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Data Assimilation at KIAPS and plans for use of TROPICS observations

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(*Korea Institute of Atmospheric Prediction Systems*)

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1. Introduction to KIAPS

KIAPS and KMA

기상청
Korea Meteorological Administration

Develops NWP systems for KMA

Cooperation with KMA to improve NWP system

3 R&D groups...

Founder and overall manager of KIAPS

Operates NWP systems produced by KIAPS

Numerical Modeling Group

Data Assimilation Group

- Observation Processing Team
- DA Techniques Team
- DA Diagnostics Team

Operational System Group

KIAPS timeline

KIAPS

Feb 2011 — First KIAPS project established by KMA.

Mission

- Develop an atmosphere-only global NWP system for KMA.

Apr 2019 – End 2019 — KIM (Korean Integrated Model) global NWP system made operational at KMA.

Sep 2020 — Second KIAPS project established by KMA.

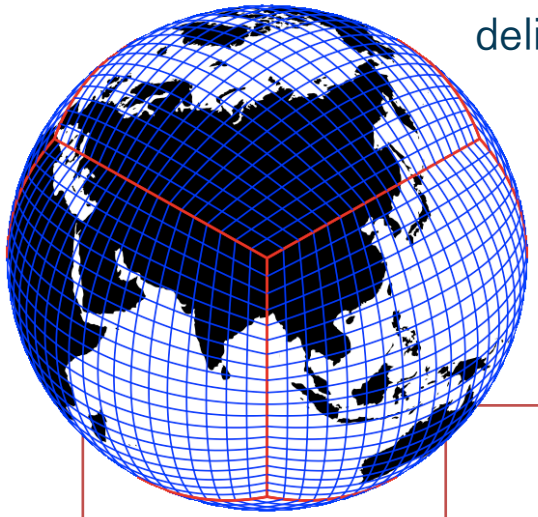
Mission

- Cover 30-day range, with an Earth system model.
- Also support high-resolution NWP over East Asia.

End 2026

KIAPS and KIM

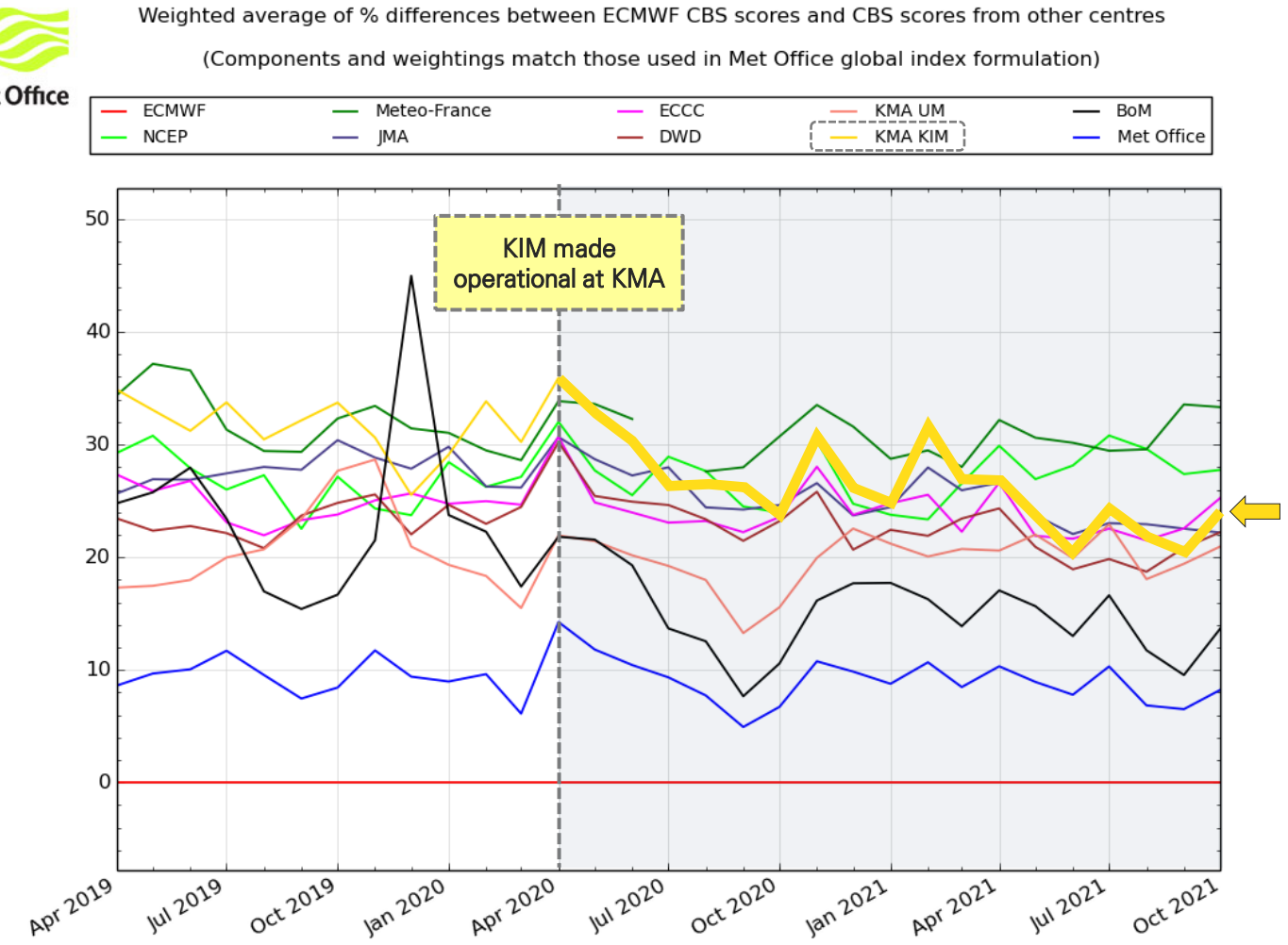
The **Korea Institute of Atmospheric Prediction Systems (KIAPS)** delivered the global NWP system to the Korea Meteorological Administration (KMA)



KIM: Korean Integrated Model
Cubed sphere grid structure global model
Horizontal resolution: NE360NP3 ~ 12km
Vertical resolution: 91 levels with 1 Pa top

	Dynamics	Physics
Numerical method	Spectral Element method	RRTMG-K (Baek 2017) Noah LSM (Koo et al. 2017) Scale-aware PBL (Shin & Hong 2015) Scale-aware CPS (KIAPS-SAS) (Han and Pan 2011, Kwon and Hong 2017) Adjustment SCV (Hong et al. 2013) WSM5 MPS (Hong et al. 2004) Prognostic cloud (Park et al. 2015)
Spherical grid	Cubed-sphere (Equi-angular gnomonic projection)	
Equation	Non-hydrostatic (Perturbation form)	
Temporal approximation	Split-explicit RK3, second-order for nonlinear equation	
Explicit spatial diffusion	6^{th} order horizontal diffusion + divergence damping	

