13p.07

Recent upgrades and progress of satellite radiance data assimilation at JMA

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1. Outline of NWP systems at JMA

Specifications of JMA's deterministic forecast models and data assimilation systems.
Details are available on the https://www.jma.go.jp/jma/jma-eng/jma-center/nwp/nwp-top.htm .

Model	Global Spectral Model & Analysis (GSM, GA)	Meso-scale Model & Analysis (MSM, MA)	Local Forecast Model & Analysis (LFM, LA)
Horizontal res.	TQ959 (~13 km)	5 km	2 km
vertical lev. (top.)	L128 (0.01hPa)	L96 (37.5 km)	L76 (21.8 km)
Forecast range (Initial time)	5.5 days (06,18UTC) 11 days (00,12UTC)	78h (00,12 UTC) 39h (03,06,09,15,18,21 UTC)	18h (00,03,06,09,12,15,18,21 UTC) 10h (1 hourly, the others)
Data Assimilation (inner loop horizontal res.)	4D-Var (TL319, ~55km) + LETKF Hybrid + outer-loop iteration	4D-Var (15 km)	Hybrid 3D-Var (5 km)
Assimilation window	6h (-3h ~ +3h)	3h (-3h30m ~ +30m)	1 hourly update cycle for 3h (-3h30m ~ +30m)
RTM for Radiance assimilation	RTTOV 13.0 (10.2 coefficients)	RTTOV 13.0 (13.0 coefficients)	
Cut off time	Early Analysis: 2h20m Cycle Analysis: 11h50m (00, 12UTC), 7h50m (06, 18UTC)	50min	30min

*) Red indicates updates in the operational system since ITSC-24.

Satellite data used in the operational assimilation systems. (as of May 2025)

Type	Satellite/Instrument	Global Analysis	Meso-scale Analysis	Local Analysis
MW Sounder	NOAA-15,18,19, Metop-B,-C/AMSU-A	Radiance	Radiance	Radiance
	NOAA-19,Metop-B,-C/MHS	Radiance	Radiance	Radiance
	DMSP-F17,18/SSMIS	Radiance	-	-
	Suomi-NPP, NOAA-20,21/ATMS	Radiance (T,H)	Radiance (H)	Radiance (H)
IR Sounder	Metop-B,-C/IASI	Radiance (T,H)	Radiance (T,H)	Radiance (H)
	NOAA-20,21/CrIS	Radiance (T,H)	Radiance (T,H)	Radiance (H)
MW Imager	DMSP-F17,18/SSMIS	Radiance	Radiance, Rain Rate	Radiance
	GCOM-W/AMSR2	Radiance	Radiance, Rain Rate	Radiance, Soil Moisture
	GPM-core/GMI	Radiance	Radiance, Rain Rate	Radiance
VIS/IR Imager	Himawari-9	CSR, AMV	CSR, AMV	CSR, AMV
	GOES-18	CSR, AMV	-	-
	Meteosat-9,10	CSR, AMV	-	-
	NOAA-15,18,19, Metop-B,-C/AVHRR	AMV	-	-
	Suomi-NPP, NOAA-20/VIIRS	AMV		
	LEOGEO composite image	AMV	-	-
Scatterometer	Metop-B,-C/ASCAT	OSWV	OSWV	OSWV Soil Moisture(-B)
Radio Occultation	Metop-B/GRAS	Bending Angle	Refractivity	-
	TerraSAR-X/IGOR	Bending Angle	Refractivity	-
	TanDEM-X/IGOR	-	Refractivity	-
Radar	GPM/DPR	-	Relative Humidity	-

*) Blue indicates all-sky assimilation.

