8th May, 2025

Korea Meteorological Administration
Numerical Modeling Center

Assessing the Forecast Impact of Simulated GeoHIS Radiance using KIM-OSSE

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Background

■ KMA (Korea Meteorological Administration) plans to operate **GeoHIS** by 2037.

○ Thousands of channels in the range of about 670~2,250 cm^{-1} for temperature and humidity profile retrieval.

○ High temporal and spatial resolution (ex: 30 min and 4 km)

※ **GeoHIS:** Hyperspectral Infrared Souder onboard geostationary satellite

■ WMO "**Global Ring**" vision: 5 GeoHISs until 2040 (WMO, 2019).

※ **WMO**, 2019: Vision for the WMO integrated global observing system in 2040, WMO Doc., 1243, 47pp.

[Global GeoHIS Observations]

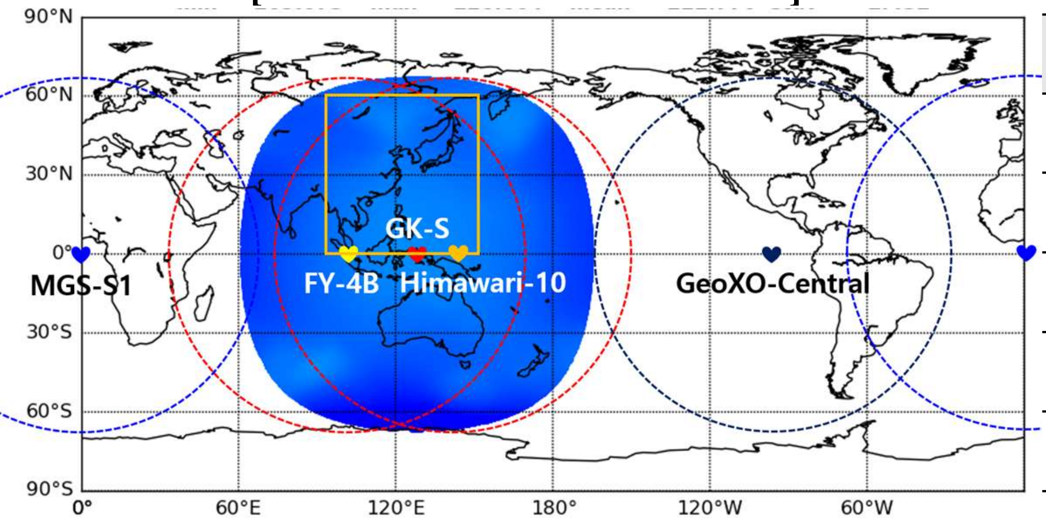


Table 1. List of GeoHIS operation plans according to operational nations.

Op. time	Op. nation	Satellite	Sensor	Spatial Res. (km)	Temporal Res.	# of channels	Wavenumber (cm^{-1})	Interval (cm^{-1})
'16.12.	China	FY-4A	GIIRS	16	1 hr (China area)	1,650	700~2250	0.625
'21.6.	China (105°E)	FY-4B C('26)~E('28)	GIIRS2	12	45 min. (China area)	1,650	680~2250	0.625
'26.	Europe (0°E)	MTG-S1 S2('33)	IRS	4	30 min./6hr (Europe/FD)	1,740	680~1,210 1,600~2,250	0.604
'29	Japan (140.7°E)	Himawari-10	GHMS	4	15 min/1hr (FD: LZA≤60)	1,672	680~2,250	0.625
'36	USA (105°W)	GeoXO-Central	GXS	4	30 min. (FD)	1,672	670~1,100 1,700~2,250	0.500

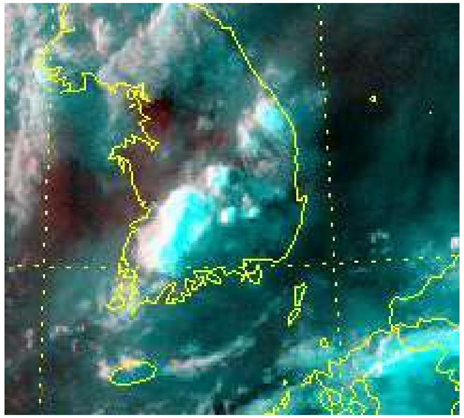
*FY(FengYun), **GeoHIS**(Geostationary Hyperspectral Infrared Sounder), **GeoXO**(Geostationary Extended Observations), **GHMS**(Geostationary HiMawari Sounder), **GIIRS**(Geostationary Interferometric Infrared Sounder), **GXS**(GeoXO Sounder), **IRS**(InfraRed Sounder), **MTG**(Meteosat Third Generation)

Objectives

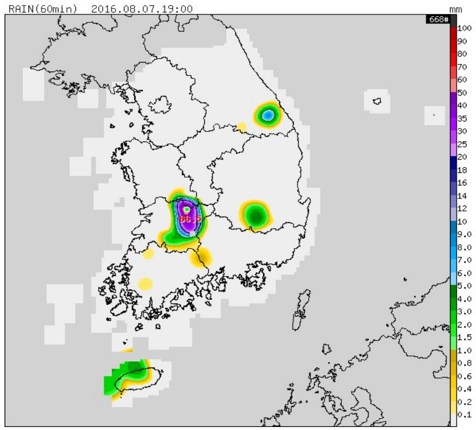
1. GeoHIS improves real-time forecasting

- Instability, Total Precipitable Water, and wind shear from GeoHIS
  (Menzel et al., 2018; Holmlund et al., 2021; Li et al., 2021)

[Severe Weather Monitoring]



Meso-scale Convective Cloud



AWS rain gauge: 66.5 mm hr^{-1}

2. GeoHIS radiance enhances data assimilation

- Contributing to improved accuracy in operational NWP
  (Joo et al., 2013; Eresmaa et al., 2017; Okamoto et al., 2020; Noh et al., 2021)

[Initial field → NWP Improvement]

(T, Q, Wind)

enhancing NWP Accuracy

■ **KIM** (**K**orean **I**ntegrated **M**odel): KMA's current operational global NWP model

Purpose: Assessing the impact of data assimilation through GeoHIS radiance in KIM predictions in terms of synoptic scale predictability using geopotential height, temperature, vapor, and wind speed throughout the troposphere

* **NWP**(Numerical Weather Prediction)

Method and Data

KIM-OSSE

(**K**orean **I**ntegrated **M**odel-**O**bserving **S**ystem **S**imulation **E**xperiment)

