Hybrid data assimilation in the KIM forecasting system at KMA

Ji-Hyun Ha[1], Hyo-Jong Song[2], Yong Hee Lee[1], Yoon-jeong Hwang[1], Dayoung Choi[1]

[1]KMA, [2]Myongji University

with contributions of NMC staff

Numerical Modeling Center, KMA

Korea Meteorological Administration

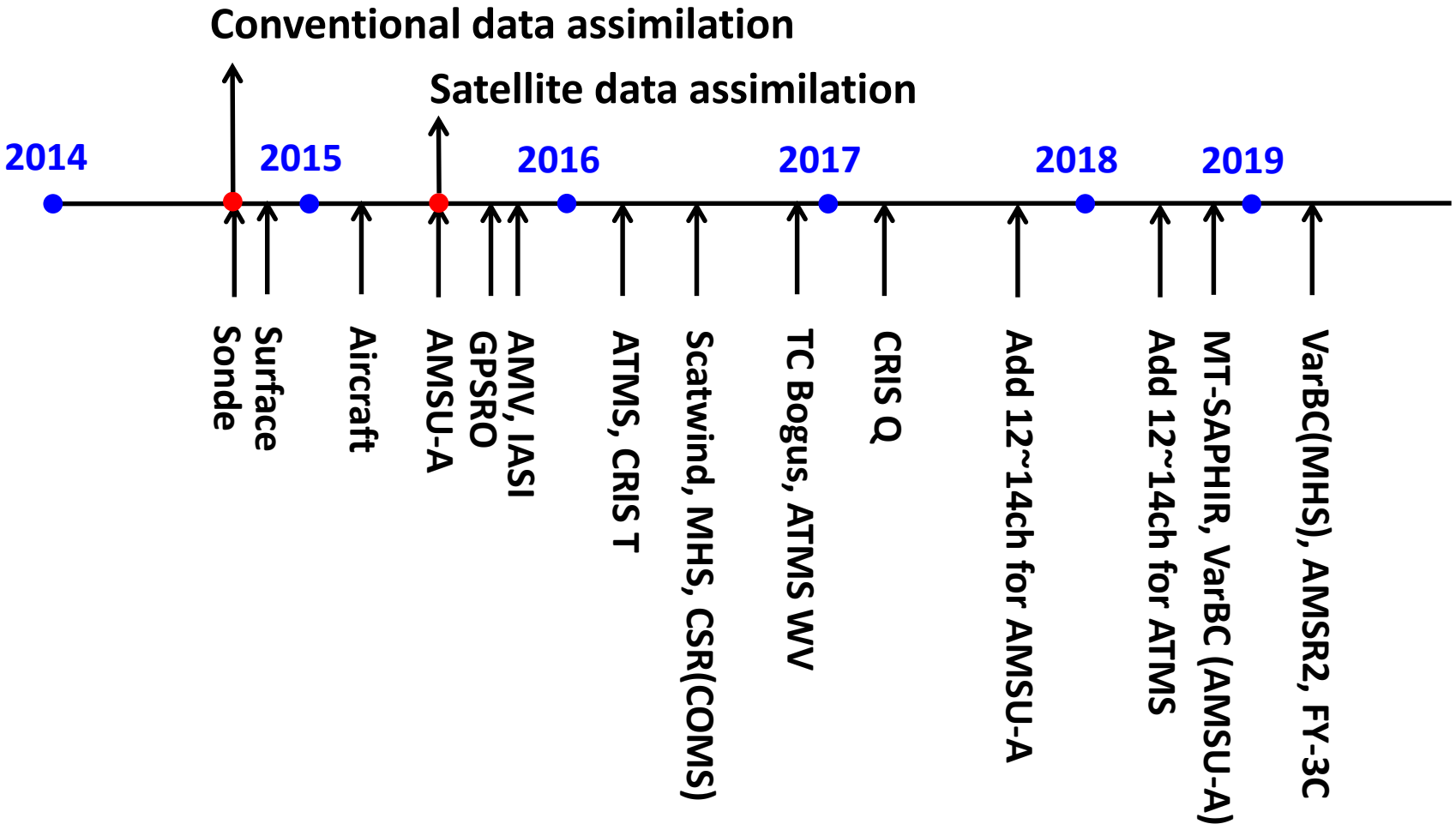
Introduction

- A global NWP model (KIM: Korean Integrated Model~12.5km) (Choi et al. 2014; Choi and Hong, 2016) and its data assimilation system built on a cubed-sphere grid has been developing by KIAPS (Korean Institute of Atmospheric Prediction Systems).
- NMC at KMA has run the KIM forecast system as semi-real time forecast since April 2019 and plans to run as real-time operation since 2020.