CSR: Clear Sky Radiance on water vapor channels,
AMV: Atmospheric Motion Vector,
OSWV: Ocean Surface Wind Vectors

2. List of Upgrades

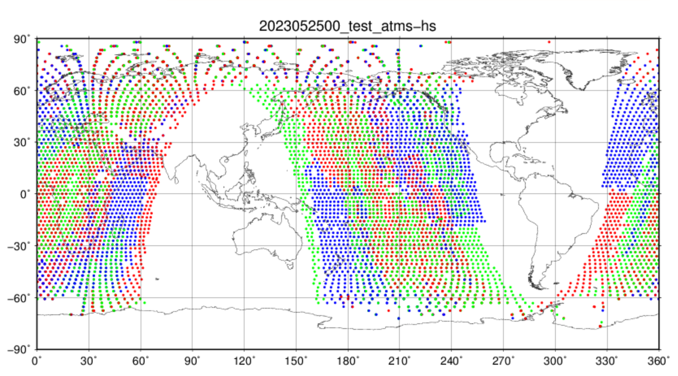
- Assimilation of GOES-18/CSR,AMV replacing GOES-17 (GA, May 2023)
- Resume use of Meteosat-10/CSR,AMV replacing Meteosat-11 (GA, May 2023)
- Upgrade to the JMA's 11th generation supercomputer systems, including all NWP subsystems (Mar. 2024)
- Assimilation of NOAA-21/ATMS, CrIS (GA, MA and LA, Mar. 2024) ⇒ 2.1
- Upgrading the coefficients and sea surface emissivity models used in RTTOV-13.0 (MA and LA, Feb. 2025) ⇒ 2.2
- Assimilation of window channels of AMSU-A and ATMS (23.8 and 31.4GHz) (MA and LA, Feb. 2025) ⇒ 2.3

2.1 Assimilation of NOAA-21/ATMS, CrIS

Data quality and observation error settings

- Observation errors are estimated based on statistics (standard deviation) of O-B (observation – first-guess).
- The standard deviations of O-B for each channel are similar to or smaller than Suomi-NPP and NOAA-20.The same observation errors and QC thresholds as for those satellites were applied.

Data coverage of ATMS in GA

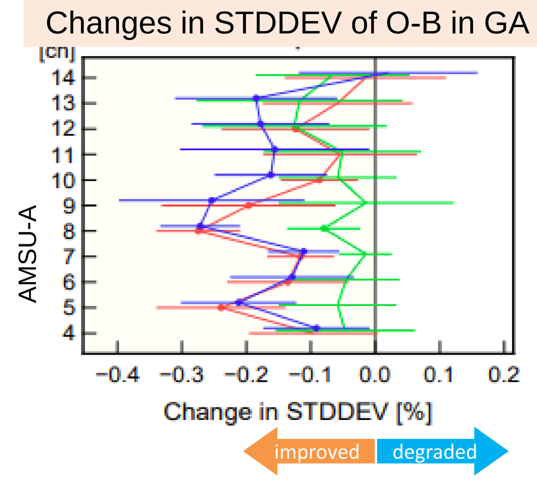


Suomi-NPP, NOAA-20, NOAA-21

Data coverage

- Overlapped observation data from three satellites are thinned to one of them.
- The number of data used increased about 10% (ATMS) and up to 35% (CrIS T-channels) with the addition of NOAA-21.

Changes in STDDEV of O-B in GA



CrIS only, ATMS only, AMTS+CrIS

Impact on forecasts

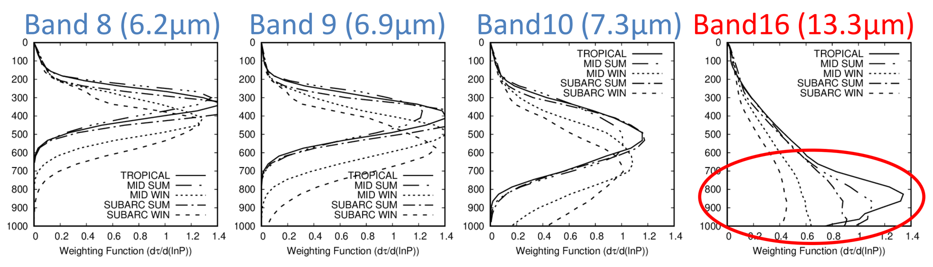
- Data assimilation experiments showed that the addition of NOAA-21 to GA improved the first-guess (short-range forecast) accuracy resulting in the changes in the O-B standard deviation of AMSU-A. The lower channels are mainly attributable to ATMS, and the upper channels are to CrIS.
- GSM forecast accuracy improved mainly in T and Z, especially in the tropics. MSM and LFM forecast accuracies were almost neutral.

