4p.12

Recent upgrades and progresses 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 *http://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)* ←TL959 (~20 km)	5 km	2 km
vertical lev. (top.)	L128 (0.01hPa)	L96 (37.5 km) ←L76 (21.8 km)	L76 (21.8 km)
Forecast range (Initial time)	5.5 days (06,18UTC) 11 days (00,12UTC)	78h (00,12 UTC) ←51h 39h (03,06,09,15,18,21 UTC)	10h (1 hourly)
Data Assimilation (inner loop horizontal res.)	4D-Var (TL319, ~55km) + EnKF Hybrid + outer-loop iteration	4D-Var (15 km)	Hybrid 3D-Var (5 km)
Assimilation window	6h (-3 ~ +3 hours)	3h (-3h30min ~ +30min)	1 hourly update cycle for 3h (-3h30min ~ +30min)
RTM for Radiance assimilation	RTTOV 13.0 (10.2 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-23.
*) *Italic* indicates plans to be implemented in Mar. 2023.

Satellite data used in the operational assimilation systems. (as of Mar. 2023)

Type	Satellite/Instrument	Global Analysis	Meso-scale Analysis	Local Analysis
MW Sounder	NOAA15,18,19, Metop-B,-C/AMSU-A	Radiance	Radiance	Radiance
	NOAA19,Metop-B,-C/MHS	**Radiance**	Radiance	Radiance
	DMSP-F17,18/SSMIS	**Radiance**	-	-
	Suomi-NPP, NOAA20/ATMS	Radiance (T,**H**)	Radiance (H)	Radiance (H)
	FY-3C/MWHS-2	**Radiance**	-	-
IR Sounder	Metop-B,-C/IASI	Radiance (T,*H*)	*Radiance (T,H)*	*Radiance (H)*
	Suomi-NPP, NOAA20/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-16,(17)	CSR, AMV	-	-
	Meteosat-9,11	CSR, AMV	-	-
	NOAA15,18,19, Metop-B,-C/AVHRR	AMV	-	-
	Aqua,Terra/MODIS	AMV	-	-
	Suomi-NPP, NOAA20/VIIRS	*AMV*		
	LEOGEO composite image	AMV	-	-
Scatterometer	Metop-B,-C/ASCAT	OSWV	OSWV	*OSWV* Soil Moisture
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

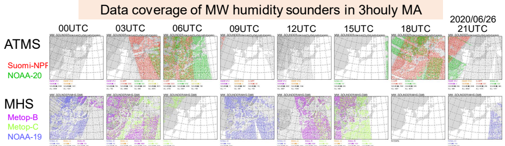
2. List of Upgrades

- Use of Metop-C/AMSU-A, MHS (LA, Nov. 2021)
- Use of Metop-C/IASI (GA, Nov. 2021)
- Additional use of AMUS-A/ch 8-11 with model top extension (MA, Mar. 2022)
- Implementation of hybrid 3D-Var (La, Mar. 2022) (Yokota, S., et al., 2022)
- Update RTTOV v10.2 to v13.0 (minimal changes) (GA and MA, Jun.; LA, Aug. 2022)
  - ⇒ See 1p.06 poster (by N. Kusano)
- Use of Suomi-NPP, NOAA-20/ATMS (183GHz) (MA, Jun.; LA, Aug. 2022)
- Switch IODC Meteosat-8 to Meteosat-9 AMV and CSR (GA, Jun. 2022)
- Switch Meteosat CSR to stored CSR in ASR product (GA, Oct. 2022)
- Switch Himawari-8 to Himawari-9 AMV and CSR (GA, MA and LA, Dec. 2022)
- Additional use of Hyperspectral IR sounders' humidity channels (GA, Mar. 2023)
- Use of Hyperspectral IR sounders (MA and LA, Mar. 2023)

2.1 Use of Suomi-NPP, NOAA-20/ATMS in MA and LA

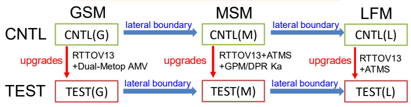
- Complementary data coverage of humidity sounders
  - In addition to MHS, ATMS 183GHz humidity channels are assimilated in MA and LA.
  - The coverage of ATMS in PM orbits is complementary to that of MHS in AM orbits.
  - Data assimilation experiments adding ATMS show improvements in the water vapor field in short-range forecast in MA and LA.

