Recent upgrades and progresses of satellite radiance data assimilation at JMA

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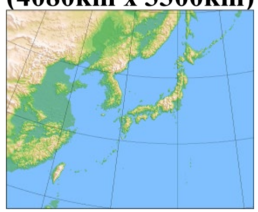
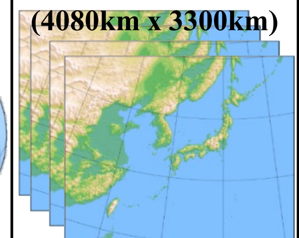
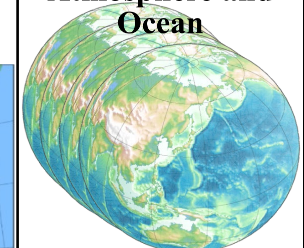
Topics

- Current NWP systems
- Recent upgrades and progresses
- Planned upgrades

Current NWP models in JMA

(since ITSC-22, as of June 30, 2021)

	In Operation					
	Global Spectral Model **GSM**	Meso-Scale Model **MSM**	Local Forecast Model **LFM**	Global Ensemble **GEPS**	Meso-scale Ensemble **MEPS**	Seasonal Ensemble **CPS2**
objectives	Short- and Medium-range forecast	Disaster reduction Aviation forecast	Aviation forecast Disaster reduction	One-week forecast Typhoon forecast Early warning on extreme weather One-month forecast	Disaster reduction Aviation forecast	Seasonal forecast (three month forecast, cold/warm season outlook) El Nino outlook
Forecast domain	Global 	Japan and its surroundings (4080km x 3300km) 	Japan and its surroundings (3160km x 2600km) 	Global 	Japan and its surroundings (4080km x 3300km) 	Coupled Global Atmosphere and Ocean 
Horizontal resolution	TL959 (0.1875 deg)	5km	2km	TL479 / TL319 (0.375 / 0.5625 deg)	5km	Atmos.: 1.125 deg Ocean:0.3-0.5x1 deg
Vertical levels / Top	128 0.01 hPa	76 21.8km	76 21.8km	128 0.01 hPa	76 21.8km	Atmos.: 60 (~0.1 hPa) Ocean: 52 with BBL* *Bottom Boundary Layer
Forecast Hours (Initial time)	132 hours (06, 18 UTC) 264 hours (00, 12 UTC)	51 hours (00, 12 UTC) 39 hours (03, 06, 09, 15, 18, 21 UTC)	10 hours (00-23 UTC hourly)	132 h (06, 18 UTC)* 264 h (00 UTC) 432 h (12 UTC) 51 members Extend to 816 h (2 times/week) 25 members	39hours (00,06,12,18 UTC) 21 members	210 days (00UTC) 51 members / month
Initial Condition	Global Analysis (Hybrid 4D-Var)	Meso-scale Analysis (4D-Var)	Local Analysis (3D-Var)	Global Analysis with ensemble perturbations (SV, LETKF)	Meso-scale Analysis with ensemble perturbations (SV)	JRA-55 with ensemble perturbations (BGM)

* when a TC of TS intensity or higher is present or expected in the RSMC Tokyo - Typhoon Center's area of responsibility (0º–60ºN, 100ºE–180º).

(since ITSC-22, as of June 30, 2021)