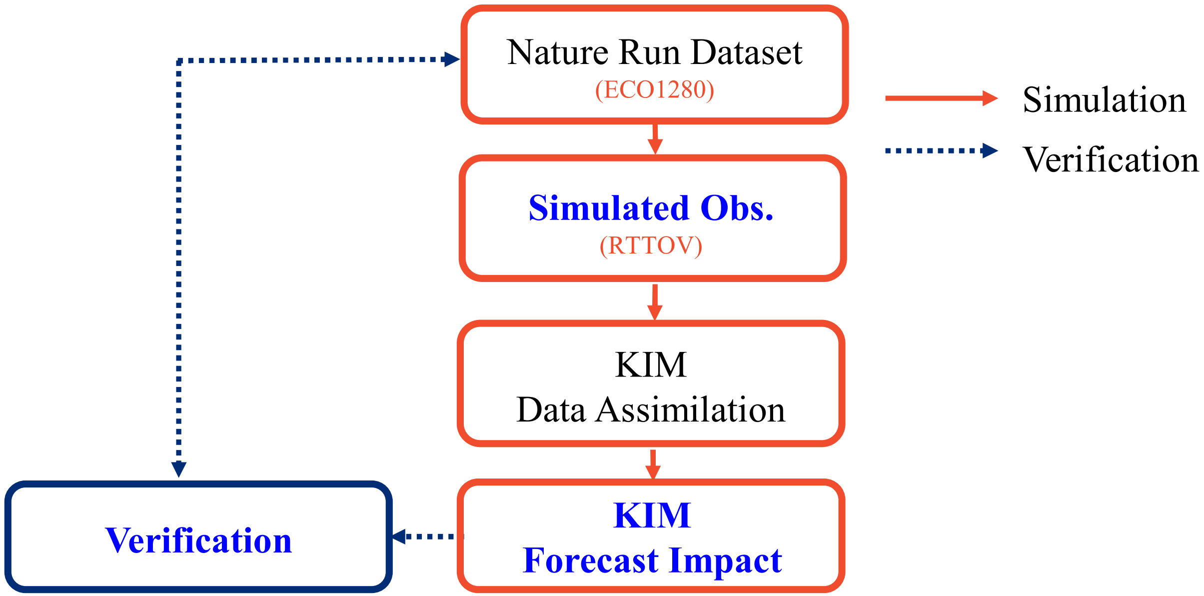


Fig. 1. Research flow chart for forecast impact analysis using KIM-OSSE.

Table 2. Information about the ECO1280 Nature Run dataset.

ECO 1280 Nature Run dataset	
Model	ECMWF (IFS cycle 43r1)
Distribution	**CIRA/CSU** (Cooperative Institute for Research in the Atmosphere at Colorado State University)
Coordinate	Cubic octahedral grid
Resolution	**Hor.: 9 km, Ver.: 137 layers** (TCo1279L137)
Period	14 months (2015. 9. 30.~2016. 11. 30.) **- Oct. 2015 (1 month): 1 hr interval**, others: 3 hr int.

*__ECO__: ECMWF Cubic Octahedral, **RTTOV**: Radiative Transfer for TIROS Operational Vertical Sounder

Experimental Design

Table 3. KIM Specification used in this study.

KIM specifications	
Model	KIM4.1 (NE180, Horizontal: 25 km)
Data assimilation	H4DEV (Hybrid 4D Ensemble Variational DA, NE090 50 km)
Experiment period	**2023.9.30~10.31.**
Verification period	2023.10.5~10.25.
CTL	17 observations (conventional + satellites)
EXP-1	18 observations: CTL + **GeoHIS radiance at 1 hr intervals**
EXP-2	18 observations: CTL + **GeoHIS at 3 hr intervals**

Table 4. List of simulated observations used in the KIM-OSSE.

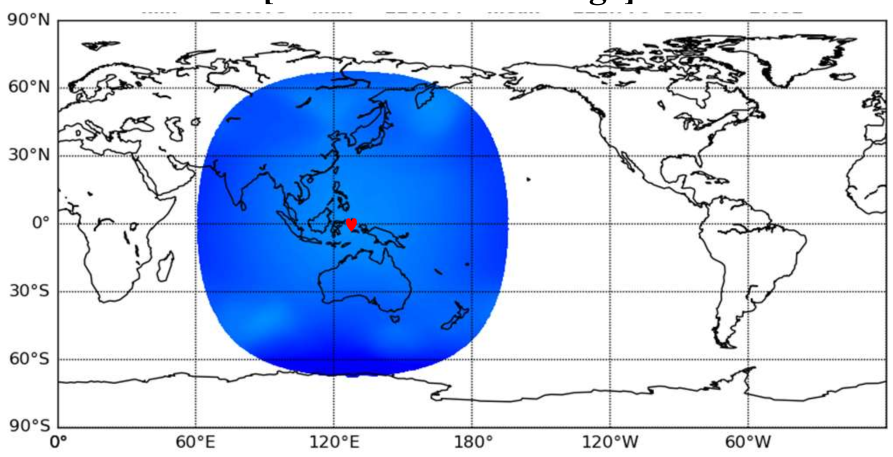
Experiments	Type (Name)
CTL	**MW Sounder** (AMSU-A, ATMS, MHS, MWHS2), **MW Imager** (AMSR2), **IR Sounder** (IASI, CrIS), **AMV, Scatterometer** (SCAT Wind), **IR Imager** (CSR/GK-2A, CSR/Himawari, CSR/MSG), **GNSS** (GNSS RO, Ground-based)**,** **Conventional** (Aircraft, Radiosonde, Surface)
EXP	**CTL + IR Sounder (GeoHIS)**

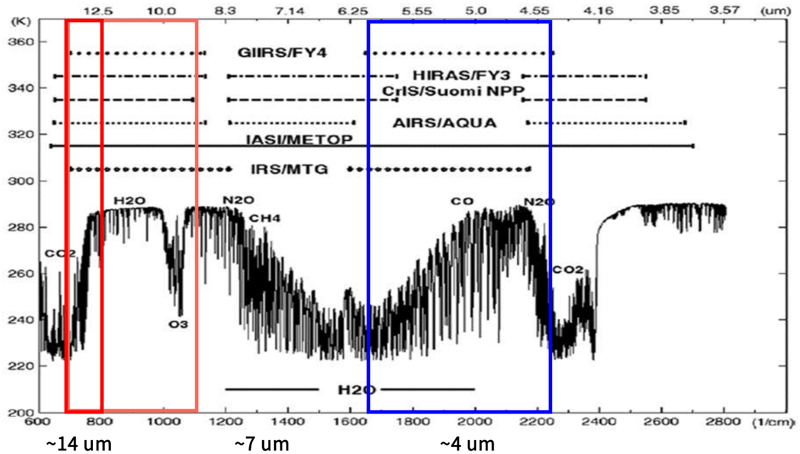
■ KIM forecast impact by using simulated GeoHIS radiance

○ Calculate the CTL and EXP RMSE using NR data as a reference

○ Improvement rate (%): $(\mathrm{RMSE}_{\mathrm{CTL}} - \mathrm{RMSE}_{\mathrm{EXP}})/\mathrm{RMSE}_{\mathrm{CTL}} \times 100$

Simulated GeoHIS radiances





CO$_2$ absorption band (for temp. sounding retrieval)

Fig. 2. Observation coverage (GK2A: 0°N, 128.2°E) and band characteristics (Menzel et al., 2018).

Table 5. Characteristics of simulated GeoHIS.

Position	GK2A location (Lat.: 0°N, Lon.: 128.2°E)
Spatial and temporal resolution	16 km and 1 hour
Wavenumber range (Spectral res.)	700~1,130 cm^{-1} (0.625 cm^{-1})
Number of channels	42 (69)
Channel selection (Wavenumber)	**Ch1(700 cm^{-1})~8, 11~17, 19, 21, 25, 27, 29, 31, 33, 35~45, 53, 55, 57, 59, 61, 64, 67, 81, 93(757.5 cm^{-1}),** 97~629(1092.5 cm^{-1})

○ DA preprocessing (Kim and Kang, 2022a; b)

- Exclude radiance less than 1.5 km due to Ɛsfc and Tskin

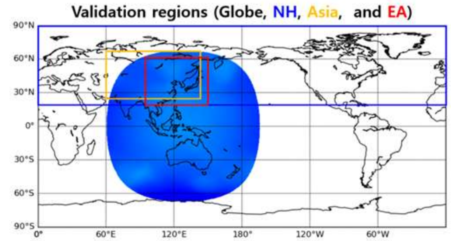
→ **42 channels** (Ch 1~93, **700~757.5 cm^{-1}**)

- Also, high latitude data considering slant path effect (SZA ≥ 55˚)
- Cloud screening (ECMWF), bias correction , thinning (3˚ int.)