Operational system: Performance



Plot produced using Met Office software, with permission

Weighted RMSE %age differences relative to ECMWF

$$\sum_{\text{component (c)}} \left(\frac{\text{RMSE} - \text{RMSE}_{\text{ECMWF}}}{\text{RMSE}_{\text{ECMWF}}} \right) \times w_c$$

where $\sum_c w_c = 100$

Component weights w_c

Area	Parameter	Forecast range				
		T+24	T+48	T+72	T+96	T+120
NH	PMSL	6.4	6.4	6.4	6.4	6.4
	500 hPa GPH	2.4	2.4	2.4	2.4	2.4
	250 hPa Wind	2.4	2.4	2.4	2.4	2.4
TR	850 hPa Wind	2.0	2.0	2.0	2.0	2.0
	250 hPa Wind	1.2	1.2	1.2	1.2	1.2
SH	PMSL	3.2	3.2	3.2	3.2	3.2
	500 hPa GPH	1.2	1.2	1.2	1.2	1.2
	250 hPa Wind	1.2	1.2	1.2	1.2	1.2

- Verification against own analyses
- 1.5° x 1.5° verification grid

Aims of the second KIAPS project

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Project period: Late 2020 – end 2026.

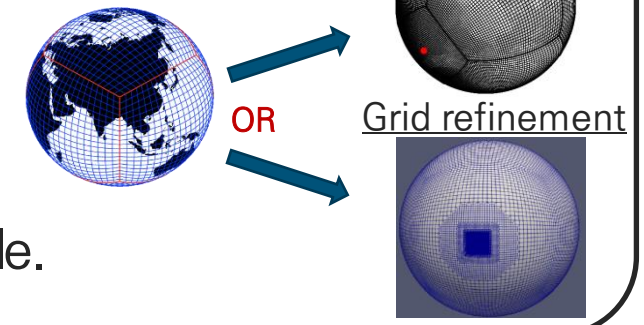
Unified framework for seamless prediction from very short range (~6 hours) to extended medium range (~30 days)

Coupling to various Earth system components

Original plan:

Single, integrated NWP system

- Earth system including convection permitting scale
- Grid refinement
- Hourly atmospheric DA cycle.



- Expansion of observation usage
- Variable resolution grids
- Scale-aware physics
- Big size ensemble
- Coupled with various Earth components

Target models and DA cycles

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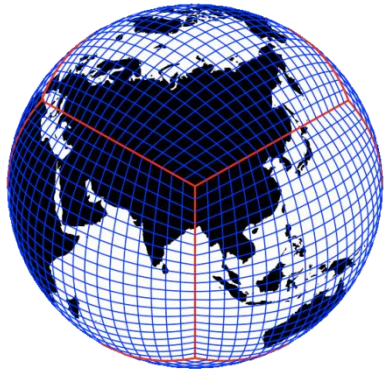
Revised plan:

Main global system

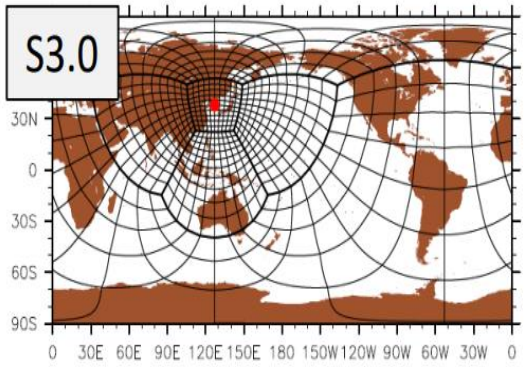
- Atmosphere – land – sea ice – ocean – aerosol model.
- Quasi-uniform grid. Deterministic ~8 km; Ensemble ~15 km.
- DA methods: Up to 200-member LETKF; hybrid-4DEnVar.
- 6-hourly (or maybe 3-hourly) DA cycle, with 6-hour windows.



+

Short-range, high-resolution system for East Asia

- Atmosphere – land model.
- Extreme grid refinement: ~3-5 km over East Asia.
- DA methods: LETKF. Merge larger scales from main system.
- 1-hourly DA cycle, with 1-hour windows. (Focus on radar DA.)



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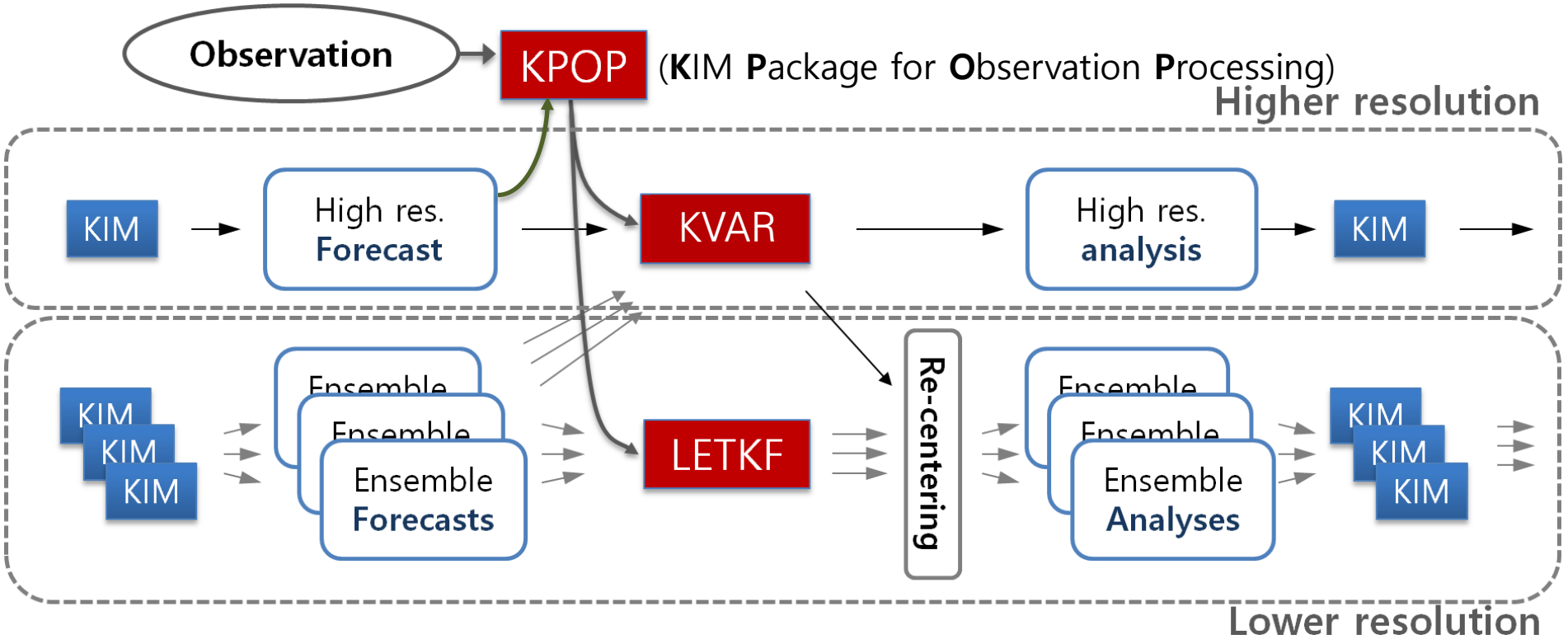
II. KIAPS DA system and experience with 183 GHz all-sky radiances

