



# Use of satellite Hyperspectral IR sounder\* observation in JMA NWP systems and expectation for future NOAA IR sounding mission

\* hereafter, refer to as **HSS**

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## 1. JMA's deterministic global NWP system

1. Coverage and Impacts of HSS data in JMA global NWP system




1. Usage status of HSS data in JMA global NWP system

1. Impact study of Geo HSS OSSE

1. Summary and expectation for future HSS observation

# JMA's deterministic NWP model and DA system

## In Operation

	Global Spectral Model <b>GSM</b>	Meso-Scale Model <b>MSM</b>	Local Forecast Model <b>LFM</b>
Objectives	Short- and Medium-range weather forecast	Disaster reduction Aviation forecast Precipitation forecast	Aviation forecast Disaster reduction
Forecast domain	Global 	Japan and its surroundings (4080 km x 3300 km) 	Japan and its surroundings (3160 km x 2600 km) 
Horizontal resolution	TL959, approx. 20 km (0.1875 deg.)	5 km	2 km
Vertical levels / Top	128 0.01 hPa	76 21.8 km	58 20.2 km
Forecast Hours (Initial time)	264 hours (00, 12 UTC) 132 hours (06, 18 UTC)	51 hours (00, 12 UTC) 39 hours (03, 06, 09, 15, 18, 21 UTC)	10 hours (00-23 UTC hourly)
Initial Condition	<b>Global Analysis</b> (Hybrid 4D-Var)	<b>Meso-scale Analysis</b> (4D-Var)	<b>Local Analysis</b> (3D-Var)

Satellite and conventional data are assimilated in data assimilation (DA) systems.

### Global Analysis

6-hourly DA for delayed and early analysis  
6-hr data assimilation window  
Data cut-off time 2hr 50min.  
(earliest case)

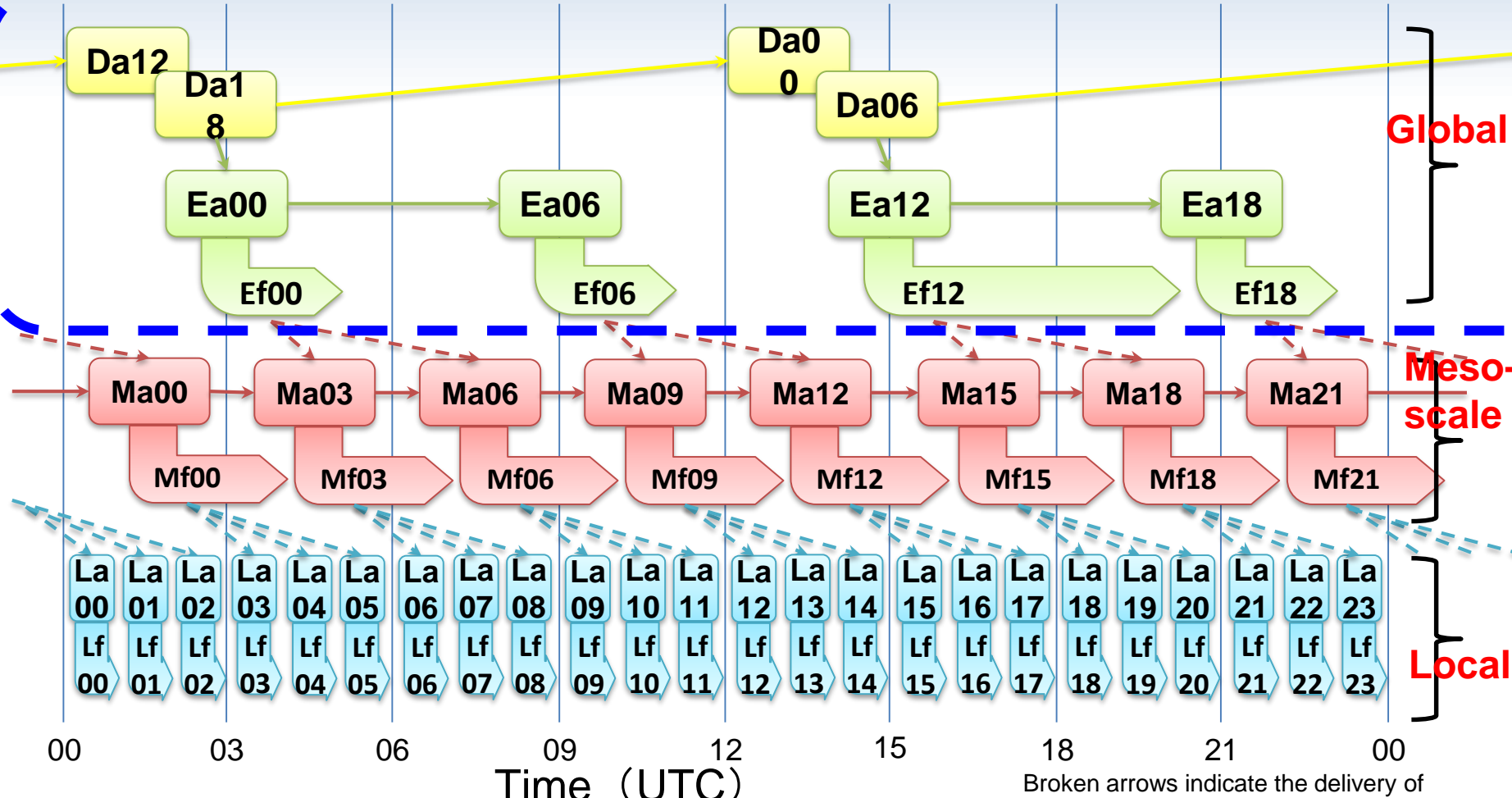
### Meso-scale Analysis

3-hourly DA  
3-hr data assimilation window  
Data cut-off time 50 min.

### Local Analysis

Hourly DA  
3-hr data assimilation window  
Data cut-off time 30 min.

# Dependency of JMA NWP systems and procedure of the data assimilation and NWP model forecasting



**Global**  
Global delayed analysis (Da) can use much observation data with its delayed cut-off time. First-guess from Da is used for early analysis (Ea). And Ea is used as initial condition for global forecast (Ef).

**Meso-scale**  
Global forecast (Ef) provides lateral boundary conditions for Meso-scale analysis (Ma). Ma is used as initial condition for Meso-scale forecast (Mf).

