Recent developments in satellite data assimilation at JMA

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1.Outline of NWP systems at JMA

Specifications of JMA's forecast model and data assimilation systems.
Details are available on the *http://www.jma.go.jp/jma/en/NMHS/JMA_RSMC.html* .

Model	Global Model & Analysis (GSM,GA)	Global Ensemble Model (GEPS)	Meso-scale Model &Analysis (MSM,MA)	Local Forecast Model &Analysis (LFM, LA)
Horizontal / vertical res.	TL959 / L100 (up to 0.01hPa)	TL479 / L100 (up to 0.01hPa)	5 km / L76 (*1) (up to 22 km)	2 km / L58 (up to 20 km)
Forecast range (Initial time)	84h (00,06,18UTC) 264h (12UTC)	5.5 days (06,18UTC) 11 days (00,12UTC)	39h (3 hourly)	9h (1 hourly)
Data Assimilation (inner loop horizontal res.)	4D-Var (TL319)		4D-Var (15 km)	3D-Var (5 km)
Assimilation window	6h (-3 ~ +3 hours)		3h (-3 ~ 0 hours)	1 hourly update cycle for 3h (-3 ~ 0 hours)
RTM for Radiance assimilation	RTTOV 10.2			
Cut off time	Early Analysis: 2h20m Cycle Analysis: 11h50m (00, 12UTC), 7h50m (06, 18UTC)		50m	30m

(*1) The number of vertical layers is increased from 48 to 76.

Satellite data used in the operational assimilation systems.
Items in red were implemented in the operational system since ITSC-20.

Satellite/Instrument		GA	MA	LA
Sounder	NOAA-15, 18, 19, Aqua, Metop-A, B / AMSU-A	Radiance		Radiance
	NOAA-18, 19, Metop-A, B / MHS			
	Suomi-NPP/ATMS Megha-Tropiques / SAPHIR	Radiance	Under development	
	Aqua / AIRS, Metop-A, B / IASI Suomi-NPP/CrIS	Radiance		
MW Imager	GCOM-W1 / AMSR2, GPM / GMI	Radiance	Radiance, Rain rate	Radiance, SMC
	DMSP-F17,18 / SSMIS (including 183GHz)			Radiance
VIS/IR Imager	Himawari-8, Meteosat-8, 10, GOES-13, 15	Radiance		
		AMV		
	Aqua, Terra / MODIS, NOAA, Metop / AVHRR, LEO-GEO	AMV		
Scatterometer	Metop-A, B / ASCAT	Ocean surface wind	Ocean surface wind	SMC
GNSS RO	Metop-A, B, COSMIC, GRACE-A, B TerraSAR-X, TAMDEM-X	Bending angle	Refractivity	Under development
Precipitation Radar	GPM / DPR		Relative humidity	

2. List of Upgrades

- ASCAT (MA, Dec. 2015) (Moriya 2016)
- GPM/DPR (MA, Mar. 2016) (Y. Ikuta 2016)
- GPM/GMI (GA,MA, Mar. 2016) (M. Kazumori 2016)
- Hiwawari-8 AMV (GA,MA,LA, Mar. 2016) (K.Yamashita 2016)
- Hiwawari-8 CSR (GA,MA, Mar. 2016) (M. Kazumori 2016)
- GNSS RO (MA, Mar. 2016) (Hirahara et al. 2017)
- Radiance and soil moisture content (LA, Jan. 2017) (Y. Ikuta 2017)
- S-NPP/ATMS (GA, Mar. 2017) (Hirahara et al. 2017)
- S-NPP/CrIS (GA, Mar. 2017) (N. Kamekawa and M. Kazumori 2017)
- SSMIS/ch9-11(GA, Mar. 2017) (Y. Murakami and M. Kazumori 2017)
- Improvement of GNSS RO utilization (GA, Jul. 2017)

2.1 Suomi-NPP/ATMS, CrIS and DMSP/SSMIS(183GHz)

- Clear radiances from the Suomi-NPP/ATMS, CrIS and DMSP/SSMIS have been operationally assimilated into GA since Mar. 2017.
- Suomi-NPP/ATMS → poster (by Y. Hirahara)
- Suomi-NPP/CrIS → oral presentation (by N. Kamekawa)
- DMSP-F17,18/SSMIS(183GHz) → poster (by Y. Murakami)