Hybrid-4DEnVar (H4DEV)

- Adds (hourly) 4D ensemble covariance to 3DVAR-FGAT
- Ensemble forecasts provided by LETKF-based EPS
- **Alpha control variable** used to introduce and localize ensemble covariance



KIM resolution (NE360NP3 ~ 12 km)
Ensemble resolution (NE144NP3 ~ 32 km), 50 members
Analysis resolution (NE144NP3 ~ 32 km)

Ensemble B fraction:
0.7 near tropics,
0.3 near poles

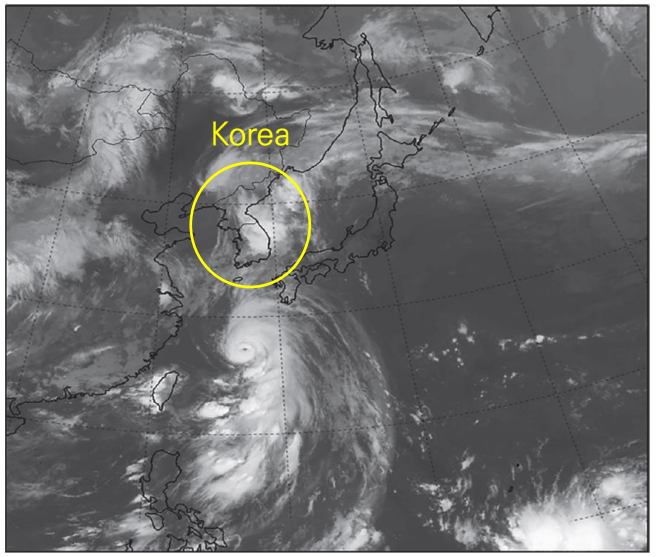
Observation usage in KIAPS

Observation type		ECMWF	KIAPS	Observation type		ECMWF	KIAPS
1	SONDE	○	○	2	ATMS	○	○
3	SURFACE	○	○	4	AMV	○	○
5	AIRCRAFT	○	○	6	GPS-RO	○	○
7	SCATWIND	○	○	8	Geo. Radiance	MeteoSat, Himawari, GOES,	MeteoSat Himawari GOES, GK2A
9	AMSU-A	○	○	10	SSMIS	○	○
11	MHS	○	○	12	TC bogus	×	○
13	IASI	○	○	14	AMSR2	○	○
15	CrIS	○	○	16	MT-SAPHIR	○	○
17	AIRS[1]	○	×	18	MWHS2	○	○
19	ALADIN	○	○	20	GMI	○	×
21	Ground GNSS	○	△	22	Ozone	○	×

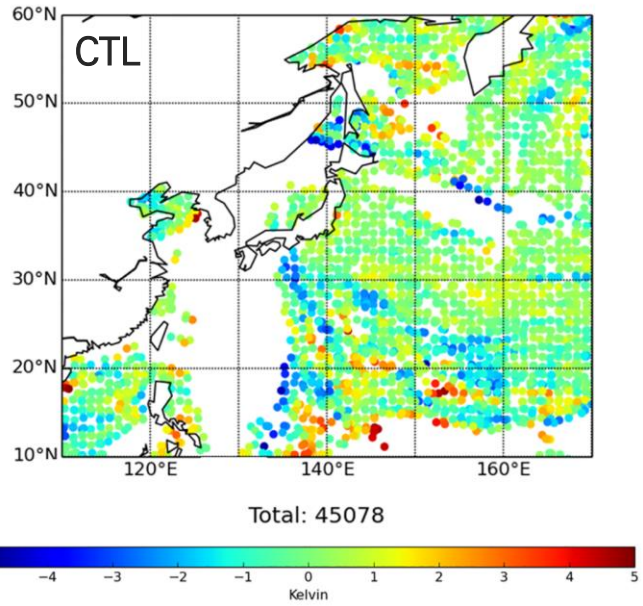
SCATWIND: Scatterometer wind
HIRS: High-resolution Infrared Radiation Sounder
AMSU-A: Advanced Microwave Sounding Unit-A
MHS: Microwave Humidity Sounder
AIRS: Atmospheric Infrared Sounder
IASI: Infrared Atmospheric Sounding Interferometer
AMSR2: Advanced Microwave Scanning Radiometer 2
ALADIN: Atmospheric LAser Doppler INstrument
CrIS: Cross-track Infrared Sounder
ATMS: Advanced Technology Microwave Sounder
AMV: Atmospheric Motion Vector
GPS-RO: GPS Radio occultation
CSR: Clear Sky Radiance
SSMIS: Special Sensor Microwave Imager Sounder
MWHS2: MicroWave Humidity Sounder 2
GMI: GPM Microwave Imager
MT-SAPHIR: Megha Tropiques - Sounder Atmospherique de Profil d'Humidite Intertropical par Radiometrie

Experience with 183 GHz all-sky radiances (1)