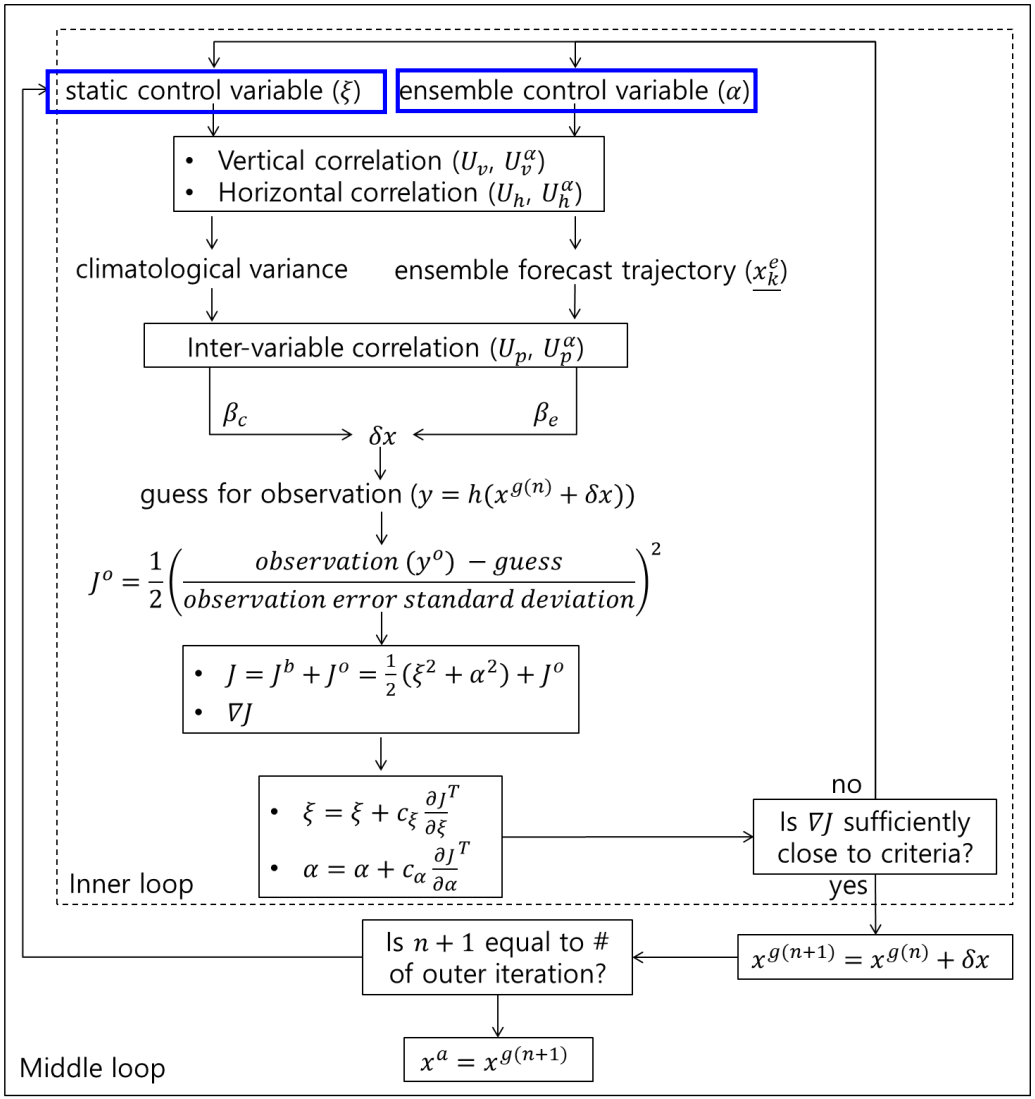
Progress of data assimilation system

Date	description
2015.7~2017.3	3DVar (Song and Kwon, 2015; Song et al., 2017; Ha et al., 2018)
2017.4	**Hybrid 4DEnVar** (H4DEV, using LETKF)
2018.3	4 mid-loop H4DEV (without re-running of the NWP model)
2019.10	**Increase of ensemble BEC ratio** (0.3→0.7)
2020.4 (planned)	Increase of horizontal resolution of ensemble forecast (50km→32km)

Progress for the data assimilation : observations



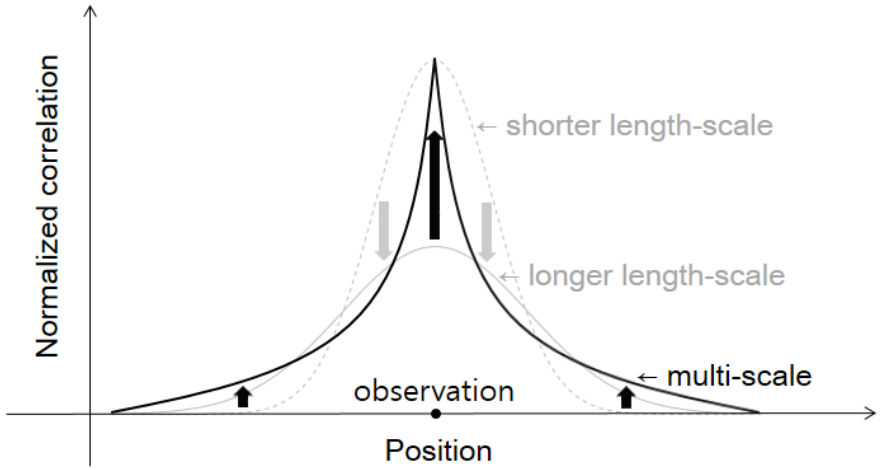
4D Ensemble Variational Assimilation

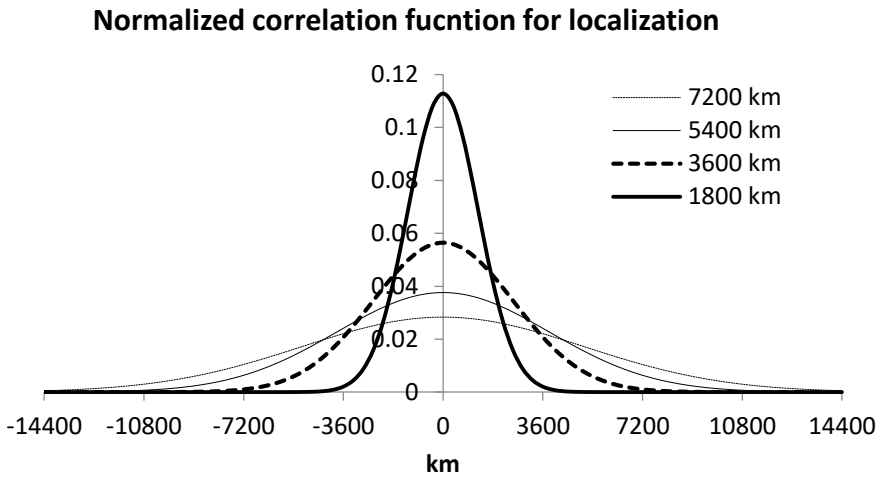


- Every mid-loop, brightness temperature and Jacobian of RTTOV are re-calculated without re-running of the NWP model.
- To localize the ensemble, the Gaussian function for correlation is used.

Song et al. (2018)

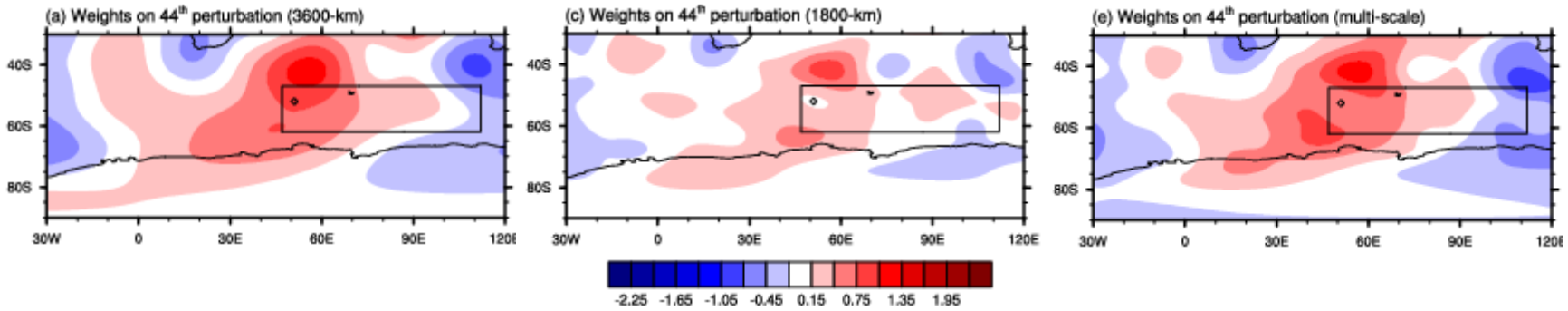
Multi-resolution minimization





- Resolution of minimization also increases from 3600 km to 900 km in the way of 1/2*localization scale.