Operationally Assimilated Satellite Data

Type	Satellite/Instrument	Global Analysis	Meso Analysis	Local Analysis
1. MW Sounder	NOAA15,18,19,Metop-A,-B,-C,Aqua/AMSU-A	Radiance	Radiance	Radiance (no Metop-C)
	NOAA18,19,Metop-A,-B,-C/MHS	Radiance (all-sky)	Radiance	Radiance (no Metop-C)
	DMSP-F17,18/SSMIS	Radiance (all-sky)	-	-
	Suomi-NPP, NOAA20/ATMS	Radiance (all-sky)	-	-
	Megha-Tropiques/SAPHIR	Radiance (all-sky)	-	-
	FY-3C/MWHS-2	Radiance (all-sky)		
2. IR Sounder	(Aqua/AIRS)	Radiance	-	-
	Metop-A,B/IASI	Radiance	-	-
	Suomi-NPP, NOAA20/CrIS	Radiance	-	-
3. MW Imager	DMSP-F17,18/SSMIS	Radiance (all-sky)	Radiance, Rain Rate	Radiance
	GCOM-W/AMSR2	Radiance (all-sky)	Radiance, Rain Rate	Radiance
	GPM-core/GMI	Radiance (all-sky)	Radiance, Rain Rate	Radiance
	(FY-3C/MWRI)	Radiance (all-sky)	-	-
	(Coriolis/WindSat)	Radiance (all-sky)	-	-
4. VIS/IR Imager	Himawari-8	CSR, AMV	CSR, AMV	CSR, AMV
	~~GOES-15~~, GOES-16,17	CSR, AMV	N/A	N/A
	Meteosat-8,11	CSR, AMV	N/A	N/A
	NOAA15,18,19,Metop-A,-B/AVHRR	AMV	N/A	N/A
	Aqua,Terra/MODIS	AMV	N/A	N/A
	LEOGEO composite image	AMV	N/A	N/A
5. Scatterometer	Metop-A,-B,-C/ASCAT	OSWV	OSWV(Metop-A, -B only)	-
6. Radio Occultation	Metop-A,-B/GRAS	Bending Angle	Refractivity	-
	TerraSAR-X/IGOR	Bending Angle	Refractivity	-
	TanDEM-X/IGOR	-	Refractivity	-
	COSMIC/IGOR	Bending Angle	Refractivity	-
7. Radar	GPM/DPR	-	Relative Humidity	-
8. Soil Moisture	GCOM-W/AMSR2	-	-	Soil Moisture
	Metop-A,-B/ASCAT	-	-	Soil Moisture

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

The recent upgrades in the use of satellite radiance data since ITSC-22

Contained in this presentation
Other presentation in ITSC-23

- December 11, 2019
  - All-sky MW assimilation (GA)
    - microwave imagers (GCOM-W/AMSR2, GPM/GMI, DMSP-F17,F18/SSMIS, Coriolis/WindSat, FY-3C/MWRI)
    - 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.
- July 29, 2020
  - Additional use of Surface-sensitive CSR bands of Himawari-8 (LA)
    - surface-sensitive bands 9 and 10 in addition to band 8
- September 15, 2020
  - Metop-C/AMSU-A and MHS (GA)
- May 25, 2021
  - Metop-C/AMSU-A and MHS (MA)

GA: Global Analysis
MA: Meso-scale Analysis
LA: Local Analysis

Progresses on major development

Contained in this presentation
Other presentation in ITSC-23

- Late June, 2021! (GA)
  - All-sky assimilation of additional MW humidity sounders (2p.15)
    - Suomi-NPP,NOAA-20/ATMS, DMSP-F17,F18/SSMIS, Megha-Tropiques/SAPHIR, FY-3C/MWHS-2
  - Assimilation of GOES-17/CSR
  - Switch of channel-selected IASI radiance dataset (616 to 500 ch).
  - Upgrades other than Radiance assimilation
    - Assimilation of GOES-17/AMV, QC update for GOES/AMV, Bias correction scheme update for Aircraft temperature
- On-going
  - Assimilation of surface-sensitive microwave radiance using dynamically estimated emissivity. (4p.09)
  - Development on All-sky IR radiance assimilation (9.04)

see also ITSC-22 5p.06

All-sky MW radiance assimilation in GA

Dec 11, 2019 (GA)

JMA developed an all-sky microwave radiance assimilation scheme for microwave imagers and microwave water-vapor sounders, including outer-loop iterations for trajectory updates in the 4D-Var minimization process for effective assimilation of cloud and precipitation.
Data assimilation experiments shows improvement on geopotential height and other elements for forecast range up to 120 hours. TC track forecast errors were decreased over the forecast range up to 72 hours with statistical significance.
Further development of all-sky assimilation of MW humidity sounders is reported in the poster (2p.15, Shimizu).

