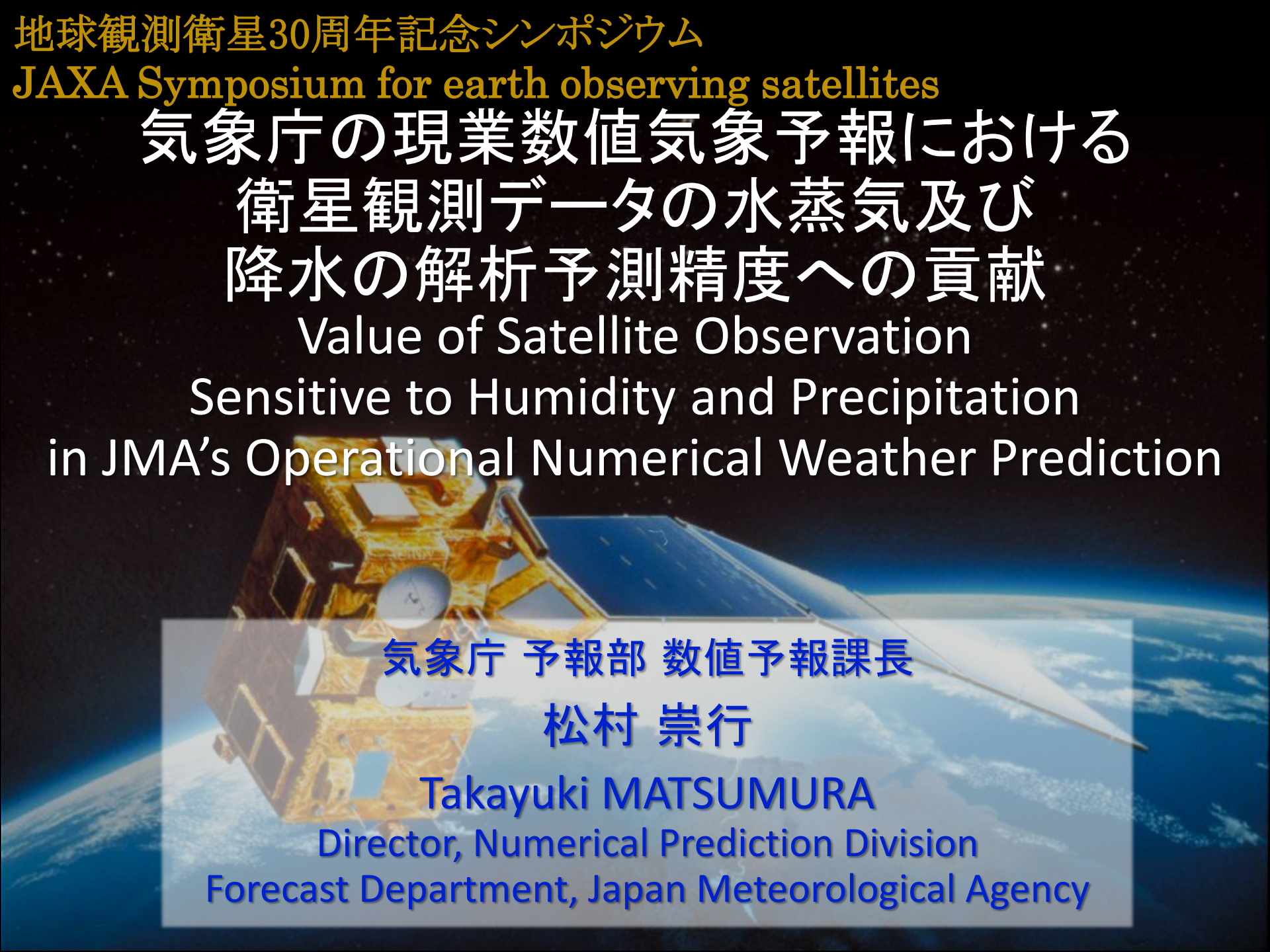
地球観測衛星30周年記念シンポジウム
JAXA Symposium for earth observing satellites

気象庁の現業数値気象予報における衛星観測データの水蒸気及び降水の解析予測精度への貢献

Value of Satellite Observation Sensitive to Humidity and Precipitation in JMA's Operational Numerical Weather Prediction



気象庁 予報部 数値予報課長

松村 崇行

Takayuki MATSUMURA

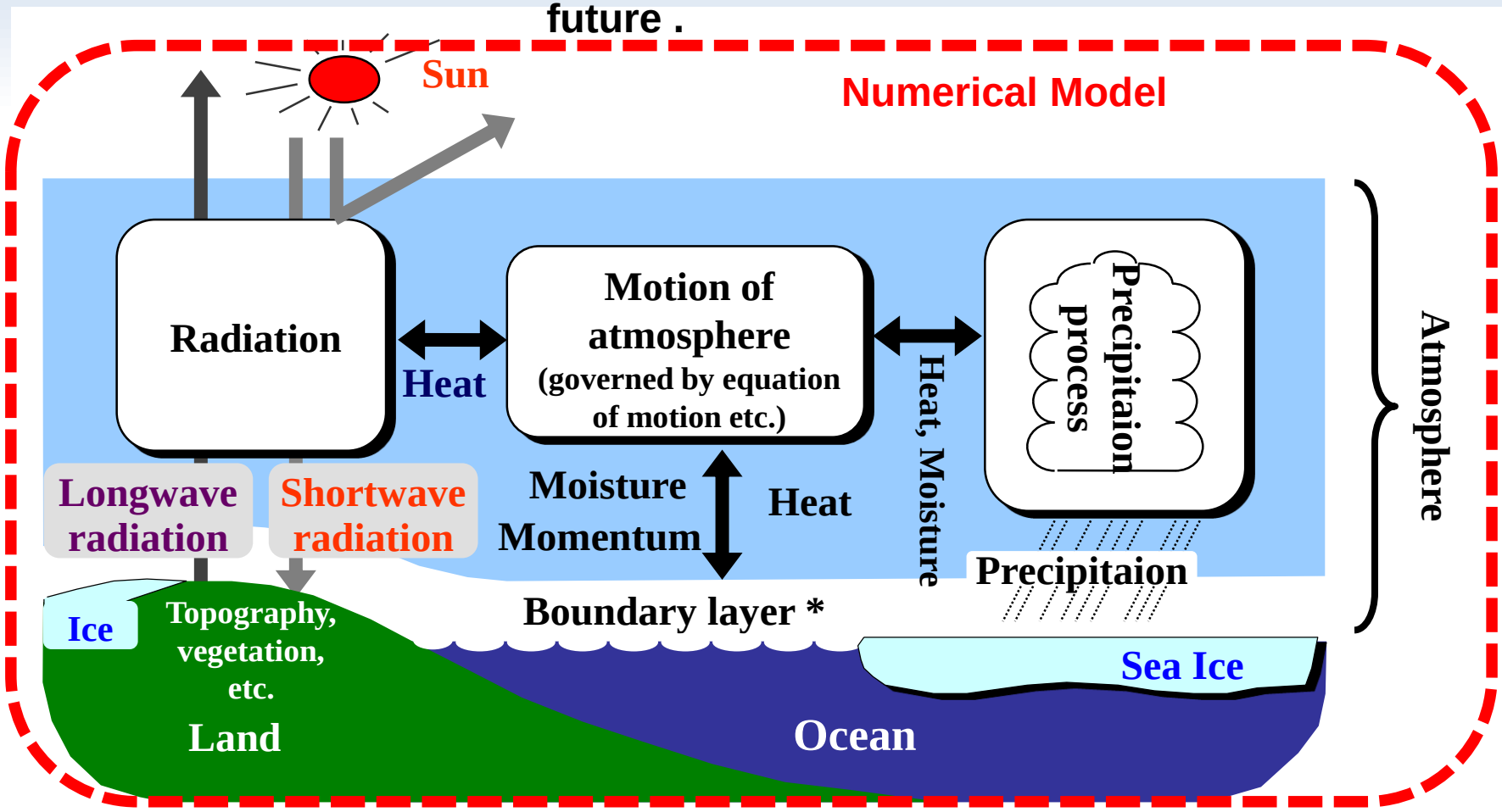
Director, Numerical Prediction Division

Forecast Department, Japan Meteorological Agency

What is NWP?