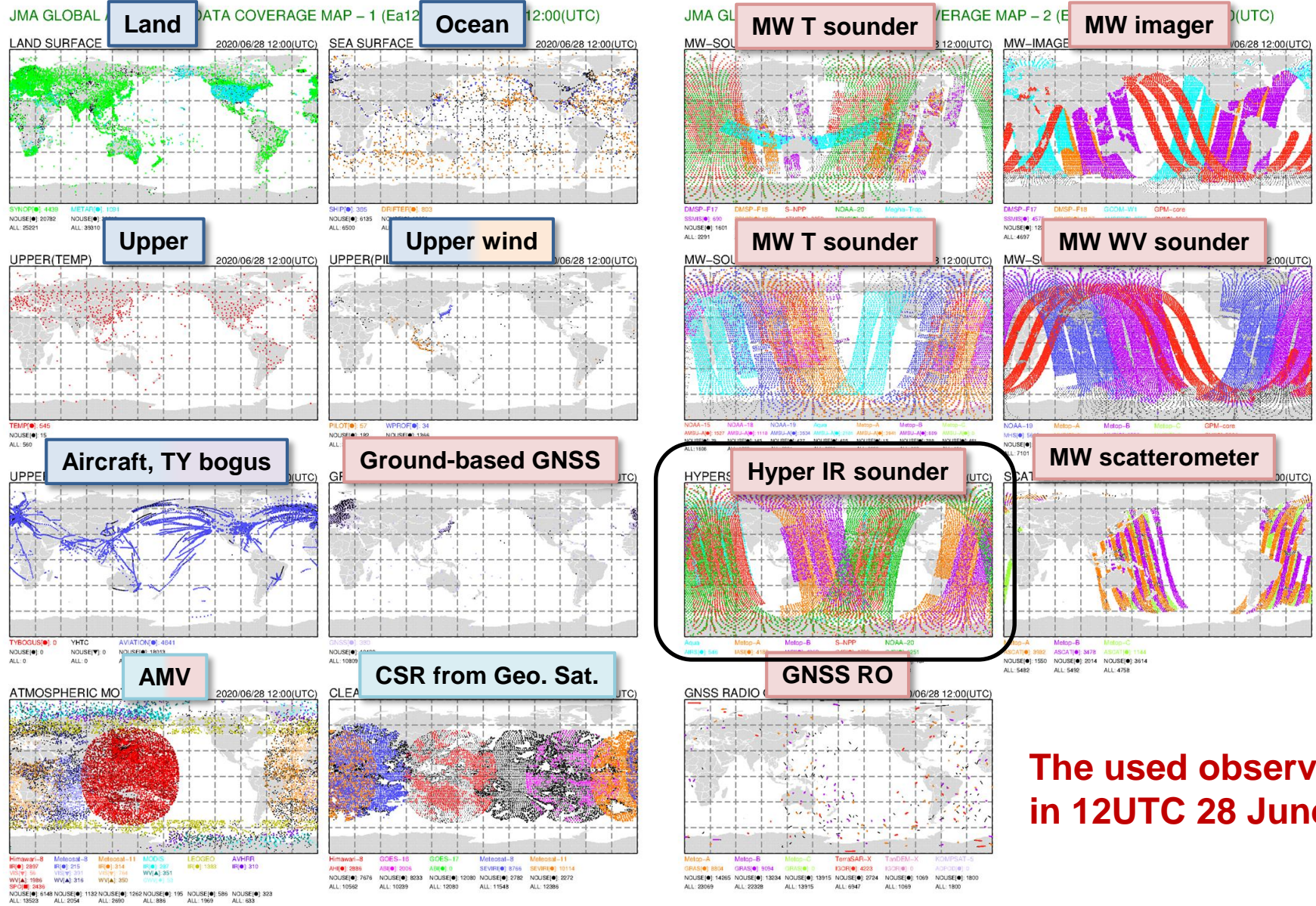
**Local**  
Meso-scale forecast (Mf) provides lateral boundary conditions for local analysis (La). La is used as initial condition for local forecast (Lf).  
Three DA systems use real-time satellite data, e.g., ADV observations

- Da: Global delayed analysis
- Ea: Global early analysis  
Ef: Global forecast
- Ma: Meso-scale analysis  
Mf: Meso-scale model forecast
- La: Local analysis  
Lf: Local Forecast Model forecast

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# Space-based and ground-based observations are assimilated to produce initial conditions in JMA global NWP system



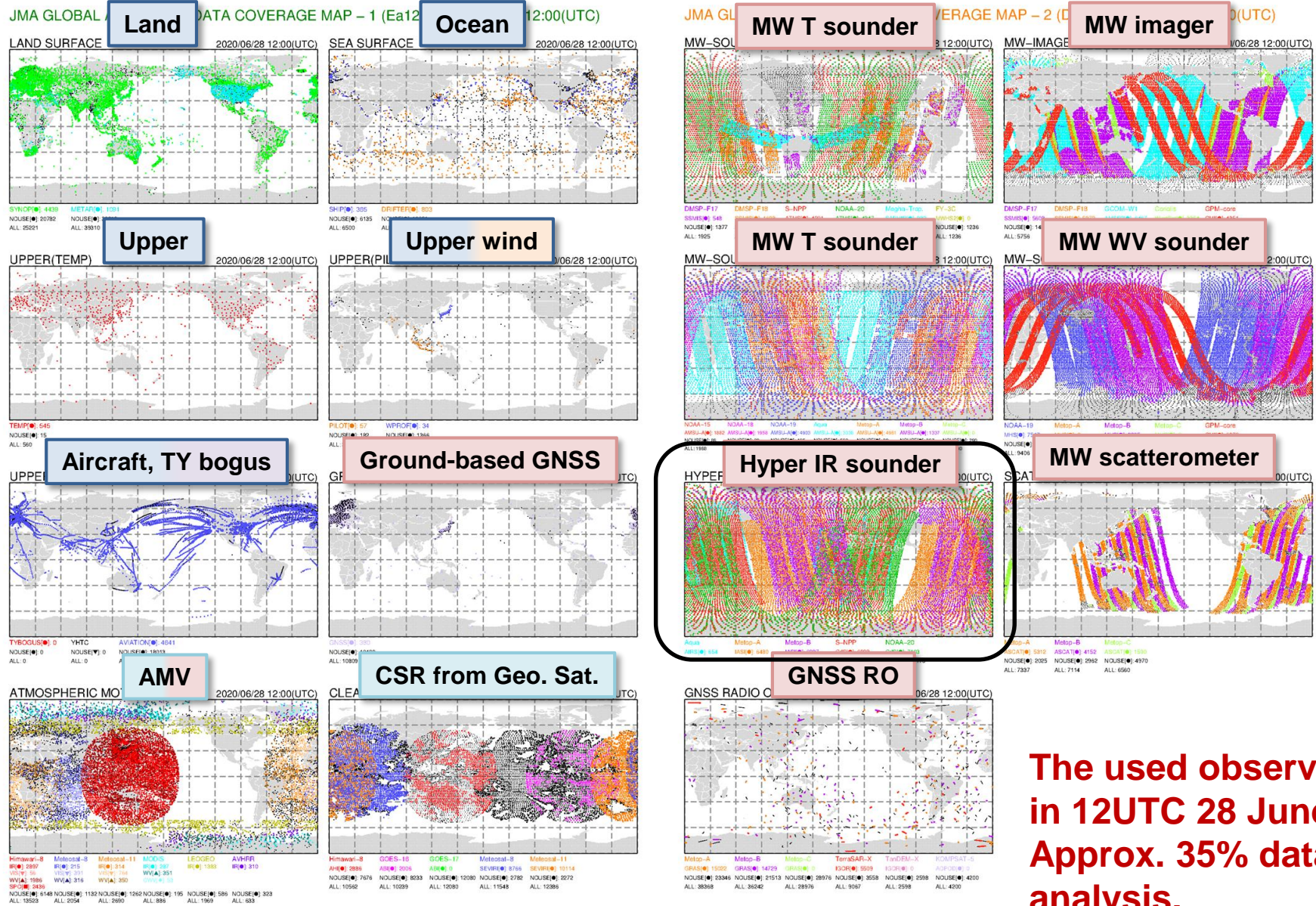
Hyper IR sounding data are key data set among operationally used observation data in JMA NWP system.