Key components of all-sky microwave radiance assimilation

1. **Cloud and precipitation radiative transfer model**

   RTTOV_SCATT developed by NWP-SAF in EUMETSAT

2. **Cloud and precipitation-capable forecast model**

   JMA global model, GSM (TL959L100) as of Nov. 2016

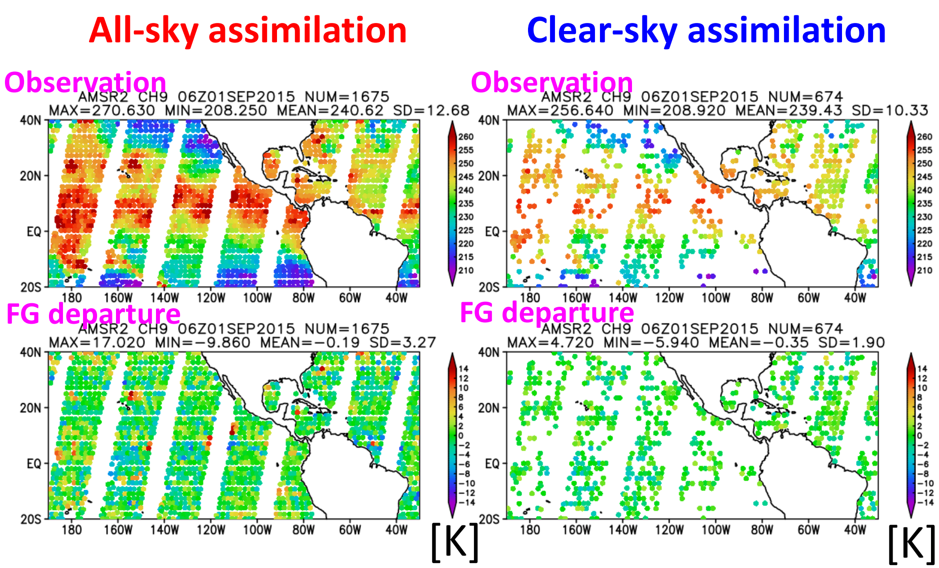
3. **MW Radiance observations**

   MW-Imagers (AMSR2, GMI, SSMIS, **Windsat, MWRI**)

   \+ MW Sounders (MHS, GMI)

4. **Data assimilation methods**

   4D-Var data assimilation + Outer-loop iteration



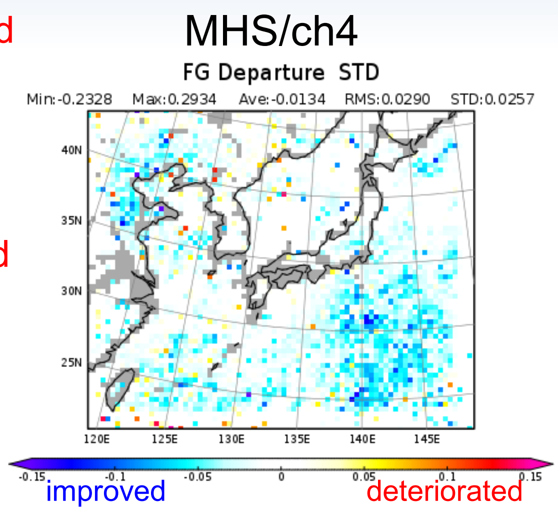
Modified QC:
Super-observation for MW imager channels (19V,23V, 37V)
Removal of biased data (Cold-sector biases, Deep convective areas (183GHz)
Obs. error assignment based on a symmetric clouds amount in DA