* **GK2A**(GEO-KOMPSAT-2A, Geostationary Korea Multi-Purpose Satellite-2A)

Forecast impact (hourly data)

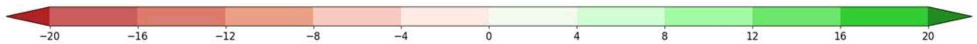
$$\text{Improvement Rate}(\%) = \frac{\text{RMSE}_{\text{CTL}} - \text{RMSD}_{\text{EXP}}}{\text{RMSE}_{\text{CTL}}} \times 100$$



Improvement rate (%) at 00 UTC

2023100500 - 2023102500, TARGET INIT, KATSTYLE

	Globe						Northern Hemisphere						Asia						East Asia					
	0	24	48	72	96	120	0	24	48	72	96	120	0	24	48	72	96	120	0	24	48	72	96	120
Q 700hPa	-1.64	-0.37	-0.41	0.15	0.51	0.11	-0.70	0.17	0.38	0.73	0.94	0.41	-0.58	0.21	2.14	2.87	2.55	3.36	-3.46	-0.24	2.13	1.79	1.30	0.87
WS 250hPa	-0.21	-0.54	-0.28	0.29	0.27	-0.19	-0.19	-0.04	0.27	1.06	0.45	0.28	-0.22	-0.12	-1.68	1.83	3.58	4.88	-0.10	1.07	0.13	1.34	3.04	3.46
WS 500hPa	-0.25	0.16	0.15	0.71	0.43	0.27	-0.14	0.33	0.44	1.25	0.98	0.65	-0.68	-0.22	0.33	2.08	3.26	4.02	-1.12	-0.52	-0.50	1.44	1.97	1.06
WS 850hPa	-0.06	0.06	0.42	0.12	0.53	0.14	0.06	0.16	0.53	0.85	0.22	0.37	-0.38	-0.34	0.15	3.46	3.05	1.90	-0.57	-0.19	0.42	3.60	1.67	1.14
GPH 250hPa	13.77	3.63	0.77	0.64	0.57	0.34	11.38	3.64	0.99	1.10	0.33	0.24	11.72	2.31	-1.14	3.24	5.24	6.66	9.95	1.68	-3.05	0.30	3.55	5.17
GPH 500hPa	9.74	3.77	1.55	1.26	0.97	0.61	8.42	2.82	1.34	1.44	1.18	0.80	9.01	3.18	1.41	4.11	5.73	7.38	12.04	3.45	-0.11	2.84	2.92	3.15
GPH 850hPa	-0.01	-0.23	0.06	0.04	0.21	0.49	-0.01	-0.03	-0.02	0.38	0.22	0.41	-0.07	-0.00	0.01	1.12	1.14	2.04	0.01	-0.07	0.18	2.21	0.73	1.19
T 250hPa	-0.33	-0.11	-0.04	-0.10	0.05	-0.45	-0.43	-0.19	0.08	0.63	0.32	-0.44	-0.57	-0.35	-1.48	0.26	3.95	4.30	-1.57	-0.42	-1.11	-0.34	3.25	2.34
T 500hPa	0.25	0.33	0.11	0.21	0.21	0.46	-0.16	-0.05	0.00	1.15	0.13	0.78	-0.52	-1.11	-1.22	2.21	3.24	5.03	0.20	-1.47	-1.95	0.84	0.90	3.67
T 850hPa	1.08	1.05	0.85	0.66	0.81	0.71	0.26	0.37	0.65	0.60	0.47	0.26	-0.42	0.16	0.74	1.80	2.72	4.53	0.39	0.22	0.75	1.70	0.89	3.73



Statistical significance levels

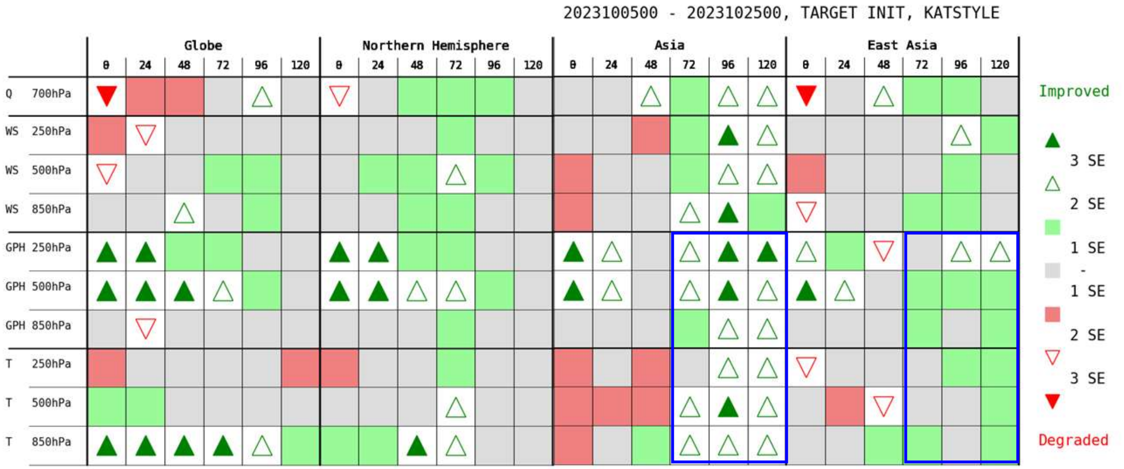
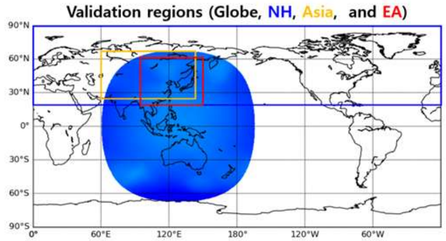


Fig. 3. Scorecard (improvement rate, %) and statistical significance levels (1~3σ, approximately 68~99%) for atmospheric variables and regions at 00 UTC during the period of 5~25 October 2023. T, GPH, WS, and Q denote temperature (K), geopotential height (m), wind speed (m s^{-1}), and relative humidity (%), respectively. **Positive values and green color indicate improvement.**

Temporal observation density impact (1 vs 3 hrs)

$$\text{Improvement Rate}(\%) = \frac{\text{RMSE}_{\text{CTL}} - \text{RMSD}_{\text{EXP}}}{\text{RMSE}_{\text{CTL}}} \times 100$$