Aqua/AIRS  
Metop-A,B/IASI  
S-NPP,NOAA-20/CrIS

The used observation data coverage in 12UTC 28 June 2020 early analysis



# Space-based and ground-based observations are assimilated to produce initial conditions in JMA global NWP system



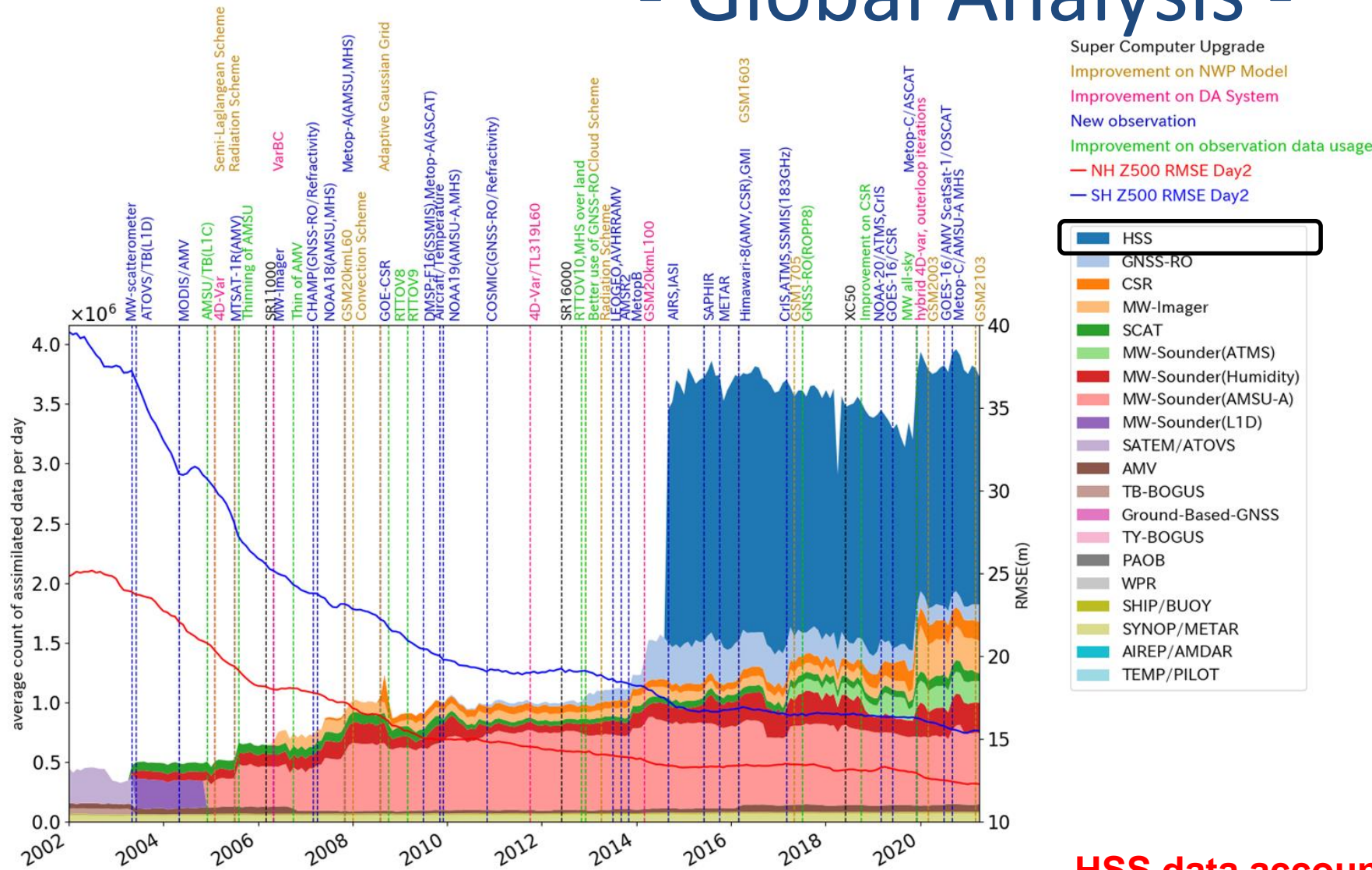
Hyper IR sounding data are key data set among operationally used observation data in JMA NWP system.

Aqua/AIRS  
Metop-A,B/IASI  
S-NPP,NOAA-20/CrIS

The used observation data coverage in 12UTC 28 June 2020 delayed analysis. Approx. 35% data increase in the delayed analysis.

# Assimilated Data Amount History

## - Global Analysis -



### Major events in HSS data use

2014.09:

Aqua/AIRS, Metop-A,B/IASI radiance data assimilation started.

2017.03:

Suomi-NPP/CrIS radiance data assimilation started.

2018.11:

Suomi-NPP/CrIS radiance data assimilation switched from NSR(Normal Spectral Resolution) to FSR(Full Spectral Resolution)

2019.03:

NOAA-20/CrIS radiance data assimilation started.

2020.12

S-NPP,NOA-20/CrIS(FSR) Direct Broadcast radiance data assimilation started.

2021.06:

Metop-A,B/IASI radiance dataset assimilation switched from NESDIS(616ch) to EUMETSAT(500ch). Direct Broadcast radiance data(EUMETSAT 500ch) assimilation started.

2021.09:

Metop-A/IASI radiance data assimilation ended.

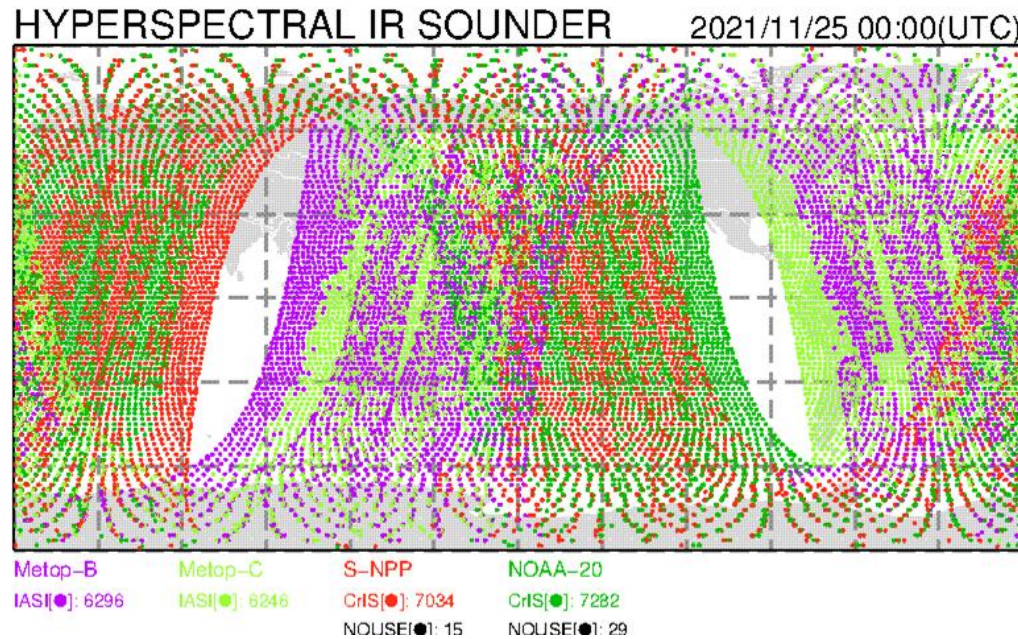
2021.11:

**HSS data accounts for about half of all data.**



# Current usage of HSS in JMA

IASI and CrIS radiance data have been operationally assimilated into JMA's global Numerical Weather Prediction (NWP) system since September 2014. HSS data contribute to the accuracy of NWP forecasts.



