Assimilating All-Sky Himawari-8 Satellite Infrared Radiances: Preliminary Case Studies

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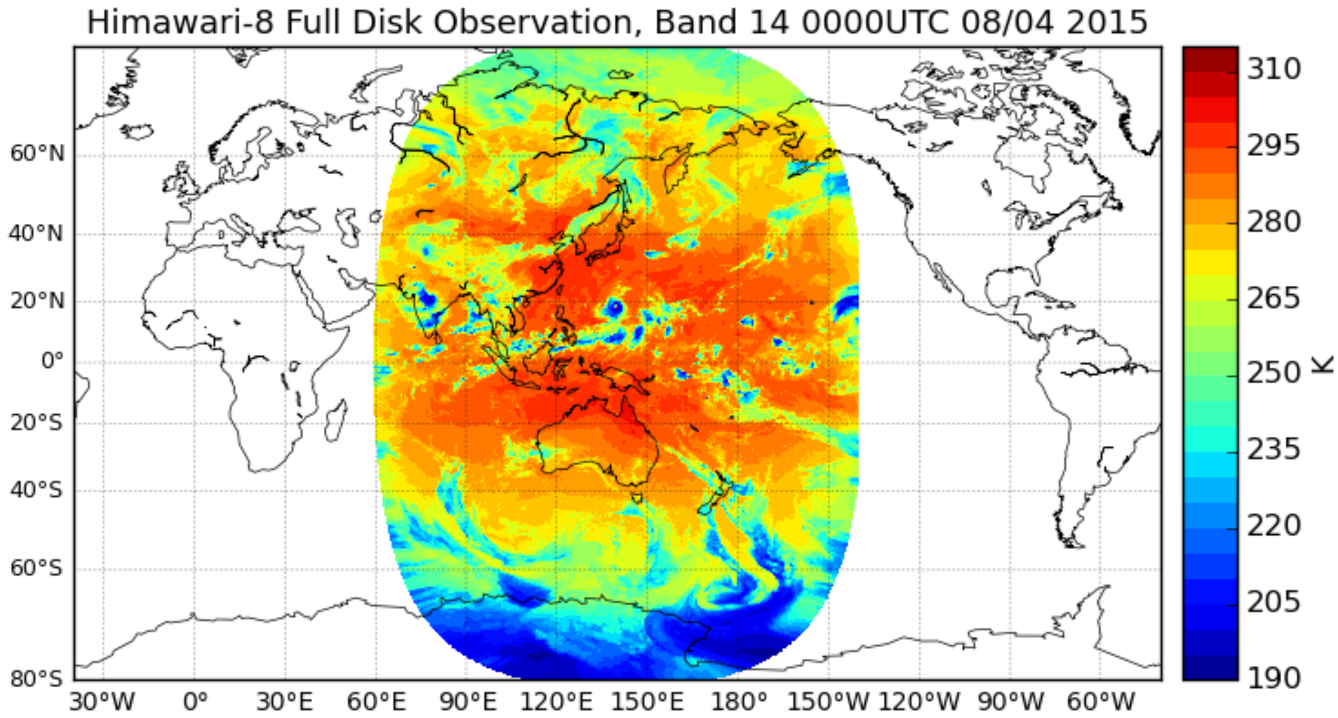
Data Assimilation Seminar, 21 Dec. 2016, RIKEN AICS, Kobe, Japan

Contents

Why geostationary satellite radiances?

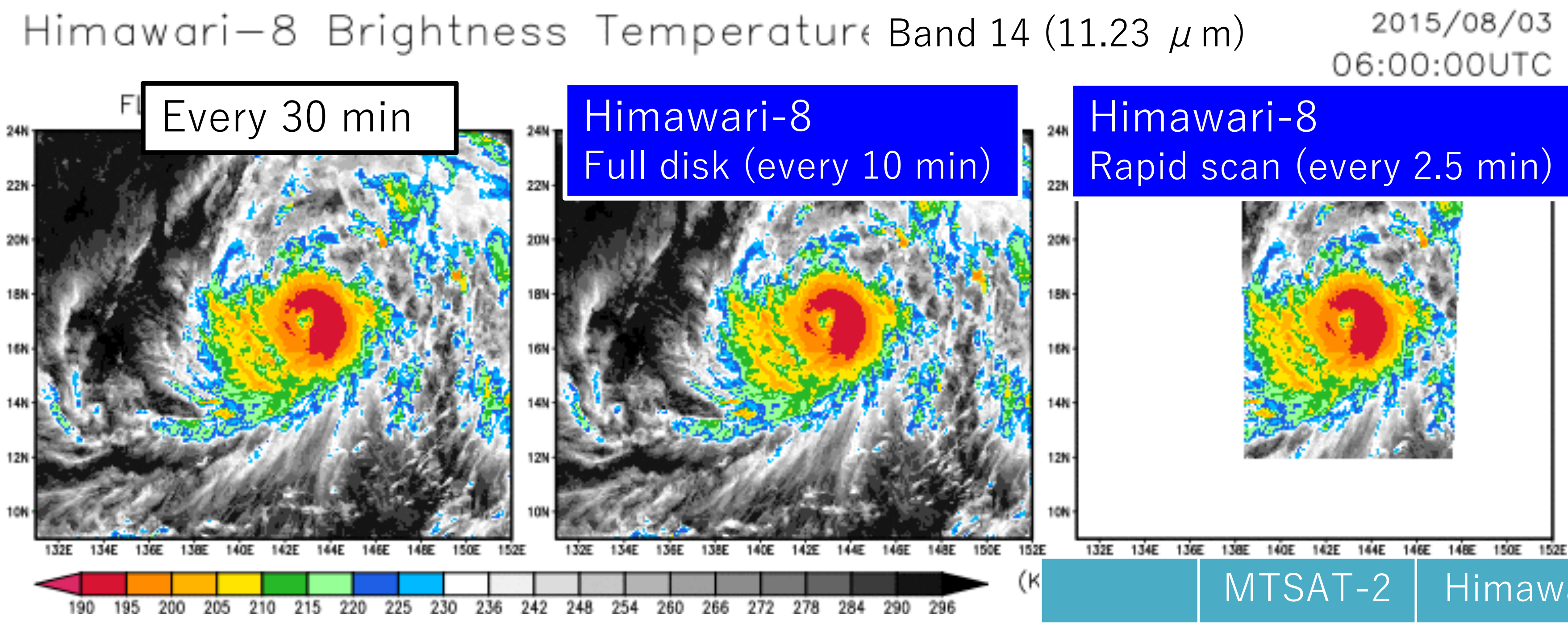
- High spatiotemporal coverage
  - Conventional observations are generally limited over the ocean.



Himawari-8: A new generation satellite

Providing observation "Big Data"   Similar to GOES-R

– High-spatiotemporal resolution radiance obs in 16 bands.



	MTSAT-2		Himawari-8	
VIS	1		3	
NIR	0	5	3	16
IR	4		10	

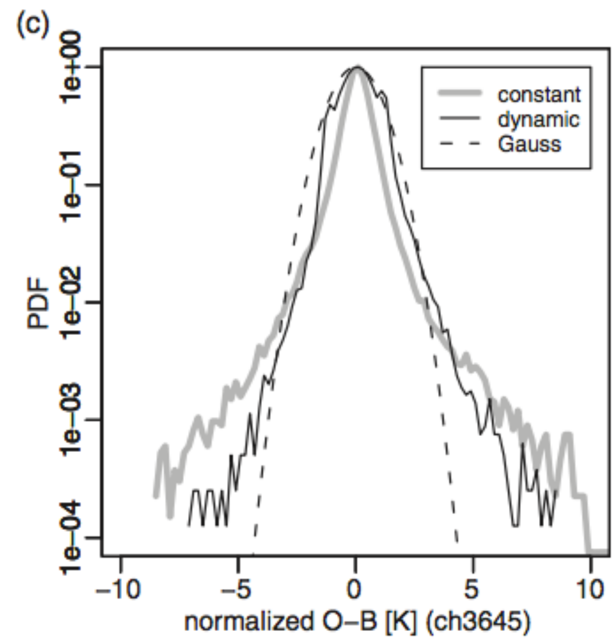
Number of bands

Infrared (IR) radiance assimilation

is expected to improve moisture, clouds, and wind fields (Otkin 2012JGR).

- Issues in all-sky assimilation
  - Strong nonlinearity
  - Non-Gaussianity

Geer and Bauer (2011QJRMS)
Okamoto et al. (2014QJRMS)
Harnisch et al. (2016QJRMS)

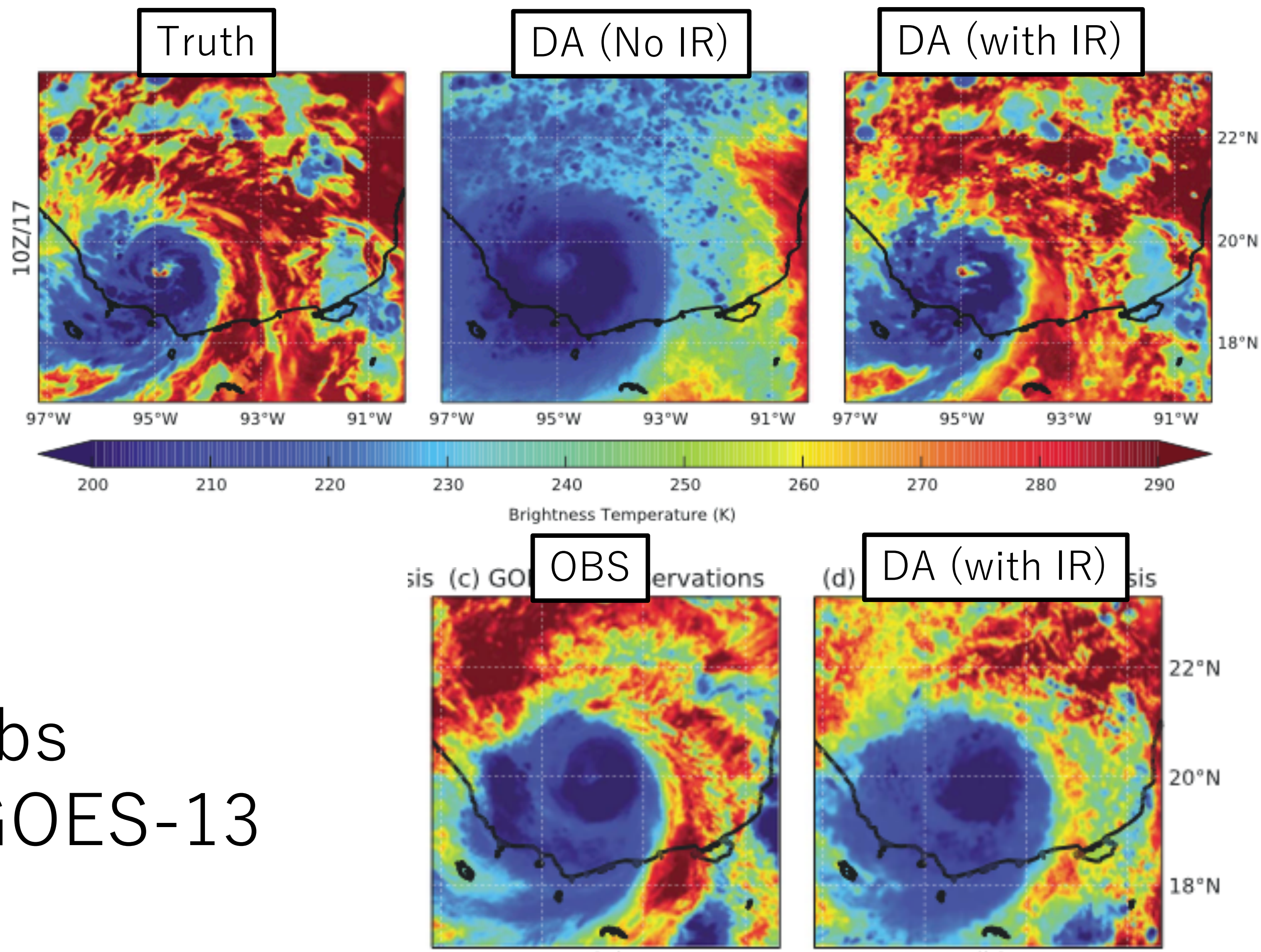


O–B PDF
Okamoto et al. (2014QJRMS)

Promises shown by Zhang et al. (2016)

OSSE

Real obs
from GOES-13



Scope of this study

- To implement obsope for Him8 obs into SCALE-LETKF
- To assimilate real Him8 obs for several cases (tropical cyclone and heavy rainfall)

