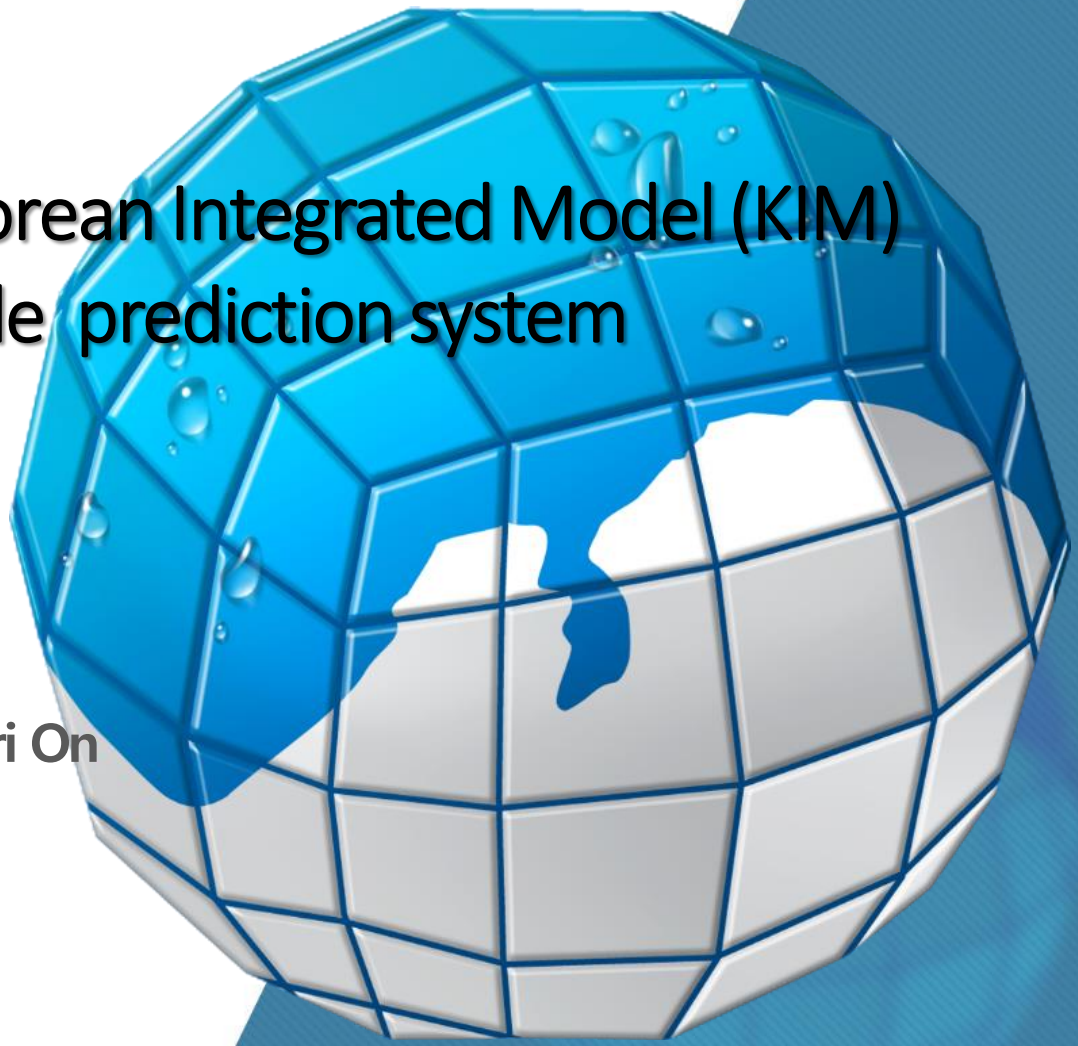
EMMDA conference in Delhi, India

Introduction to the Korean Integrated Model (KIM) based global ensemble prediction system