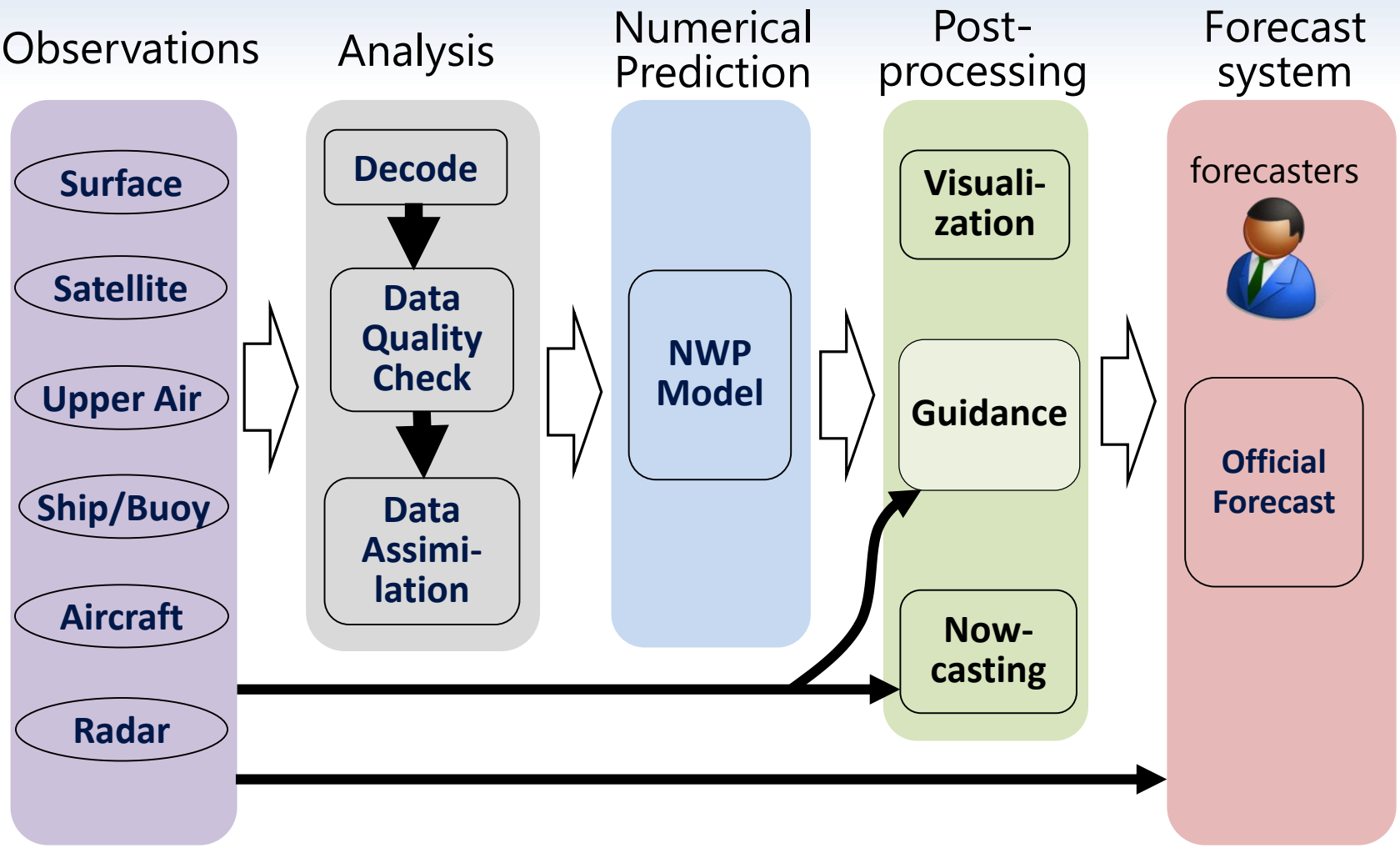
Numerical Weather Prediction

The basic idea of NWP is to make initial state of the atmosphere at a initial time and to use the governing equations of fluid dynamics and thermodynamics to estimate the atmospheric state at some time in the future .

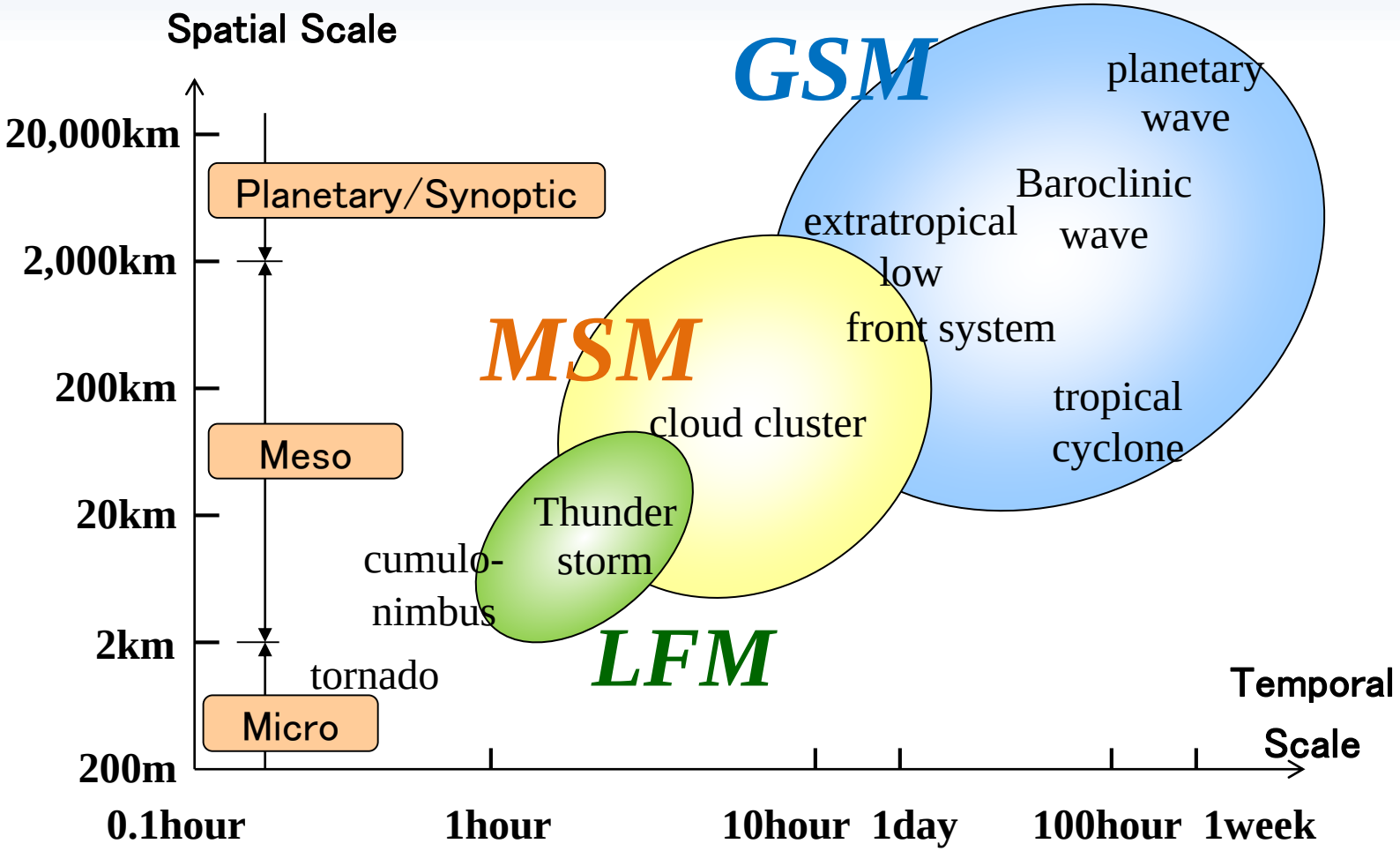


* Boundary layer is the layer of fluid near a boundary that is affected by friction against that boundary surface, and possibly by transport of heat and other variables across that surface.