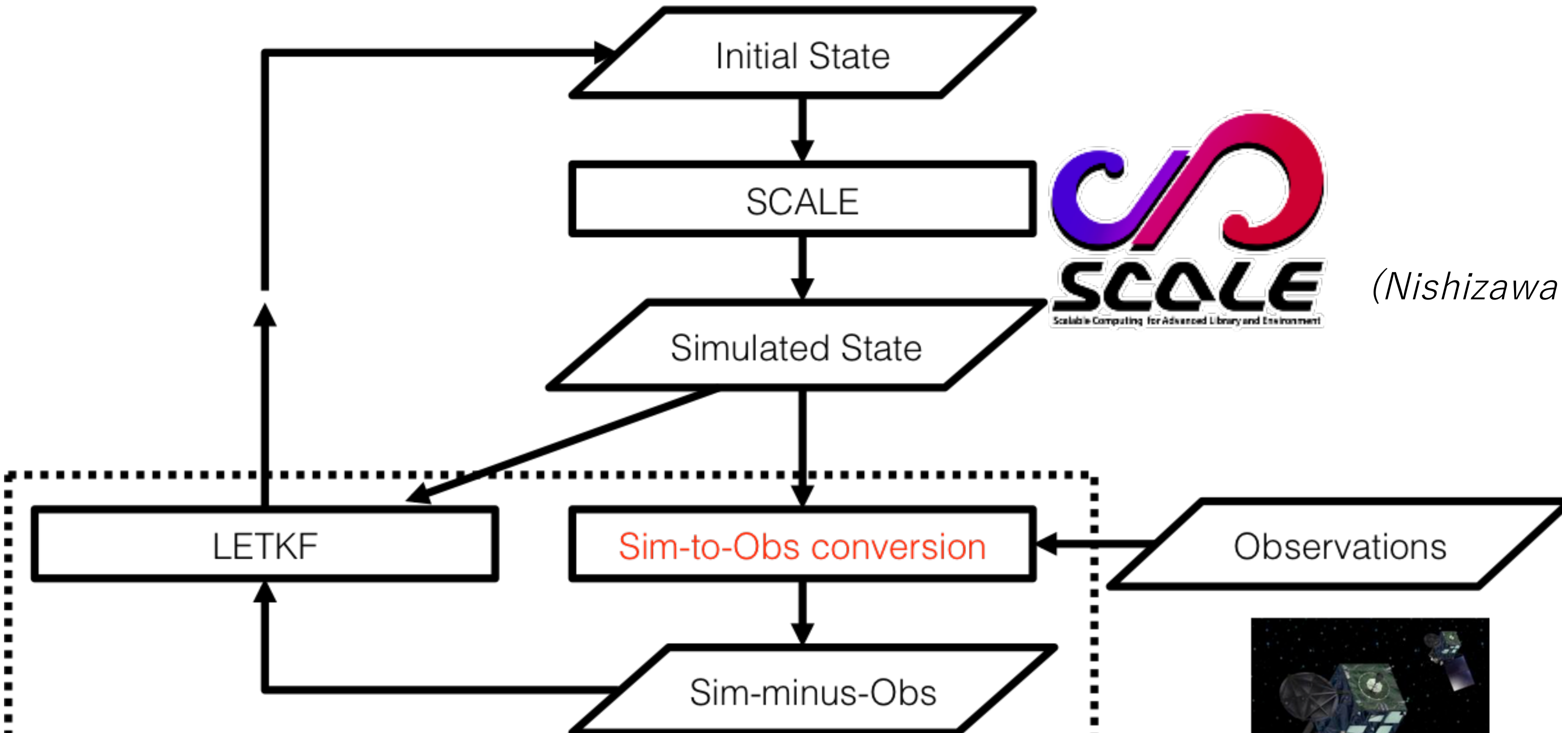
Some important topics (e.g., observation errors and bias correction) are beyond the scope.

Contents

- Introduction
- Implementation of obsope
- Typhoon Soudelor (2015)
- Kanto-Tohoku heavy rainfall
- Summary

The SCALE-LETKF system

Lien et al. (2016)



Broad-sense DA

(Nishizawa et al. 2015)

Flowchart of SCALE-LETKF

Himawari-8
Bessho et al. (2016)

Observation operator

Model variables (t, q_v, $q_c \cdots$)

↓

Forward RTM (RTTOV 11.2)

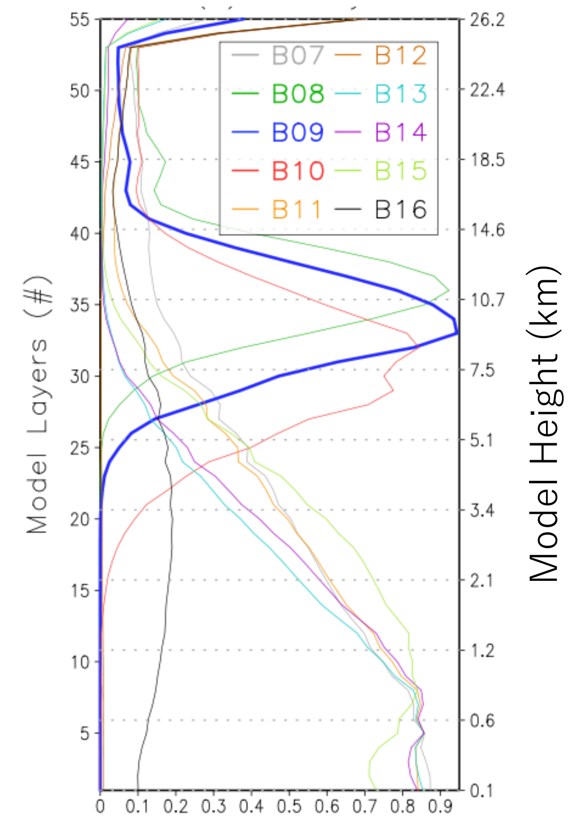
→ Brightness Temp.

→ Clear-sky Weighting Function

Band #	Wave length (μm)	Supposed Uses
7	3.9	moisture at lower levels
8	6.2	moisture at mid / upper levels
9	6.9	moisture at mid levels
10	7.3	moisture at mid levels
11	8.6	SO_2
12	9.6	O_3
13	10.4	cloud imagery / cloud top
14	11.2	cloud imagery / SST
15	12.4	cloud imagery / SST
16	13.3	cloud top

Assimilated (band 9)

http://www.jma-net.go.jp/msc/ja/



Weighing function

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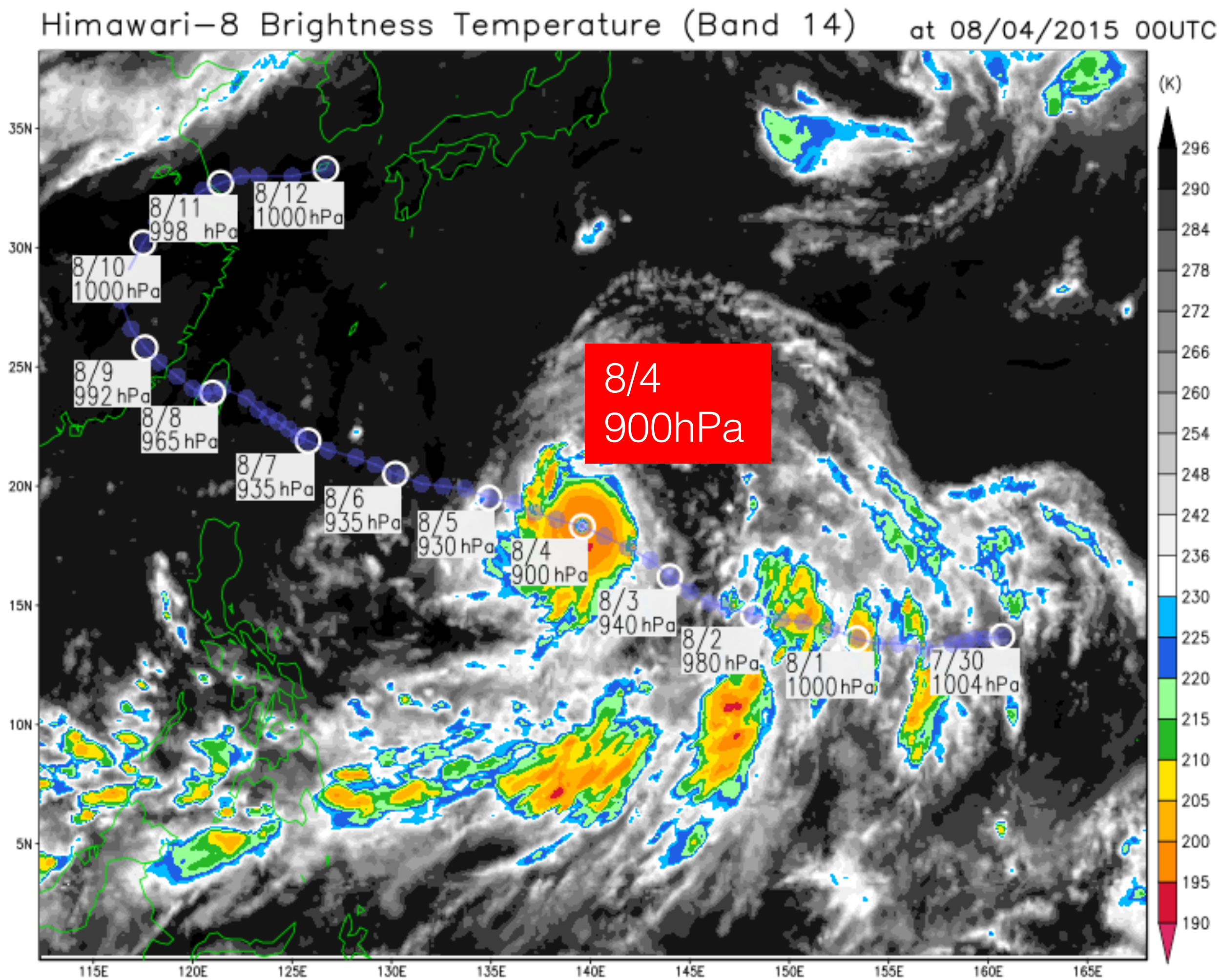
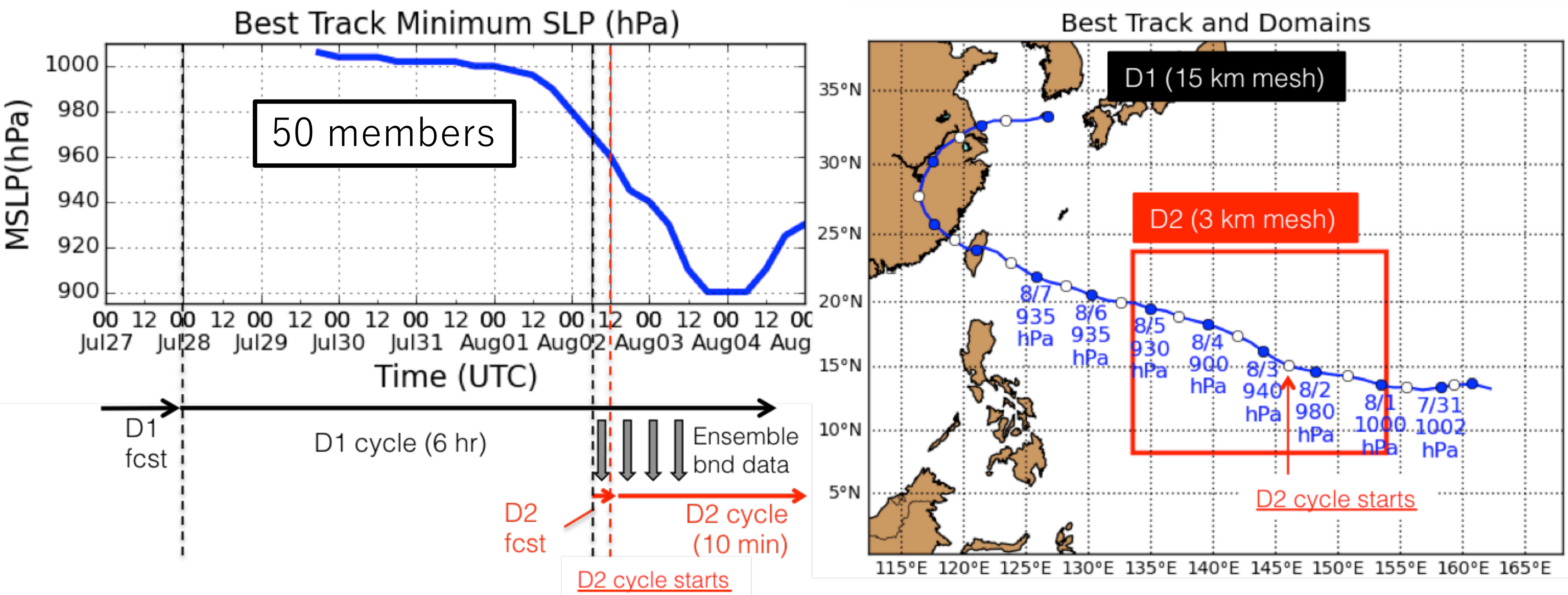
Typhoon Soudelor (2015)

- The strongest western North Pacific TC in 2015.
- Himawari-8 observed successfully!