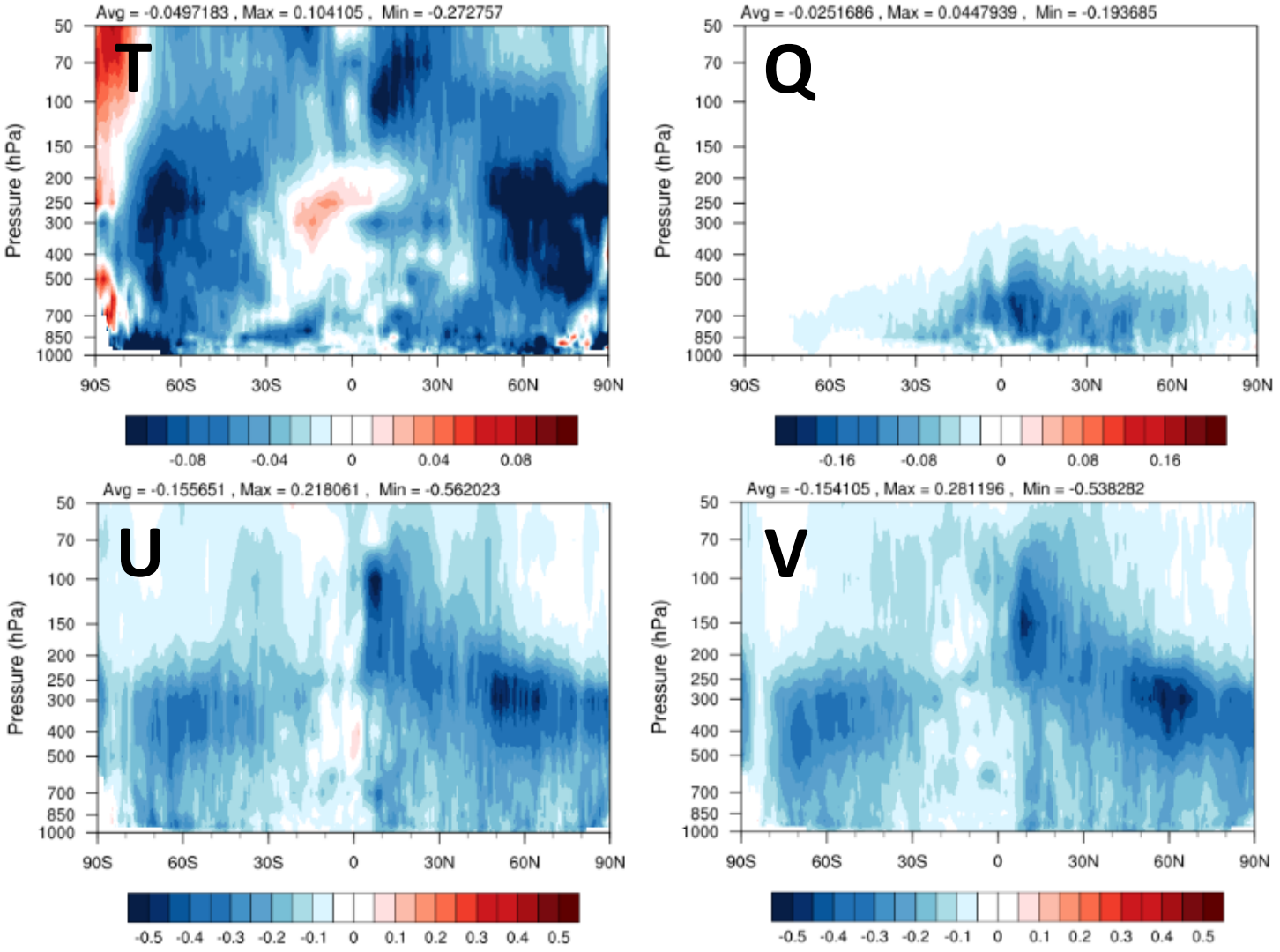
increments



Song (2019)