Flow chart of making forecast



Spatial and Temporal Scale of Atmospheric Phenomena



Data assimilation systems of NPD/JMA

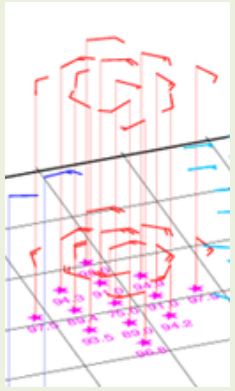
	Global Analysis (GA)	Meso-scale Analysis (MA)	Local Analysis (LA)
Analysis scheme	4D-Var		3D-Var
Analysis time	00, 06, 12, 18 UTC	00, 03, 06, 09, 12, 15, 18, 21 UTC	hourly
Data cut-off time	2 hours 20 minutes [Early Analysis] 11 hours 50 minutes (00, 12 UTC) 7 hours 50 minutes (06, 18 UTC) [Cycle Analysis]	50 minutes	30 minutes
Horizontal resolution (inner-model resolution)	TL959 / 0.1875 deg (TL319 / 0.5625 deg)	5 km (15 km)	5km
Vertical levels	100 levels up to 0.01 hPa	48 levels up to 21.8km	58 levels up to 21.8km
Assimilation window	-3 to +3 hours of analysis time	-3 hours to analysis time	-3 hours to analysis time (1hourly update cycle)

Observation assimilated for NWP

In-situ Obs.

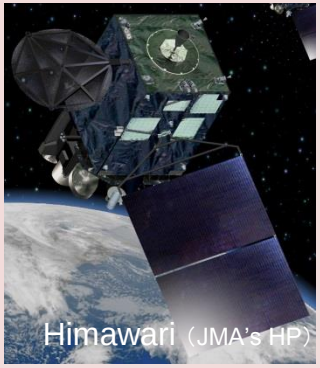
GNSS Reciever
(From Obs. Department)

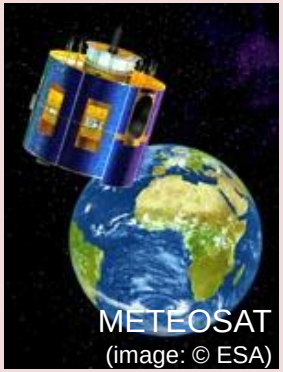
Ground-based Remote Sensing

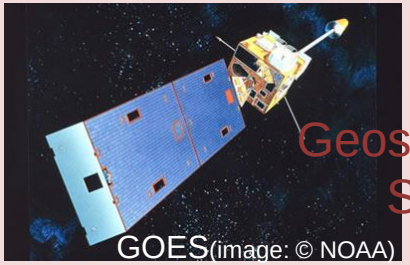


Typhoon Bogus

Pseudo Obs.

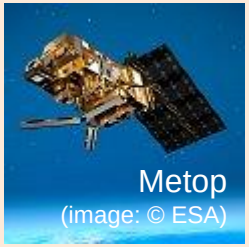


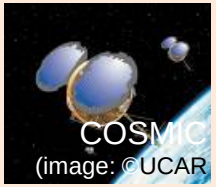


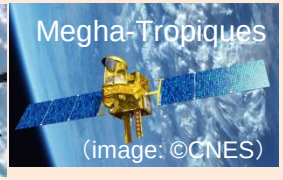


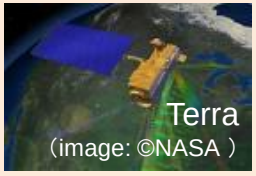
Geostationary Satellites

Operational satellites



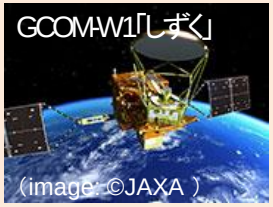






R&D satellites

LEO Satellites



GNSS RO Satellites

Operational History of JAXA's Satellite Data Usage

Date	Assimilation System	Satellite Data
Oct. 2003 ~ Dec. 2010	Mesoscale Analysis	TRMM/TMI: Precipitation Intensity, Total Precipitable Water
Nov. 2004 ~ Dec. 2010	Mesoscale Analysis	Aqua/AMSR-E: Precipitation Intensity, Total Precipitable Water
May 2006	Global Analysis	TRMM/TMI: Radiation
Dec. 2010 ~ Oct. 2011	Mesoscale Analysis	Aqua/AMSR-E: Precipitation Intensity, Radiation
Dec. 2010 ~ Oct. 2015	Mesoscale Analysis	TRMM/TMI: Precipitation Intensity, Radiation
Sep. 2013	Global and Mesoscale Analyses	GCOM-W/AMSR2: Radiation, Precipitation Intensity (only for MA)
Mar. 2016	Global and Mesoscale Analyses	GPM-core/GMI: Radiation, Precipitation Intensity (only for MA)
Mar. 2016	Mesoscale Analysis	GPM-core/DPR: Reflectivity
Jan. 2017	Local Analysis	GCOM-W/AMSR2: Radiation, Soil Moisture Content GPM-core/GMI: Radiation