3.1 Additional use of CO_2 band of the geostationary satellites' CSR

CO_2 band CSR

- CSRs at WV bands have been widely used at NWP centers. In addition to the WV bands, the use of the CO_2 band has been developed (Okabe and Okamoto 2023).
- CO_2 band (13.3-13.4 μm) CSRs have information about temperature and WV in the middle and lower troposphere.
- Accurate LST is necessary for assimilating CO_2 band because it is sensitive to LST. Retrieval of LST enables the use of CO_2 band over land.

Weighting functions of Himawari-8/AHI



Retrieval of Land Surface Temperature (LST)

Observation of window band CSR → Atmospheric profile of background in the model

$$B(\mathrm{BT}) = \tau_t \varepsilon_s B(\mathrm{LST}) + \int_{\tau_t}^{1} B(\mathrm{T})d\tau + (1-\varepsilon_s)\tau^2 \int_{\tau_t}^{1} \frac{B(\mathrm{T})}{\tau^2} d\tau$$

Retrieved LST

These terms for window band are so small that the difference between actual observation and model would be considered negligible.

B: the Planck function, BT: brightness temperature, τ_t: the surface to space transmittance, ε_s:the surface emissivity, τ: transmittance at a certain height, T: atmospheric temperature, h: the Planck constant, k: the Boltzmann constant, ν: frequency, c: the light speed.

Impact on forecasts

- Data assimilation experiments were conducted using JMA's global data assimilation system of JMA (as of Mar. 2024). CO_2 band CSRs of Geostationary satellites (Himawari-8, GOES-16,18, Meteosat-9 and -10) were additionally used in the experiments. (August 2023 and January 2024)
- Mainly over continents in the summer hemisphere, the biases of lower air temperature and specific humidity improved in the analysis, then its forecasts improved as well.

2.2 Upgrading the coefficients and sea surface emissivity models used in RTTOV-13.0

- The radiative transfer model used in the JMA's NWP systems (GA, MA and LA) was updated from RTTOV 10.2 to 13.0 in 2022. To ensure a reliable update, the first step was to make minimal changes so as not to change the data assimilation result too much. (Reported in ITSC-24, 1p.06)
- As the second step, RTTOV coefficients and sea surface emissivity models were updated (MA and LA) and are being updated (GA). The accuracy of the calculations was confirmed to have improved (except CrIS).
- With these changes, scan bias corrections (static bias correction at each FOV) for polar orbit satellites were updated. Parameters used for QC (e.g., obs. errors, thresholds) were validated and updated as necessary.
- The impact on forecast accuracy was not very significant, but the data assimilation systems for Tb are now more ideal than before.

2.3 Assimilation of window channels of AMSU-A and ATMS

AMSU-A and ATMS window channels

- Window channels of AMSU-A and ATMS (23.8GHz and 31.4GHz) were previously used only for QCs. These are sensitive to humidity in the lower troposphere and similar to the microwave imager channels that have already been assimilated. These can complement and extend data coverage of the lower humidity observation.

Data assimilation settings

- Observation errors are estimated based on standard deviation of O-B. Observation error inflations are set equal to the corresponding microwave imager channels.
- In addition to the same QCs as the other temperature channels, a QC was applied to remove more strictly land/sea mixed FOVs due to the larger FOV of sounders.