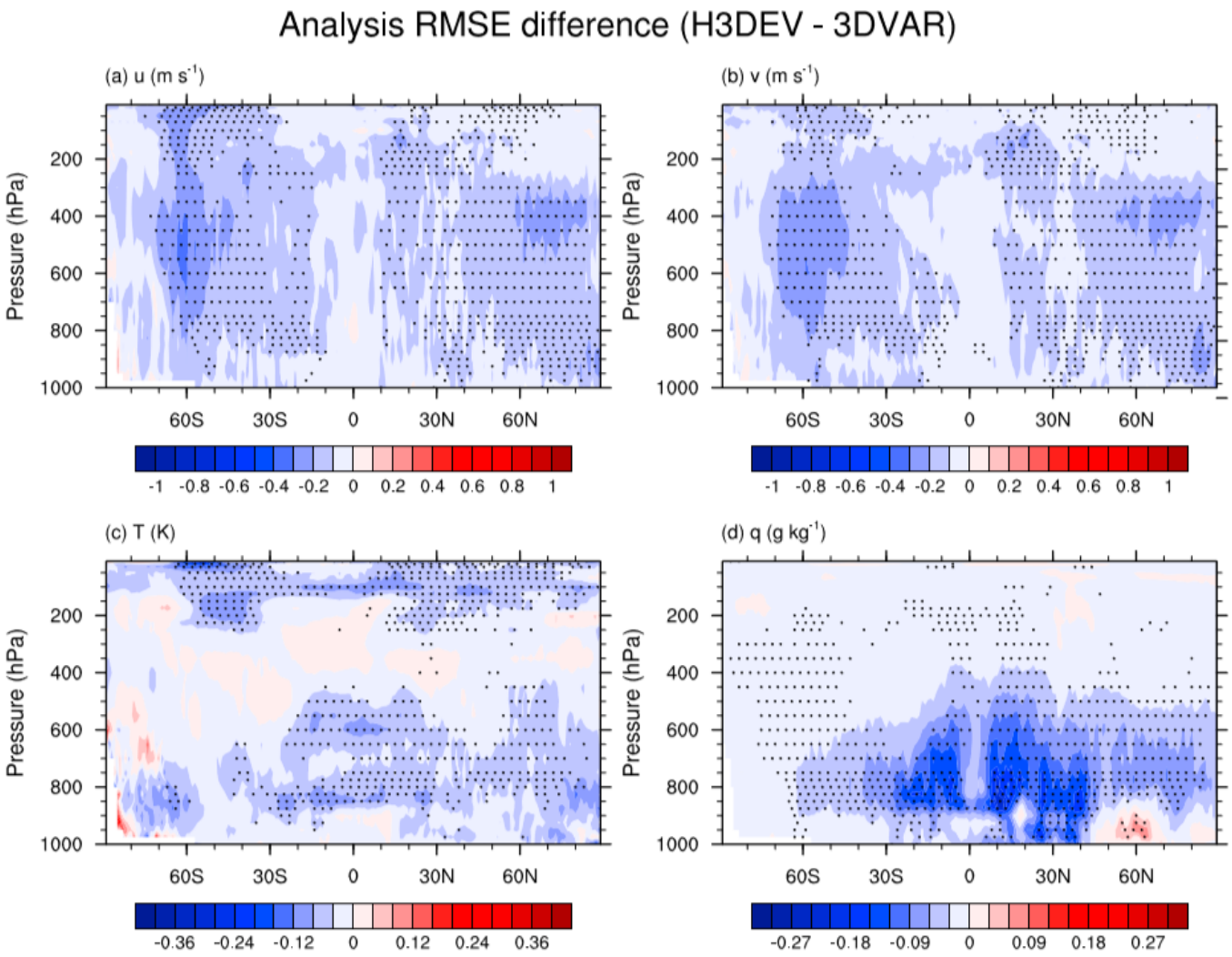
Impact of multi-scale localization

- Comparison between multi-scale(ML) and single localization (SL)



1. Impact of Ensemble BEC

- Comparison between H3DEV and 3DVAR

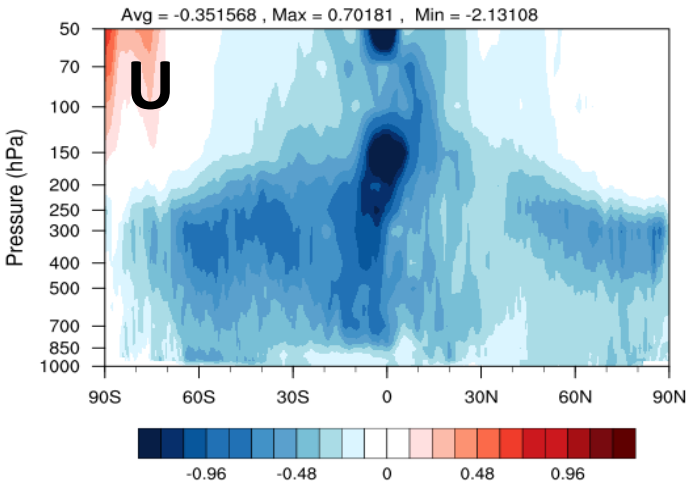


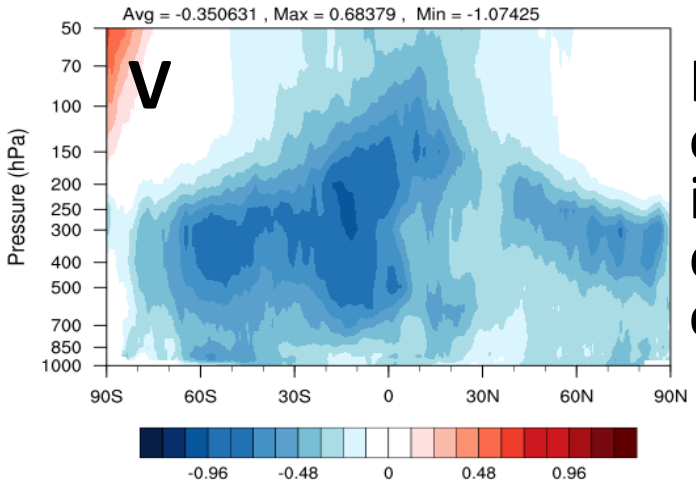
In this experiment, ensemble forecast is prepared.

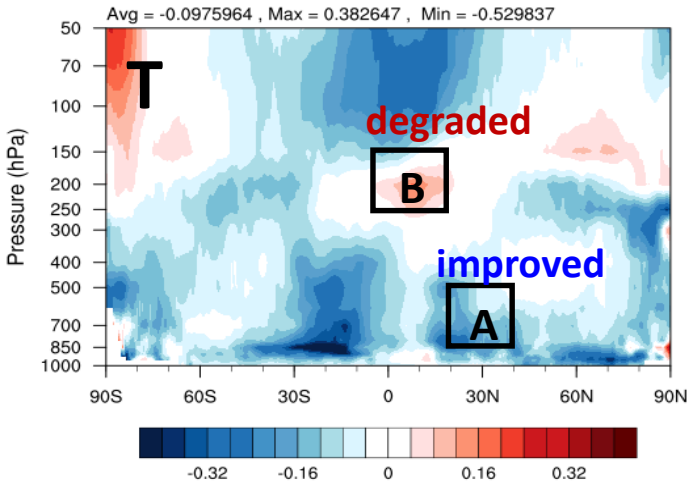
Song et al. (2017)

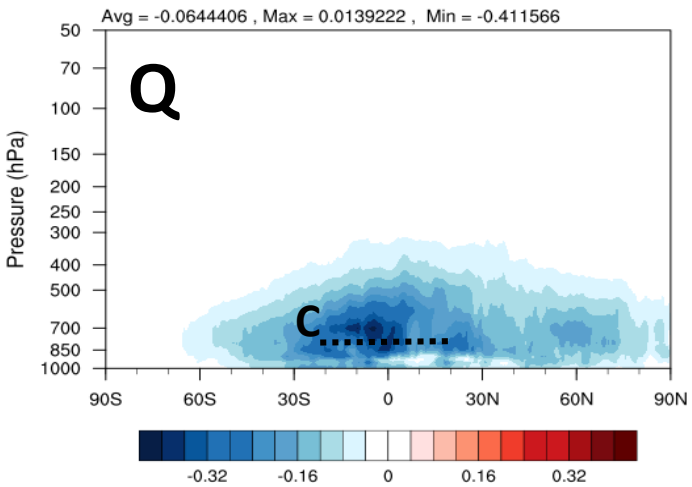
Impact of the Ensemble BEC on the analysis