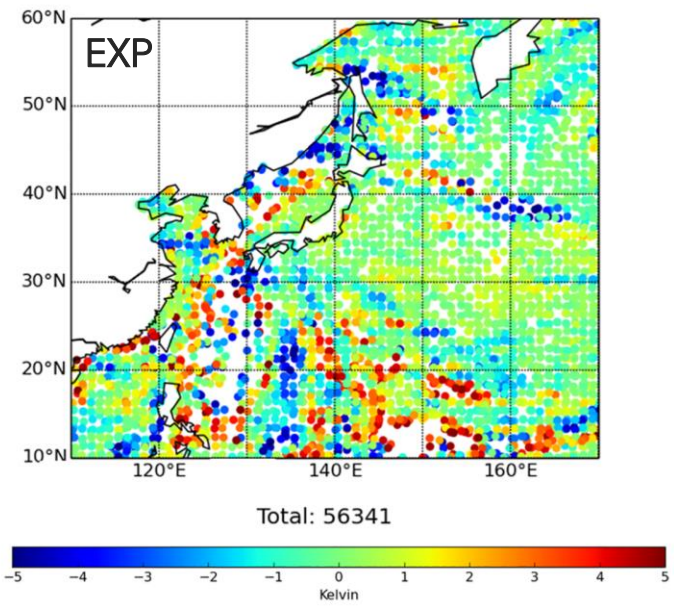
COMS IR (10.8 um) @ 2018070200



MHS ch05: O-B @ 2018070200



MHS ch05: O-B @ 2018070200



E.g., Tropical cyclone

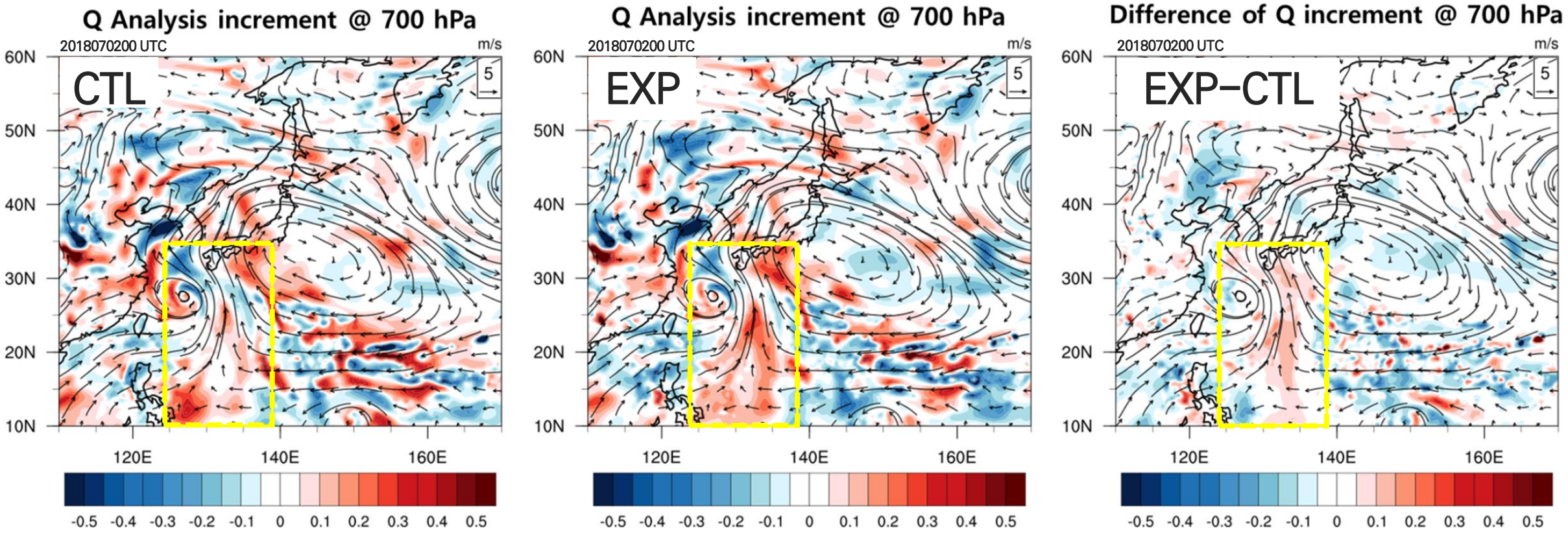
A frontal system extending parallel to and along most of the length of Japan was present, and a tropical cyclone (*Prapiroon*) moved northwestward from the western Pacific.

CTL (clear-sky MHS assimilation) shows void regions around convection areas, while EXP (all-sky MHS assimilation) provides O-B results over the East Asian basin.

Based on a comparison of the observation coverage for the frontal convection, the strength of the convection clusters over Japan was expected to be more correct in the all-sky experiment.

Lee et al. (QJRMS, 2020)

Experience with 183 GHz all-sky radiances (2)



The moisture advection over Japan is strong in both the CTL and EXP. Specifically, northward moisture advection is strong at the eastern area of tropical cyclone.

The EXP provides more humid conditions relative to the CTL. This moisture advection may enhance the pre-existing convection clusters over Japan.

Lee et al. (QJRMS, 2020)

Experience with 183 GHz all-sky radiances (3)