Experimental design



	D1 (15 km mesh)	D2 (3 km mesh)
Obs	PREPBUFR (6 hr)	PREPBUFR (10 min), Best Track TC vital (MSLP & position, 1hr), Himawari-8 (10 min)

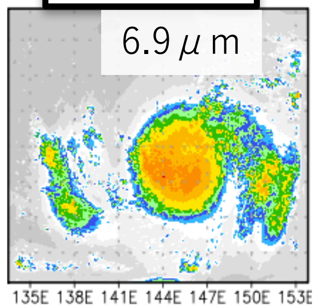
First step analysis

Band 9 :
0.05° x0.05°
Obs err: 5 K

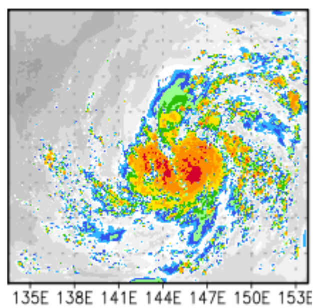
Directly assimilated

Band 9

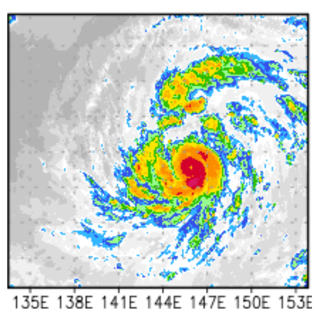
First Guess

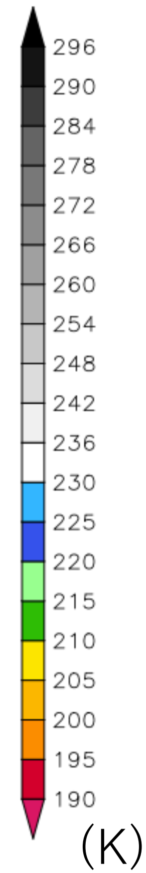


Analysis



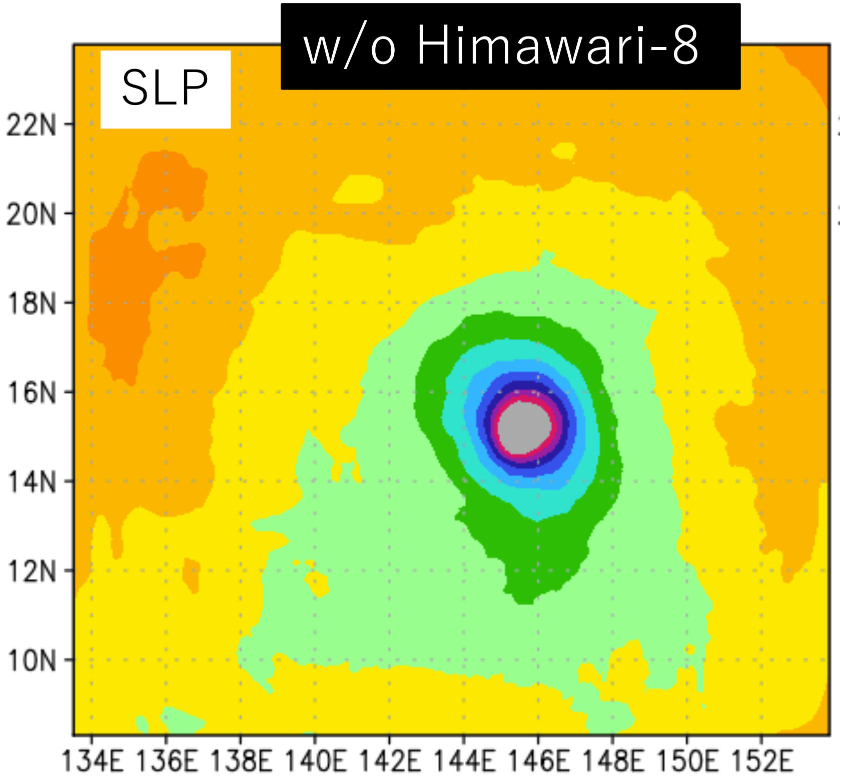
Himawari-8



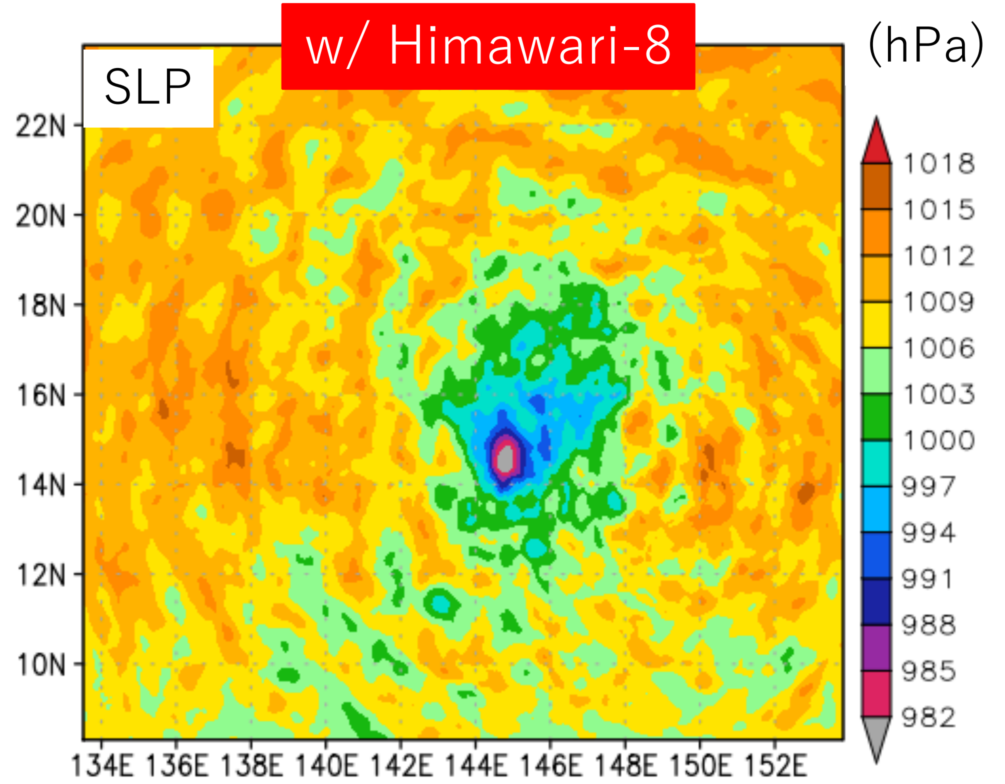


First trial failed

After 12 cycles (2hr)



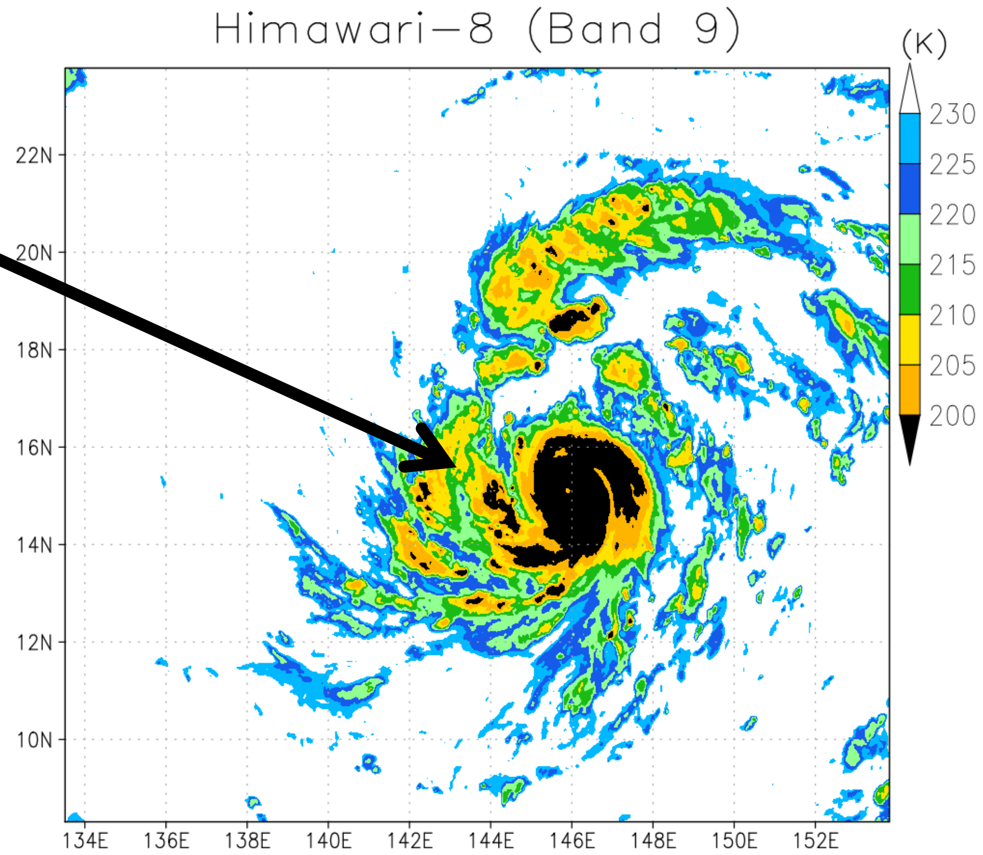
Noisy SLP analysis



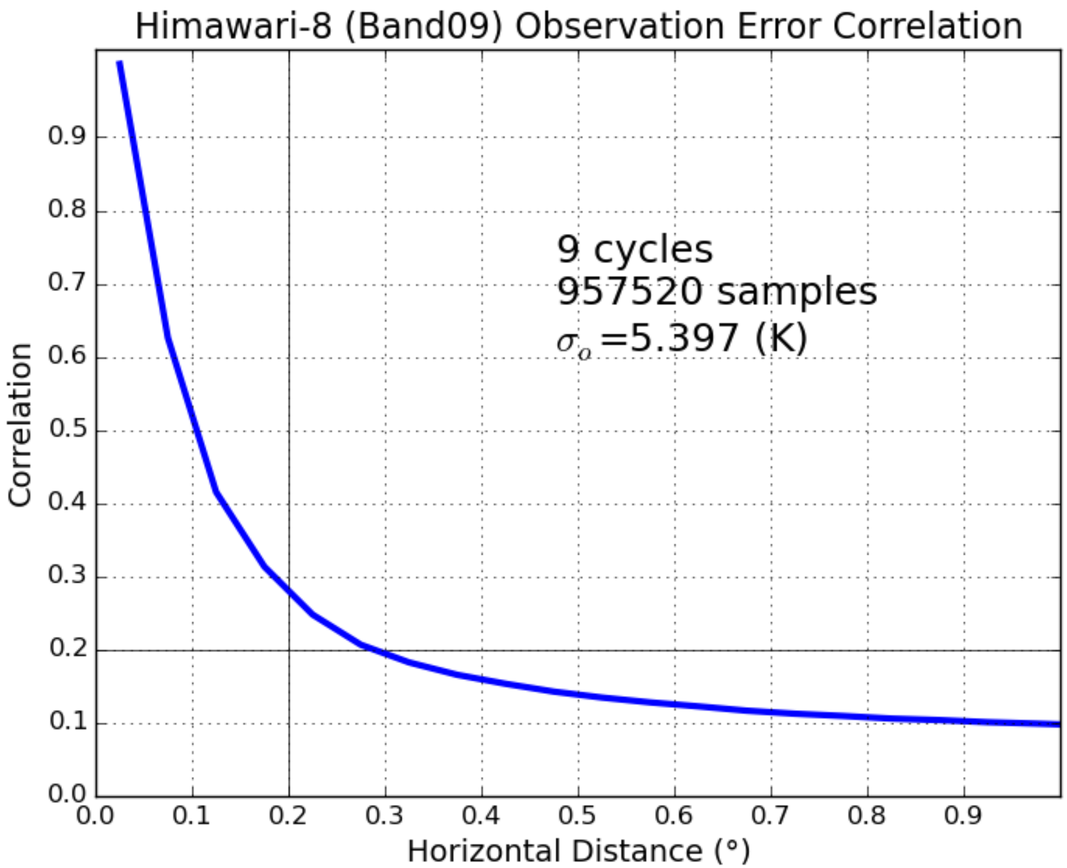
Remedies

- Applying large obs err in the first 12 cycles (2 hr)