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Thanks to many KIAPS staffs

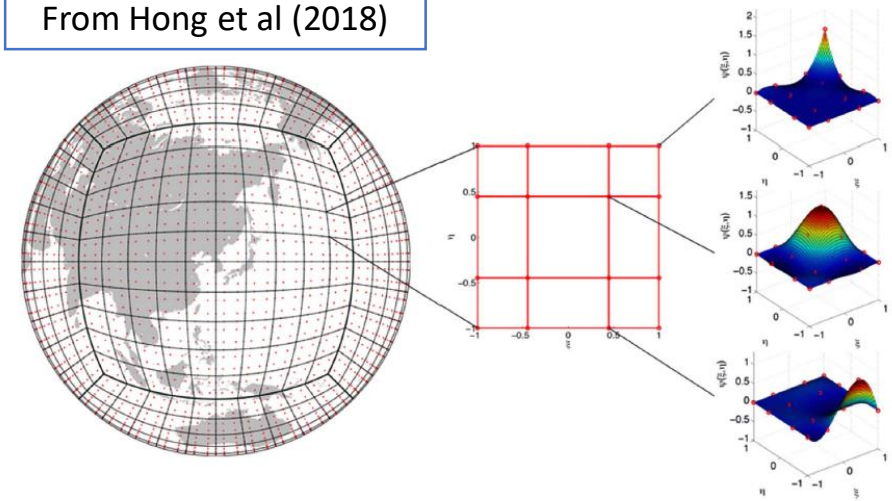
Numerical Weather Modeling Center, KMA

Korean Integrated Model (KIM)

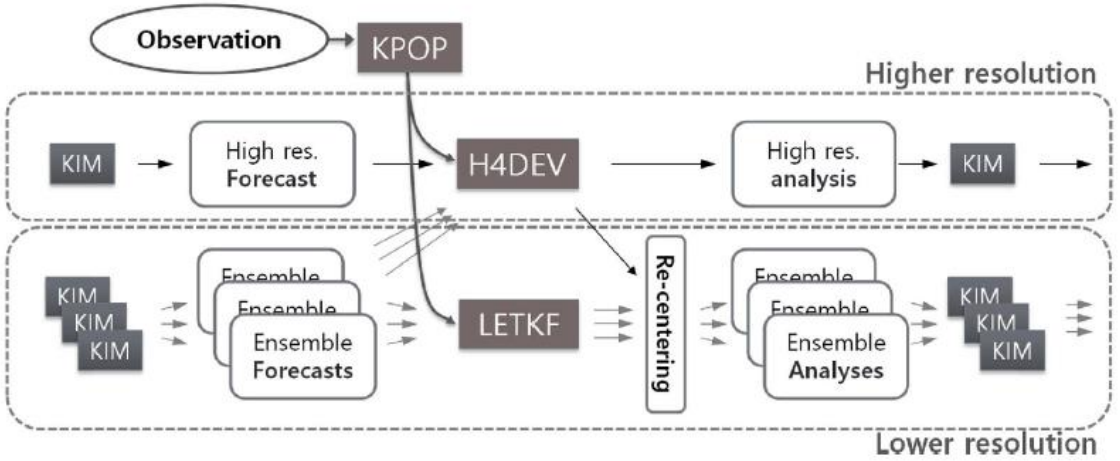
The global NWP system developed by KIAPS for 9 years

- Spectral-element non-hydrostatic dynamical core on a cubed sphere grid
- The vertical coordinate is a hybrid sigma dry-pressure coordinate

From Hong et al (2018)



From Kwon et al (2018)



- Hybrid four-dimensional ensemble variational data assimilation (4DEnVar) on its native grid

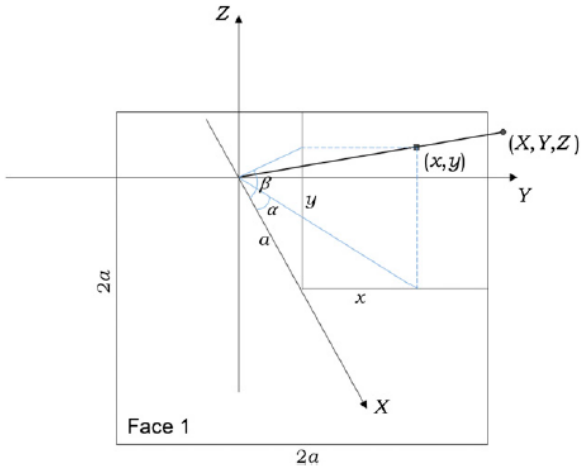
KIM Global EPS system

		KIM-GEPS	Operational (MOGREPS-G)
Ensemble DA	Data Assimilation (ensemble size)	LETKF (50)	ETKF (48)
	Localization	Horizontal, vertical	Horizontal, vertical
	Inflation	Adaptive multiplicative, Additive, RTPS (KIM3.5)	Multiplicative
Initial Surface Perturbations		-	SST, SMC, Tsoil
Stochastic Physics		SPPT, SPDT, SSST (KIM3.5)	Random Parameter, SKEB
Re-centering to the global analysis		u, v, t, q(50%), psfc(100%)	u, v, t, q, π
Horizontal/vertical resolutions		ne090np3(~50km) / L91(0.1hPa)	N400(~32km) / L70(80km)
Ensemble size for forecast products		Control + 13 perts (in semi-operations)	25 with Time Lagging (Control + 12perts + 12perts from -6hr cycle)