（Kazumori and Kadowaki 2017, Shimizu et al. 2020）

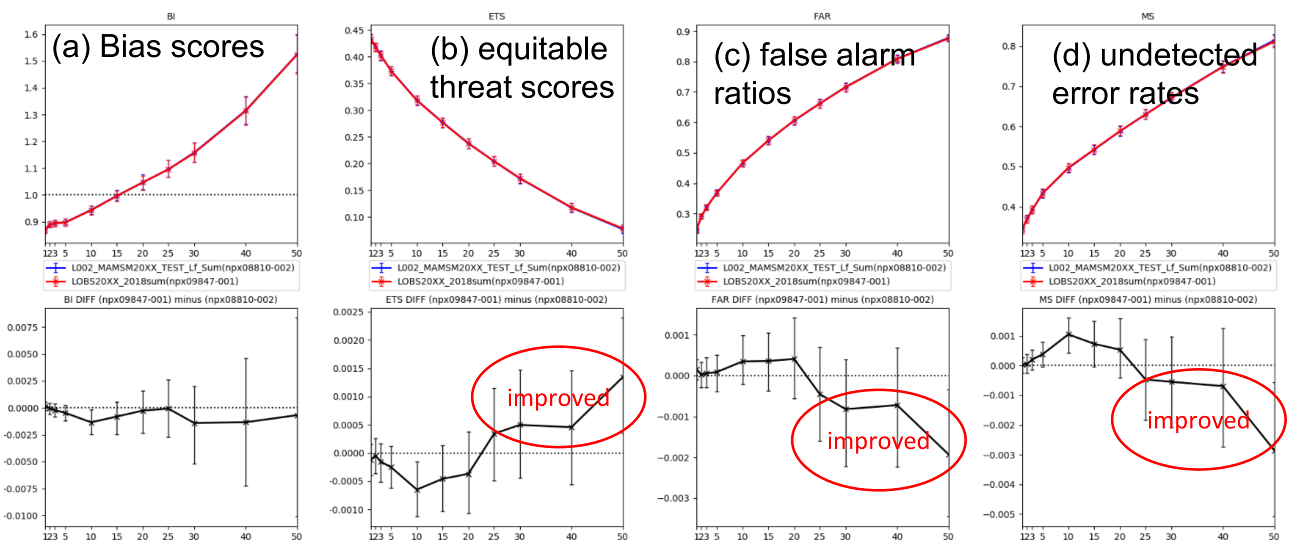
Additional Use of Surface Sensitive Himawari-8 CSR (Band 9,10) in LA

July 29, 2020 (LA)

JMA began to assimilate surface-sensitive CSRs from Himawari-8 (bands 9 and 10) in the local NWP system in addition to the use of band 8.
Land surface temperature is retrieved from window band(13) CSR in the radiative transfer (RT) calculation as in GA and MA.
Positive impacts on WV and temperature field accuracies for the first guess were shown in the assimilation experiment, which also revealed slight improved precipitation forecasting scores for heavy rain.
(Okabe 2021)



Normalized changes in the standard deviation of first guess departures for MHS (channel 4) [%]. The decrease of standard deviation implies reduction of the error of WV field in LFM first guess.
Test period: June 27 to July 8, 2018



Statistical precipitation scores during the validation period from June 27 to July 8, 2018.
(a) Bias scores, (b) equitable threat scores, (c) false alarm ratios and (d) undetected error rates for three-hour cumulative precipitation forecasts with different thresholds (x axis) against radar/raingauge-analyzed precipitation. Top panels: Red lines are scores for TEST and black lines are for CNTL. Bottom panels: Differences between TEST and CNTL scores (TEST - CNTL).