- Rejecting too low (200 K) Himawari-8 obs



Horizontal obs err correlation



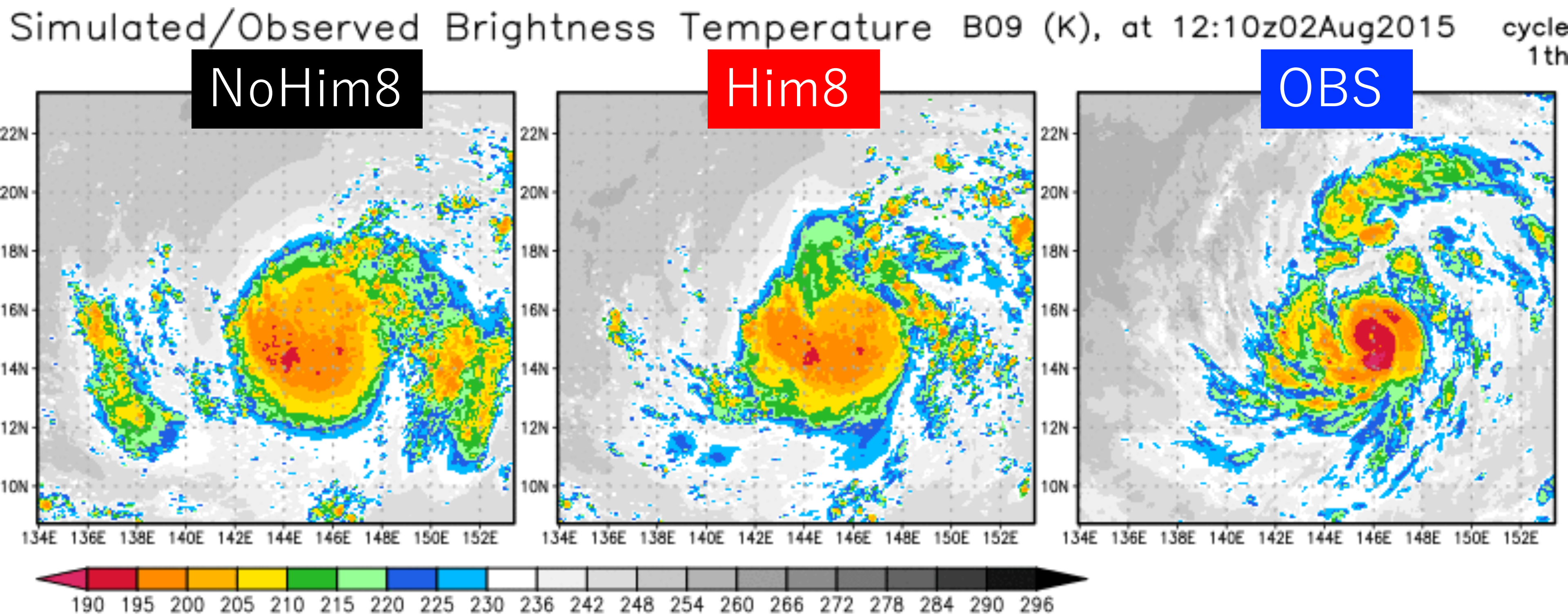
Estimated horizontal observation error correlation for Himawari-8 observation (band 9).

Based on innovation statistics (Desroziers et al. 2005)

$$\mathbf{R} = \left\langle \mathbf{d}^a \left(\mathbf{d}^b\right)^{\mathbf{T}} \right\rangle$$

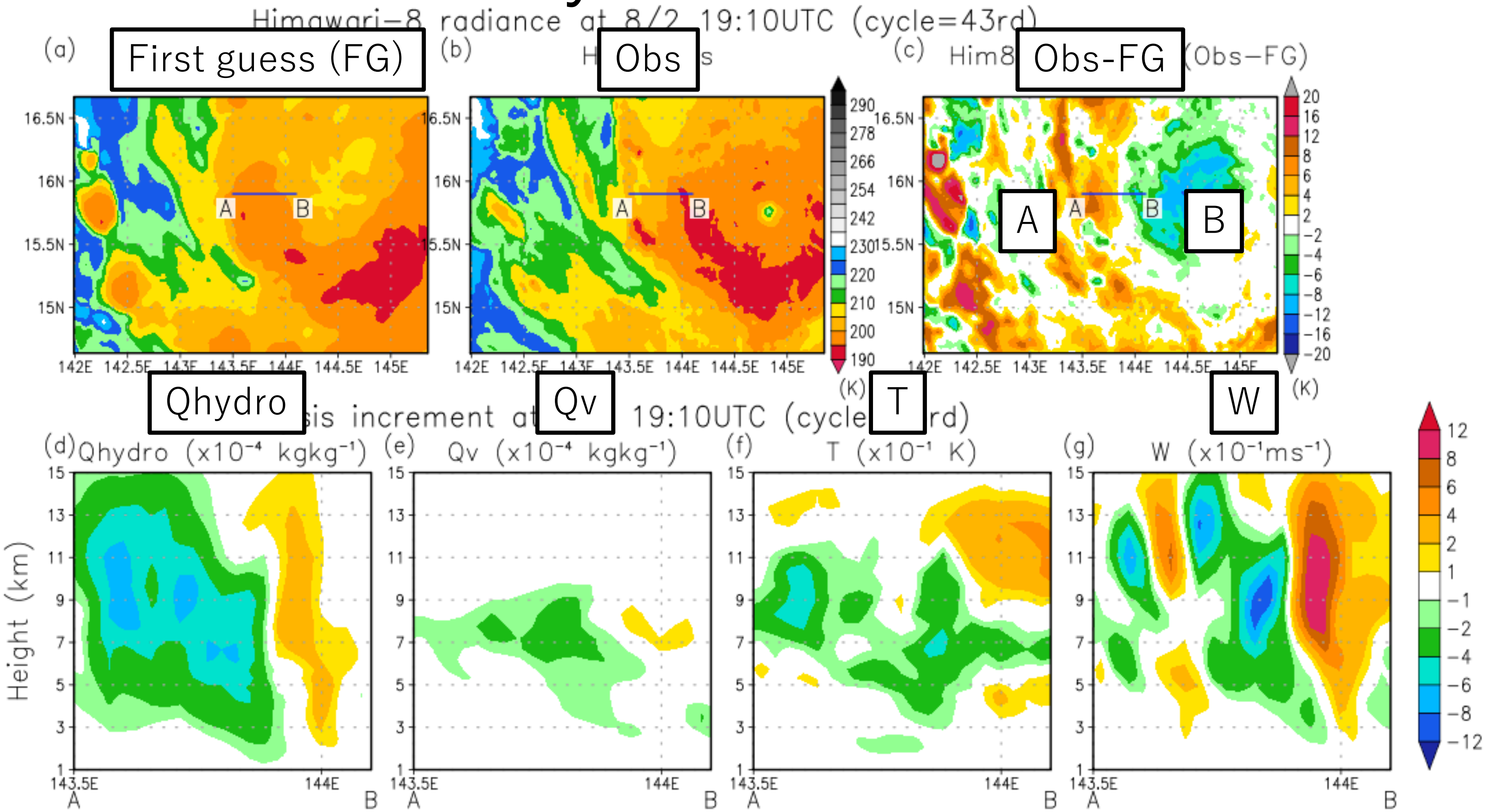
- Thinning out Himawari-8 obs into 0.20° x 0.20° .

Analysis (Him8 radiance)



Horizontal maps of Himawari-8 brightness temperature (K) of band 9 (6.9 μm).

Analysis increment



Analysis (Outer rainband)

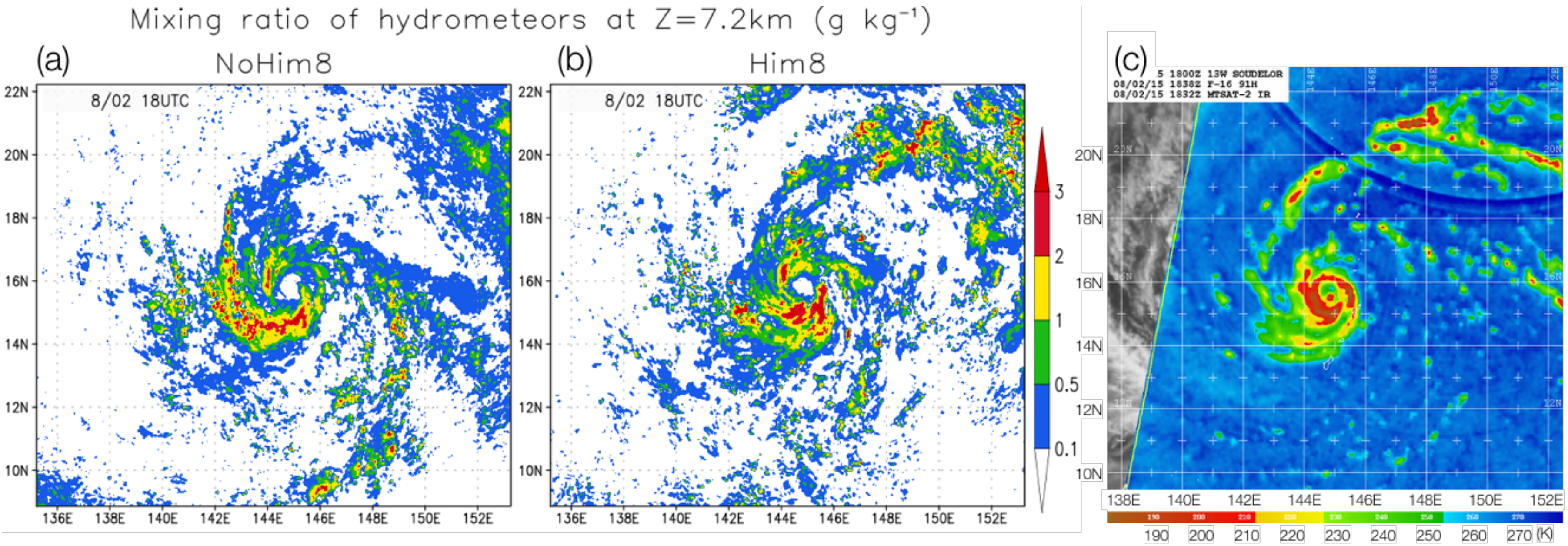
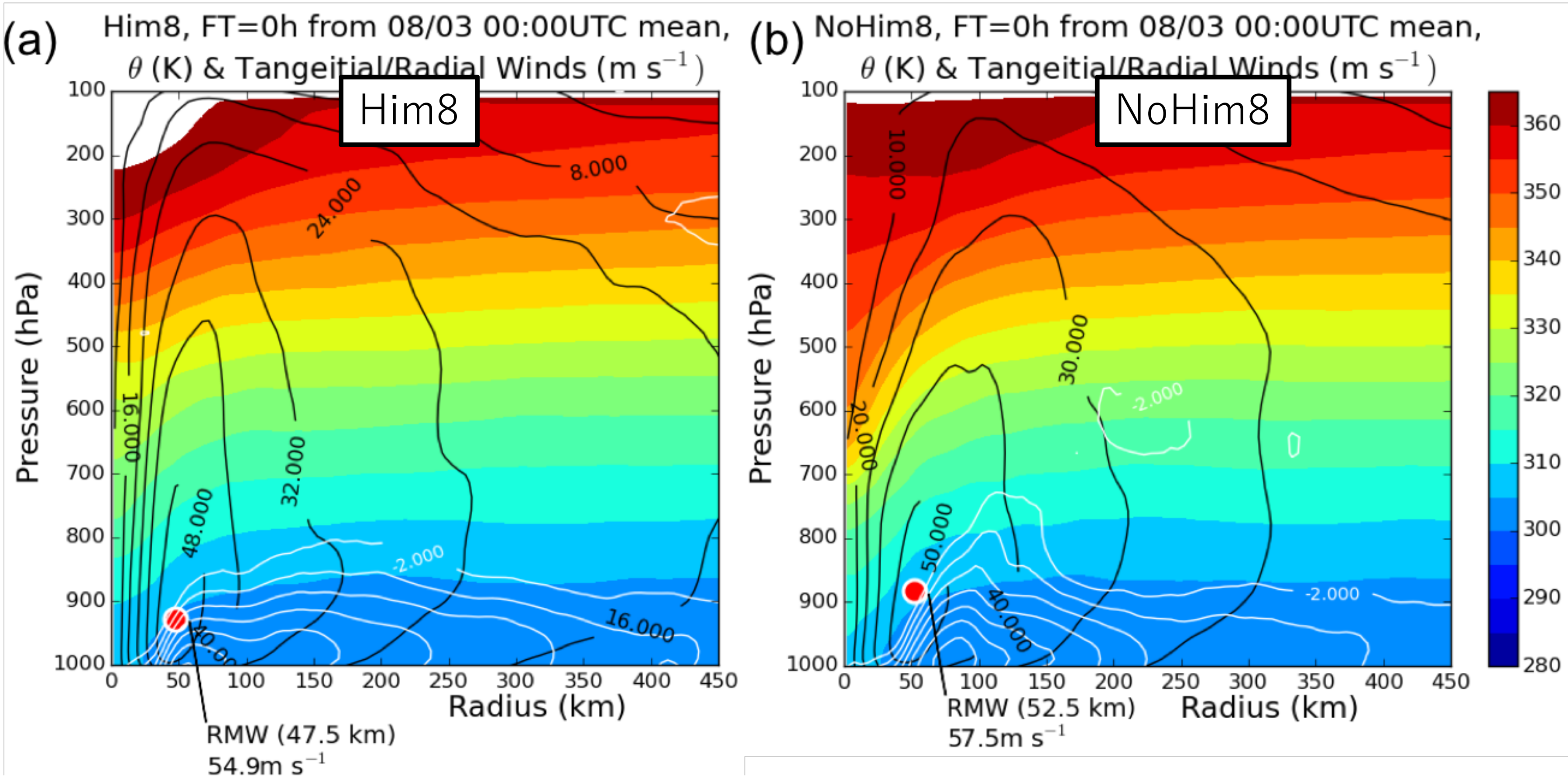


Fig. 4. (a),(b) Mixing ratio of hydrometeors (sum of cloud water, rain, cloud ice, snow, and graupel; g kg^{-1}) at Z = 7.2 km of the analysis ensemble mean in (a) NoHim8 and (b) Him8 at 1800 UTC 2 August. (c) Microwave satellite imagery (91h GHz on the Special Sensor Microwave Imager/Sounder (SSMIS) F16) at 1838 UTC 2 August, which is available online from the Naval Research Laboratory–Monterey at http://www.nrlmry.navy.mil/TC.html.