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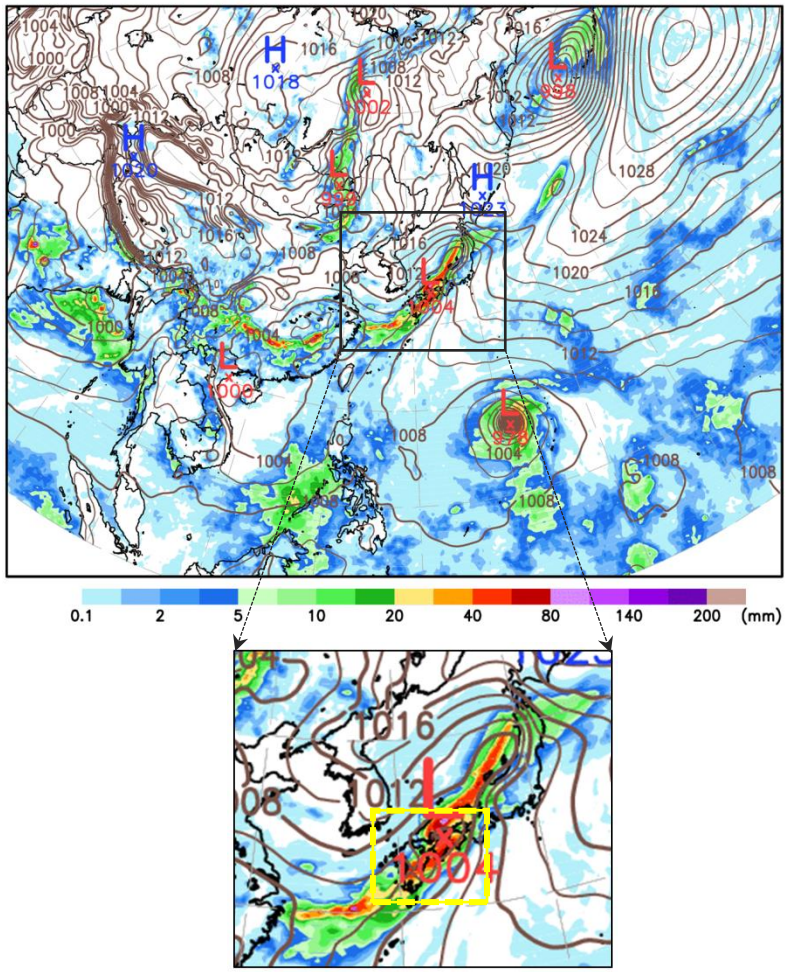
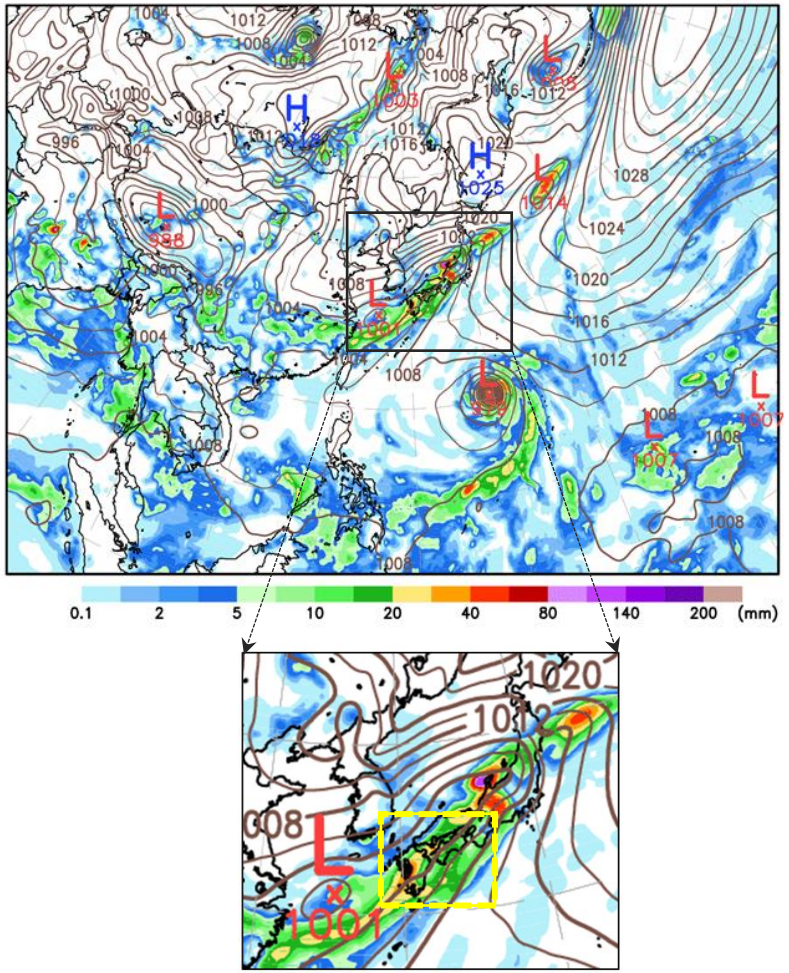
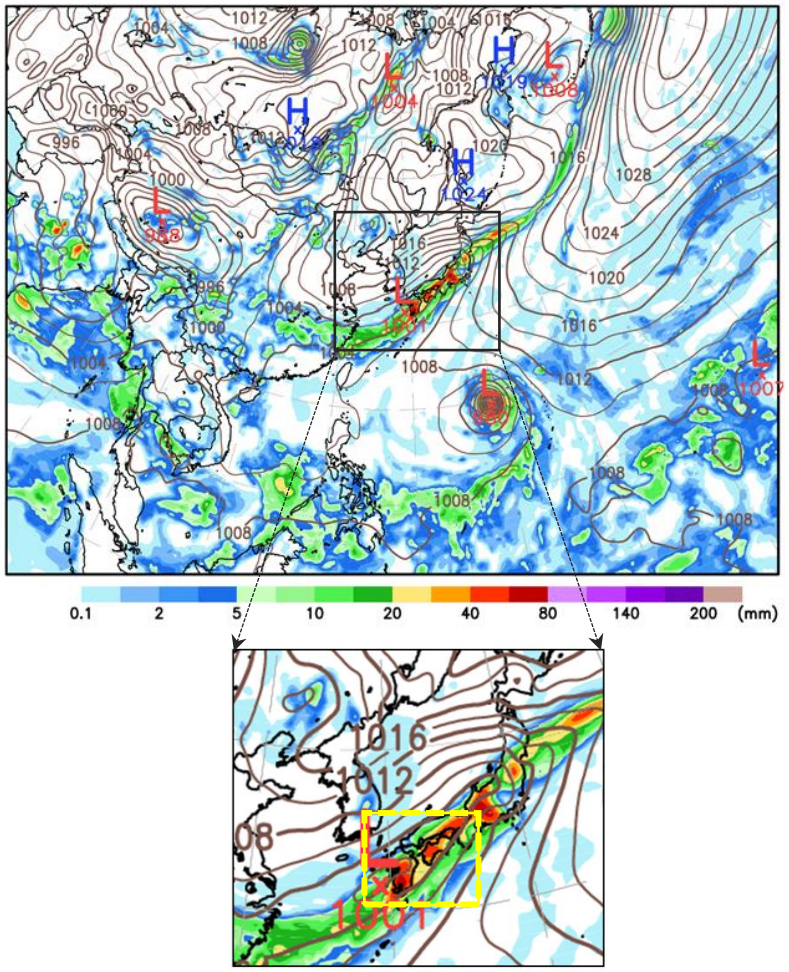
ECMWF: 2018070700 (12-hr forecast)



CTL: 2018070700 (120-hr forecast)



EXP: 2018070700 (120-hr forecast)



The deviations in precipitation over the southwestern part of Japan between the CTL and EXP forecasts are apparent.
The 120-hr forecast of the CTL loses information regarding the heavy rainfall over the region.

* The solid line represents sea level pressure (hPa) and the colour shading represents the 6-hr accumulated precipitation (mm).

Lee et al. (QJRMS, 2020)

Observation operator for all-sky assimilation

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RTTOV-SCATT v13 hydrometeors	KIM hydrometeors
hydro_frac(1) : nlevels of cloud cover (0-1)	cld : cloud fraction in atmosphere layer (0-1)
hydro(1) : nlevels of rain (kg/kg)	tqr : rain water content from mps*, cps** and scv*** (kg/kg)
hydro(2) : nlevels of frozen precipitation (kg/kg)	tqs : snow content from mps, cps and scv (kg/kg)
hydro(3) : nlevels of graupel (kg/kg)	qg : graupel content from mps (kg/kg) → 0.0
hydro(4) : nlevels of liquid water (kg/kg)	tqc : cloud liquid water from mps, cps and scv (kg/kg)
hydro(5) : nlevels of ice water (kg/kg)	tqi : cloud ice content from mps, cps and scv (kg/kg)

*mps : microphysical scheme (grid-scale, prognostic)
**cps : convective parameterization scheme (subgrid-scale, diagnostic)
***scv : shallow-convection parameterization scheme (subgrid-scale, diagnostic)

https://nwp-saf.eumetsat.int/site/software/rttov/download/coefficients/rttov-v13-coefficient-download/#MW_optical_depth_coefs_and_RTTOV-SCATT_optical_properties

- **Rain** : Mie sphere, Marshall-Palmer size distribution (unchanged since latest v12 Mietables)
- **Snow** : ARTS large plate aggregate, Field07 tropical size distribution (updated for v13)
- **Graupel** : ARTS column, Field07 tropical size distribution (new in v13)
- **Cloud liquid** : Mie sphere, Gamma size distribution implemented within the new modified gamma framework (mostly unchanged in terms of optical properties, but with small differences from the previous gamma distribution, which was implemented internally using some scientific shortcuts)
- **Cloud ice** : ARTS large column aggregate, Gamma PSD with generalised modified gamma parameters mu = 0, lambda = 1e4, gamma = 1 and N0 free (updated for v13)