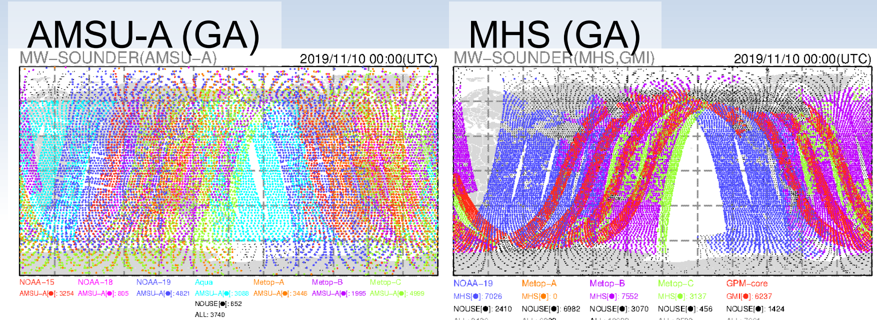
Assimilation of Metop-C/AMSU-A,MHS in GA,MA

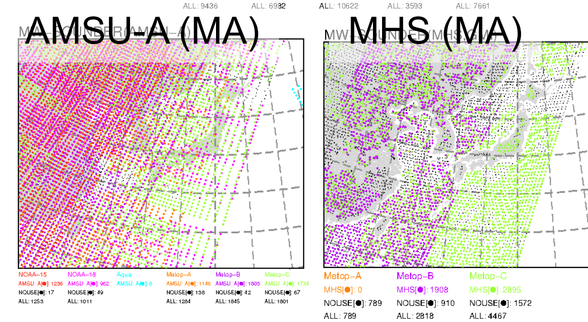
September 15,2020 (GA), May 25, 2021 (MA)

Assimilation of Metop-C/AMSU-A and MHS data has started in GA and MA. QC processes and settings for the assimilation follow those implemented for other AMSU-A and MHS in each system as there are no significant differences in data quality. Positive impacts on WV and temperature field accuracies for the first guess were found.

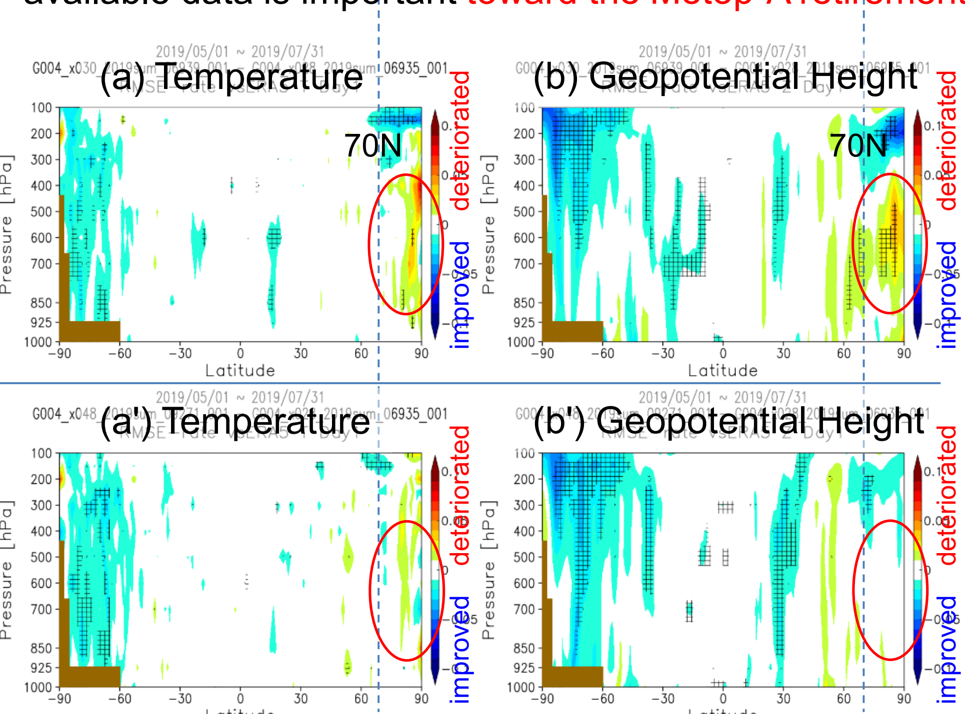
In GA, the forecast fields of temperature, geopotential height, humidity and wind speed in the mid-latitudes of the mid to upper troposphere were improved. Limited channels are assimilated in the north polar region (see the figures below).