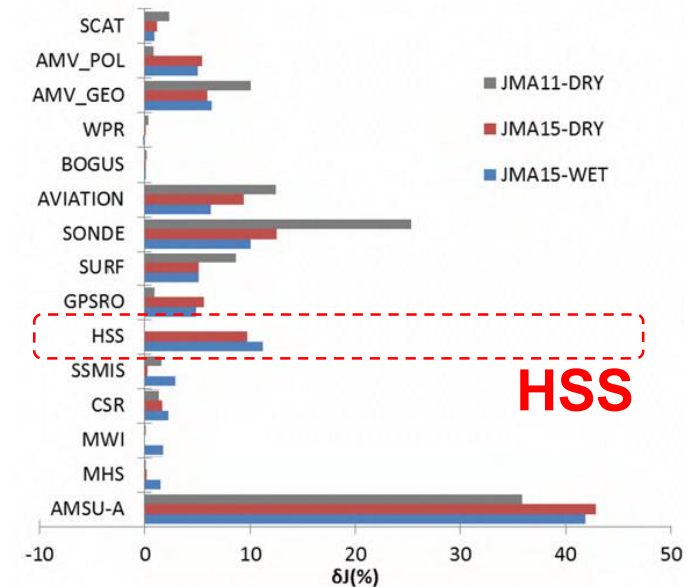
Morning 0930D

Afternoon 1330A

Metop-B/IASI Metop-C/IASI

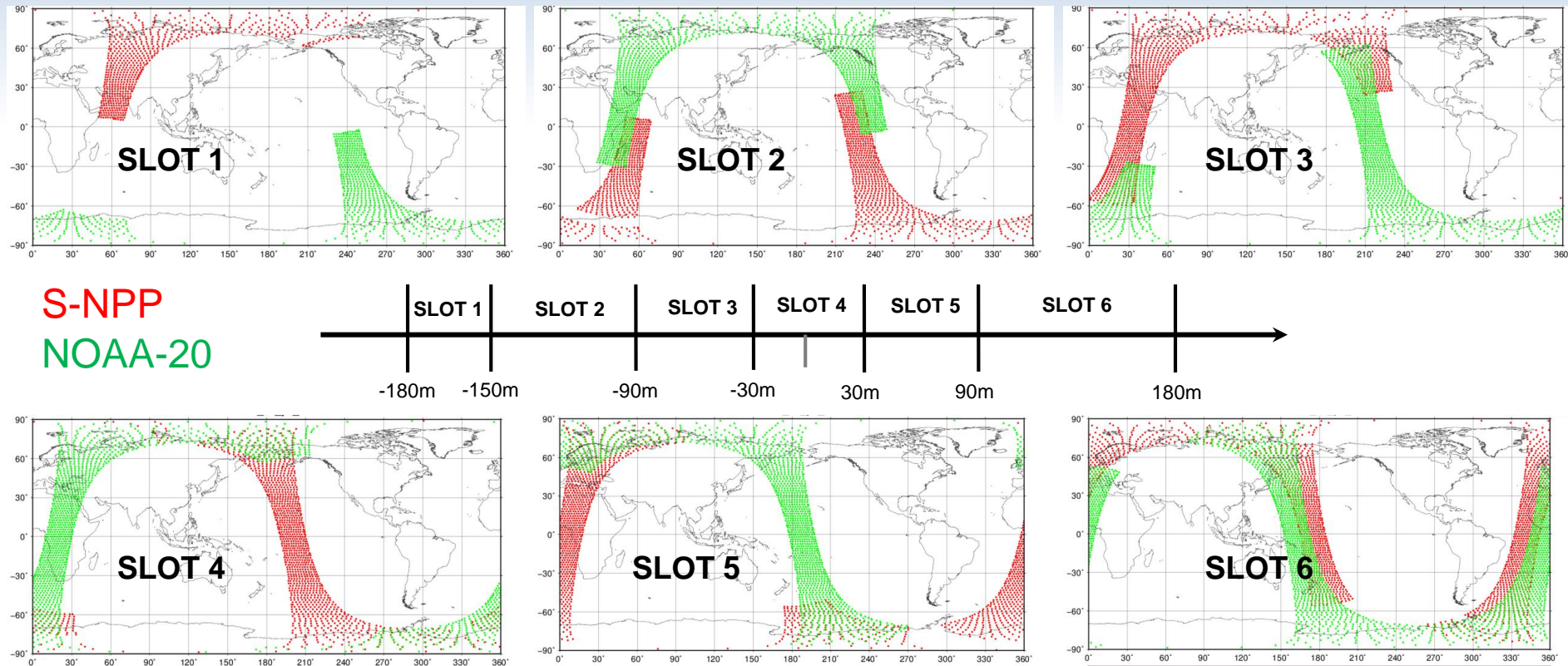
S-NPP/CrIS NOAA-20/CrIS

FSO:JMA



Forecast Sensitivity to Observations (%)  
(Ishibashi:2016)

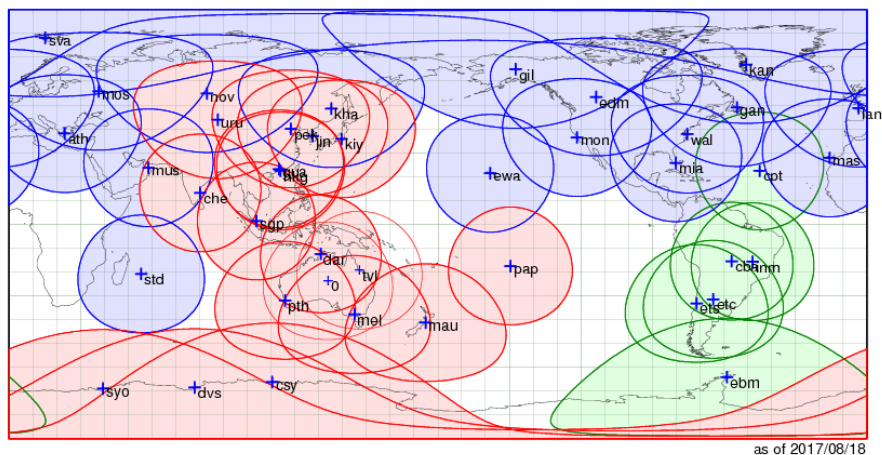
# CrIS Coverage by each assimilation slot



Equator crossing times between S-NPP and NOAA-20 is close.  
By data assimilation slot, suitable to keep the satellite data coverage for 6-hour interval global data assimilation system.

# Use of DBNet data

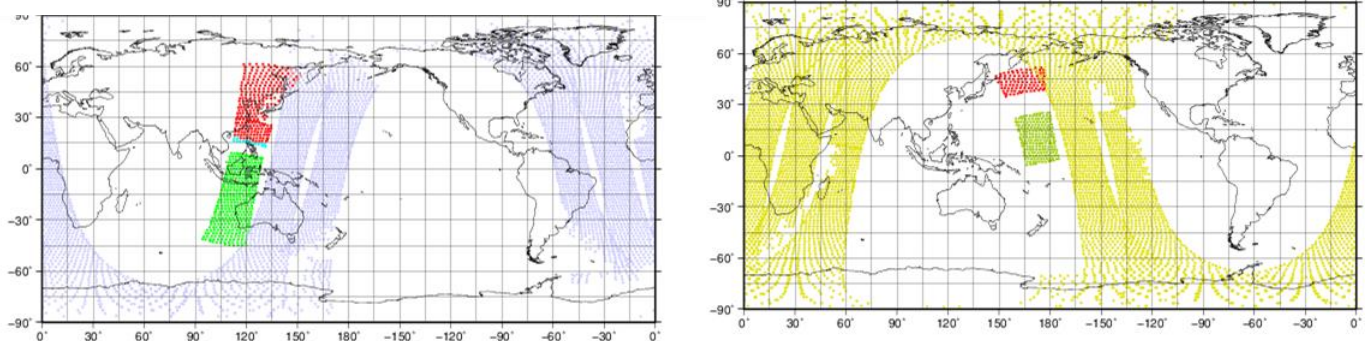
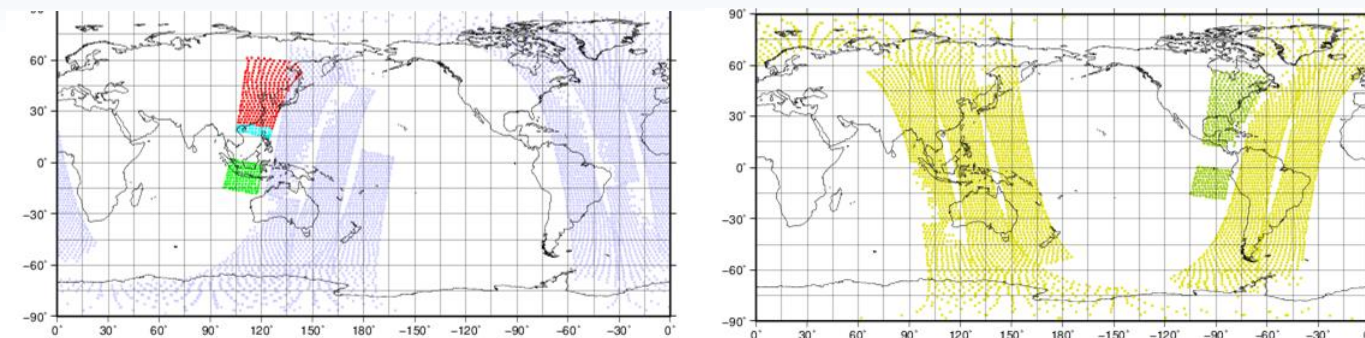
## Global map of DBNet data coverage



The DBNet (Direct Broadcast Network) is operational arrangement under the World Meteorological Organization to provide NWP centers with ATOVS data received at direct readout stations within 30 minutes of observation.