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III. TROPICS Pathfinder evaluation and plans for use of TROPICS observations

Observed TB @ 2021080818

* Observations w/o bias correction

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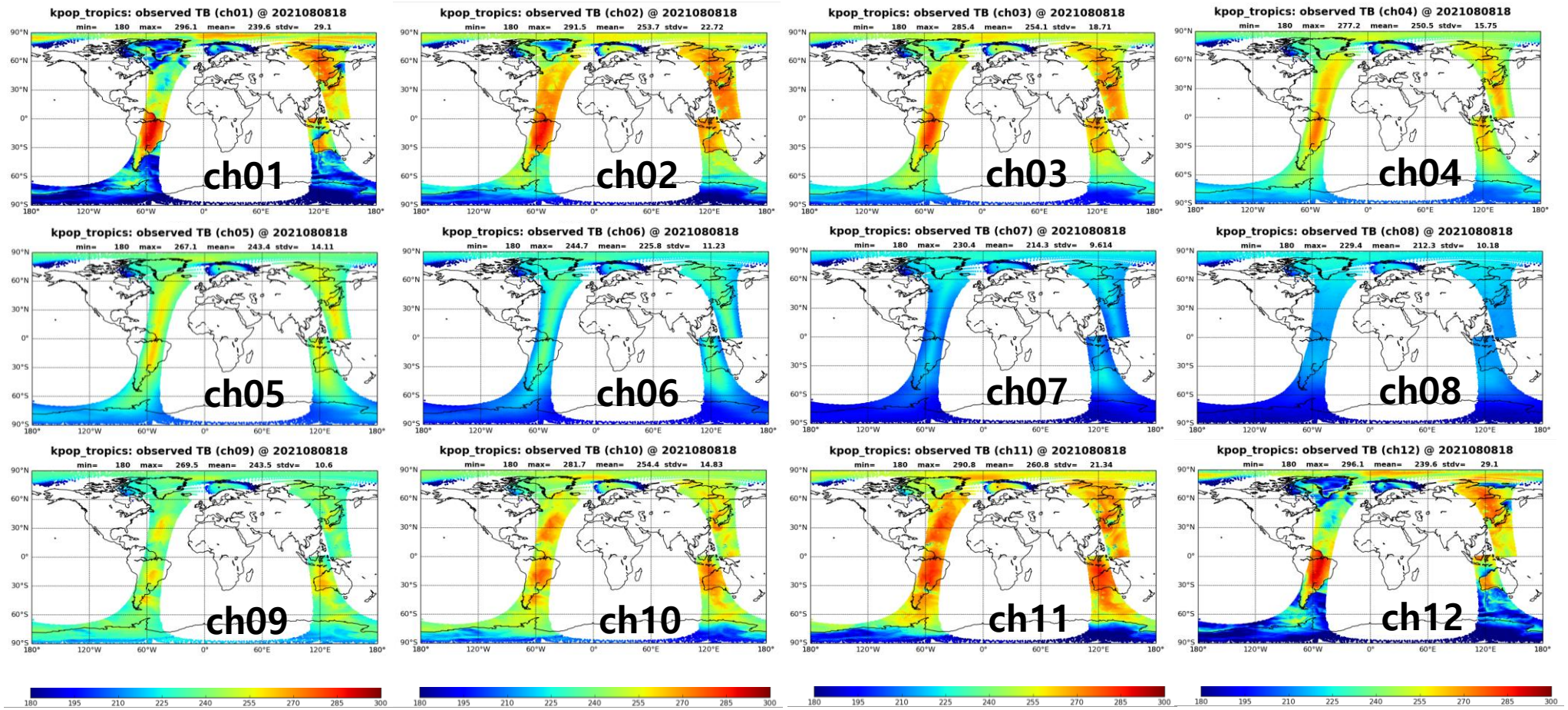

Temperature Channels 1-8

Water vapor Channels 9-12

[Issue] mismatch between file name and header information for satellite id

(ex.) File name : rtcoef_tropics_0_tropics.dat

Header in the file: 53 1 103 ! Platform sat_id instrument

Simulated TB (Calculated from KIM) @ 2021080818

* Clear-sky assimilation w/o cloud masking

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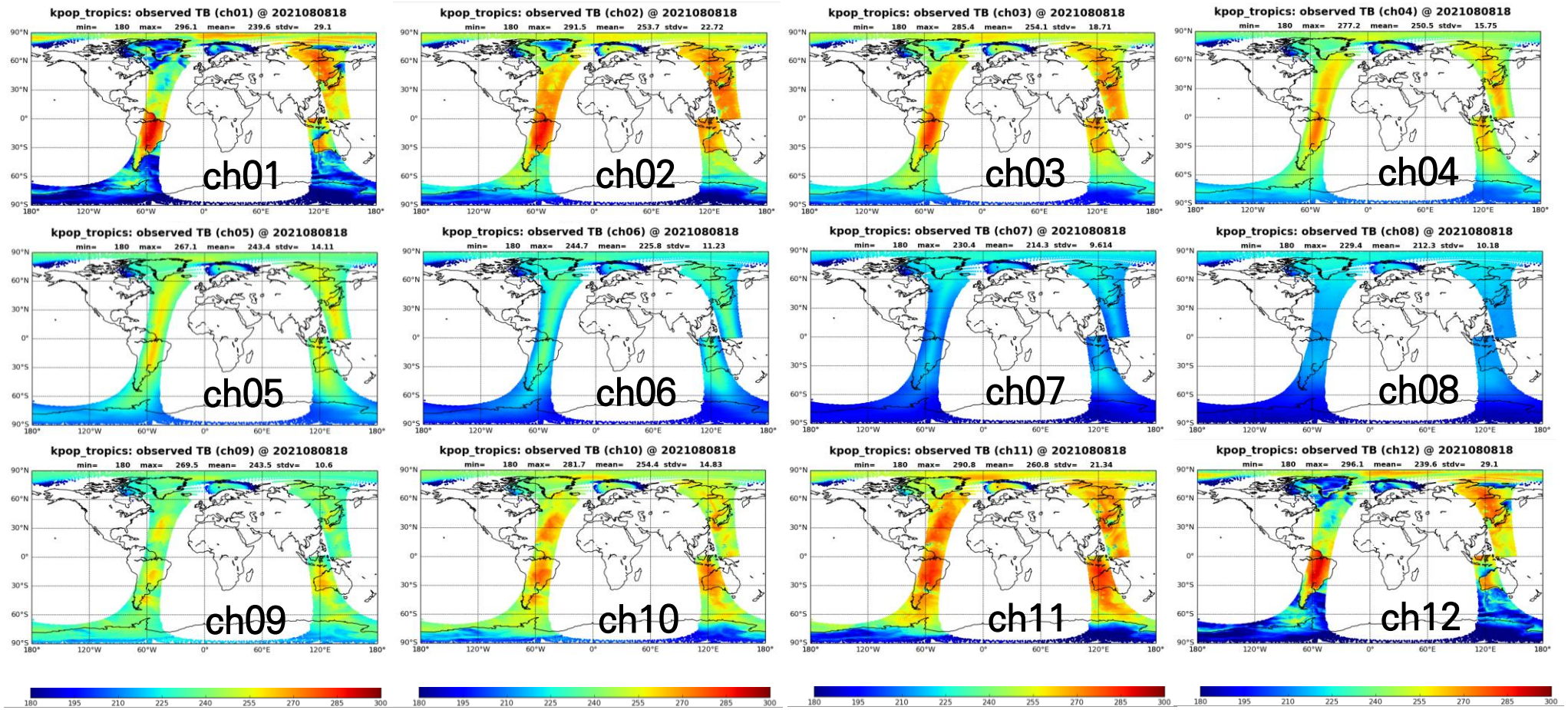