- Comparison between H4DEV and 3DVAR (but obs in 4D)
- *Negative means the improvement of the H4DEV*



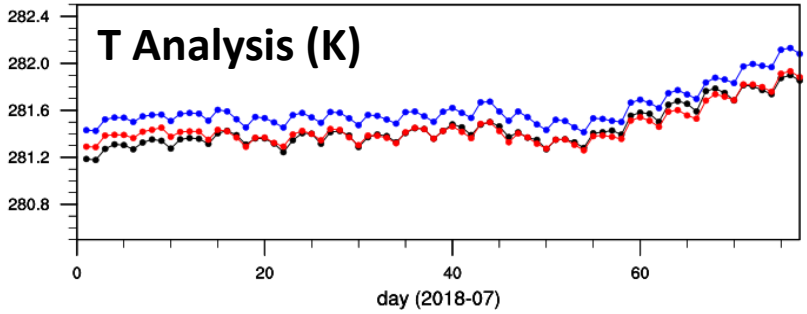


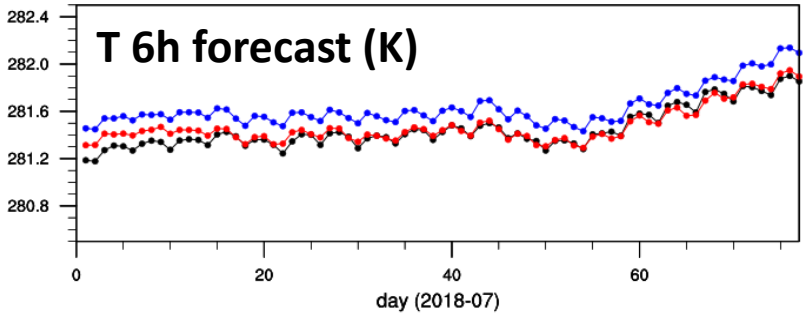


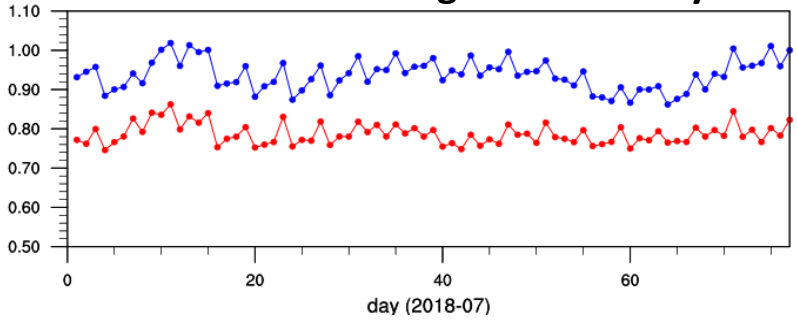


In this experiment, ensemble forecast is made in each data assimilation cycle.