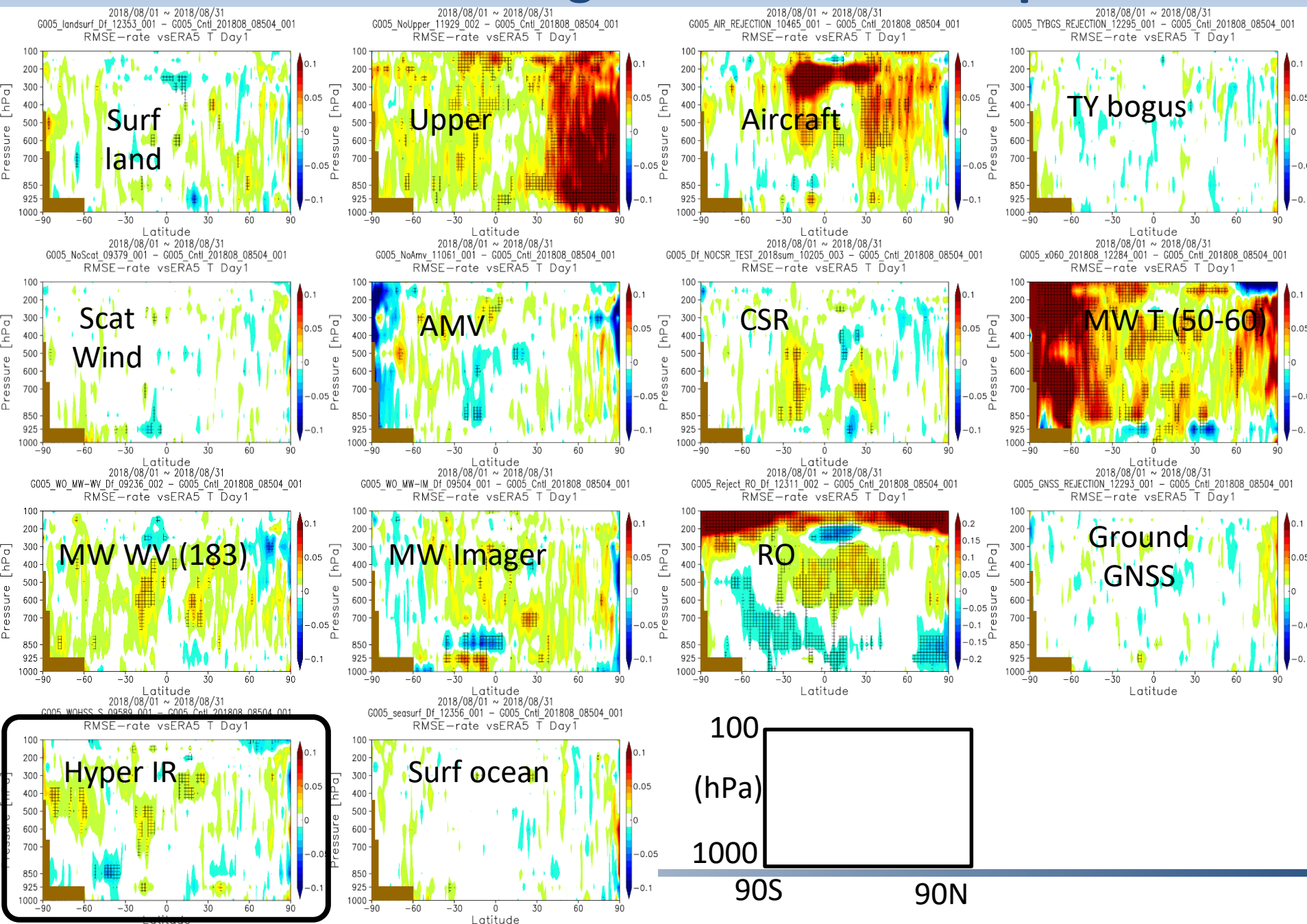
DBNet data is valuable for operational NWP system, especially for short data cut off time system.

## JMA Global early analysis(6 hourly) data cut-off 2 hr. 50min.



NOAA(0)	EUM(4668)	JMA(261)	BoM(357)	CMA(0)
KMA(17)	NEA(0)	HKO(0)	NIWA(0)	INPE(0)
CONAE(0)	CIMSS(0)	Météo-France(0)	IMD(0)	LAN(0)

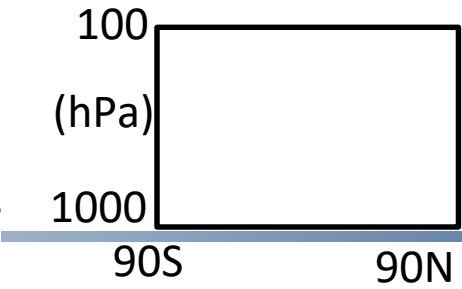
# Normalized change of RMSE of Temperature Day 1 forecast



Control : JMA operational global NWP  
 Test: Data denial experiment  
 Period : Aug. 2018

Data denial experiment demonstrated  
 Hyperspectral IR sounder has the impact of the forecast accuracy on the upper troposphere.

Warmer: degradation  
 Colder: improvement  
 Reference: ERA5



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# Usage status of other NWP centers