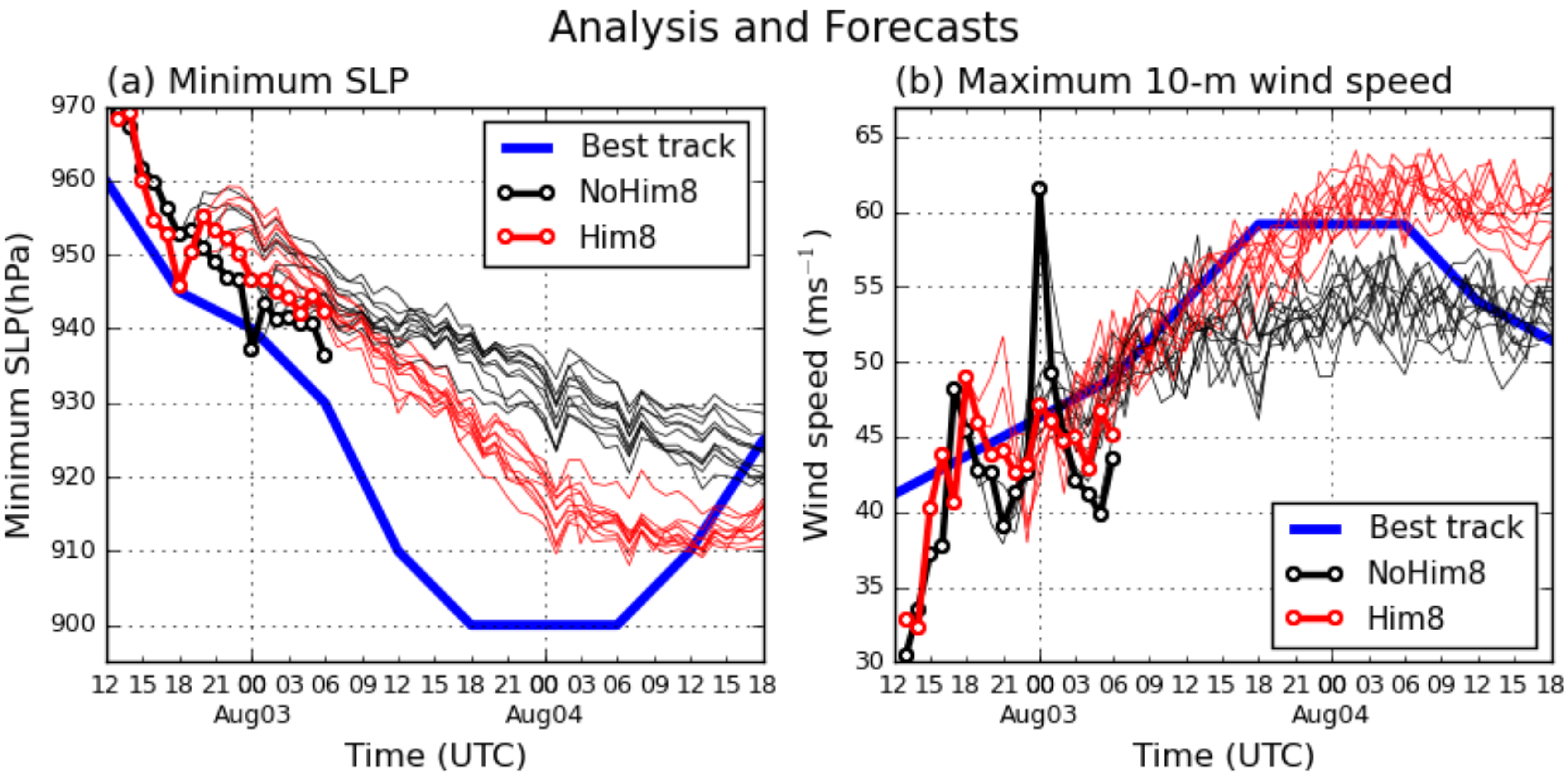
Analysis (TC center)



Colors: θ (K), black contours: tangential wind (m s^{-1}), white contours: radial wind (m s^{-1})

Azimuthally averaged structure of Typhoon Soudelor (2014) in (a) Him8 and (b) NoHim8, respectively.

TC intensity forecasts



Time series of (a) minimum sea level pressure (MSLP; hPa) and (b) maximum 10-m wind speed (m s^{-1}) of Soudelor.

Interpretation of the intensity forecasts

- Inner/warm cores
  - Zhang and Chen (2012GRL), Chen and Zhang (2013JAS)
  - Ohno et al. (2016JAS)
    - Steeper eyewall slopes
  - Miyamoto and Takemi (2015JAS)
    - Larger Rossby numbers

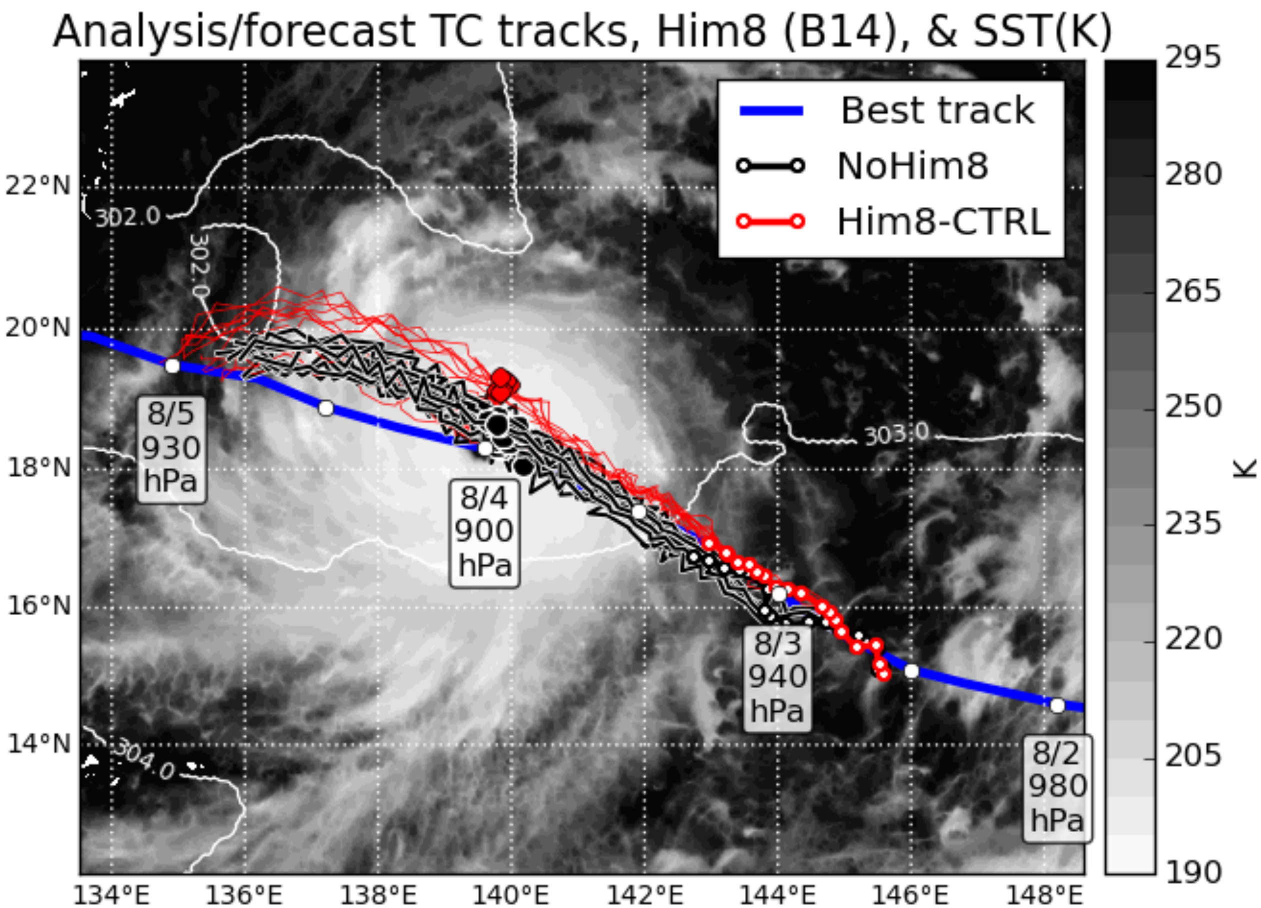
$$\mathrm{Ro} \equiv v_m/(\mathrm{RMW} \cdot f)$$

v_m: Maximum tangential velocity

f: Coriolis parameter

- Outer rainband
  - May and Holland (1999JAS)
- Track (SST) difference?

TC track forecasts

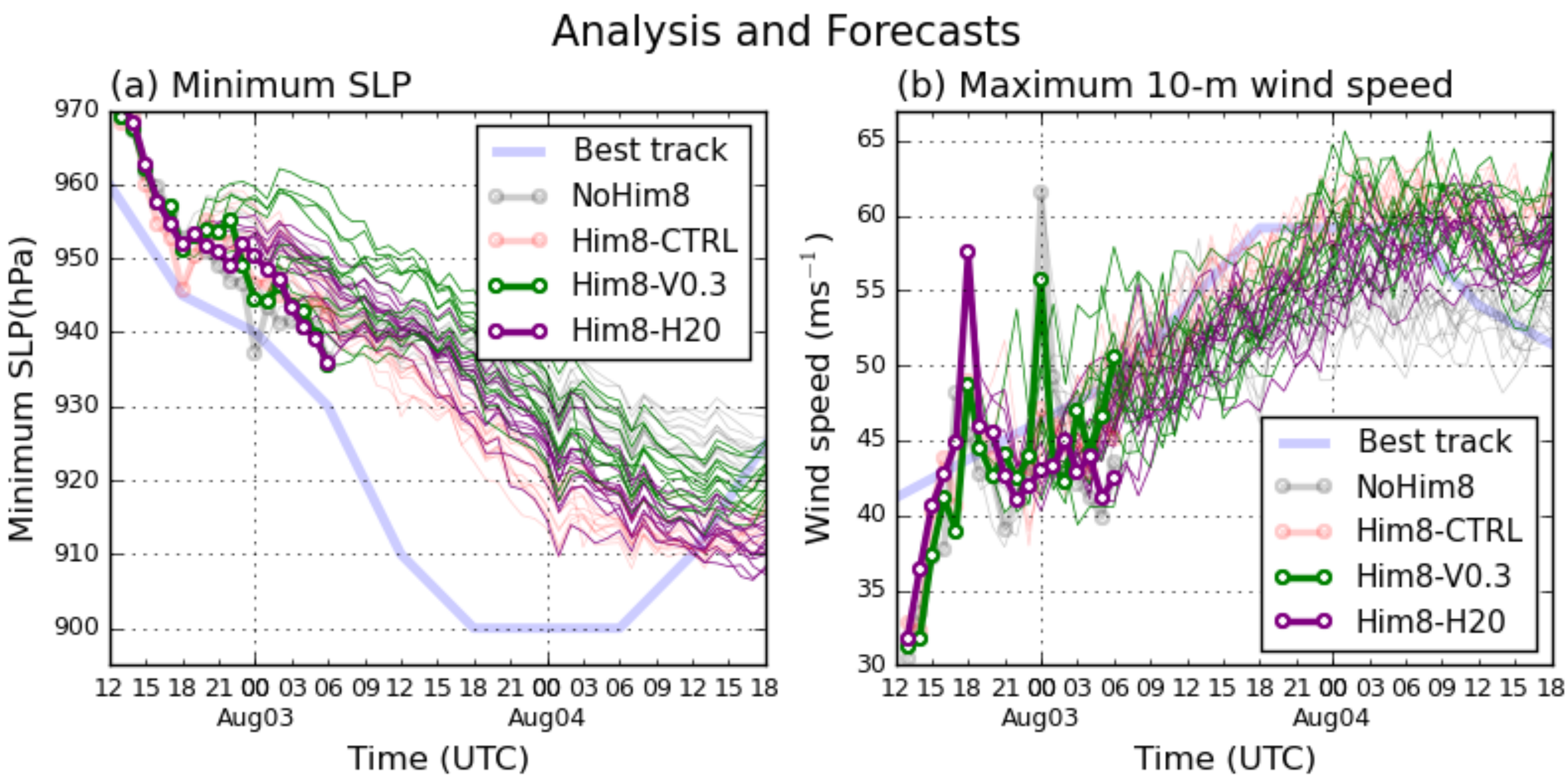


Horizontal map of the analysis and forecast TC tracks.