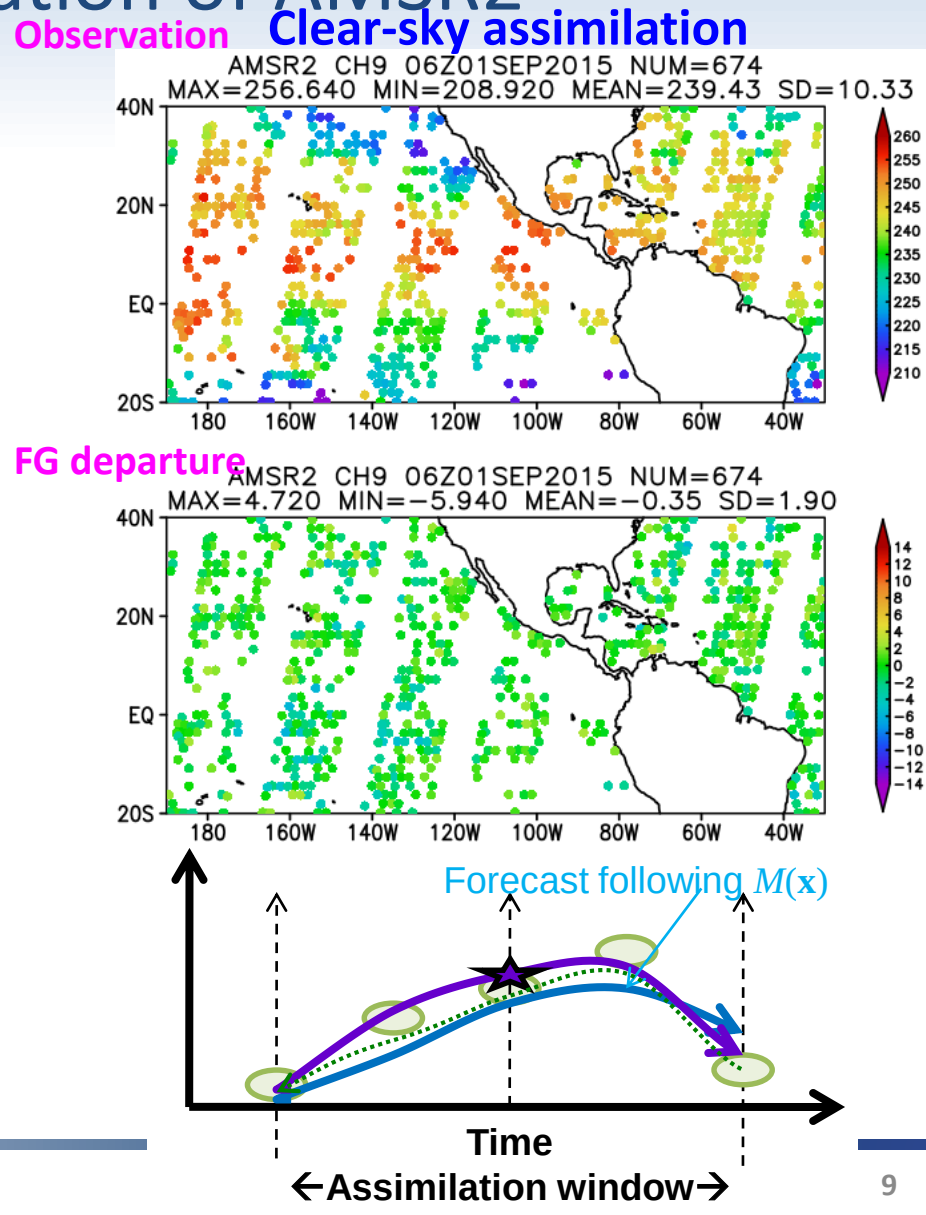
1. **Mesoscale Analysis: Advanced Microwave Scanning Radiometer 2 (AMSR2) onboard Global Change Observation Mission – Water "SHIZUKU" (GCOM-W)**
2. Global and Mesoscale Analyses: Global Precipitation Measurement (GPM) Microwave Imagery (GMI) onboard GPM-core Satellite
3. Mesoscale Analysis: Dual-frequency Precipitation Radar (DPR) onboard GPM-core Satellite

EXAMPLE OF OPERATIONAL USE OF SATELLITE OBSERVATION SENSITIVE TO HUMIDITY AND PRECIPITATION

Direct Assimilation of Radiance Data

- Clear-sky Assimilation of AMSR2 -

- Satellite radiance data are assimilated directly using 4D-Var.
  - Brightness temperature (Tb) is simulated using radiative transfer model such as RTTOV from NWP forecast data.
  - Only Tb in clear-sky area is assimilated.
- Data are assimilated in Global, Mesoscale and Local Analyses.



OSE results in JMA Meso-scale NWP system for the operational use of AMSR2 data

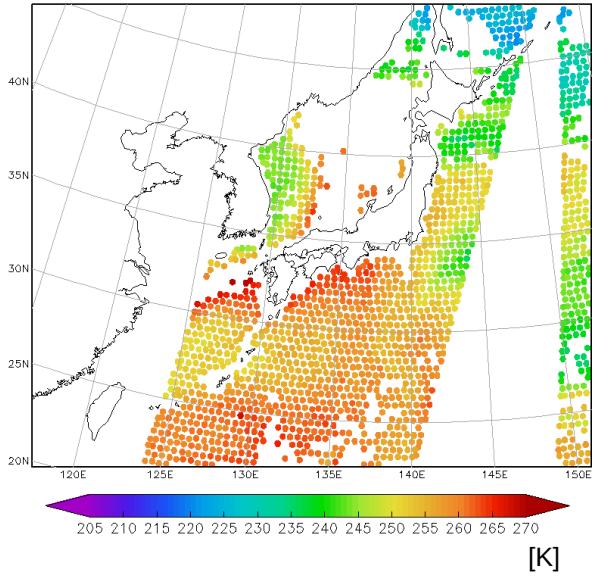
A case study: A heavy precipitation event in the Kyusyu Island in Japan

Period: 4 – 14 July 2012

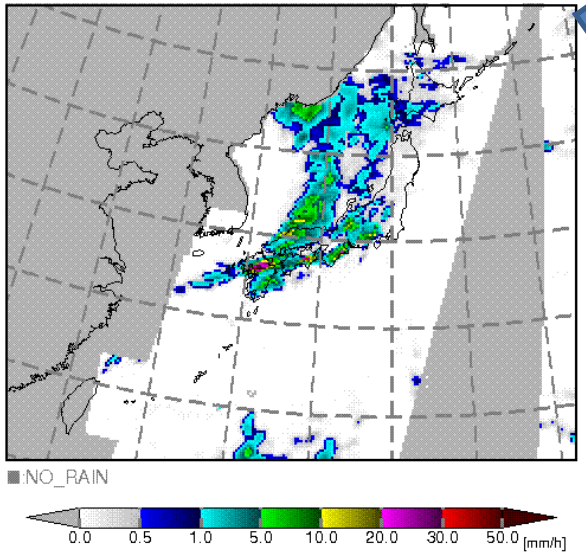
Improvement of humidity fields using AMSR2 data such as radiation and precipitation intensity

An example of assimilated AMSR2 data distribution (18 UTC 11 July 2012)

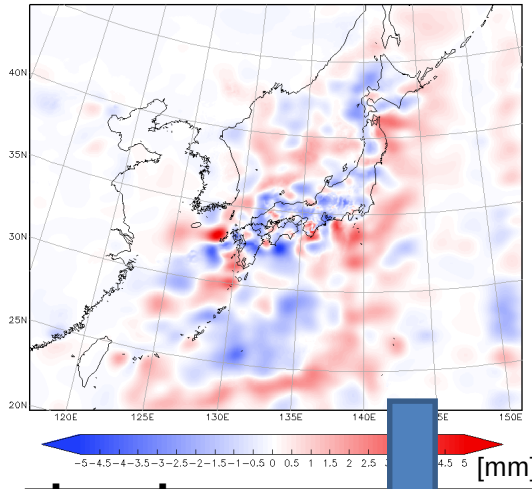
23GHz V-pol. Tb



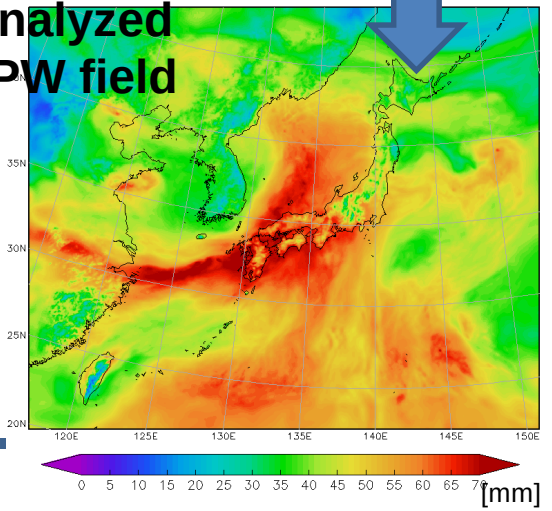
Rain Rate [mm/hr]



TPW increment



Analyzed TPW field



Impacts on humidity field

TPW Analysis(Test)