## ITSC-23 HSS NWP Survey

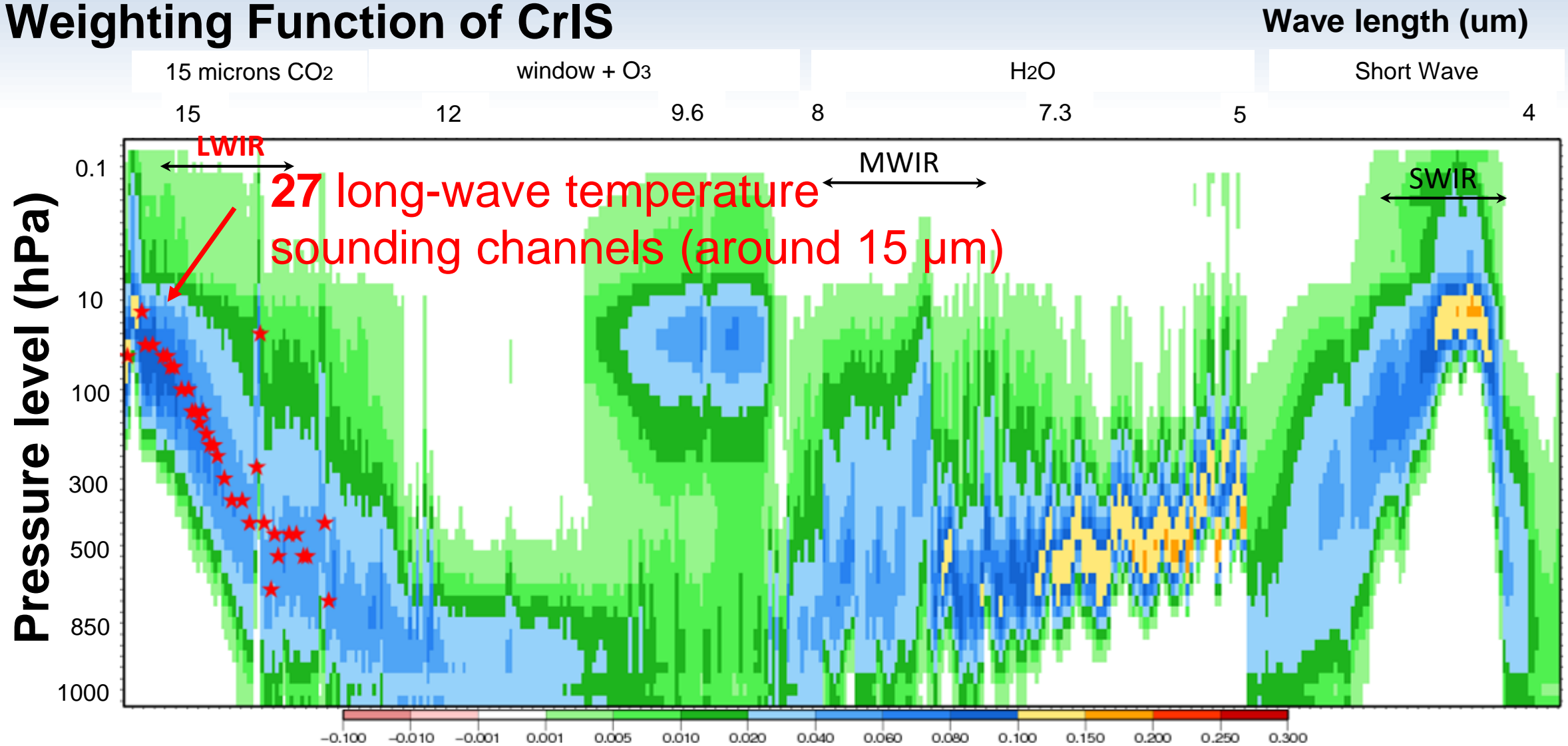
As of 2021.11.26 online

Centre	IASI											CrIS									
	Satellite			15 microns (1)		Window + O3 (2)		H2O (3)		Short Wave (4)		Satellite		15 microns (1)		Window + O3 (2)		H2O (3)		Short Wave (4)	
	MA	MB	MC	Land	Ocean	Land	Ocean	Land	Ocean	Land	Ocean	NPP	N20	Land	Ocean	Land	Ocean	Land	Ocean	Land	Ocean
ECCC(Canada)		X	X	75	75	0	23	35	35	0	9 (6)	X	X	44	44	0	17	29	29	0	13 (6)
ECMWF(Europe)		X	X	153	153	28	28	38	38	1 (*)	1 (*)	X	X	88	88	23	23	37	37	0	0
MET Norway(Norway)																					
US-FNMOC/NRL(USA)				25	51	0	0	0	18	0	0			27	45	0	34	0	41	0	0
DWD(Germany)	X	X	X	0	62	0	0	0	16	0	0			0	0	0	0	0	0	0	0
Met Office(UK)		X	X	87 (5)	87	12 (5)	19	32 (5)	32	0	0	X	X	75 (5)	75	15 (5)	27	32 (5)	32	0	0
DMI(Denmark)																					
JMA(Japan)		X	X	0	68	0	0	0	0	0	0	X	X	25	27	0	0	0	0	0	0
Meteo France(France)	X	X	X	99	99	8	9	21	21	0	0	X	X	42	55	0	8	0	5	0	0
NCEP(USA)	X	X		116	116	45	45	4	4	0	0	X	X	69	69	15	15			0	0
BoM(Australia)	X	X		87(5)	87	14	21	30(5)	30	0	0	X		34	75	12	27	31	32	0	0
CPTEC/INPE(Brazil)																					
OMSZ(Hungary)																					
SMHI (Sweden)	x	x																			
ITAF-COMET(Italy)																					
KMA(Korea)	X	X		94	124	11	29	6	30	0	0	X									
NCMRWF(India)		X	X	116	116	45	45	32	32			X	X	75	75	15	27	32	32		
NIWA(New Zealand)				87 (5)	87	12 (5)	19	32 (5)	32	0	0			75 (5)	75	15 (5)	27	32 (5)	32	0	0
CMA(CHINA)	X	X		119		0		4	4												
CHMI(Czech Republic)																					

JMA assimilated the HSS radiance data from 15 microns(CO2 band).  
Increase of channel for assimilation is our future work.