In MA, the forecast scores are neutral, but increase of available data is important toward the Metop-A retirement.





Coverage maps of AMSU-A and MHS. **Metop-C** is plotted with **light-green** dots.



Zonal mean of relative improvement in root mean square errors for 1-day forecasts for (a) (a') temperature and (b) (b') geopotential height against ERA5 analysis. The verification period is from May 1 to July 31, 2019.

Top panels: assimilation effect of Metop-C/AMSU-A and MHS. Remained bias of AMSU-A seems to cause the negative impact in the north polar region (circled). The bias correction scheme is under investigation.

Bottom panels: Same as top panels, but ch7,8 of Metop-C/AMSU-A are not assimilated in the area north of 70N. Operational use of Metop-C/AMSU-A in GA is started with the setting.

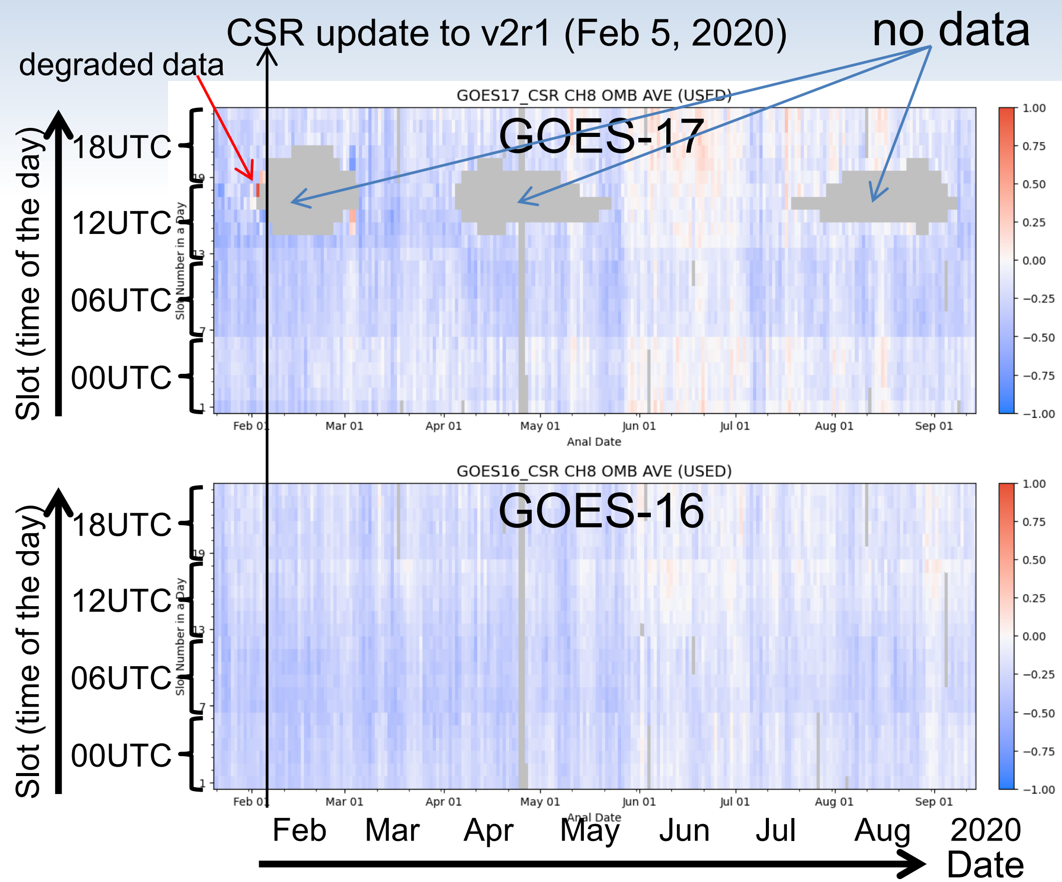
Assimilation of GOES-17/CSR in GA

Late June, 2021 (GA)