1hr-temporal resolution

	Globe						Northern Hemisphere						Asia						East Asia					
	0	24	48	72	96	120	0	24	48	72	96	120	0	24	48	72	96	120	0	24	48	72	96	120
Q 700hPa	-1.64	-0.37	-0.41	0.15	0.51	0.11	-0.70	0.17	0.38	0.73	0.94	0.41	-0.58	0.21	2.14	2.87	2.55	3.36	-3.46	-0.24	2.13	1.79	1.30	0.87
WS 250hPa	-0.21	-0.54	-0.28	0.29	0.27	-0.19	-0.19	-0.04	0.27	1.06	0.45	0.28	-0.22	-0.12	-1.68	1.83	3.58	4.88	-0.10	1.07	0.13	1.34	3.04	3.46
WS 500hPa	-0.25	0.16	0.15	0.71	0.43	0.27	-0.14	0.33	0.44	1.25	0.98	0.65	-0.68	-0.22	0.33	2.08	3.26	4.02	-1.12	-0.52	-0.50	1.44	1.97	1.06
WS 850hPa	-0.06	0.06	0.42	0.12	0.53	0.14	0.06	0.16	0.53	0.85	0.22	0.37	-0.38	-0.34	0.15	3.46	3.05	1.90	-0.57	-0.19	0.42	3.60	1.67	1.14
GPH 250hPa	13.77	3.63	0.77	0.64	0.57	0.34	11.38	3.64	0.99	1.10	0.33	0.24	11.72	2.31	-1.14	3.24	5.24	6.66	9.95	1.68	-3.05	0.30	3.55	5.17
GPH 500hPa	9.74	3.77	1.55	1.26	0.97	0.61	8.42	2.82	1.34	1.44	1.18	0.80	9.01	3.18	1.41	4.11	5.73	7.38	12.04	3.45	-0.11	2.84	2.92	3.15
GPH 850hPa	-0.01	-0.23	0.06	0.04	0.21	0.49	-0.01	-0.03	-0.02	0.38	0.22	0.41	-0.07	-0.00	0.01	1.12	1.14	2.04	0.01	-0.07	0.18	2.21	0.73	1.19
T 250hPa	-0.33	-0.11	-0.04	-0.10	0.05	-0.45	-0.43	-0.19	0.08	0.63	0.32	-0.44	-0.57	-0.35	-1.48	0.26	3.95	4.30	-1.57	-0.42	-1.11	-0.34	3.25	2.34
T 500hPa	0.25	0.33	0.11	0.21	0.21	0.46	-0.16	-0.05	0.00	1.15	0.13	0.78	-0.52	-1.11	-1.22	2.21	3.24	5.03	0.20	-1.47	-1.95	0.84	0.90	3.67
T 850hPa	1.08	1.05	0.85	0.66	0.81	0.71	0.26	0.37	0.65	0.60	0.47	0.26	-0.42	0.16	0.74	1.80	2.72	4.53	0.39	0.22	0.75	1.70	0.89	3.73

3hr-temporal resolution

	Globe						Northern Hemisphere						Asia						East Asia					
	0	24	48	72	96	120	0	24	48	72	96	120	0	24	48	72	96	120	0	24	48	72	96	120
Q 700hPa	-0.17	0.01	-0.27	-0.08	0.18	-0.20	0.20	-0.37	-0.67	-0.46	0.27	-0.35	0.70	0.36	1.39	1.26	1.89	1.03	-0.86	-0.09	0.51	0.69	2.06	-0.60
WS 250hPa	-0.26	0.04	0.15	0.87	1.38	1.20	-0.51	-0.04	0.04	0.92	0.34	0.08	0.02	-0.24	1.07	0.94	2.86	4.17	-0.31	0.60	2.39	0.74	3.66	4.32
WS 500hPa	-0.11	0.08	0.09	0.58	0.84	0.91	-0.03	0.31	0.14	0.25	0.56	0.31	-0.09	0.01	0.68	1.21	1.85	3.75	-0.54	0.01	1.36	0.59	2.43	2.08
WS 850hPa	0.04	0.01	0.34	0.73	0.72	0.39	0.06	0.10	0.63	0.65	0.10	-0.14	0.01	0.19	1.12	3.03	2.39	1.11	-0.28	0.24	1.47	3.21	2.20	1.71
GPH 250hPa	6.31	3.10	1.63	1.83	1.94	1.58	5.36	2.44	0.51	0.43	0.87	0.86	2.98	2.13	0.66	2.62	3.42	4.37	4.39	3.23	-0.48	0.80	2.27	3.57
GPH 500hPa	2.76	1.30	1.04	1.38	1.45	1.22	2.24	1.00	0.74	0.36	0.95	0.66	1.67	1.72	1.89	1.87	3.30	4.57	4.30	2.99	1.24	1.41	2.61	3.28
GPH 850hPa	0.01	-0.10	0.18	0.46	0.84	1.33	0.06	-0.01	0.20	0.18	0.17	0.37	0.08	-0.04	0.30	0.36	0.73	1.35	0.06	0.21	0.95	0.85	1.36	1.17
T 250hPa	-0.29	0.58	0.71	0.70	1.09	0.69	-0.43	-0.48	0.06	-0.34	-0.08	-0.48	-0.56	0.57	0.96	0.10	3.22	3.61	-0.78	1.50	2.37	0.76	3.76	2.88
T 500hPa	0.37	0.66	0.68	0.71	1.25	1.23	-0.03	0.54	0.30	0.29	0.16	0.55	0.32	0.39	1.12	0.93	2.33	4.13	-0.25	1.42	2.13	0.28	0.70	3.28
T 850hPa	-0.21	0.05	0.42	0.58	0.81	0.66	-0.46	-0.09	0.60	0.50	0.07	-0.0	-0.39	-0.27	1.06	1.54	2.88	2.98	0.01	0.16	2.52	2.40	2.75	2.62

Fig. 4. Scorecard (improvement rate, %) for atmospheric variables and regions at 00 UTC during the period of 5~25 October 2023. T, GPH, WS, and Q denote temperature (K), geopotential height (m), wind speed (m s^{-1}), and relative humidity (%), respectively. **Positive values and green color indicate improvement.**

Summary and Future plan

■ Summary

○ **KIM-OSSE experiments**: CTL (17 observations), EXP-1 (CTL+**GeoHIS_1hr**), and EXP-2 (CTL+**GeoHIS_3hr**)

- GeoHIS improves **GPH** in mid- to upper-level (500~250hPa)
- Noticeable improvement of GPH in middle-upper level over the Asia and East Asia region

Region	GPH at 500 hPa pressure level (00UTC)		
	Analysis field	Forecast field	
Northern hemisphere	8.4%	(24~72 hrs) 1.4~2.8%	95% confidence level
Asia (East Asia)	**9.0% (12%)**	(24 hrs) 3.2%, (72~120 hrs) 4.1~7.4%	

- The higher temporal resolution (hourly) of GeoHIS enhances the improvement rate compared with its coarse counter part (3 hourly)

■ Future plan: GeoHIS DA improvement, Double- and multi-GeoHIS applications (obs. schedule, channel etc)

- Cho et al., 2025: Forecast Impact of the Geostationary Hyperspectral Infrared Sounder (GeoHIS) using the Korean Integrated Model-Observing System Simulation Experiment (KIM-OSSE). Atmosphere-Korea, 35(1), 39-49 (in Korean with English abstract).
- Cho et al., 2025: KIM Forecast Impact according to Observation Density of the Next-generation GeoHIS: KIM-OSSE Experiment (in progress).

Korea Meteorological Administration
Numerical Modeling Center

Thank you for your attention!