# Used channels

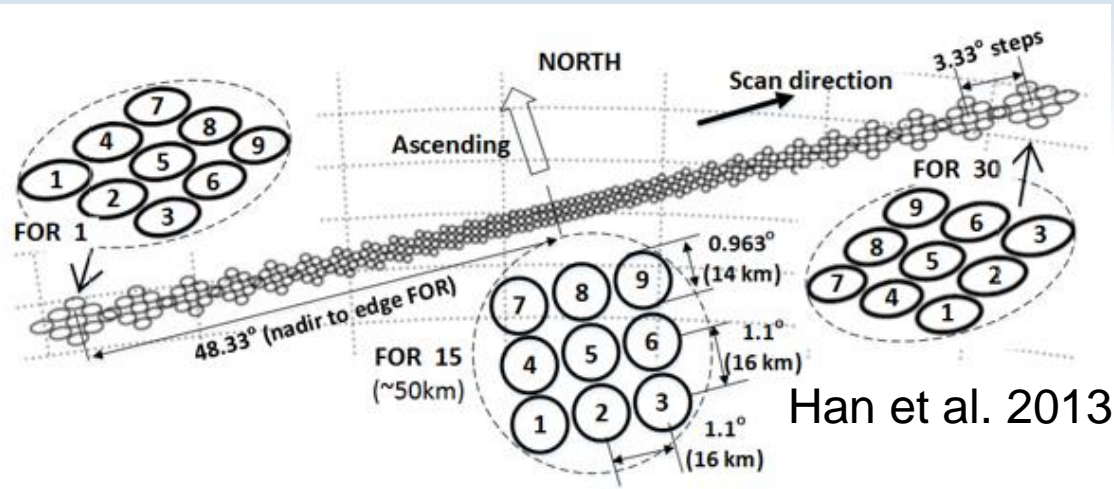
## Weighting Function of CrIS







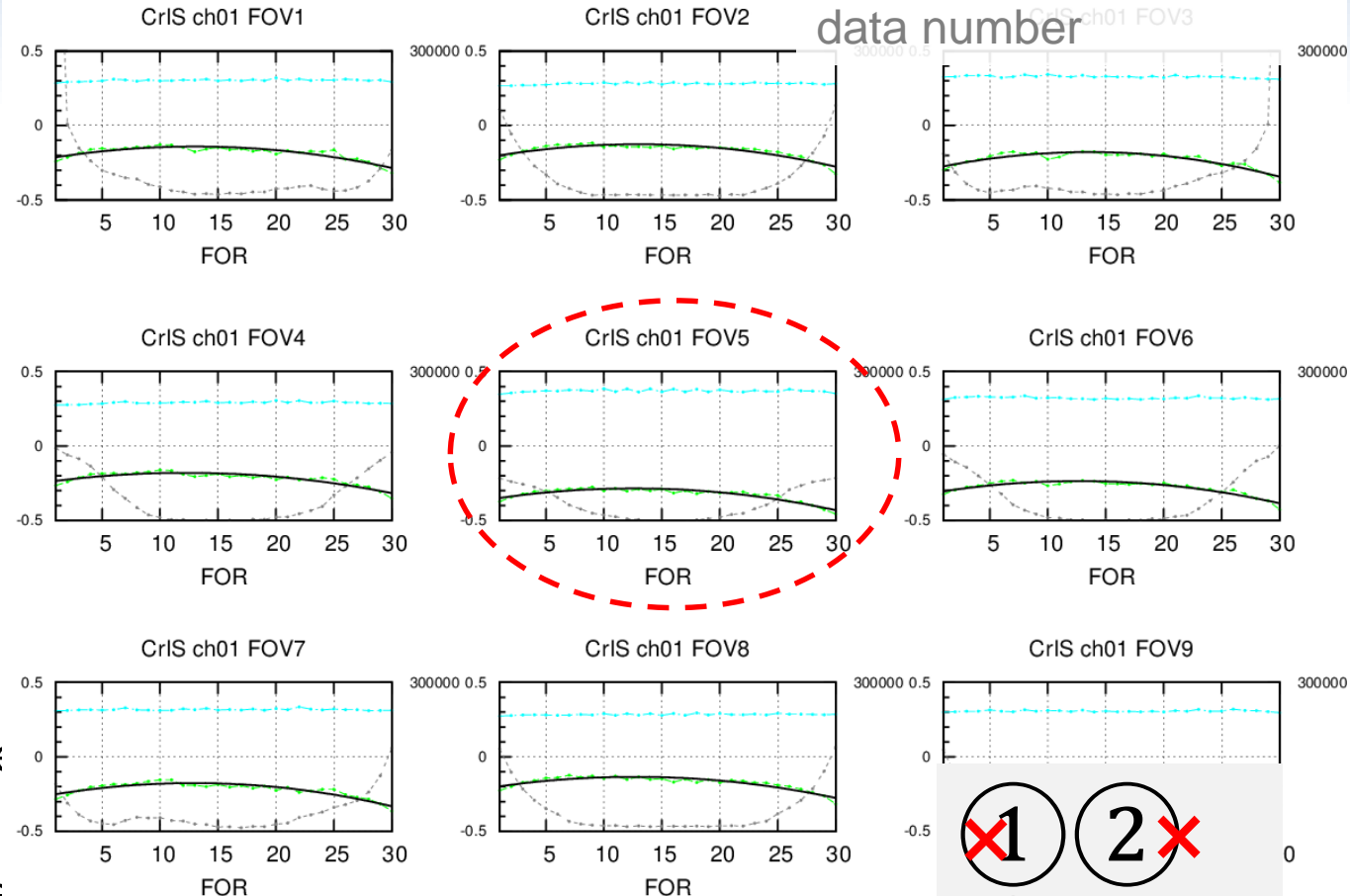
# FOV spatial resolution



O-B mean scan bias

O-B std scan bias

data number

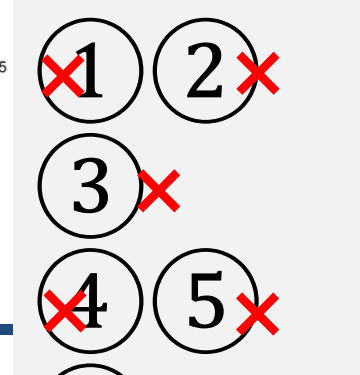


Since there is bias in specific FOV, the used FOV number is limited. The original spatial resolution of the instrument cannot be fully utilized.

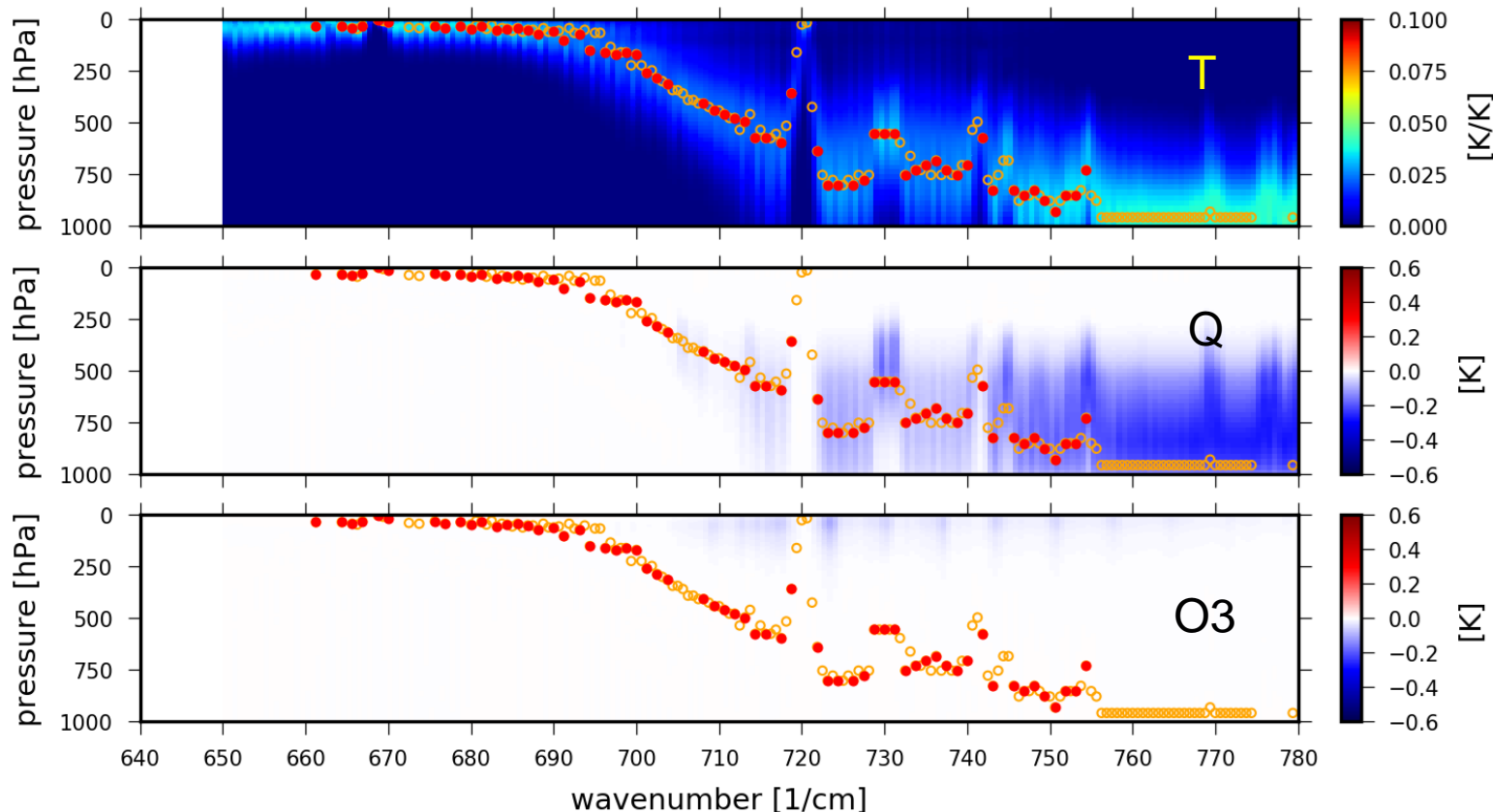
In data assimilation, the data is thinned to eliminate the horizontal observation error correlation.

Therefore, the spatial resolution may be acceptable even if it degrades from the current state.

Negative bias only for FOV5  
Standard deviation is also larger than other FOVs



# Channel Selection



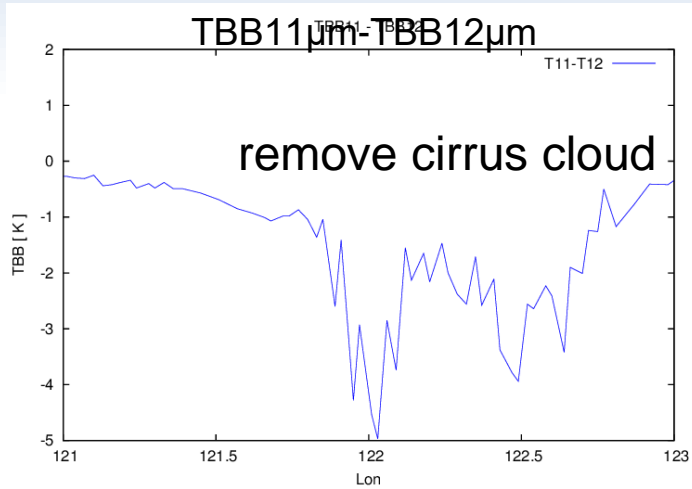
$$\frac{\partial T_B}{\partial T}, \frac{\partial T_B}{\partial(\ln q)}$$

Sensitivity analysis based on Jacobian calculation by RTTOV.

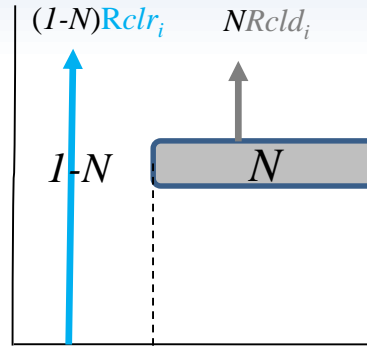
1. Use a channel in the CO2 absorption band with a wavelength of 15 microns (<wavenumber 780 [1 / cm]).
1. Excludes channels that are sensitive to water vapor and ozone.
1. If the channel numbers are adjacent, exclude one channel. to reduce the effect of interchannel observation error.
4. check the O-B histogram.