TPW diff (Test – Control)

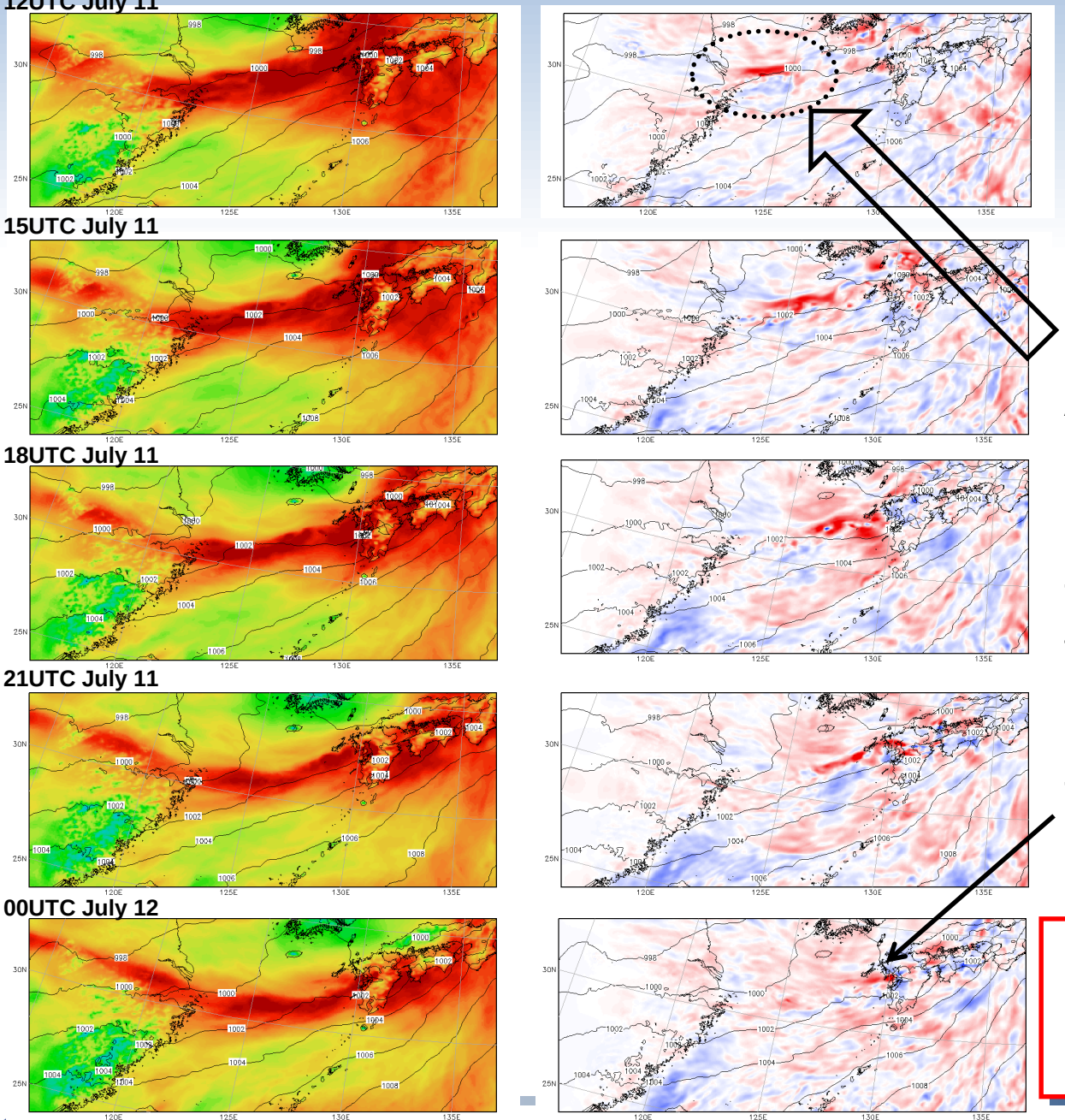
12UTC July 11

15UTC July 11

18UTC July 11

21UTC July 11

00UTC July 12



Test: With AMSR2
Control: Without AMSR2

Assimilation of AMSR2 data increases TPW in the northern edge of front

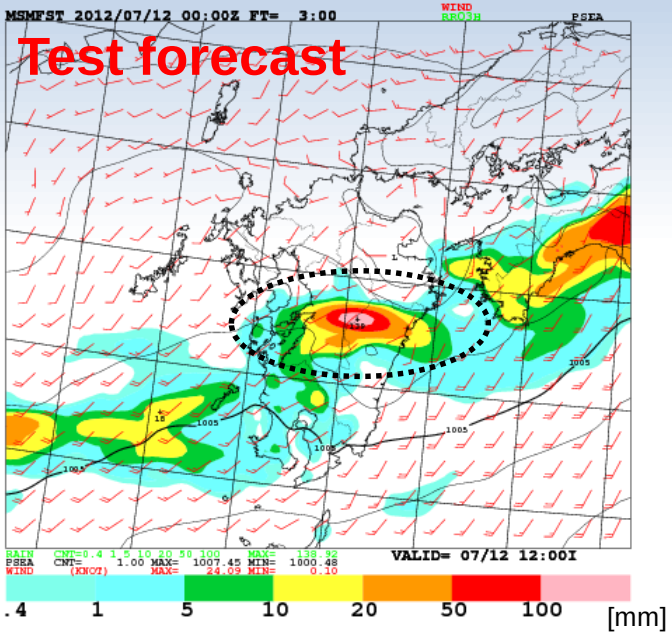
The change are produced from a cycling of the data assimilation.

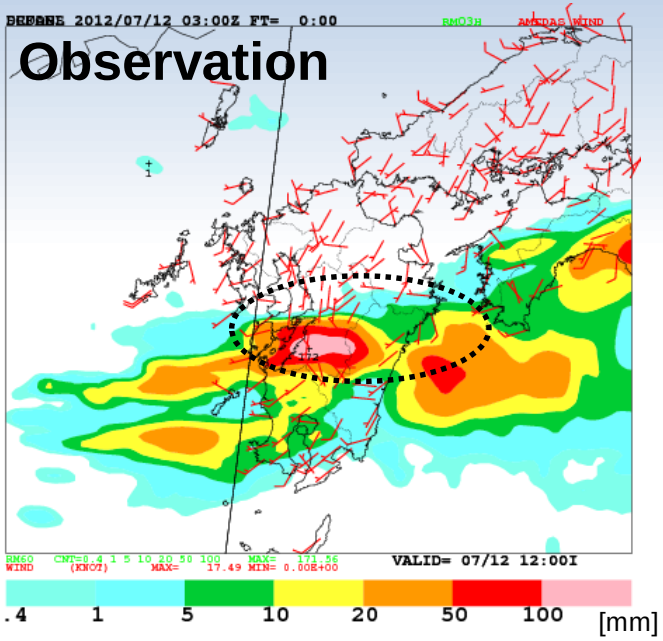
The change reached in the northern Kyushu on 00UTC 12 July 2012.