Backup slides

Forecast impact (hourly data)

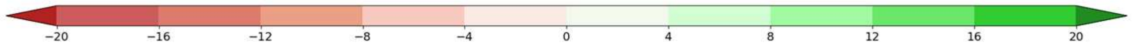
$$\text{Improvement Rate}(\%) = \frac{\text{RMSE}_{\text{CTL}} - \text{RMSD}_{\text{EXP}}}{\text{RMSE}_{\text{CTL}}} \times 100$$

Improvement rate (%) at 00 UTC

2023100500 - 2023102500, TARGET INIT, KATSTYLE

	Globe						Northern Hemisphere						Tropics					
	0	24	48	72	96	120	0	24	48	72	96	120	0	24	48	72	96	120
Q 700hPa	-1.64	-0.37	-0.41	0.15	0.51	0.11	-0.70	0.17	0.38	0.73	0.94	0.41	-2.19	-0.75	-0.86	0.06	0.26	0.06
WS 250hPa	-0.21	-0.54	-0.28	0.29	0.27	-0.19	-0.19	-0.04	0.27	1.06	0.45	0.28	0.06	-0.81	-1.13	-1.41	-0.68	-0.79
WS 500hPa	-0.25	0.16	0.15	0.71	0.43	0.27	-0.14	0.33	0.44	1.25	0.98	0.65	-0.81	-0.15	-0.22	-0.85	-0.57	-1.52
WS 850hPa	-0.06	0.06	0.42	0.12	0.53	0.14	0.06	0.16	0.53	0.85	0.22	0.37	-0.20	-0.54	-0.28	-1.23	-1.04	-1.26
GPH 250hPa	13.77	3.63	0.77	0.64	0.57	0.34	11.38	3.64	0.99	1.10	0.33	0.24	15.48	3.77	-0.38	-2.16	-2.74	-3.33
GPH 500hPa	9.74	3.77	1.55	1.26	0.97	0.61	8.42	2.82	1.34	1.44	1.18	0.80	13.01	6.39	2.89	0.60	-1.13	-1.96
GPH 850hPa	-0.01	-0.23	0.06	0.04	0.21	0.49	-0.01	-0.03	-0.02	0.38	0.22	0.41	-0.04	-0.54	-0.20	-0.53	-0.63	-0.58
T 250hPa	-0.33	-0.11	-0.04	-0.10	0.05	-0.45	-0.43	-0.19	0.08	0.63	0.32	-0.44	-0.46	-1.26	-1.64	-2.53	-3.25	-3.78
T 500hPa	0.25	0.33	0.11	0.21	0.21	0.46	-0.16	-0.05	0.00	1.15	0.13	0.78	1.69	1.02	-0.62	-1.85	-2.18	-2.27
T 850hPa	1.08	1.05	0.85	0.66	0.81	0.71	0.26	0.37	0.65	0.60	0.47	0.26	1.96	1.39	0.76	0.34	0.66	0.69

	Southern Hemisphere						Asia						East Asia					
	0	24	48	72	96	120	0	24	48	72	96	120	0	24	48	72	96	120
Q 700hPa	-1.34	0.10	-0.07	-0.54	0.37	-0.30	-0.58	0.21	2.14	2.87	2.55	3.36	-3.46	-0.24	2.13	1.79	1.30	0.87
WS 250hPa	-0.46	-0.78	-0.21	0.36	0.41	-0.55	-0.22	-0.12	-1.68	1.83	3.58	4.88	-0.10	1.07	0.13	1.34	3.04	3.46
WS 500hPa	0.00	0.18	0.05	0.77	0.20	0.27	-0.68	-0.22	0.33	2.08	3.26	4.02	-1.12	-0.52	-0.50	1.44	1.97	1.06
WS 850hPa	-0.07	0.41	0.75	0.24	1.32	0.43	-0.38	-0.34	0.15	3.46	3.05	1.90	-0.57	-0.19	0.42	3.60	1.67	1.14
GPH 250hPa	12.90	3.35	1.51	1.68	1.65	0.79	11.72	2.31	-1.14	3.24	5.24	6.66	9.95	1.68	-3.05	0.30	3.55	5.17
GPH 500hPa	8.50	3.17	1.28	1.23	0.79	0.39	9.01	3.18	1.41	4.11	5.73	7.38	12.04	3.45	-0.11	2.84	2.92	3.15
GPH 850hPa	0.04	-0.00	0.70	0.10	0.43	0.76	-0.07	-0.00	0.01	1.12	1.14	2.04	0.01	-0.07	0.18	2.21	0.73	1.19
T 250hPa	-0.21	0.63	0.55	0.22	0.74	0.28	-0.57	-0.35	-1.48	0.26	3.95	4.30	-1.57	-0.42	-1.11	-0.34	3.25	2.34
T 500hPa	-0.76	-0.06	0.83	0.59	1.04	0.60	-0.52	-1.11	-1.22	2.21	3.24	5.03	0.20	-1.47	-1.95	0.84	0.90	3.67
T 850hPa	1.17	1.36	1.08	0.88	1.06	0.89	-0.42	0.16	0.74	1.80	2.72	4.53	0.39	0.22	0.75	1.70	0.89	3.73



Statistical significance levels

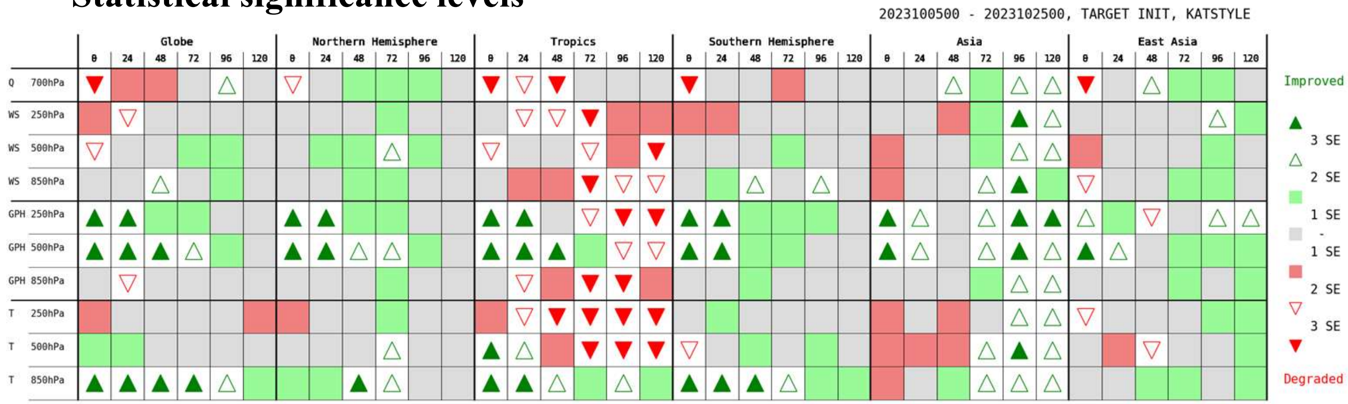


Fig. 7. Scorecard (improvement rate, %) and statistical significance levels (1~3σ, approximately 68~99%) for atmospheric variables and regions at 00 UTC during the period of 5~25 October 2023. T, GPH, WS, and Q denote temperature (K), geopotential height (m), wind speed (m s^{-1}), and relative humidity (%), respectively. Positive values and green color indicate improvement.

Improvement rate (%)

Table 6. Analysis and forecast impact (improvement rate, %) at 00 UTC based on GeoHIS data assimilation in KIM.

00 UTC (Validation period: 10.5~25.)			
Variables	Regions	Analysis field	Forecast field (24~120hrs)
Geopotential height (250~500 hPa)	Globe	9.7~13.8%	0.3~3.8%
	Northern Hemisphere	8.4~11.4%	0.9~3.6%
	Asia	9.0~13.0%	1.4~7.4%
Temperature (850 hPa)	Globe	1.1%	0.7~1.1%
	Northern Hemisphere	0.3%	0.3~0.7%
	Asia	-0.4%	0.2~4.5%

Observation density impact (1 vs 3 hrs)

$$\text{Improvement Rate}(\%) = \frac{\text{RMSE}_{\text{CTL}} - \text{RMSD}_{\text{EXP}}}{\text{RMSE}_{\text{CTL}}} \times 100$$