# Cloud QC

## 1. Split Window



## 2. CO2 Slicing (Eyre and Menzel 1989)



$$Robs_i = (I-N)Rclr_i + NRcld_i$$

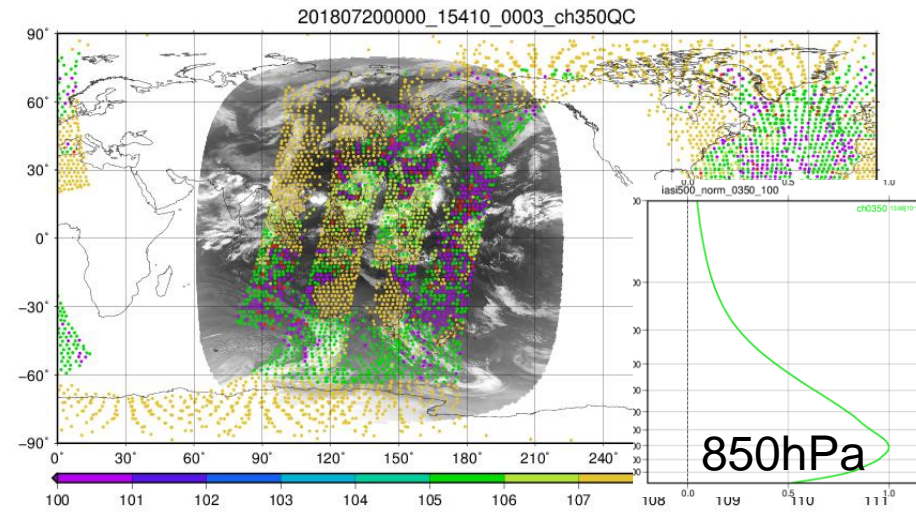
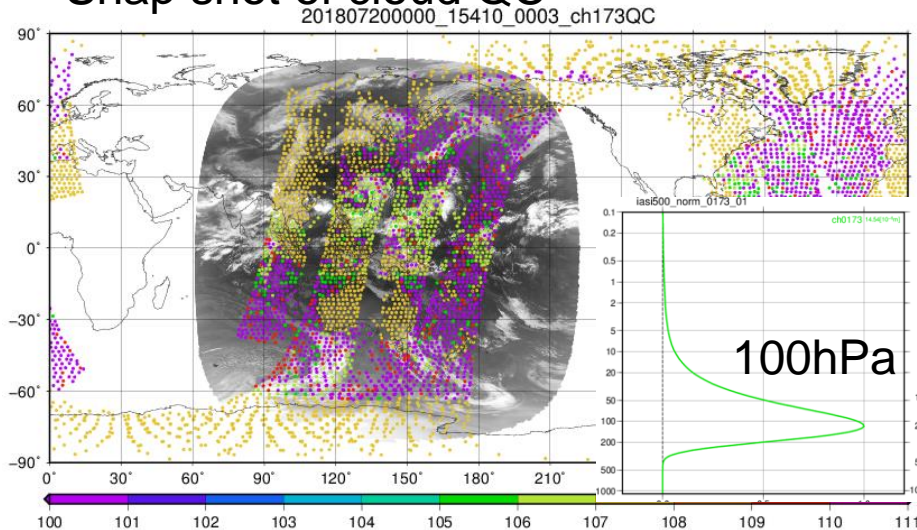
For the paired IASI CH  $k$ ,

$$R_k = (I-N)Rclr_k + NRcld_k$$

$$\left(\frac{R_{Obsk} - R_k}{R_{Obsk}}\right)^2$$

By estimating cloud top altitude, assimilate channels in clear-sky or uncontaminated condition.

## Snap shot of cloud QC



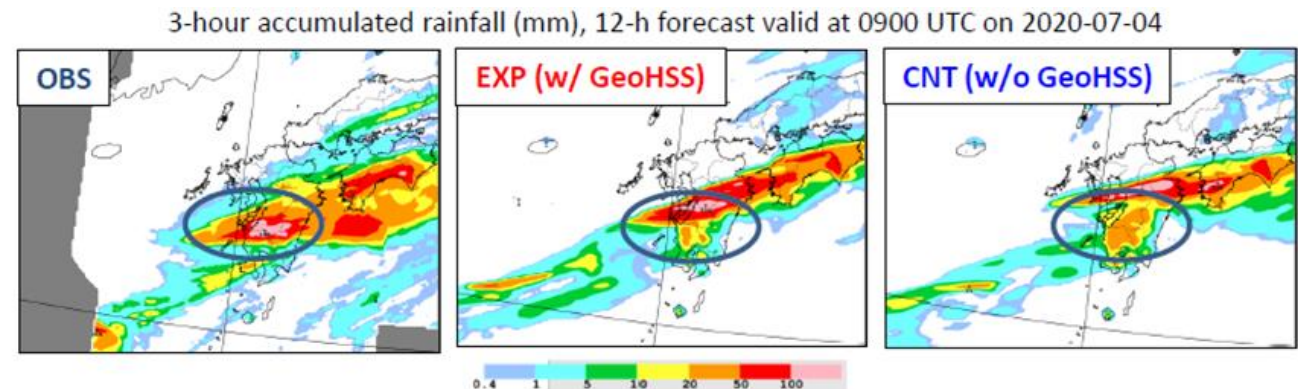
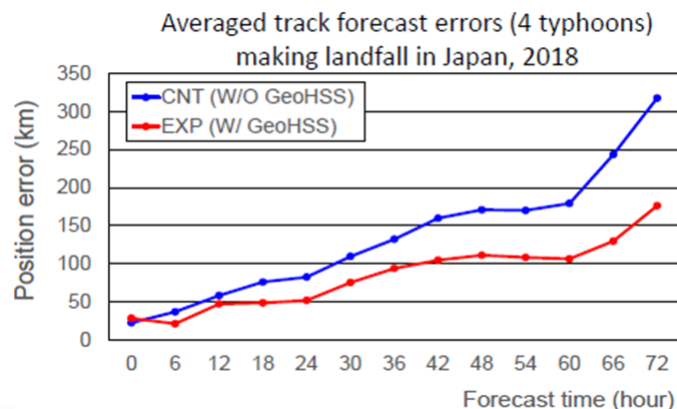
- PASS
- cloud check
- cirrus check
- Land or Sea check
- Gross Error check

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# OSSE(Global) of hyperspectral IR sounder

- Hyper IR sounder is under considered for installation on Himawari follow-on.
- Several experiments were implemented with Okamoto et al.(2020)
  - Operational DA configuration (inc. use of AIRS/CrIS/IASI in global model)
  - Hypothetical IRS on GEO at 140.7 E, hourly full-disk obs w/ 30 km spatial resolution from ERA5
- Global DA (upper figure)
  - ~140 km improvement in typhoon position for 3-d forecast (time of landing)
- Regional DA (bottom figures)
  - Better location of the heaviest rain area which caused devastating floods



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# Summary and expectation

- JMA operates global data assimilation system.
- In the global analysis, HSS data mainly are used the CO2 band (15 $\mu$ m), which is sensitive to temperature, and have impacts on the accuracy of NWP in the upper troposphere and stratosphere. Therefore, the continuity of the observation, timely and stable data delivery are highly desired.
- Current two orbit satellite configuration (i.e., morning(Metop), afternoon(JPSS) orbit) is a suitable to keep the satellite data coverage for 6-hour interval global data assimilation system.
- Thanks to the recent switch of S-NPP/CrIS to Side-2 electronics LW-Band (15 $\mu$ m), we continue the use of the HSS data in the assimilation.
- Since there is bias in specific FOV, the original spatial resolution of the instrument cannot be fully utilized. And also, the data is thinned to eliminate the horizontal observation error correlation. Therefore, the spatial resolution may be acceptable even if it degrades from the current spec.
- JMA is under considering the specifications of GEO equipped with HSS (JFY2028: Launch of Himawari 10). OSSE has confirmed that the HSS installed in GEO could contribute to the accuracy of global analysis and forecasts.

A dramatic sunset sky with orange and red clouds, and a silhouette of a city skyline at the bottom.

Thank you for your attention.