Additional experiments

Name	Himawari-8 DA	Horizontal/vertical localization scale for Himawari-8 observation
NoHim8	No	–
Him8-CTRL	Yes	50 km/0.5 ln *p*
Him8-v0.3	Yes	50 km/0.3 ln *p*
Him8-H20	Yes	20 km/0.5 ln *p*

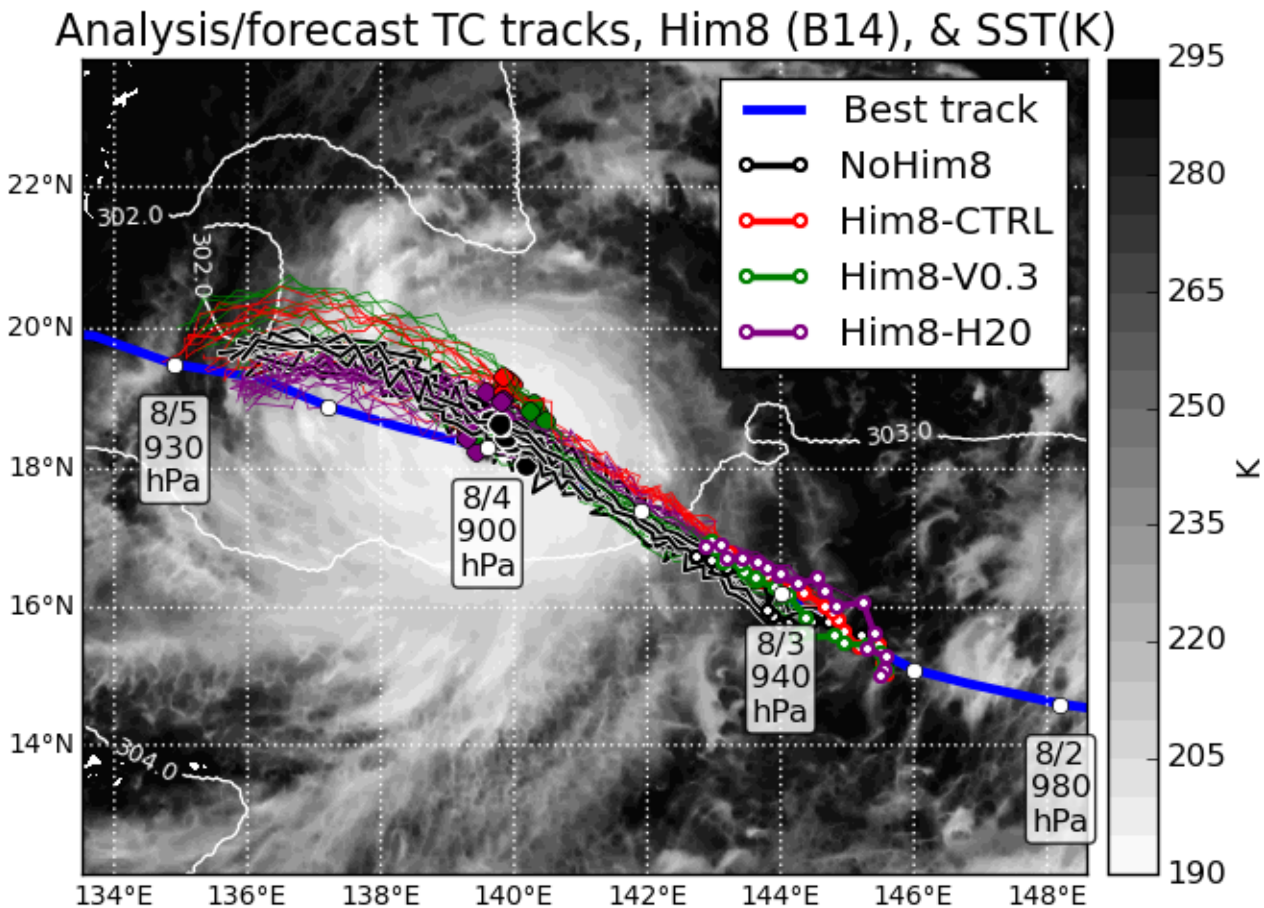
TC intensity forecasts



Time series of (a) minimum sea level pressure (MSLP; hPa) and (b) maximum 10-m wind speed (m s^{-1}) of Soudelor.

Him8-V0.3 is worse than Him8-CTRL(V0.5).

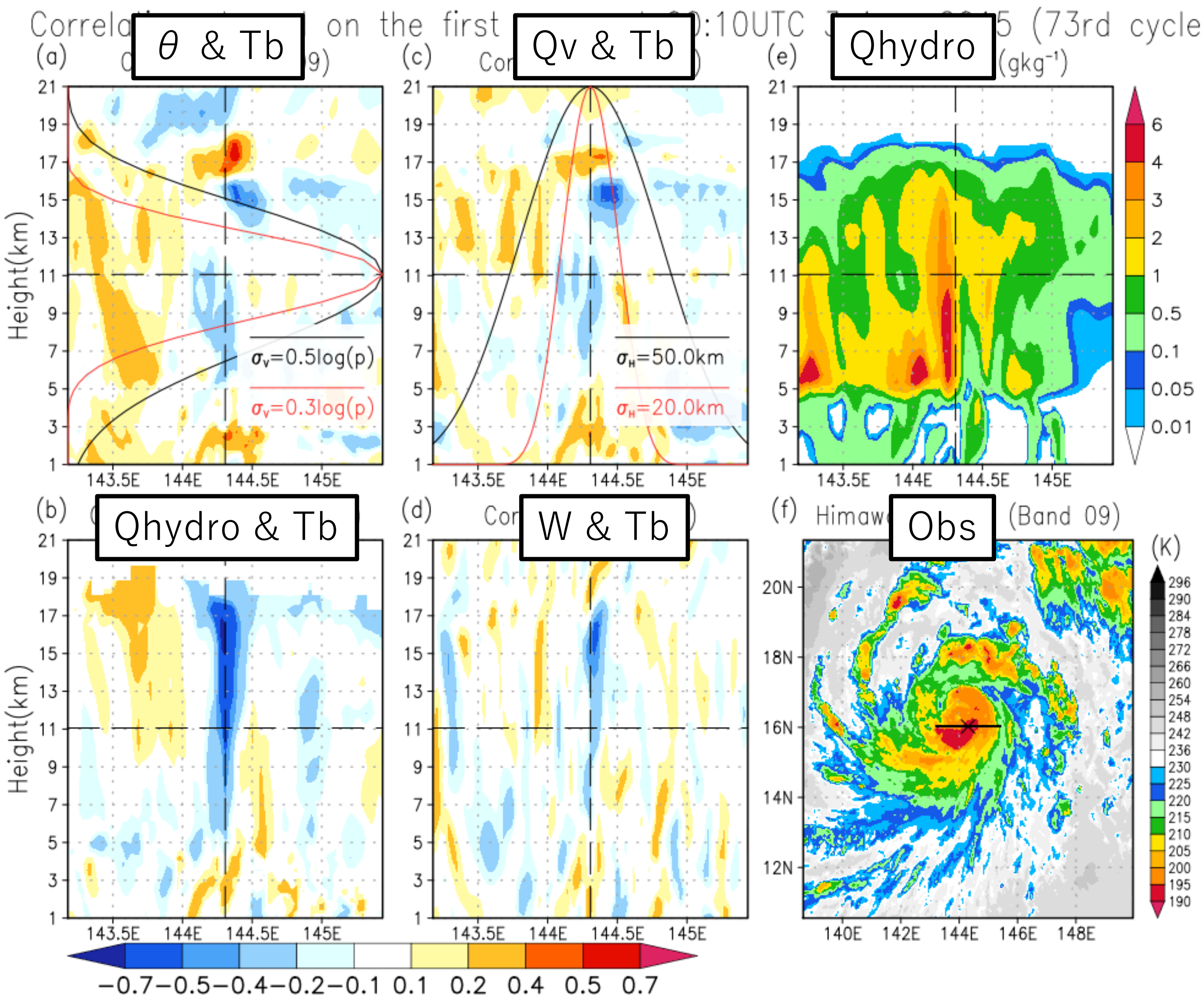
TC track forecasts



Horizontal map of the analysis and forecast TC tracks.

Him8-H20 is slightly better than Him8-CTRL(H20).

Correlation structure



Summary of the TC case

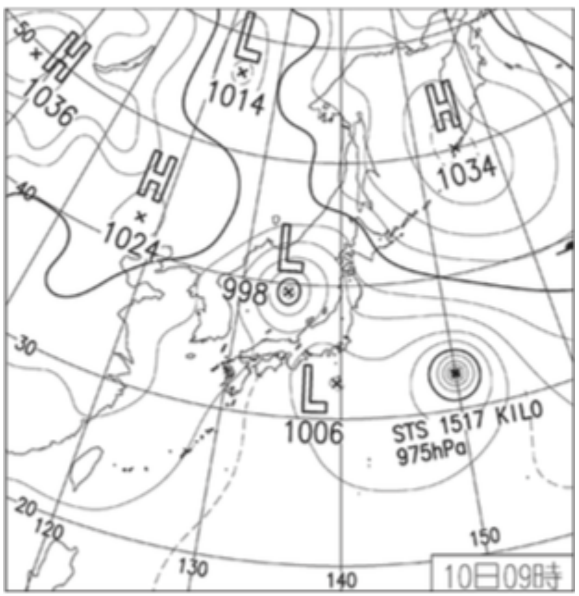
- We successfully assimilated all-sky Himawari-8 brightness temperature observation.

- The TC structure (both outer rainband and inner core) analysis and intensity forecasts were improved.