2023100500 - 2023102500, TARGET INIT, KATSTYLE

3hr-temporal resolution

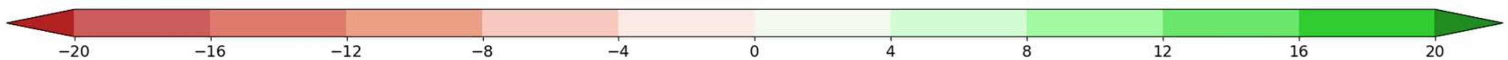
	Globe						Northern Hemisphere						Tropics					
	0	24	48	72	96	120	0	24	48	72	96	120	0	24	48	72	96	120
Q 700hPa	-0.17	0.01	-0.27	-0.08	0.18	-0.20	0.20	-0.37	-0.67	-0.46	0.27	-0.35	-0.31	0.14	-0.30	-0.12	-0.02	-0.32
WS 250hPa	-0.26	0.04	0.15	0.87	1.38	1.20	-0.51	-0.04	0.04	0.92	0.34	0.08	0.26	-0.27	-0.77	-0.81	0.58	0.33
WS 500hPa	-0.11	0.08	0.09	0.58	0.84	0.91	-0.03	0.31	0.14	0.25	0.56	0.31	-0.26	0.27	-0.01	-0.37	-0.30	-1.31
WS 850hPa	0.04	0.01	0.34	0.73	0.72	0.39	0.06	0.10	0.63	0.65	0.10	-0.14	0.21	0.04	0.35	-0.17	-0.66	-0.64
GPH 250hPa	6.31	3.10	1.63	1.83	1.94	1.58	5.36	2.44	0.51	0.43	0.87	0.86	7.42	4.17	2.42	1.19	0.54	0.47
GPH 500hPa	2.76	1.30	1.04	1.38	1.45	1.22	2.24	1.00	0.74	0.36	0.95	0.66	4.44	2.85	1.91	1.16	0.22	-0.20
GPH 850hPa	0.01	-0.10	0.18	0.46	0.84	1.33	0.06	-0.01	0.20	0.18	0.17	0.37	-0.01	-0.17	0.07	-0.43	-0.13	-0.26
T 250hPa	-0.29	0.58	0.71	0.70	1.09	0.69	-0.43	-0.48	0.06	-0.34	-0.08	-0.48	0.01	0.69	1.28	0.57	0.15	0.19
T 500hPa	0.37	0.66	0.68	0.71	1.25	1.23	-0.03	0.54	0.30	0.29	0.16	0.55	1.26	1.66	1.23	0.28	0.39	0.31
T 850hPa	-0.21	0.05	0.42	0.58	0.81	0.66	-0.46	-0.09	0.60	0.50	0.07	-0.09	0.35	0.43	0.04	-0.03	0.56	0.13

	Southern Hemisphere						Asia						East Asia					
	0	24	48	72	96	120	0	24	48	72	96	120	0	24	48	72	96	120
Q 700hPa	-0.28	0.22	0.58	0.69	0.52	0.37	0.70	0.36	1.39	1.26	1.89	1.03	-0.86	-0.09	0.51	0.69	2.06	-0.60
WS 250hPa	-0.53	0.40	0.89	1.57	2.54	2.37	0.02	-0.24	1.07	0.94	2.86	4.17	-0.31	0.60	2.39	0.74	3.66	4.32
WS 500hPa	-0.11	-0.18	0.12	1.07	1.30	1.72	-0.09	0.01	0.68	1.21	1.85	3.75	-0.54	0.01	1.36	0.59	2.43	2.08
WS 850hPa	-0.12	-0.09	0.11	1.22	1.69	1.10	0.01	0.19	1.12	3.03	2.39	1.11	-0.28	0.24	1.47	3.21	2.20	1.71
GPH 250hPa	5.29	2.05	1.80	3.22	3.24	2.14	2.98	2.13	0.66	2.62	3.42	4.37	4.39	3.23	-0.48	0.80	2.27	3.57
GPH 500hPa	1.95	0.66	1.00	2.04	1.77	1.49	1.67	1.72	1.89	1.87	3.30	4.57	4.30	2.99	1.24	1.41	2.61	3.28
GPH 850hPa	-0.11	-0.21	0.34	1.76	1.99	2.61	0.08	-0.04	0.30	0.36	0.73	1.35	0.06	0.21	0.95	0.85	1.36	1.17
T 250hPa	-0.41	1.29	1.00	1.60	2.34	1.68	-0.56	0.57	0.96	0.10	3.22	3.61	-0.78	1.50	2.37	0.76	3.76	2.88
T 500hPa	-0.15	-0.32	0.64	1.30	2.36	1.82	0.32	0.39	1.12	0.93	2.33	4.13	-0.25	1.42	2.13	0.28	0.70	3.28
T 850hPa	-0.36	-0.09	0.54	1.00	1.44	1.35	-0.39	-0.27	1.06	1.54	2.88	2.98	0.01	0.16	2.52	2.40	2.75	2.62

1hr-temporal resolution

	Globe						Northern Hemisphere						Tropics					
	0	24	48	72	96	120	0	24	48	72	96	120	0	24	48	72	96	120
Q 700hPa	-1.64	-0.37	-0.41	0.15	0.51	0.11	-0.70	0.17	0.38	0.73	0.94	0.41	-2.19	-0.75	-0.86	0.06	0.26	0.06
WS 250hPa	-0.21	-0.54	-0.28	0.29	0.27	-0.19	-0.19	-0.04	0.27	1.06	0.45	0.28	0.06	-0.81	-1.13	-1.41	-0.68	-0.79
WS 500hPa	-0.25	0.16	0.15	0.71	0.43	0.27	-0.14	0.33	0.44	1.25	0.98	0.65	-0.81	-0.15	-0.22	-0.85	-0.57	-1.52
WS 850hPa	-0.06	0.06	0.42	0.12	0.53	0.14	0.06	0.16	0.53	0.85	0.22	0.37	-0.20	-0.54	-0.28	-1.23	-1.04	-1.26
GPH 250hPa	13.77	3.63	0.77	0.64	0.57	0.34	11.38	3.64	0.99	1.10	0.33	0.24	15.48	3.77	-0.38	-2.16	-2.74	-3.33
GPH 500hPa	9.74	3.77	1.55	1.26	0.97	0.61	8.42	2.82	1.34	1.44	1.18	0.80	13.01	6.39	2.89	0.60	-1.13	-1.96
GPH 850hPa	-0.01	-0.23	0.06	0.04	0.21	0.49	-0.01	-0.03	-0.02	0.38	0.22	0.41	-0.04	-0.54	-0.20	-0.53	-0.63	-0.58
T 250hPa	-0.33	-0.11	-0.04	-0.10	0.05	-0.45	-0.43	-0.19	0.08	0.63	0.32	-0.44	-0.46	-1.26	-1.64	-2.53	-3.25	-3.78
T 500hPa	0.25	0.33	0.11	0.21	0.21	0.46	-0.16	-0.05	0.00	1.15	0.13	0.78	1.69	1.02	-0.62	-1.85	-2.18	-2.27
T 850hPa	1.08	1.05	0.85	0.66	0.81	0.71	0.26	0.37	0.65	0.60	0.47	0.26	1.96	1.39	0.76	0.34	0.66	0.69