Region A averaged: **improved**

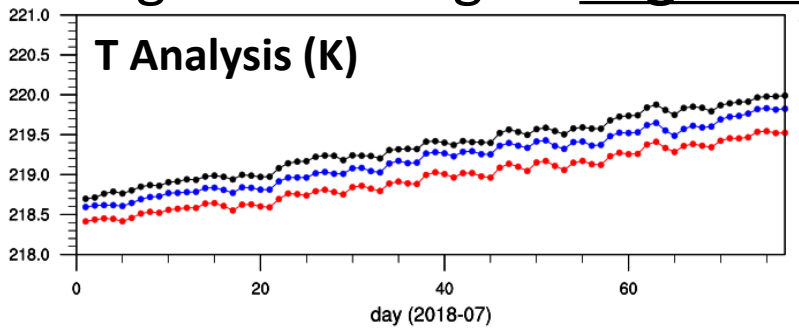


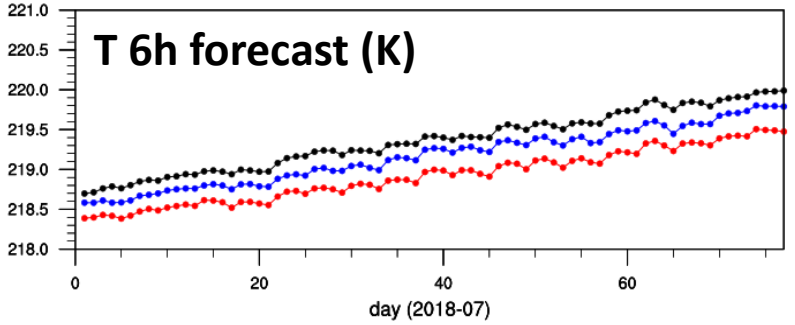


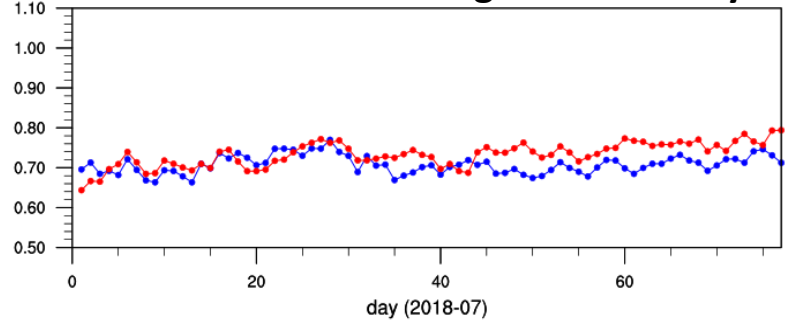


Warm bias corrected by decreasing increment in H4DEV compared to 3DVAR

Region B averaged: **degraded**





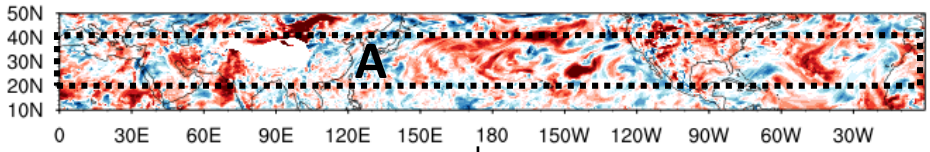


Cold bias worsened in H4DEV

2018.07.10. 00 UTC

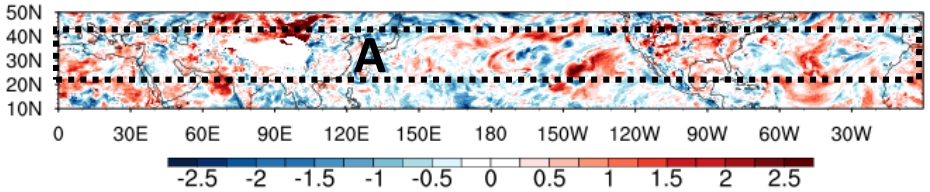
T Background error @ 800 hPa

3DVAR



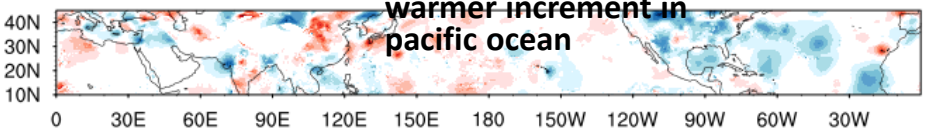
warm bias decreased

H4DEV



T Analysis increment @ 800 hPa

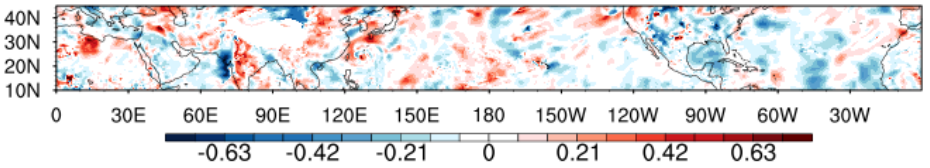
3DVAR



warmer increment in pacific ocean

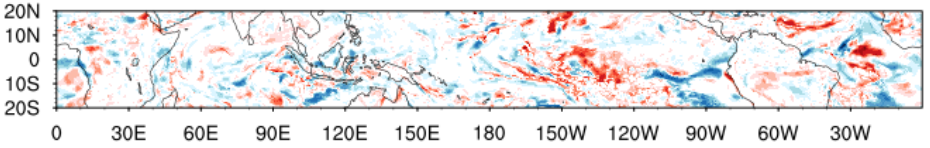
small scale feature is well captured

H4DEV



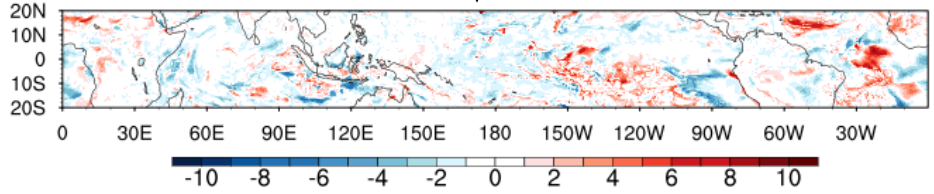
Q Background error @ 850 hPa

3DVAR



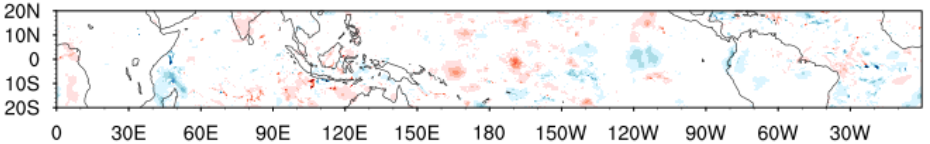
Wet bias decreased in Pacific ocean

H4DEV



Q Analysis increment @ 850 hPa

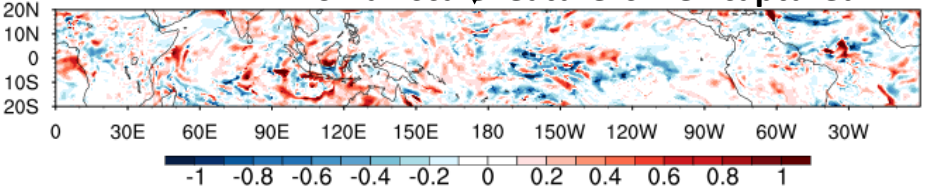
3DVAR



dry increment suppressed in the Pacific

Small scale feature is well captured

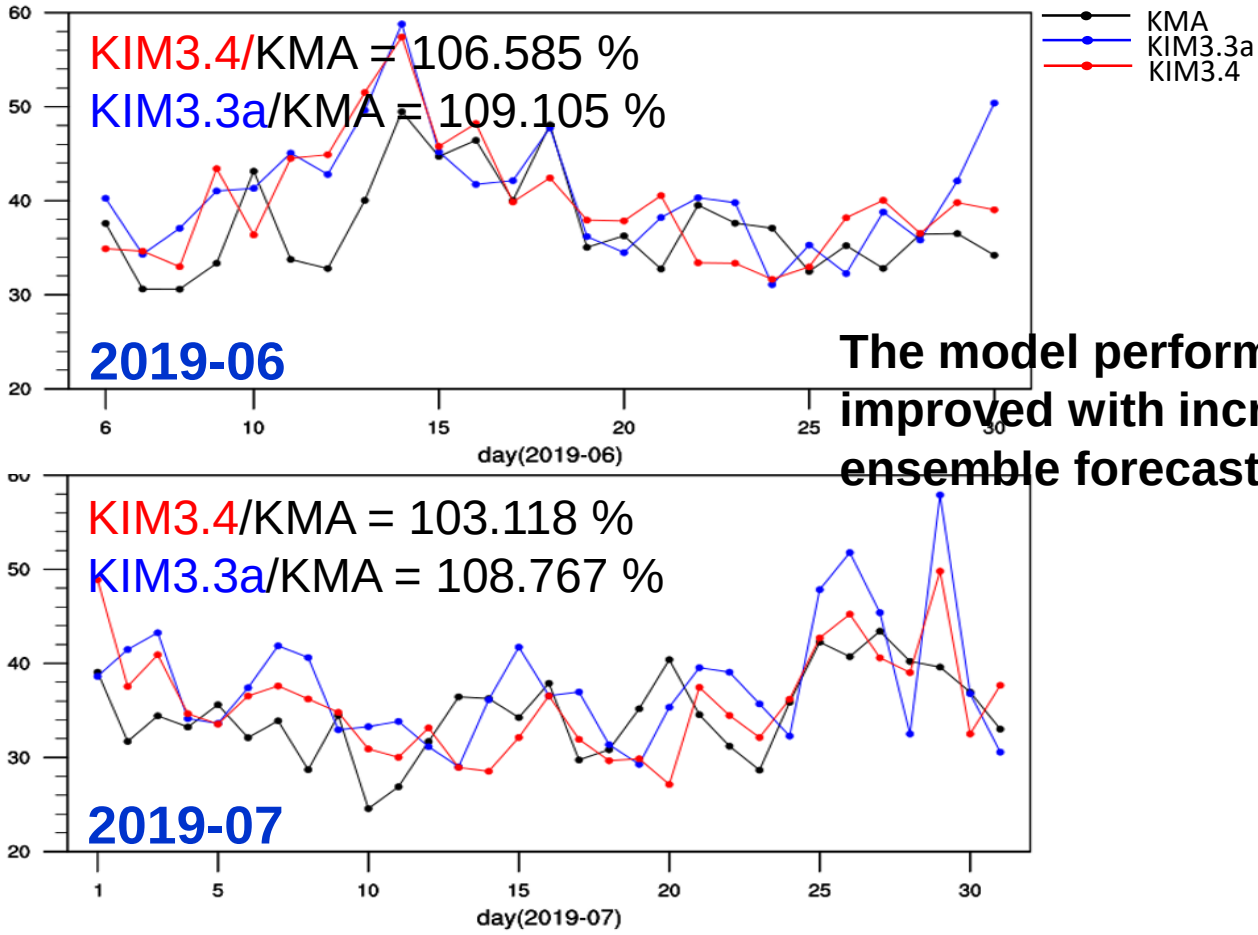
H4DEV



2. Impact of increase of ensemble BEC ratio

- The update version (KIM v3.4) includes the increase of ensemble BEC ratio (The impact of model improvement is small)