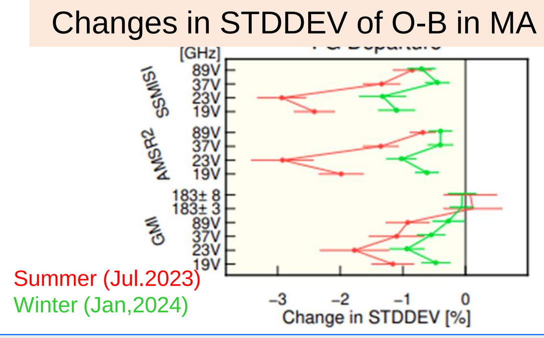
Obs. errors for window channels [K]

AMSU-A	ch1	ch2
Metop-C	2.80	2.40
NOAA-15	3.00	2.60
NOAA-18	2.80	2.40
NOAA-19	2.80	2.40
ATMS	ch1	ch2
S-NPP	2.80	2.20
NOAA-20	3.00	2.70
NOAA-21	3.00	2.70

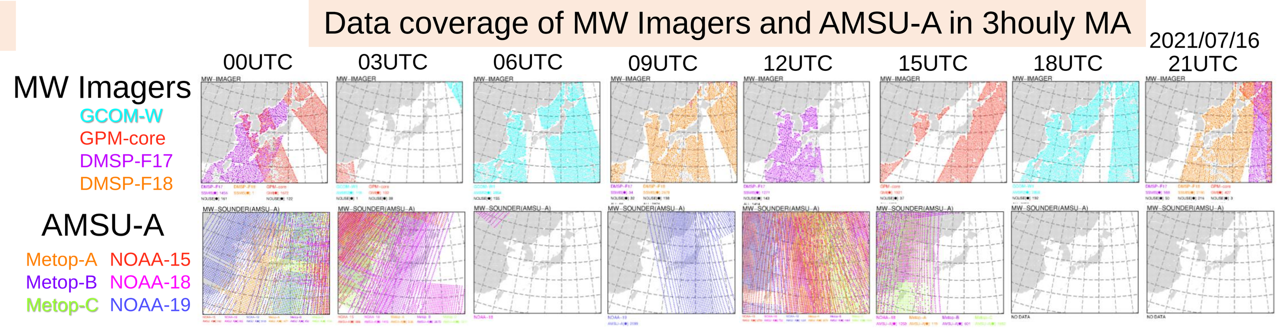
Impact on forecasts

- Data assimilation experiments showed that the addition of window channels improved the first-guess accuracy in lower troposphere humidity resulting in the changes in the O-B standard deviation of microwave imagers.
- Forecast accuracy was also improved in weak precipitation up to 24 hours for MSM and in lower troposphere humidity in the tropics for GSM.

Changes in STDDEV of O-B in MA



Data coverage of MW Imagers and AMSU-A in 3houly MA



3. Future Plans

- Upgrading the coefficients and sea surface emissivity models used in RTTOV-13.0 in GA ⇒ 2.2
- Assimilation of window channels of AMSU-A and ATMS in GA ⇒ 2.3
- Improvement of assimilation schemes for all-sky assimilation of microwave water vapor sounder in GA
  - ⇒ See 9p.06 poster (by H. Shimizu)
- Assimilation of GOSAT-GW/AMSR3 in GA, MA and LA
- Assimilation of GOES-19 and Meteosat-12 in GA
- Additional use of CO_2 band of the geostationary satellites' CSR in GA ⇒ 3.1 and MA
- All-sky infrared radiance assimilation in GA
  - ⇒ See 10.03 oral (by I. Okabe) for geostationary satellite imagers
  - ⇒ See 10.04 oral (by K. Okamoto) for IASI
- Preparation for the assimilation of Himawari-10/GHMS
  - ⇒ See 4p.05 poster (by T. Urata)

<References>

- Okabe, I., & Okamoto, K. (2023). Assimilation of surface - sensitive bands' clear - sky radiance data using retrieved surface temperatures from geostationary satellites. Quarterly Journal of the Royal Meteorological Society, 149(753), 1473-1497.

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