	Southern Hemisphere						Asia						East Asia					
	0	24	48	72	96	120	0	24	48	72	96	120	0	24	48	72	96	120
Q 700hPa	-1.34	0.10	-0.07	-0.54	0.37	-0.30	-0.58	0.21	2.14	2.87	2.55	3.36	-3.46	-0.24	2.13	1.79	1.30	0.87
WS 250hPa	-0.46	-0.78	-0.21	0.36	0.41	-0.55	-0.22	-0.12	-1.68	1.83	3.58	4.88	-0.10	1.07	0.13	1.34	3.04	3.46
WS 500hPa	0.00	0.18	0.05	0.77	0.20	0.27	-0.68	-0.22	0.33	2.08	3.26	4.02	-1.12	-0.52	-0.50	1.44	1.97	1.06
WS 850hPa	-0.07	0.41	0.75	0.24	1.32	0.43	-0.38	-0.34	0.15	3.46	3.05	1.90	-0.57	-0.19	0.42	3.60	1.67	1.14
GPH 250hPa	12.90	3.35	1.51	1.68	1.65	0.79	11.72	2.31	-1.14	3.24	5.24	6.66	9.95	1.68	-3.05	0.30	3.55	5.17
GPH 500hPa	8.50	3.17	1.28	1.23	0.79	0.39	9.01	3.18	1.41	4.11	5.73	7.38	12.04	3.45	-0.11	2.84	2.92	3.15
GPH 850hPa	0.04	-0.00	0.70	0.10	0.43	0.76	-0.07	-0.00	0.01	1.12	1.14	2.04	0.01	-0.07	0.18	2.21	0.73	1.19
T 250hPa	-0.21	0.63	0.55	0.22	0.74	0.28	-0.57	-0.35	-1.48	0.26	3.95	4.30	-1.57	-0.42	-1.11	-0.34	3.25	2.34
T 500hPa	-0.76	-0.06	0.83	0.59	1.04	0.60	-0.52	-1.11	-1.22	2.21	3.24	5.03	0.20	-1.47	-1.95	0.84	0.90	3.67
T 850hPa	1.17	1.36	1.08	0.88	1.06	0.89	-0.42	0.16	0.74	1.80	2.72	4.53	0.39	0.22	0.75	1.70	0.89	3.73



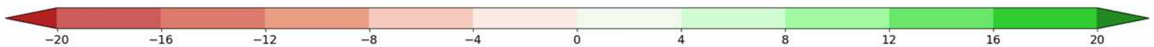
Improvement rate (%) at 12 UTC

2023100512 - 2023102512, TARGET INIT, KATSTYLE

	Globe						Northern Hemisphere					
	0	24	48	72	96	120	0	24	48	72	96	120
Q 700hPa	-1.56	-0.57	-0.45	0.09	0.08	0.12	-0.64	-0.24	-0.28	0.44	0.21	0.57
WS 250hPa	-0.37	-0.50	-0.21	0.18	-0.41	-0.05	-0.19	-0.11	-0.44	0.22	0.21	1.36
WS 500hPa	-0.31	-0.07	-0.17	0.58	0.74	0.18	0.08	0.07	0.62	0.83	1.38	1.01
WS 850hPa	0.00	0.08	-0.21	-0.09	-0.12	-0.35	0.00	0.06	0.07	0.57	0.87	0.81
GPH 250hPa	13.17	3.33	0.48	0.37	0.28	0.09	11.25	1.90	-0.32	0.32	0.37	2.12
GPH 500hPa	9.95	3.76	1.22	1.04	0.87	0.53	8.11	2.29	0.93	0.90	0.79	2.28
GPH 850hPa	0.02	0.01	-0.18	0.09	0.44	0.44	-0.03	-0.00	0.00	0.06	0.48	1.20
T 250hPa	-0.38	-0.32	-0.29	0.07	0.37	-0.65	-0.34	0.52	0.12	0.52	0.94	0.12
T 500hPa	0.19	0.42	-0.23	0.32	0.43	0.68	0.30	0.25	0.02	0.39	0.98	2.50
T 850hPa	1.27	0.83	0.35	0.37	0.39	0.21	0.35	0.35	0.01	0.31	0.49	1.47

	Tropics						Southern Hemisphere					
	0	24	48	72	96	120	0	24	48	72	96	120
Q 700hPa	-2.18	-0.88	-0.66	-0.02	-0.03	-0.11	-0.96	0.01	0.05	-0.20	0.10	-0.04
WS 250hPa	-0.43	-0.86	-0.70	-1.08	-1.23	-1.27	-0.48	-0.51	0.40	0.79	-0.64	-0.94
WS 500hPa	-0.86	-0.22	-0.83	-0.58	-0.12	-0.37	-0.27	-0.13	-0.51	0.74	0.49	-0.32
WS 850hPa	-0.04	-0.47	-0.81	-1.22	-1.04	-1.31	0.03	0.46	-0.07	-0.03	-0.45	-0.76
GPH 250hPa	16.03	3.91	-0.68	-1.90	-2.30	-2.18	11.26	3.65	2.04	1.82	1.15	-0.97
GPH 500hPa	13.67	6.72	2.36	0.56	-1.23	-1.02	8.75	3.25	1.09	1.34	1.29	-0.42
GPH 850hPa	0.07	-0.05	-0.43	-0.30	-0.52	-0.35	0.07	0.21	-0.15	0.60	1.11	0.22
T 250hPa	-0.34	-1.87	-2.74	-2.42	-2.30	-2.39	-0.45	0.00	0.55	0.68	0.75	-0.79
T 500hPa	1.58	1.16	-0.76	-1.65	-2.16	-1.68	-1.12	-0.12	-0.01	1.38	0.87	-0.27
T 850hPa	2.23	0.96	0.46	0.01	-0.02	-0.14	1.32	1.14	0.55	0.66	0.51	-0.57

	Asia						East Asia					
	0	24	48	72	96	120	0	24	48	72	96	120
Q 700hPa	-0.44	0.44	1.13	0.08	-0.07	3.64	-3.31	0.47	0.77	1.48	-1.23	1.73
WS 250hPa	0.12	-2.11	-0.56	0.27	2.53	1.54	-1.09	-1.66	-1.13	-1.35	-1.13	3.23
WS 500hPa	-0.36	-0.29	0.23	1.61	2.91	2.26	-0.65	-0.30	-1.00	-0.71	0.56	3.60
WS 850hPa	0.01	-0.28	0.57	0.98	2.11	2.63	0.05	-0.48	0.12	0.17	-1.08	1.53
GPH 250hPa	12.75	-0.01	0.55	3.16	5.69	5.63	14.57	1.58	-1.12	-2.19	1.02	5.06
GPH 500hPa	9.61	1.66	1.13	4.25	4.11	5.29	13.39	3.85	-0.52	0.40	1.45	3.75
GPH 850hPa	-0.01	-0.05	0.05	0.66	0.36	2.22	-0.05	-0.10	-0.12	0.30	-0.44	1.29
T 250hPa	-0.79	-0.77	-0.75	0.01	1.22	-0.12	-1.79	-1.22	-1.29	-2.14	-2.15	0.01
T 500hPa	-0.64	-0.19	0.54	2.00	4.40	3.88	0.50	-0.21	-0.54	-0.40	-0.10	3.65
T 850hPa	-0.04	0.09	0.52	1.13	2.10	4.13	0.57	1.16	0.01	-0.09	-0.09	3.80



Statistical significance levels

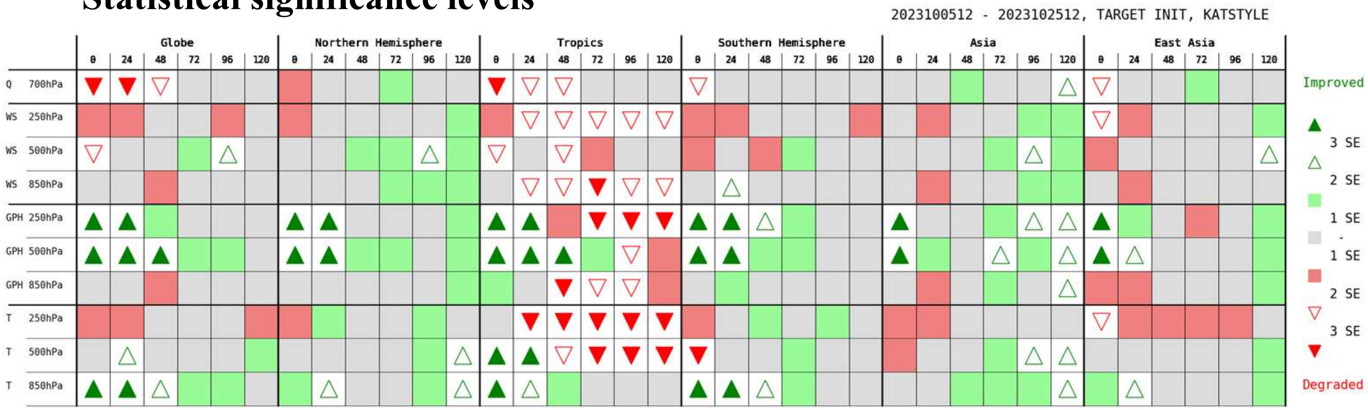


Fig. 8. Same as Figure 7 except for the 12 UTC.