- Ensemble BEC : different ensemble ratios according to latitude (0.7 at the equator, 0.3 at the pole)

NH Z500hPa RMSE



The model performance is improved with increase of ensemble forecast.

Results: observation verification

00 UTC

1-5 day

NH SH EQ

			북반구					남반구					적도					ASIA					EAST ASIA				
			1일	2일	3일	4일	5일	1일	2일	3일	4일	5일	1일	2일	3일	4일	5일	1일	2일	3일	4일	5일	1일	2일	3일	4일	5일
WIND	850hPa	RMSE	-	-	▲	▲	▲	-	▲	-	▲	▲	-	-	-	▲	▲	-	-	-	▲	▲	-	▲	-	▲	▲
GEOPOTENTIAL HEIGHT	500hPa	RMSE	-	-	▲	▲	▲	▲	▲	▲	▲	^	▲	▲	▲	-	▲	-	-	▲	▲	▲	-	-	▲	▲	▲
TEMPERATURE	850hPa	RMSE	-	-	-	-	-	-	-	▲	▲	-	-	-	-	-	-	-	-	-	-	-	-	▼	-	-	-

WND850

GPH500

T850

색상 범례 (%) 10% 구간 별 대표 색상

degradation improvement

아이콘 범례 기준의 예측성능이 비교대상보다 좋은 경우 양수(+)값

비교값없음 | ⌄⌄ ~ -20% | ⌄ ~ -10% | ▾ ~ -3% | - -3% ~ 3% | ▲ 3% ~ | ^ 10% ~ | ^^ 20% ~

6-10 day

NH SH EQ

			북반구					남반구					적도					ASIA					EAST ASIA				
			6일	7일	8일	9일	10일	6일	7일	8일	9일	10일	6일	7일	8일	9일	10일	6일	7일	8일	9일	10일	6일	7일	8일	9일	10일
WIND	850hPa	RMSE	▲	-	-	-	-	▲	-	-	▲	▲	▲	▲	▲	▲	▲	▲	-	-	▼	-	-	-	-	▼	▼
GEOPOTENTIAL HEIGHT	500hPa	RMSE	▲	-	-	-	▼	▲	▲	-	▼	▲	▲	▲	▲	▲	▲	▲	-	▼	▼	-	▲	-	▼	▼	▼
TEMPERATURE	850hPa	RMSE	-	-	-	-	▼	-	▲	-	-	-	-	▲	-	-	-	▲	▲	-	▼	⌄	-	▼	▼	▼	⌄

