-based GPS over Japan
  - 2009.11 : Assimilate refractivity from Metop/GRAS and GRACE
  - 2009.12 : Assimilate clear radiances from NOAA19/AMSU-A and MHS
- Plans
  - Assimilate clear radiances of AIRS and IASI
  - Replace retrieval temperature assimilation with radiance assimilation in MANL
    - How to estimate and correct biases?
  - Development of assimilation of rapid scan AMVs
  - Optimize observation error covariance matrices and build an observation impact estimation scheme
  - Exploit more sounder radiances over land by introducing better emissivity estimates
  - Assimilate radiances affected by clouds and rain

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