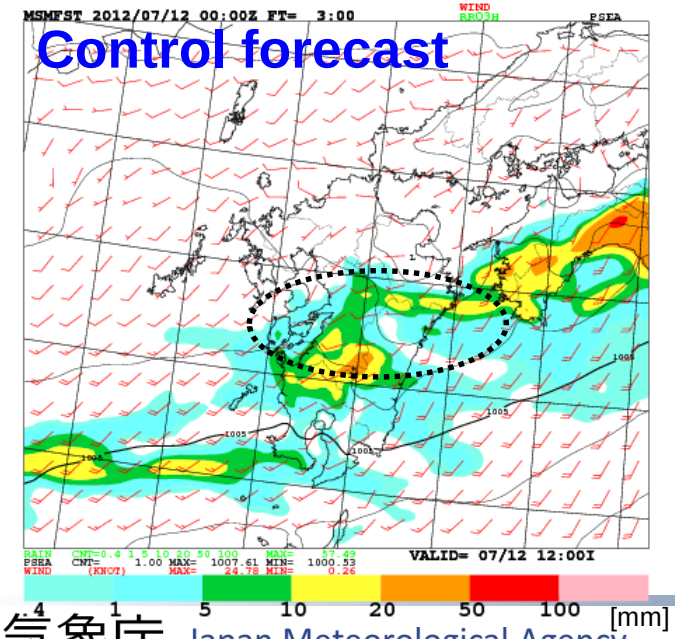
How different are precipitation forecast from this initial time?

Test: with AMSR2
Control: without AMSR2

Impact on precipitation forecast







Three-hour precipitation prediction for 00-03 UTC 12 July 2012 by JMA's Meso-Scale Model initialized at 00 UTC in the same day

Assimilation of AMSR2 data improved short range precipitation forecast (rainfall intensity and location)

Improved humidity field upstream of the Kyushu Island in the initial time brought the precipitation forecast improvement

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EXAMPLE OF OPERATIONAL USE OF SATELLITE OBSERVATION SENSITIVE TO HUMIDITY AND PRECIPITATION

GPM/GMI

Non-sun synchronous orbiting MW imager

Global Precipitation Measurement is a Joint Mission of JAXA and NASA

GPM core satellite (TRMM follow-on mission)

GMI: **G**PM **M**icrowave **I**mager

DPR: **D**ual **P**recipitation **R**adar

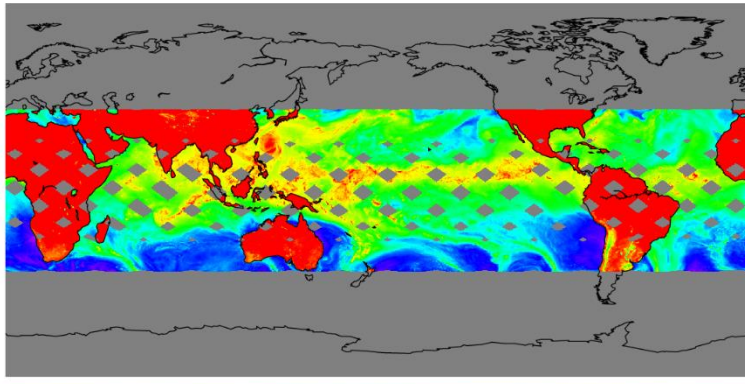
Key features of GMI for NWP

- Wide data coverage (High altitude area)
- Non Sun-synchronous orbit
- New observation channels, 166GHz, 183GHz
  for solid precipitation measurements and water vapor soundings

TMI	GMI
10.65V	**10.65V**
10.65H	**10.65H**
19.35V	**18.7V**
19.35H	**18.7H**
21.3V	**23.8V**
37V	**36.64V**
37H	**36.64H**
85.5V	**89V**
85.5H	**89H**
	166V
	166H
	183+3V
	183+7V

Central frequency [GHz]

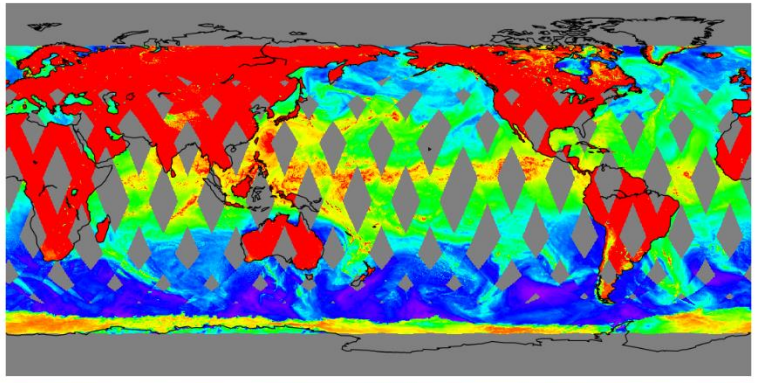
TRMM/TMI 1 day coverage



80 185 190 195 200 205 210 215 220 225 230 235 240 245 250 255 260 265 2

[K]

GPM/GMI 1 day coverage



180 185 190 195 200 205 210 215 220 225 230 235 240 245 250 255 260 265 270

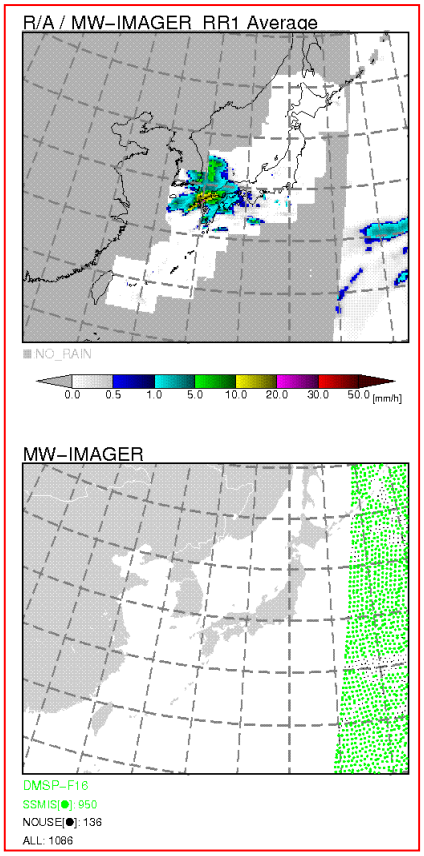
[K]

TB: 23GHzV

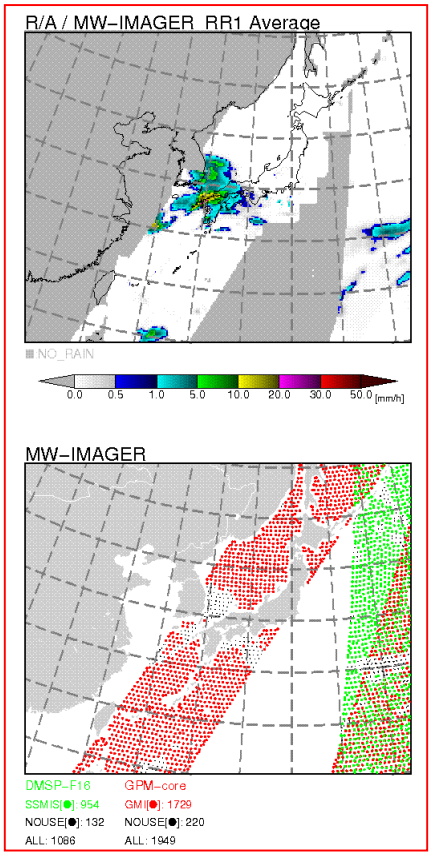
Red: for assimilation

OSE of GMI data using JMA Meso-scale NWP system

Case: A heavy precipitation event in the Kyusyu Island in Japan
Period: 3 July 2014