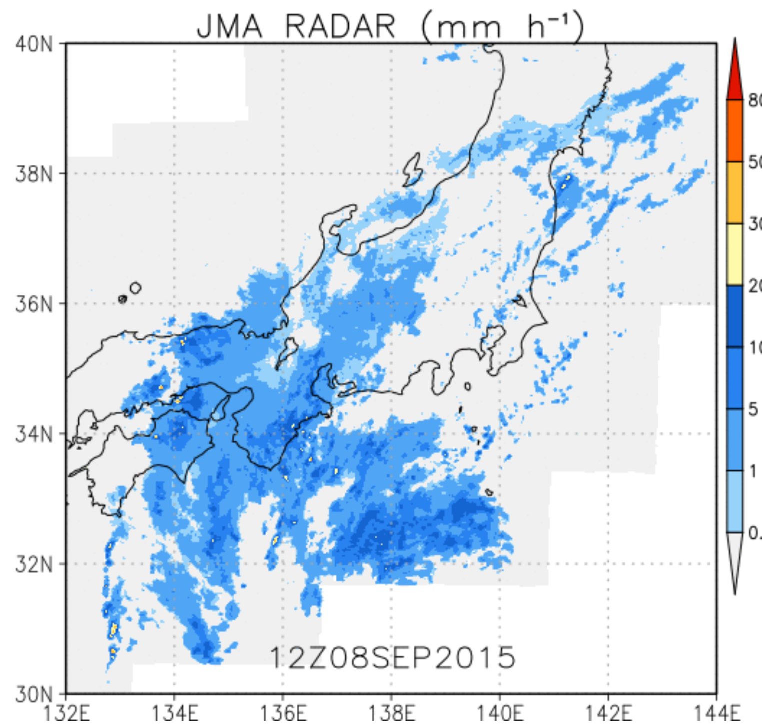
Contents

Goal

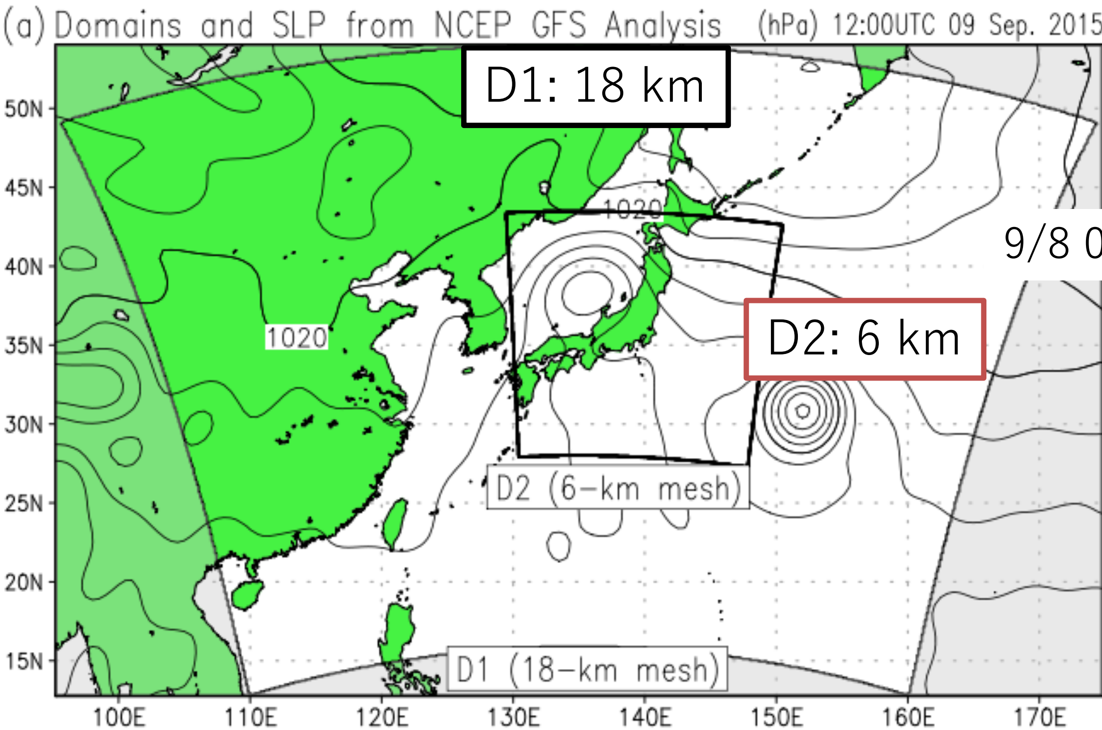
- To examine the impact of all-sky Himawari-8 DA on analyses and forecasts of Kanto-Tohoku heavy rainfall in 2015.

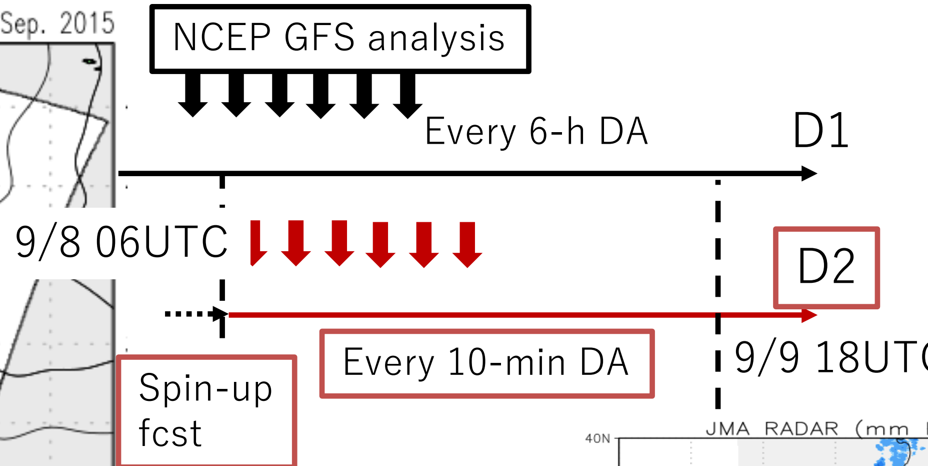


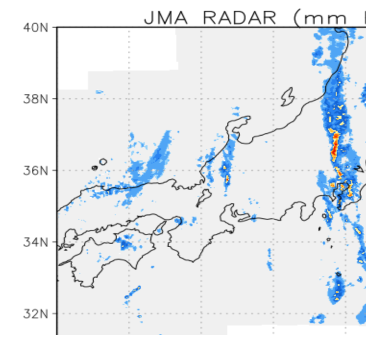
9/10 00UTC (After *Tenki*)



Experimental design





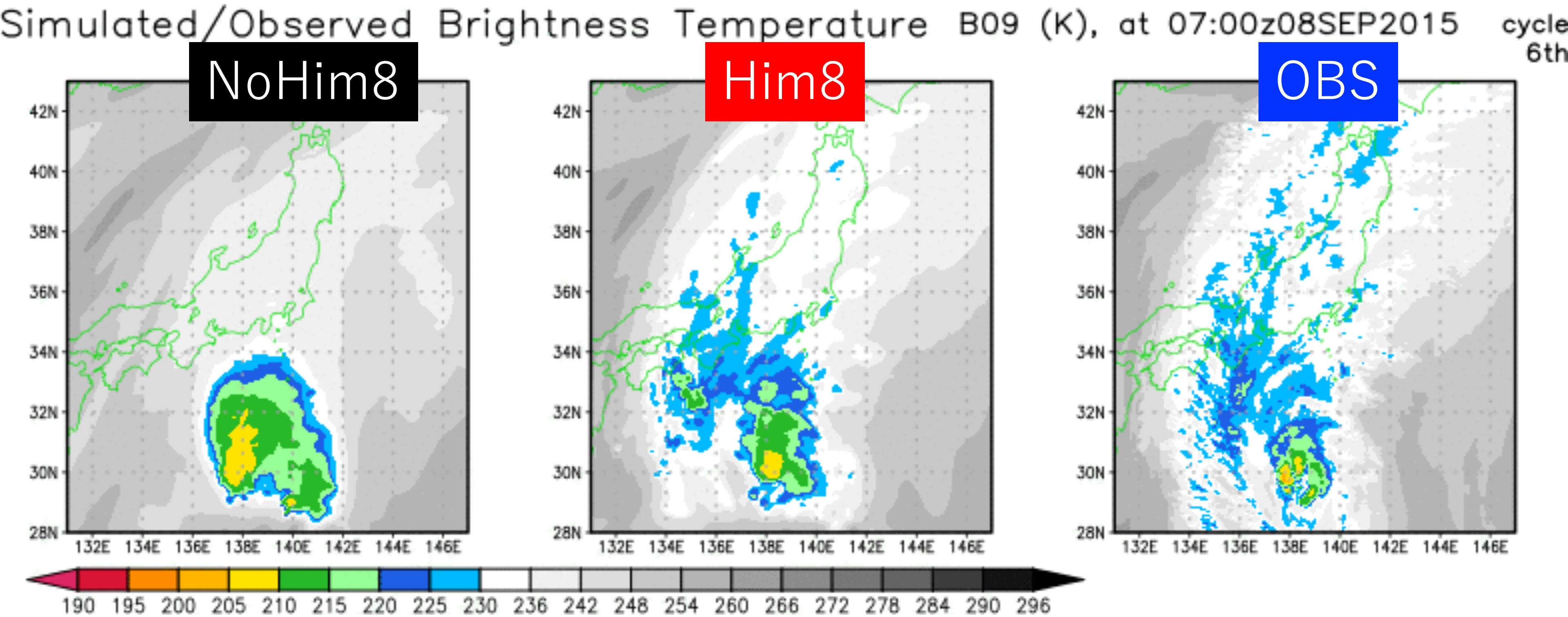


Ensemble size: 50 members

	D1 (18 km mesh)	D2 (6 km mesh)	
Obs	PREPBUFR (6 h)	NoHim8 PREPBUFR (10 min)	Him8 PREPBUFR (10 min), Himawari-8 **Band 9** (10 min)

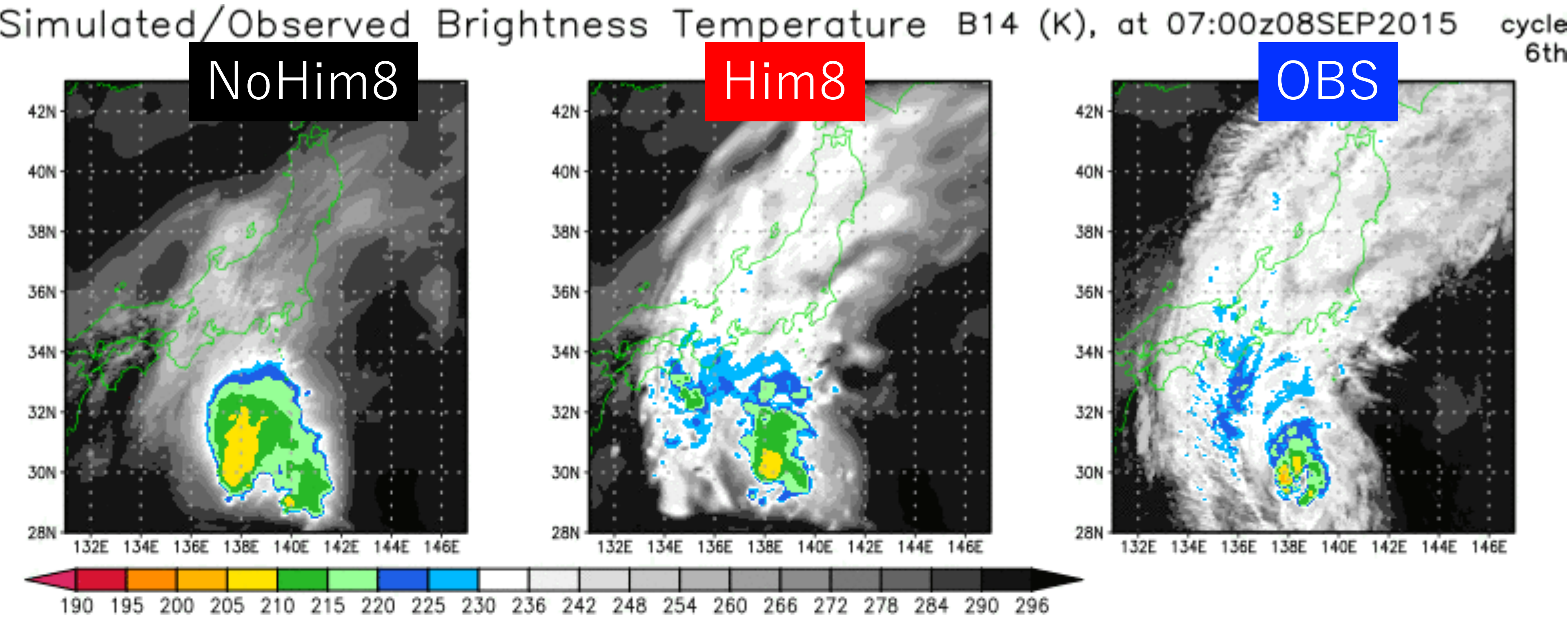
Analysis (Him8 radiance)

Directly assimilated band (B09, 6.9μm)

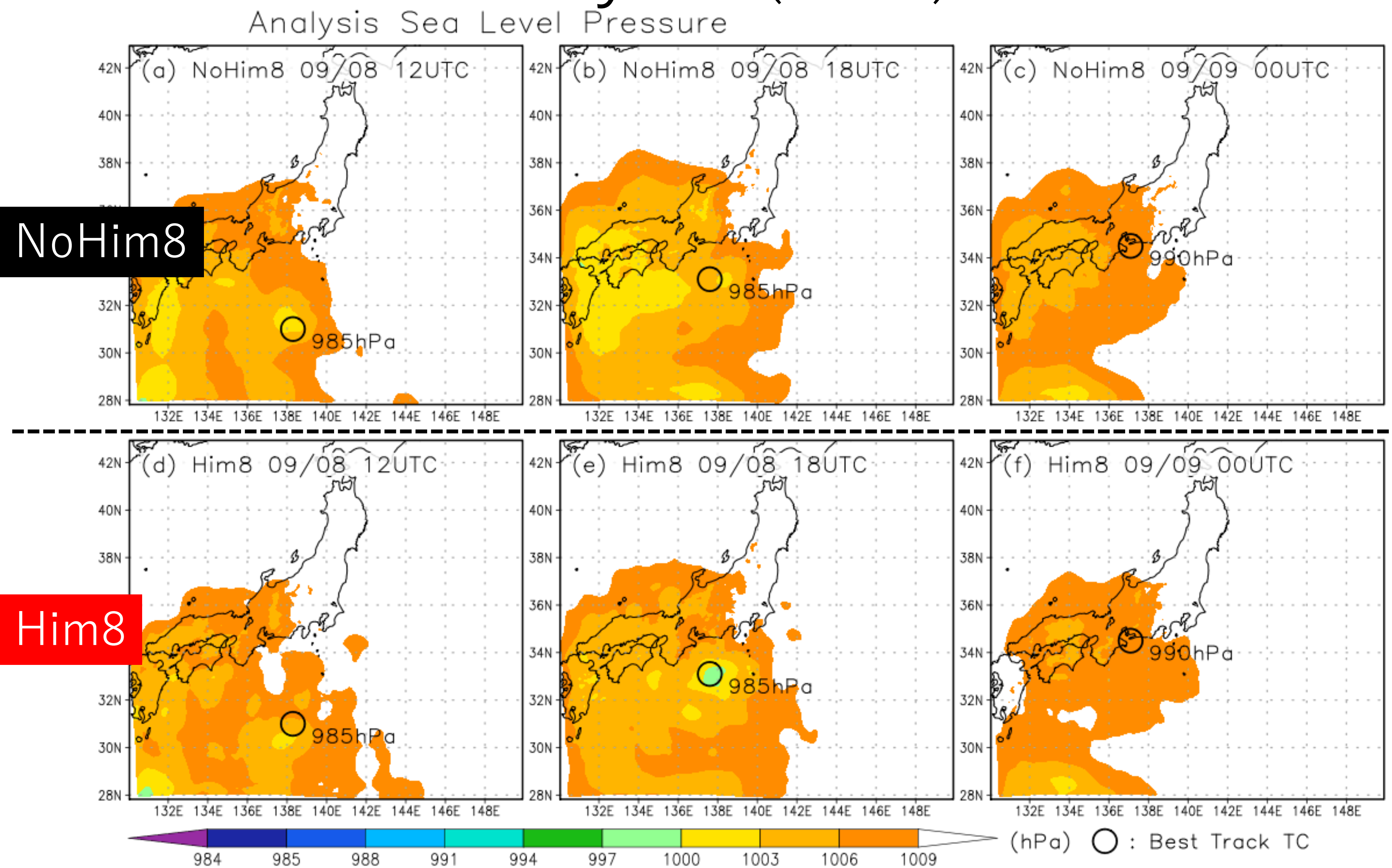


Analysis (Him8 radiance)