WND850

GPH500

T850

색상 범례 (%) 10% 구간 별 대표 색상

degradation improvement

아이콘 범례 기준의 예측성능이 비교대상보다 좋은 경우 양수(+)값

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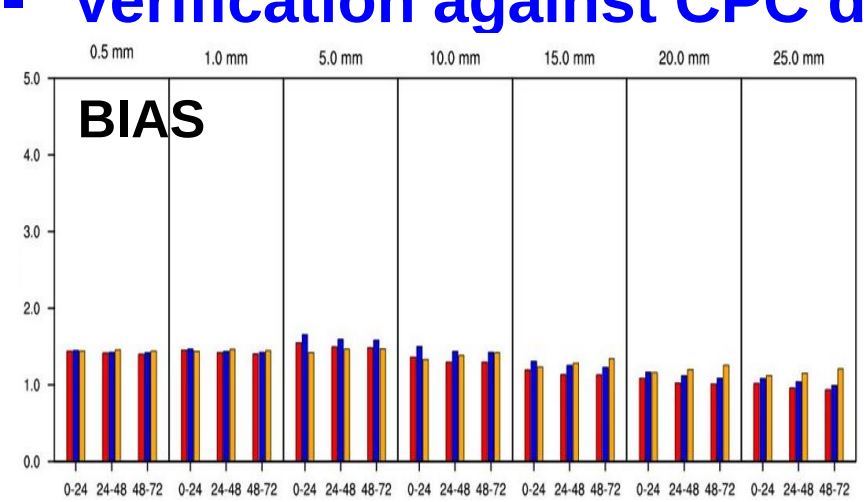
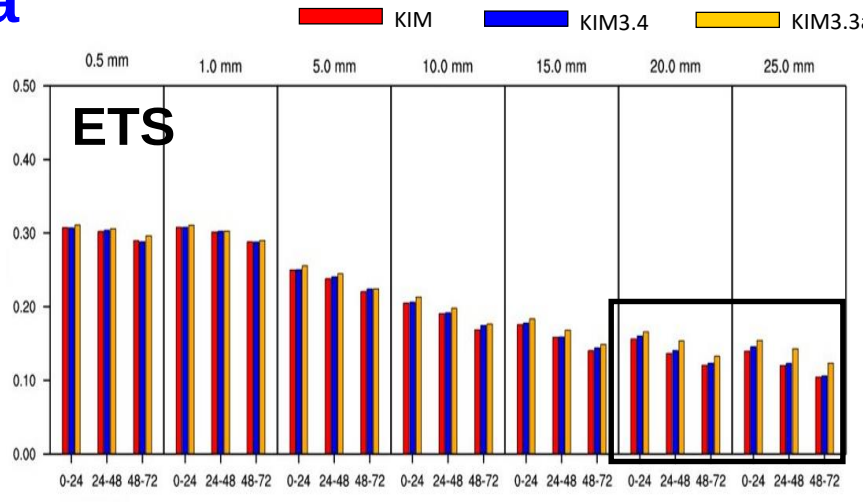
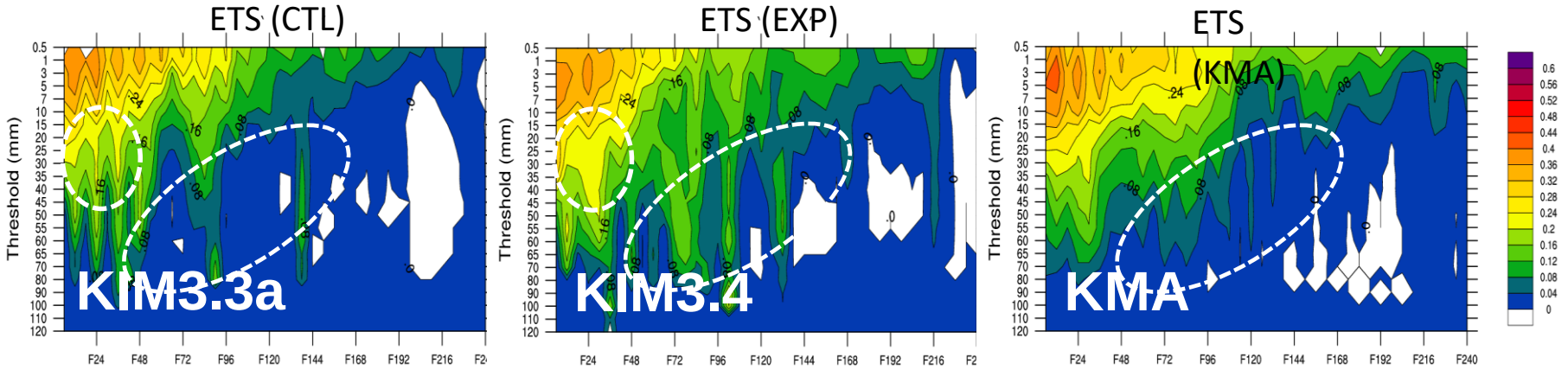
Result: Precipitation

- **Verification against CPC data**





- **Verification against reanalysis of rainfall at KMA**

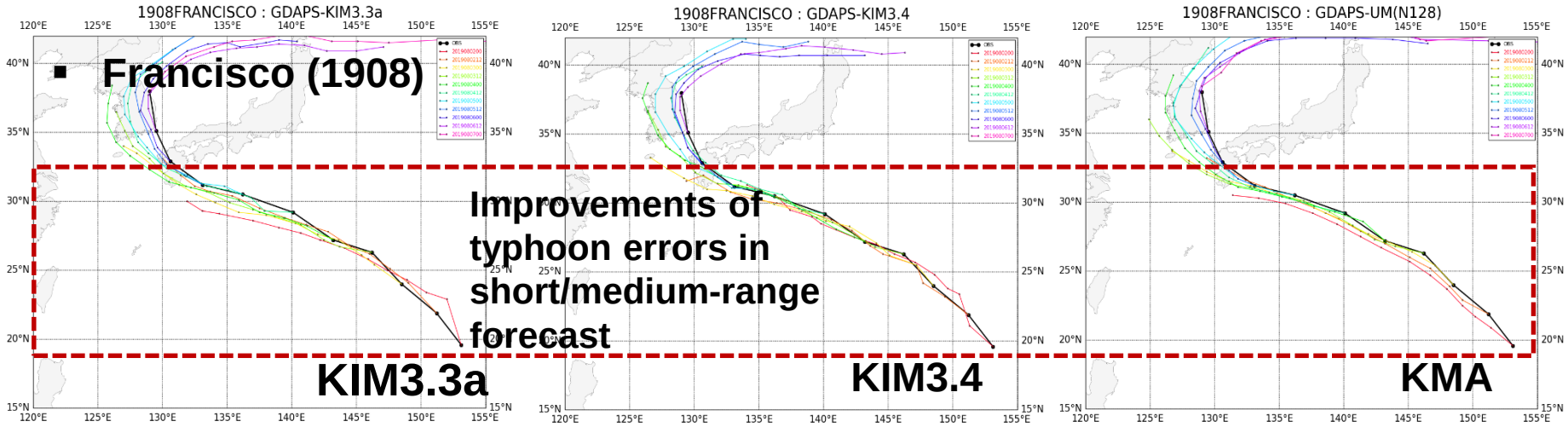


- EXP's performance improves in heavy rainfall.

Result: Typhoon track error

Case	model	Typhoon track error (km)			
		1d	2d	3d	4d
Danas (1905)	KIM3.3a	98	154	**150**	**247**
	KIM3.4	76	**129**	**171**	260
	KMA	**65**	149	192	-
Francisco (1908)	KIM3.3a	100	194	244	255
	KIM3.4	**93**	**117**	**185**	**242**
	KMA	**81**	179	271	430

* blue: smallest error



Remarks

- Impact of Ensemble BEC : the small-scale increment is well captured in H4DEV and thus, it robustly works by suppressing suspicious increments in temperature and moisture analysis. Although H4DEV works well, it tends to make the temperature increment colder in upper tropical region.
- Impact of Increase ratio of ensemble BEC: different ensemble ratios according to latitude (0.7 at the equator, 0.3 at the pole) is applied. It improves the model performance which resulted in improving the performance of heavy rainfall and typhoon track error on the Korean Peninsula.

Plans for data assimilation system

- Increase horizontal resolution of ensemble forecast in H4DEV (50→32km)
- Increase horizontal resolution for data assimilation (50→32km)
- Use more satellite data
- Variational bias correction
- Aircraft data vertical thinning/temperature bias correction
- Sonde observation error

- Satellite observation error
- Ensemble BEC ratio (upper tropical temperature)
- Localization of ensemble in hybrid data assimilation

Thank you for attention.