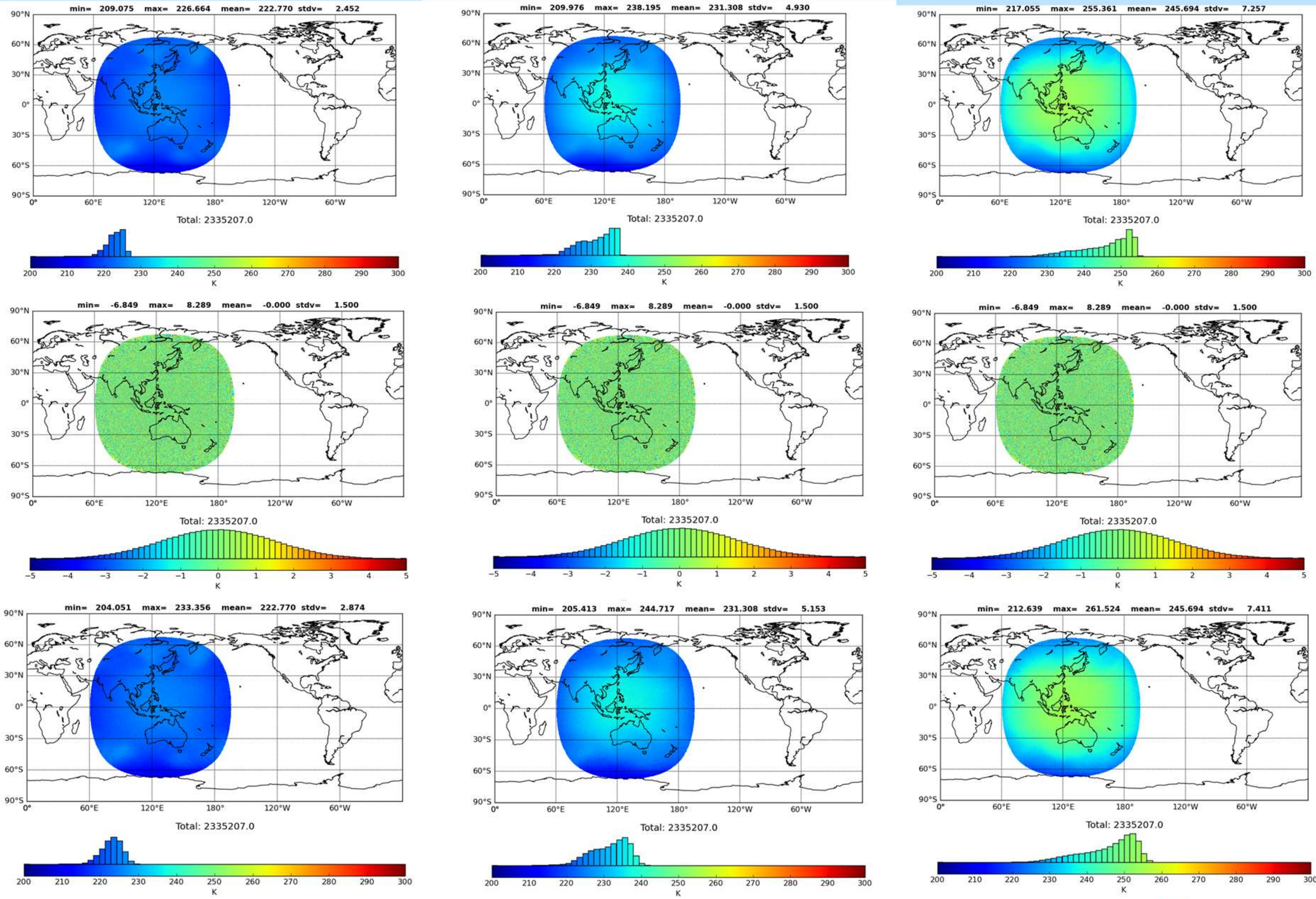
Korea Meteorological Administration
Numerical Modeling Center

ch6 | ch14 | ch25

True

Perturbation

Simulated Observation



Method and Data

Table 2. Information about the ECO1280 Nature Run dataset.

ECO 1280 Nature Run dataset	
Model	ECMWF (IFS cycle 43r1)
Distribution	**CIRA/CSU** (Cooperative Institute for Research in the Atmosphere at Colorado State University)
Coordinate	Cubic octahedral grid
Resolution	**Hor.: 9 km, Ver.: 137 layers** (TCo1279L137)
Period	14 months (2015. 9. 30.~2016. 11. 30.) - **Oct. 2015 (1 month): 1 hr interval**, others: 3 hr interval

○ Similarity between NR and real atmosphere

- Comparison of ERA-5 in zonal-averaged temp. and u/v-vector. (Cucurull et al., 2024)
- GPCP monthly mean precipitation amount (Han et al., 2023)

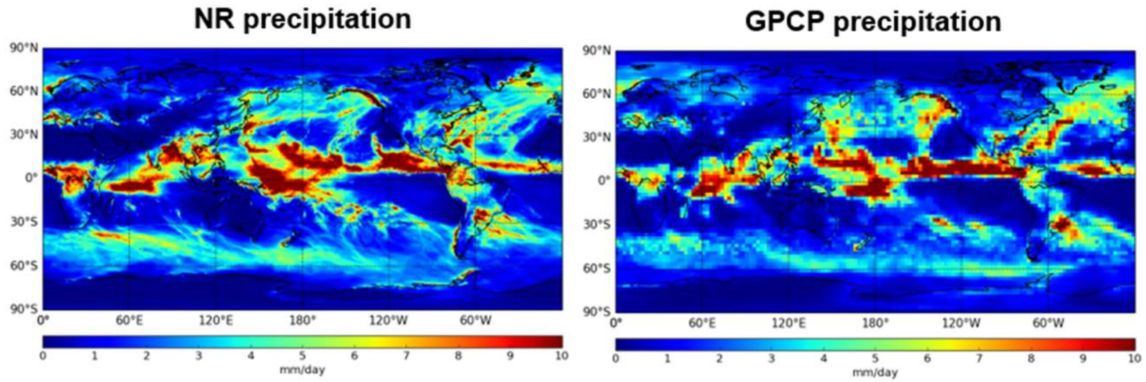


Fig. 3. Comparison of monthly mean precipitation amount (mm/day) between Nature Run and GPCP in October 2015.

*__ECO__: ECMWF Cubic Octahedral, **GPCP**: Global Precipitation Climatology Project, **ERA-5**: ECMWF Reanalysis v5