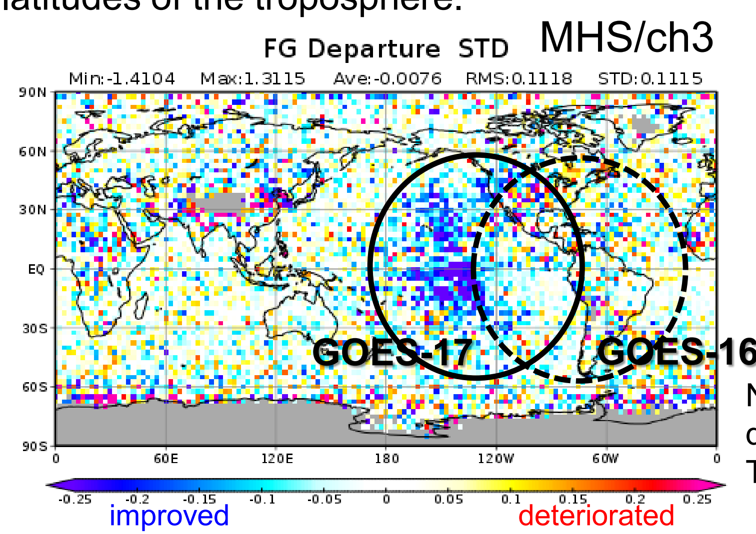
Due to the Cooling System Issue, GOES-17/ABI data are degraded before and after the equinoxes. An evaluation on the quality of GOES-17 CSR data shows that degraded data are not disseminated after the v2r1 update and the quality of QC passed data was similar to that of GOES-16.

Data assimilation experiments assimilating GOES-17 CSR (3 WV bands, same as GOES-16) showed a positive impact on water vapor field in the mid-to-upper troposphere in the GOES-17 observation area, especially outside the overlap with GOES-16.

The forecast fields of humidity and geopotential height were improved in the low- and mid-latitudes of the troposphere.



Date-time diagram of O-B mean for QC passed CSR data (6.2μm).
Top panel: GOES-17/CSR, Bottom panel: GOES-16/CSR.
No significant differences between GOES-16 and -17 for all WV bands (6.2, 6.9 and 7.3μm) and with regard to O-B standard deviations as well.



Normalized changes in the standard deviation of first guess departures for MHS (channel 3) [%].
Test period: July 21 to September 11, 2020

Planned upgrades of radiance assimilation in JMA's NWP systems (2021 to 2022)

- Use of Metop-C/IASI in GA
- Implementation of Dynamic Emissivity (DE) in GA
- Use of FY-3D/MWRI,MWHS-2 in GA
- RTTOV update v10.2 to v13.0
- Optimization of observation error
- All-sky assimilation of MW sensors in MA
- Use of Hyperspectral IR sounders in MA
- Additional use of upper channels of AMSU-A in MA with the model top expansion.
- Use of ATMS in MA and LA
- Use of Metop-C/AMSU-A,MHS in LA

Thank you!

References

- Kazumori, M., T. Kadowaki, 2017: Development of an all-sky assimilation of microwave imager and sounder radiances for the Japan Meteorological Agency global numerical weather prediction system. Tech. Proc. of 21st International TOVS Study Conference, Darmstadt, Germany 29 November - 5 December 2017.
- Shimizu, H., M. Kazumori and T. Kadowaki, 2020: Implementation of all-sky microwave radiance assimilation into JMA's global NWP system. WGNE Blue Book: Research Activities in Atmospheric and Ocean Modelling , Rep. 50.
- Okabe, I. , 2021: Operational use of Himawari-8 CSR data of band 9 and 10 in JMA's local NWP system. WGNE Blue Book: Research Activities in Atmospheric and Ocean Modelling , Rep. 51