Data coverage of MW humidity sounders in 3houly MA

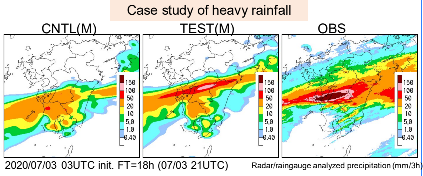


- Overall performance test combining GSM, MSM, and LFM developments.
  - Data assimilation experiments combining all developments to be in operation at the same time were conducted. Lateral boundaries were provided from each parent model (i.e. GSM for MSM, MSM for LFM).
  - A combination of individual model improvements and lateral boundaries improvements consequences the better location and amount of heavy rainfall prediction for MA and LA.
  - Lateral boundary is also important to improve regional model forecast.

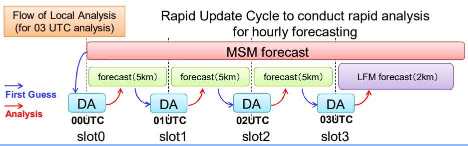
Configuration of overall performance test



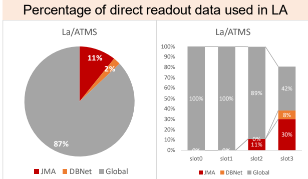
Case study of heavy rainfall



- Contribution of DBNet data to regional model analysis
  - Short latency data are important to regional model analysis with short cut-off time (MA:50min, LA:30min).
  - Direct readout data including DBNet contribute increase of available data especially near the analysis time, end of assimilation window.



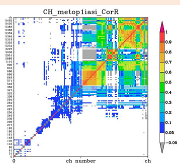
Percentage of direct readout data used in LA



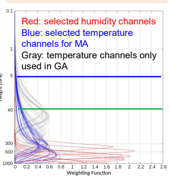
2.2 Changes in usage of Hyperspectral IR sounders

- Additional use of Hyperspectral IR sounders' humidity channels in GA
  - In addition to temperature channels, humidity channels were selected to be assimilated in the global system.
  - All candidate channels selected by sensitivity analysis based on Jacobian matrix were assimilated in a preliminary experiment and observation error correlation was analyzed. Channels with small inter-channel error correlation were subjectively picked up. (9 channels for both IASI and CrIS.)
  - Data assimilation experiments using the selected channels were conducted. Short-range forecasts for water vapor fields were improved.

IASI inter-channel observation-error correlation matrix

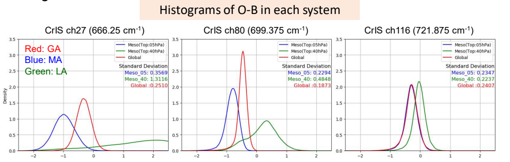


Weighting functions of selected IASI channels

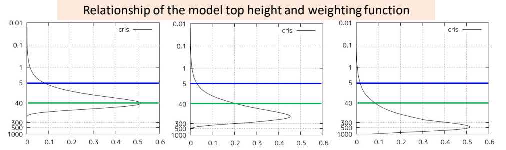


- Use of Hyperspectral IR sounders in MA and LA
  - Channels to be assimilated in the regional models were selected from those used in the global system.
  - The atmospheric profiles above the regional model-top height are extrapolated by using the U.S. Standard Atmosphere lapse rates for the radiative transfer calculations. Higher peaking channels with less accurate radiative transfer calculation were omitted by comparing O-B histograms with those of the global model. No temperature channel is available in LA.
  - Data assimilation experiments using selected channels show improvements in the water vapor field in short-range forecast.

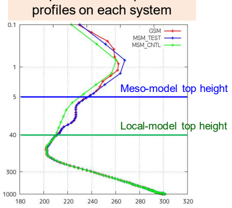
Histograms of O-B in each system



Relationship of the model top height and weighting function



Comparison of temperature profiles on each system



- Challenges in the use of Hyperspectral IR sounders
  - Optimal channel selection for each model. Consideration of inter-channel error correlation.
  - Dealing with lower model-top height of regional models. Consideration of using retrieved profiles.
  - Expanding use of lower peaking channels over land. Optimal cloud detection. all-sky assimilation.

3. Future Plans

- Use of GOES-18 AMV and CSR in GA
- *Computer system replacement*
- Use of NOAA-21/ATMS, CrIS
- Update to RTTOV-13.0 (new coefficients and functions)
  - ⇒ See 1p.06 poster (by N. Kusano)
- Use of CO2 band CSR of geostationary satellites
- Use of AMSU-A and ATMS window channels
- Implementation of Dynamic Emissivity (DE) over land for lower peaking microwave channels
- Optimization of observation error
- All-sky assimilation of microwave radiances in MA and LA
  - ⇒ See 9p.05 poster (by H. Shimizu)
- All-sky assimilation of geostationary infrared radiance
  - ⇒ See 9.04 oral presentation (by K. Okamoto)

<References>

- Yokota, S., et al., 2022: Implementation of hybrid 3DVar in JMA's local analysis, Research activities in Earth system modelling. WGNE Report, 52, 1-19.