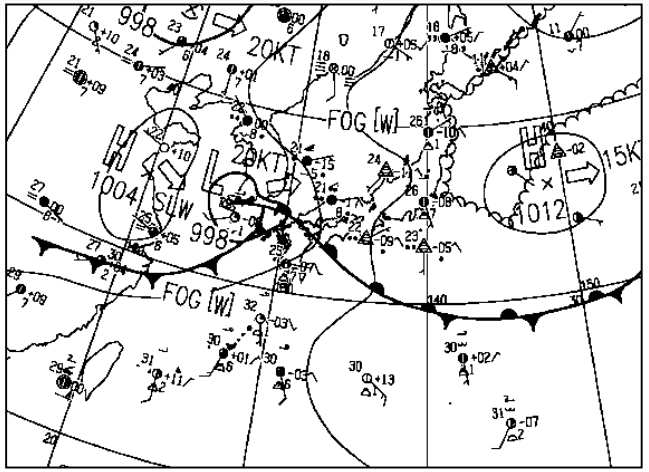
Estimated Precipitation



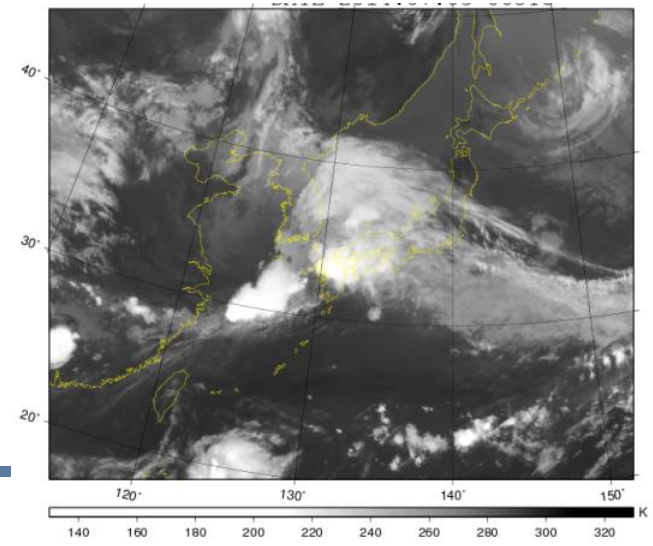
Microwave Imager
GMI
SSMIS

Coverage Map at 21UTC on 2 July 2014

Weather Map at 00UTC on 3 July 2014



MTSAT IR Image at 00UTC on 3 July 2014

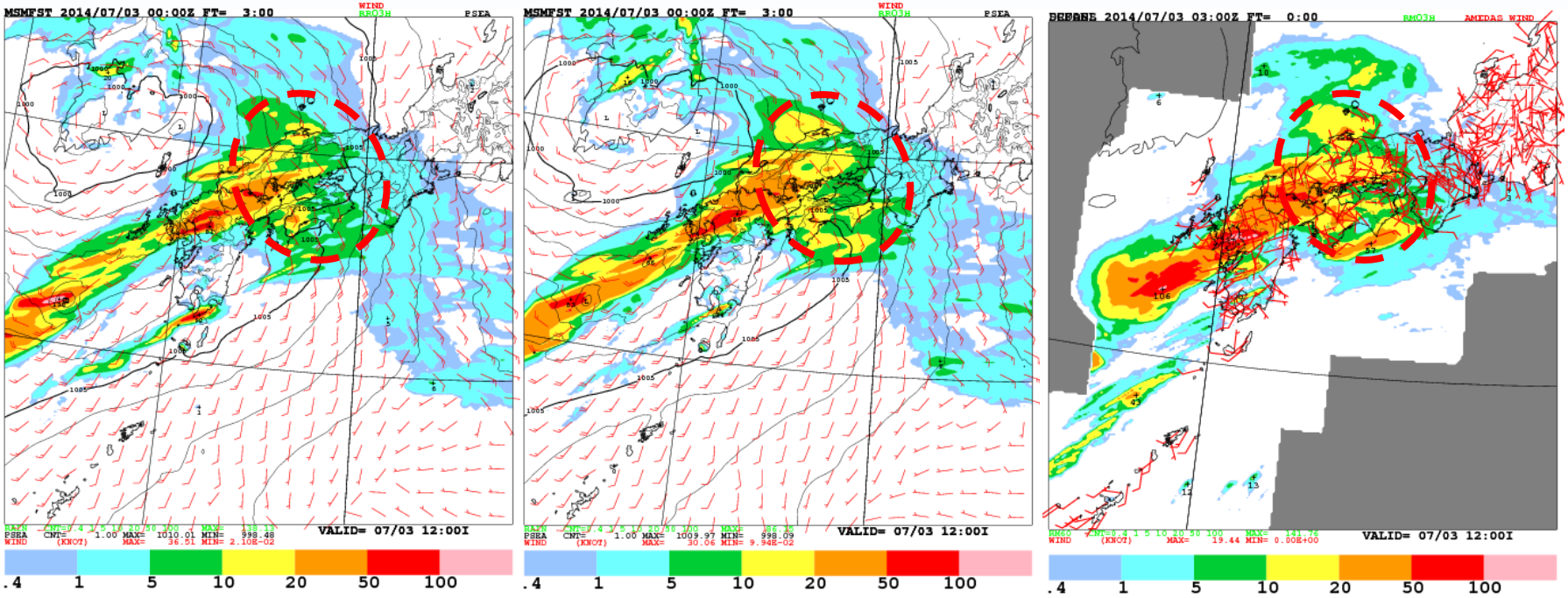


OSE Results: Impact on QPF

Three-hour precipitation prediction with the lead time of 3 hours

Initial time is 00UTC on 3 July 2014.

Control（w/o GMI） **Test（with GMI）** **Analyzed Precipitation**



Assimilation of GMI data contributed to the improvement of precipitation forecasts around the area off the coast of Sanin region and the coast of Shikoku (Red-circle area).

On the other hand, the heavy precipitation prediction over the northern part of Kyushu island doesn't change by GMI data assimilation since it is already well simulated.

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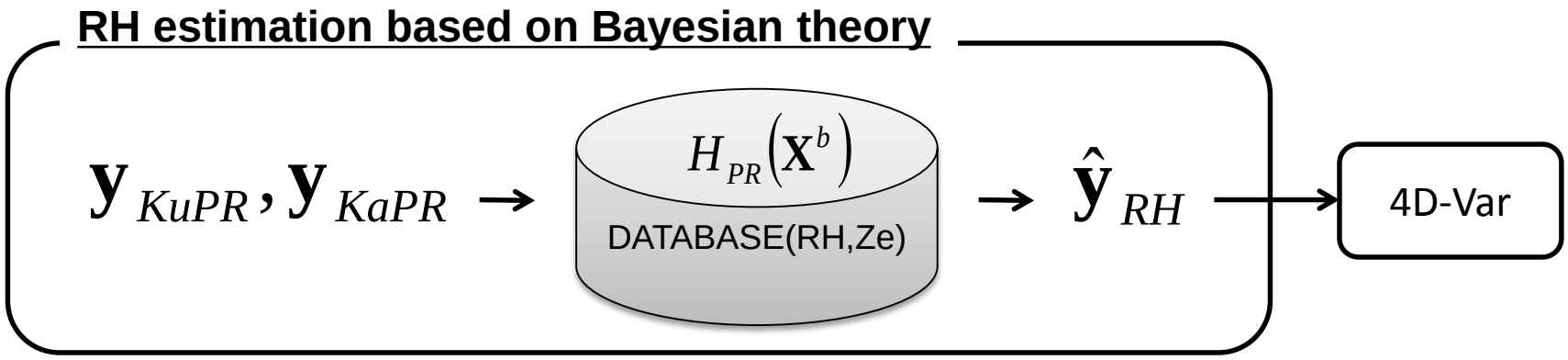
3. **Mesoscale Analysis: Dual-frequency Precipitation Radar (DPR) onboard GPM-core Satellite**

EXAMPLE OF OPERATIONAL USE OF SATELLITE OBSERVATION SENSITIVE TO HUMIDITY AND PRECIPITATION

GPM/DPR data assimilation

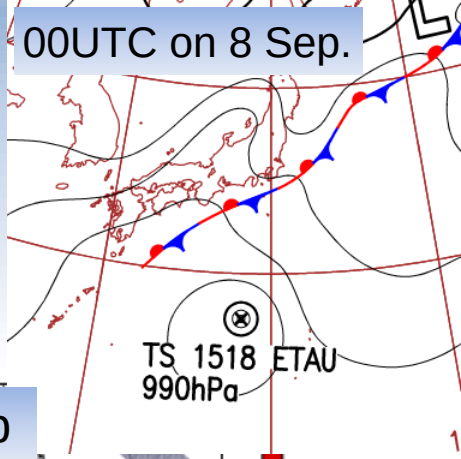
- Assimilation method of KuPR and KaPR
  - 1D+4D-Var method
    - This method is **same as ground based radar assimilation** at JMA.(Ikuta and Honda, 2011)

1. RH is retrieved from observed reflectivity, simulated reflectivity and first-guess. (Caumont et al., 2010)
2. This retrieved RH is assimilated in the same way as conventional data by 4D-Var.