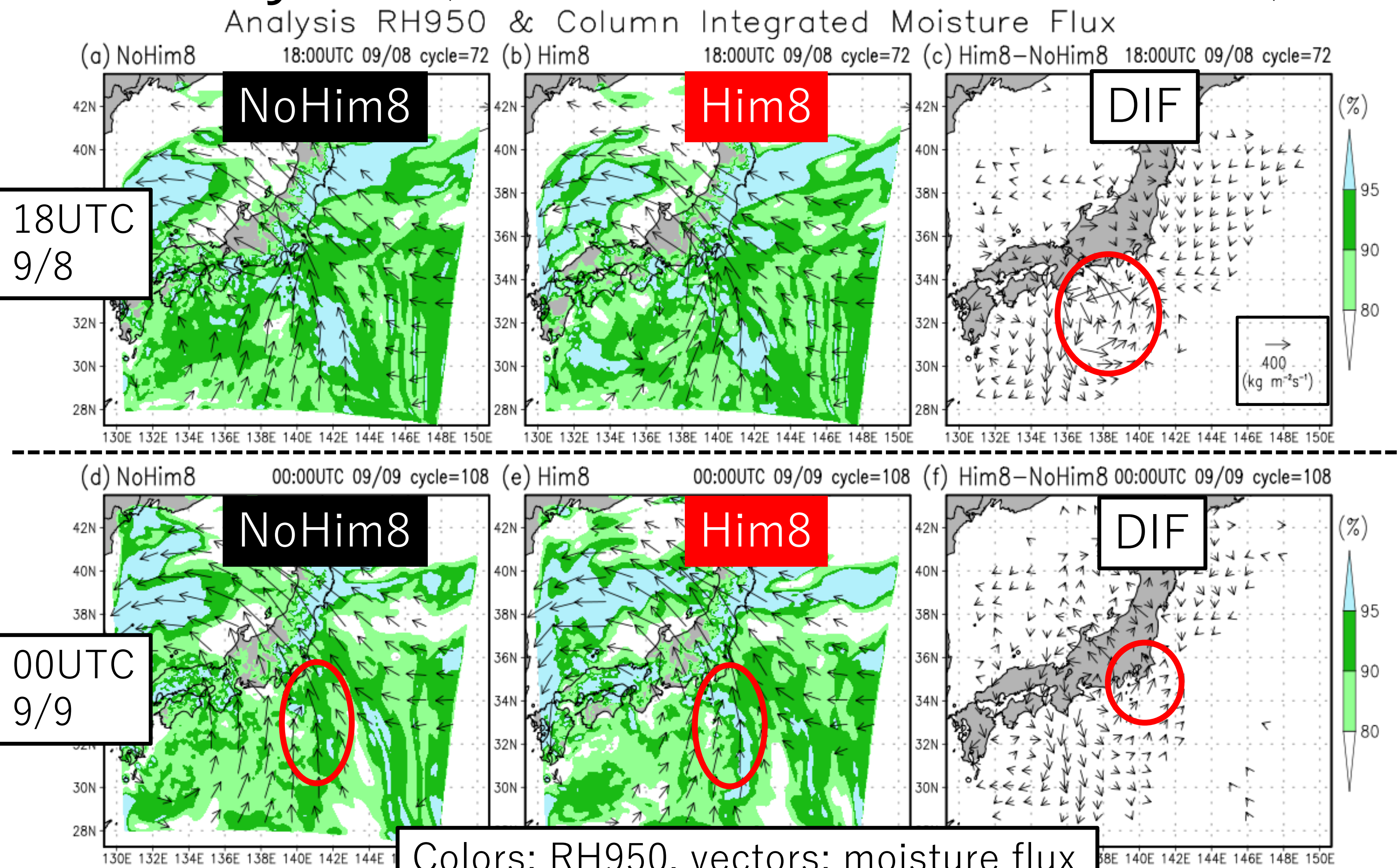
Not directly assimilated band (B14 , 11.2μm)



Analysis (SLP)



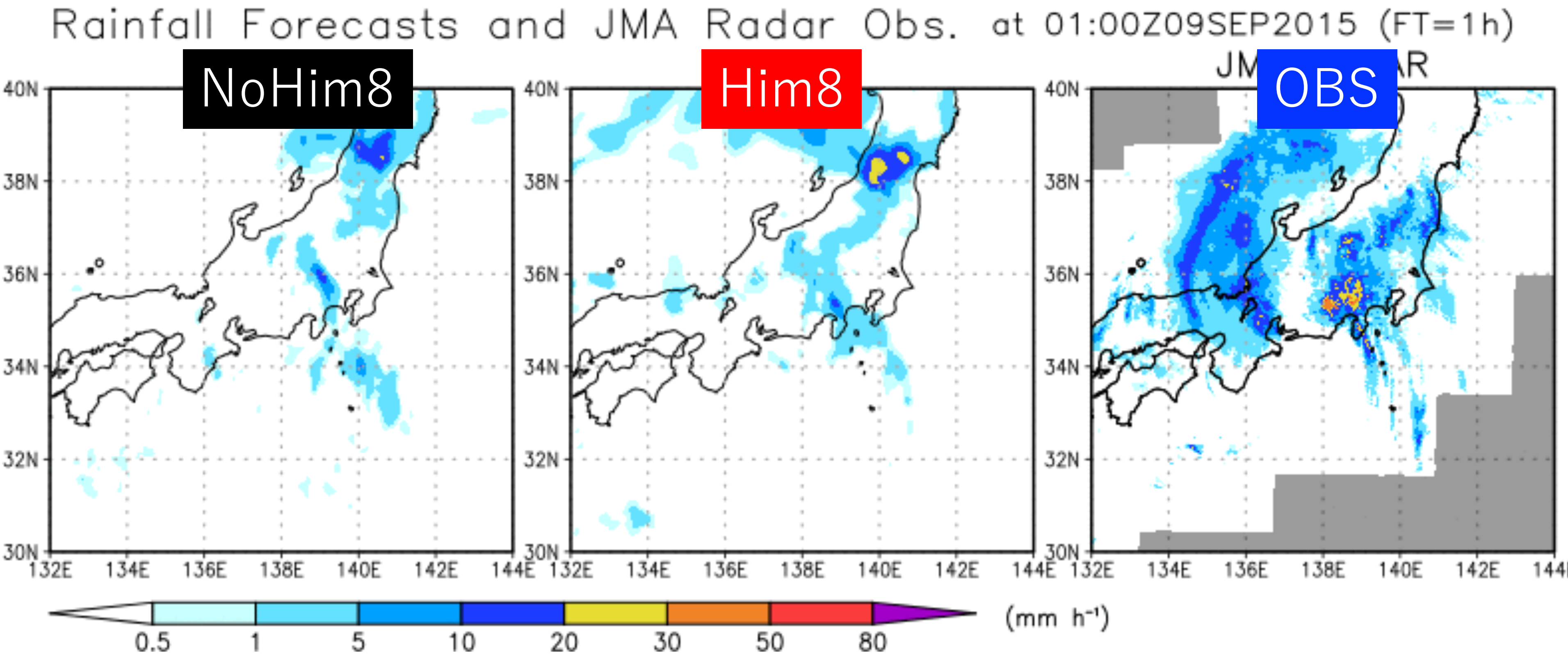
Analysis (RH950 & Moisture flux)



Colors: RH950, vectors: moisture flux

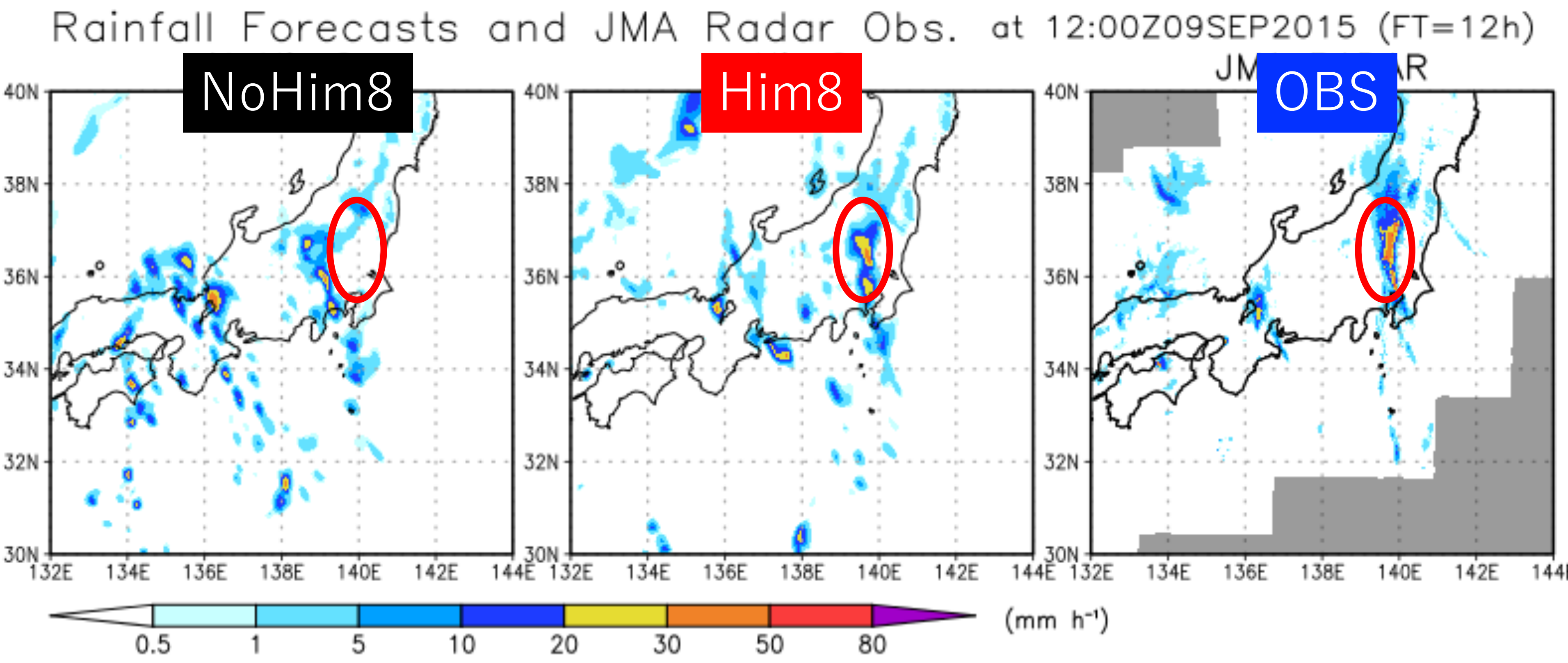
Precipitation forecast

Initialized at 9/9 00UTC (ensemble mean)



Precipitation forecast

Initialized at 9/9 00UTC (ensemble mean)



Summary of Kanto-Tohoku rainfall

We assimilated all-sky Himawari-8 obs with the SCALE-LETKF system.

- Moisture transport was improved.

- Precipitation forecast was greatly improved due to Him8 data.

Future works

- Dynamic observation error (Okamoto et al. 2014QJRMS; Harnisch et al., 2016QJRMS)
- Bias correction
- Vertical localization in cloudy sky