Temperature Channels 1-8

Water vapor Channels 9-12

Observation innovation (KIM) @ 2021080818

* Clear-sky assimilation w/o cloud masking

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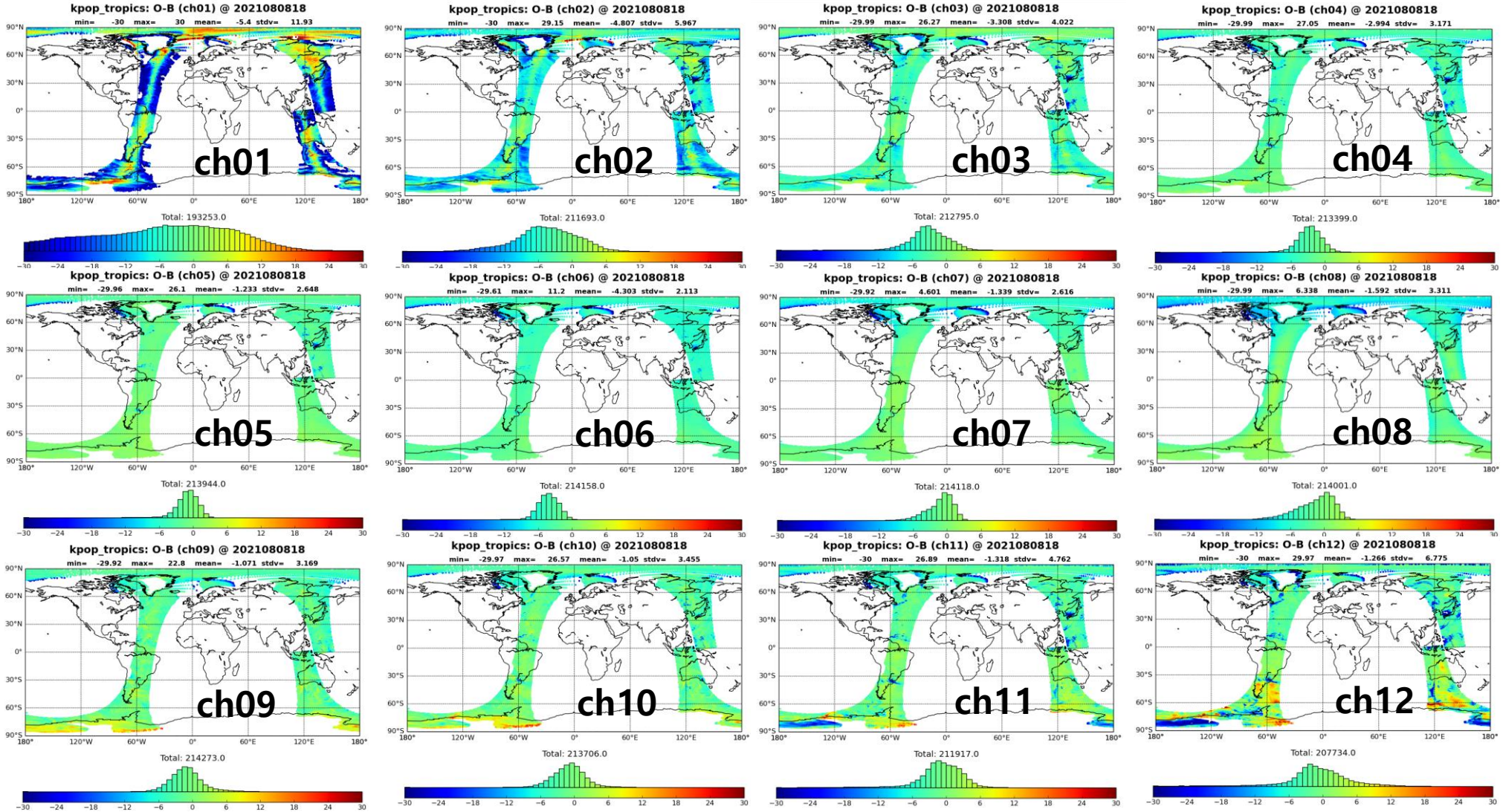

Temperature Channels 1-8

Water vapor Channels 9-12

All-sky assimilation (TROPICS ch12, 205 GHz)