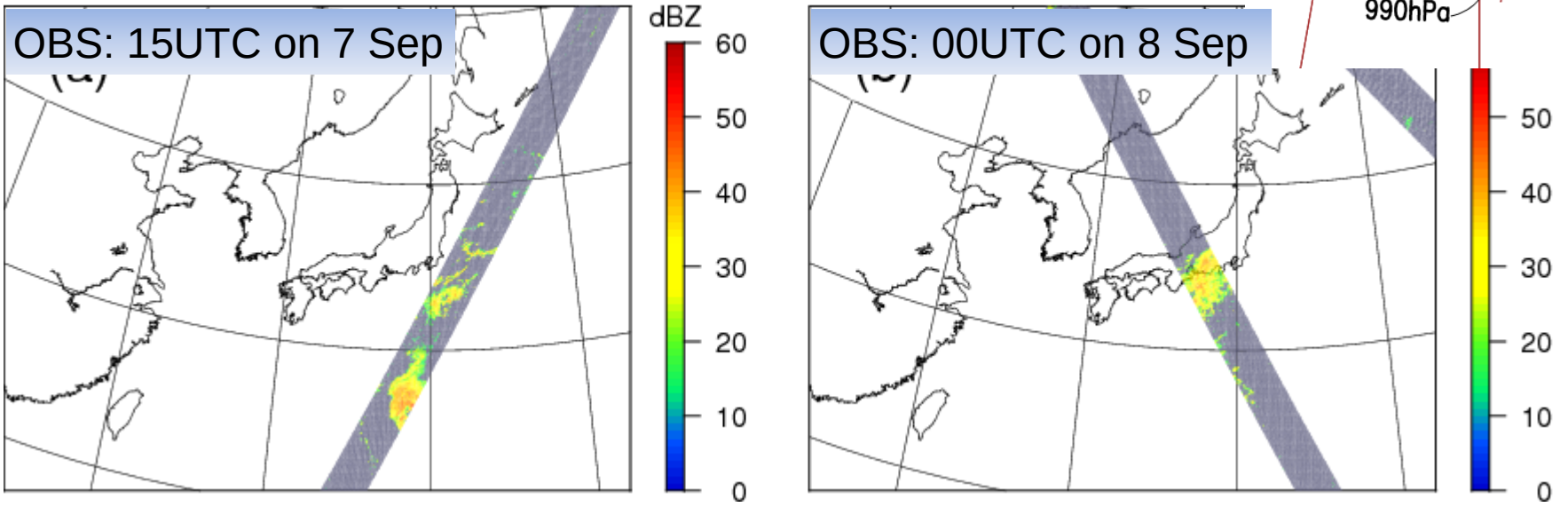


Heavy Rainfall over Kanto and Tohoku Regions

September 2015



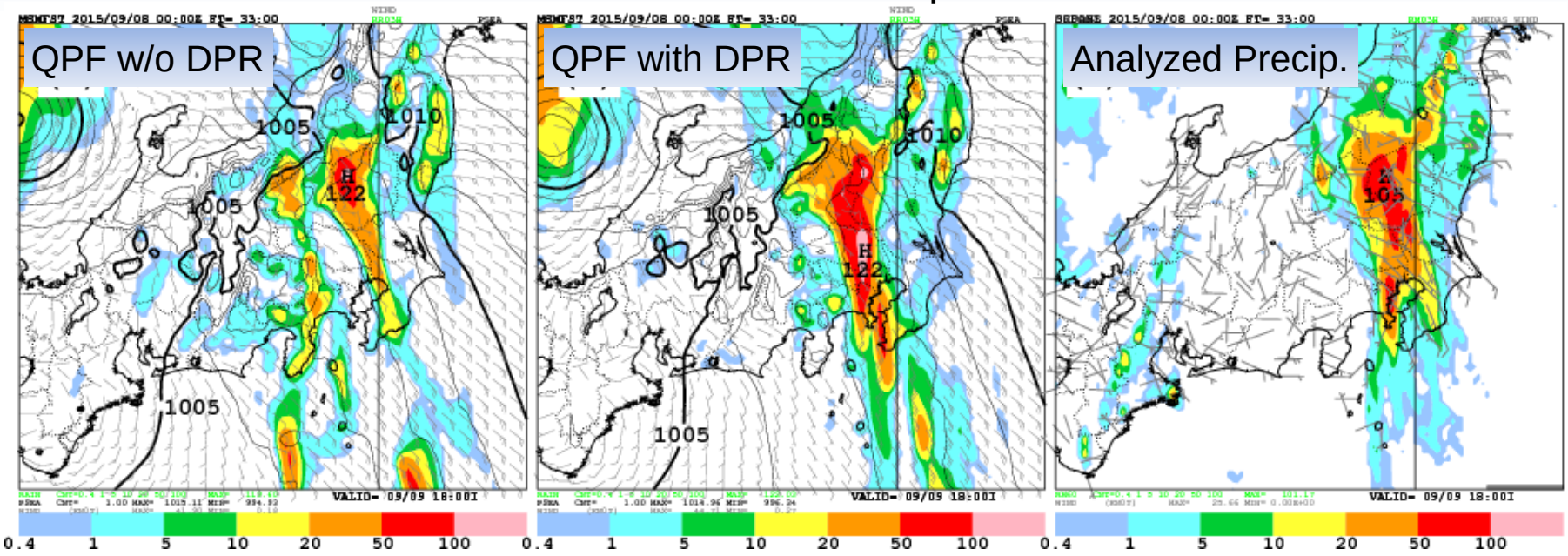
Path of GPM-core Satellite and DPR observation



- GPM/DPR captured the precipitation around Typhoon ETAU and the stationary front before the occurrence of the heavy precipitation
- Water vapour flow from the Pacific Ocean was analyzed better by assimilating GPM/DPR data

Positive Impact on QPF
Kanto-Tohoku Heavy Rainfall in Sep. 2015

Three-hour precipitation prediction with the lead time of 33 hours
Initial time is 00UTC on 8 September 2015.



- The assimilation of GPM/DPR data contributed to the better representation of heavy rainfall by having precipitation area concentrated to the western area in Kanto region.

Summary

- JMA operates the operational NWP suites to produce basic materials for various weather information.
- The accurate analysis and forecast of severe precipitation produced by NWP are essential for preventing and mitigating the effects of natural disasters.
- The space-based observations of atmospheric water vapor and precipitation are crucial, particularly over the oceans where ground-based observations are limited.
- In future, we will use the satellite data obtained from JAXA and improve the assimilation method.