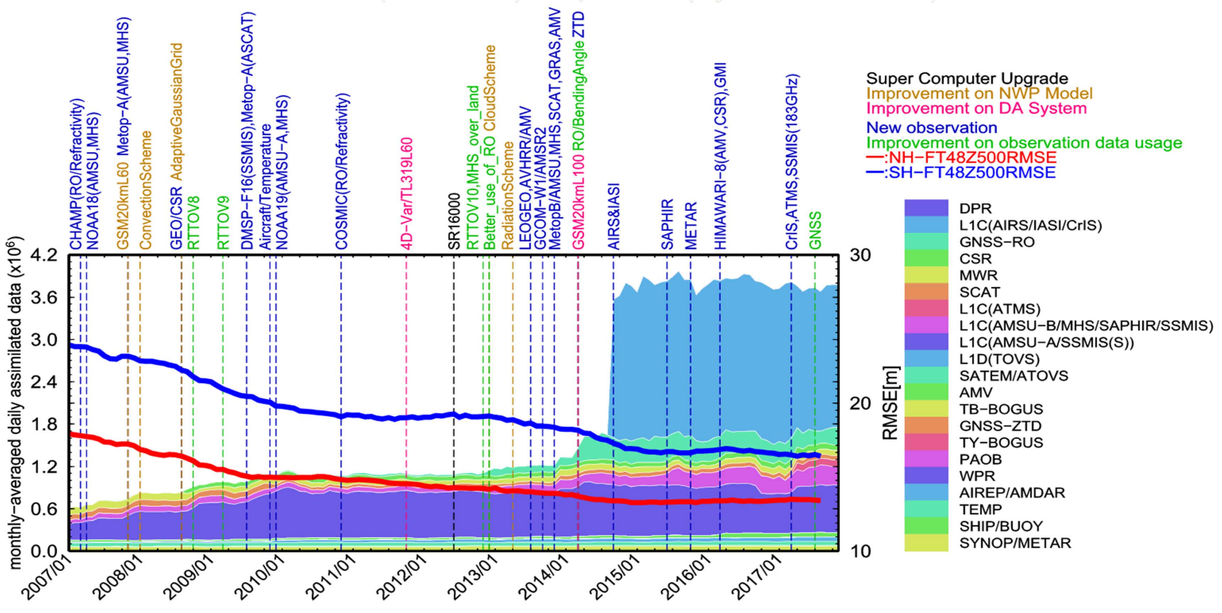


Figure 1. Time series of changes in the amount of observed data in the GA and RMSE of Z500[m] at **NH** and **SH** against initial fields for 10 years.

2.2 Assimilation of satellite data in Local Analysis

- Operational assimilation of soil moisture content (SMC) and clear sky radiance since Jan. 2017 (Ikuta 2017)
  - **SMC:** GCOM-W/AMSR2 and Metop-A,B/ASCAT
  - **CSR:** Himwari-8/AHI, GPM/GMI, GCOM-W/AMSR2, Metop-A,B/AMUS-A,MHS and DMSP/SSMIS
- Introduction of Variational Bias Correction
- Impact of satellite data assimilation in LFM
  - Improvement of water vapor profile on upper troposphere, precipitation, surface temperature and humidity

2.3 Impact of Early Analysis data delivered from DBNet

- DBNet (Direct Broadcast Network) is expanding the RARS (Regional ATOVS Retransmission Services) concept to other data types in support of a wider range of applications.
- AMSU-A and MHS radiances from the Asia-Pacific Regional ATOVS Retransmission Service (A-P RARS) have been operationally assimilated into global NWP system run by the JMA since Feb. 2007.
- Assimilation experiments for global ATOVS data without DBNet data for summer 2016 showed statistically significant negative impacts on forecast lead time against initial fields. The amount of available data is reduced by 11%.

Coverage map of DBNet

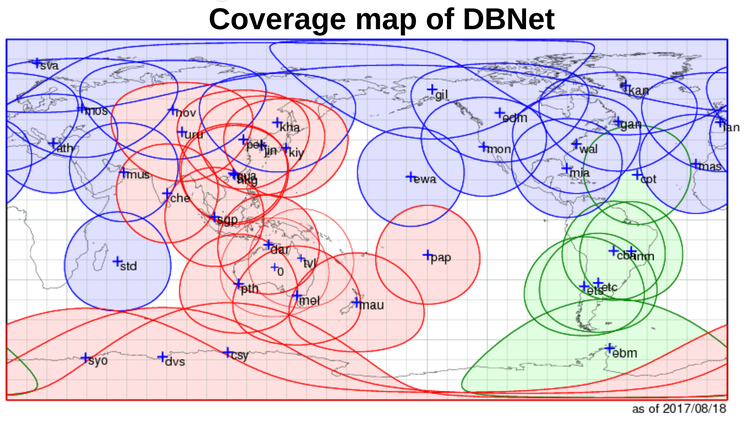
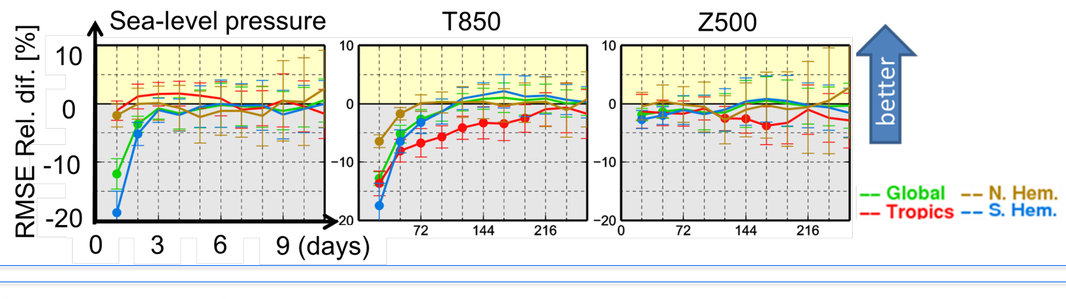


Figure 2.1 (Left) Coverage map of DBNet stations. Blue, Red and Green areas show **EARS**, **AP-RARS** and **SA-RARS** stations.

Figure 2.2 (Bottom) Normalized differences of RMSE [%] in forecast errors for sea-level pressure, 850-hPa temperature, and 500-hPa geopotential height verified against initial fields as a function of forecast range [days]. Negative values correspond to increased RMSE **w/o ATOVS data** delivered from **DBNet** assimilation.

ATOVS data from DBNet denial experiment



3. Future Plans

- Development of an all-sky assimilation of microwave imager and sounder radiances → oral presentation (by M. Kazumori)
- Development of an all-sky assimilation of infrared radiances of Himawari-8 → poster (by K. Okamoto)
- Optimization of observation error
- Introduction of inter-channel and spatial error correlations
- Use of Suomi-NPP/ATMS in MA
- Use of Hyperspectral IR sounder in MA
- Use of stratospheric channels (ch10-15) of Suomi-NPP/ATMS in GA
- Use of Humidity channels of Hyperspectral IR sounder in GA

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