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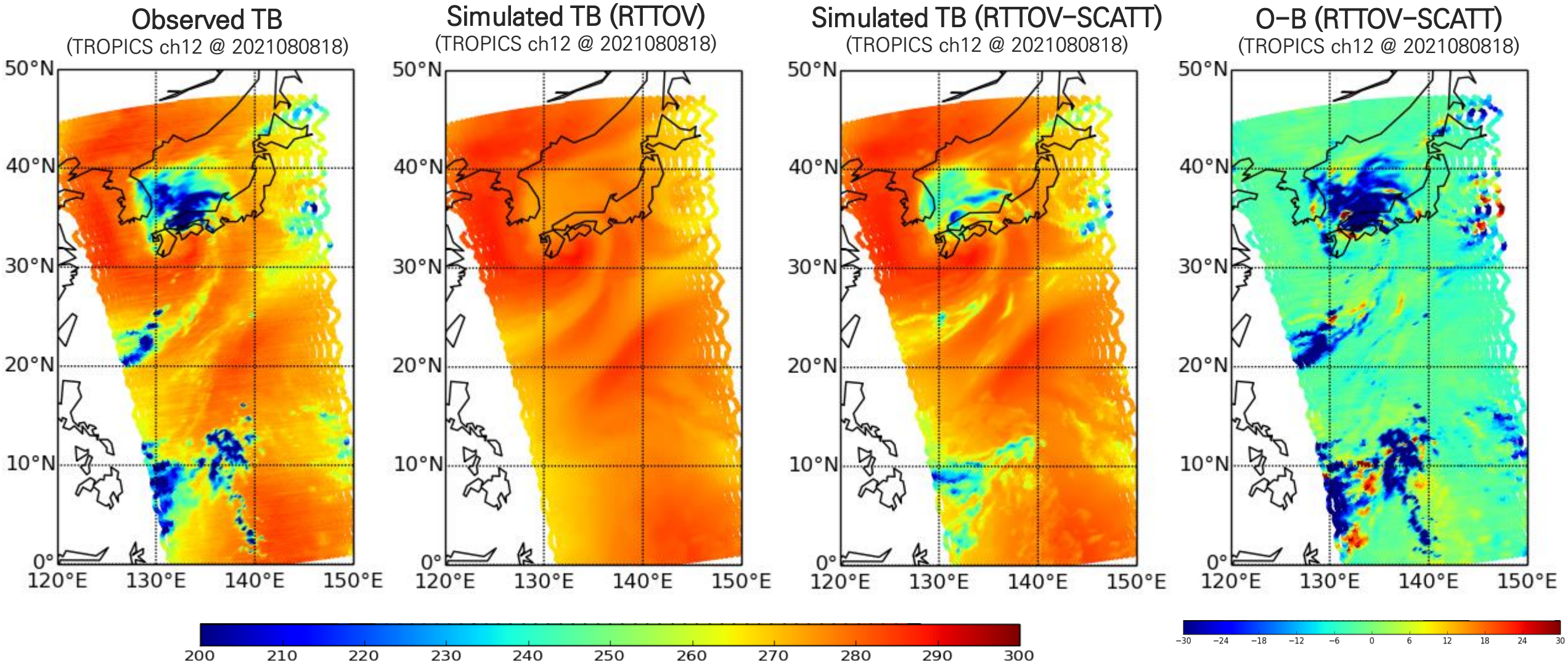

[Issue] failure to calculate rttov-scatt (version 13) at some location – memory issue? input coefficient problem?

All-sky assimilation (TROPICS ch09, 184 GHz)

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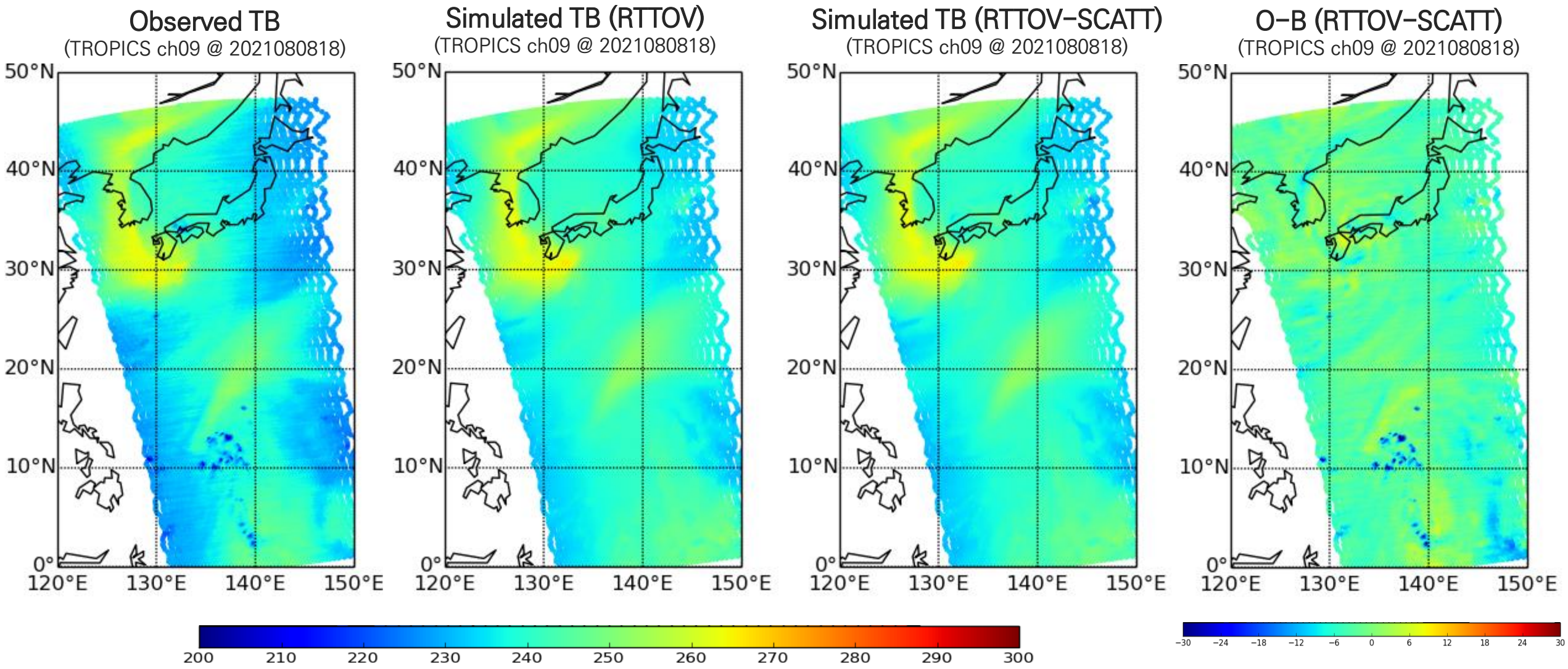

Plans for TROPICS data

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Channel usage

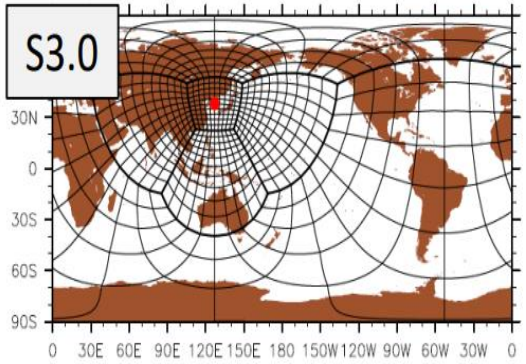
Priority plans

- Water vapor channel 184 GHz: All-sky radiance assimilation
- Temperature channels: Clear-sky radiance assimilation

※ Planning to gradually expand all-sky assimilation to more channels

Plans for high-resolution system for East Asia

- High-resolution grid: ~3-5 km over East Asia.
- DA methods: All-sky radiance assimilation with LETKF
- Hourly DA cycle: potential synergy with high temporal resolution TROPICS data



Sensitivity study for tropical cyclone cases

- TROPICS impact on TC track, intensity, and precipitation prediction skill
- Sensitivity study for TC structure change with TROPICS data usage

THANK YOU

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