KIM – LETKF

Observation operators

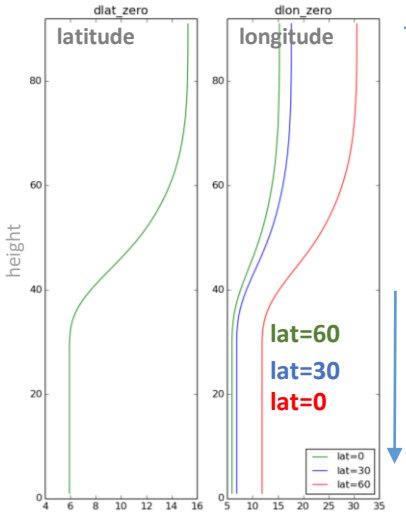
- Use bilinear interpolation between the observation point and the adjacent grid-points on a cube-face
- Which is calculated by the relationship between spherical coordinates and equiangular coordinates



Localization

- Horizontal localization:
  - Gaussian-like Gaspari-Cohn functions.
- Vertical localization:
  - For conventional data, Gaspari-Cohn functions with respect to pressure scale height.
  - For radiance data, direct use of weighting function defined by a gradient of transmittance of measured radiance.

Spatial Localization distance (degree)



Tighter localization at higher latitudes

Tighter localization in lower levels was more effective for humidity

KIM – LETKF

Inflation methods

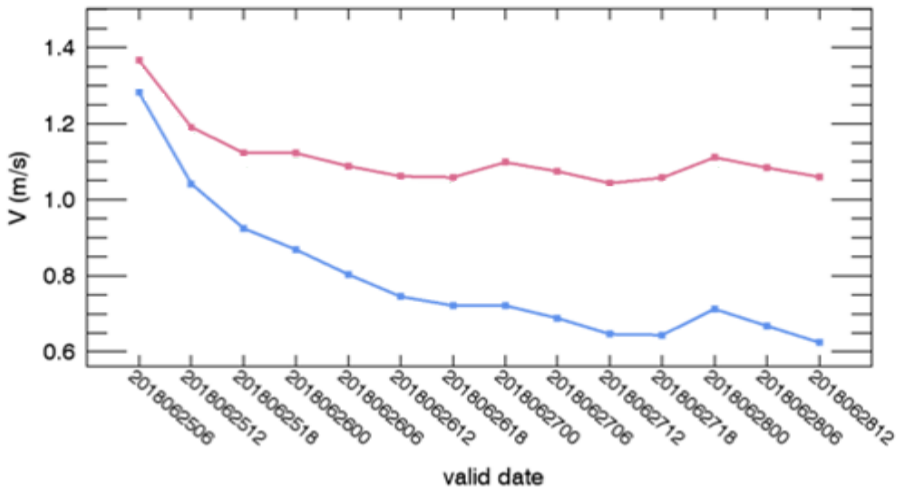
- Adaptive multiplicative inflation of Miyoshi (2011)

$$\Pr(\alpha_i^a) = N(\overline{\alpha}_i^o, v_i^o)\,\Pr(\alpha_i^b)/\text{norm}$$

- Additive Inflation
  - Make a pool of differences between T+12 and T+6 hour KIM forecasts valid at the same time, gathered for the 3-month period Sep – Dec 2016.
  - For each member *i*, a difference A_i is randomly chosen from the pool, the mean over all members subtracted, and the perturbation then scaled by w:

$A_i' = A_i - \sum_{i=1}^{50} A_i$, $x_i^a = x_i^a + w\,A_i'$, where w = 0.3

V-comp spread of 850 hPa at T+6hr



Effect of Inflations

- Adaptive multiplicative inflation by itself cannot maintain spread in the KIM LETKF
- Additive inflation has an important role
- The KIM LETKF adopted **RTPS** in KIM3.5.

Adaptive Multiplicative + Additive

Adaptive Multiplicative

Scaling and partial recentering

Scale down upper-level perturbations
Move the ensemble-mean analysis towards the deterministic analysis

$$X'_i = \underbrace{s_{ens}(X_i - \bar{X}_i)}_{\text{scale pert}} + \underbrace{(1 - w_{det})\bar{X}_i + w_{det}X_{det}}_{\text{partially recenter state}}$$

X_i Analysis of each ensemble member

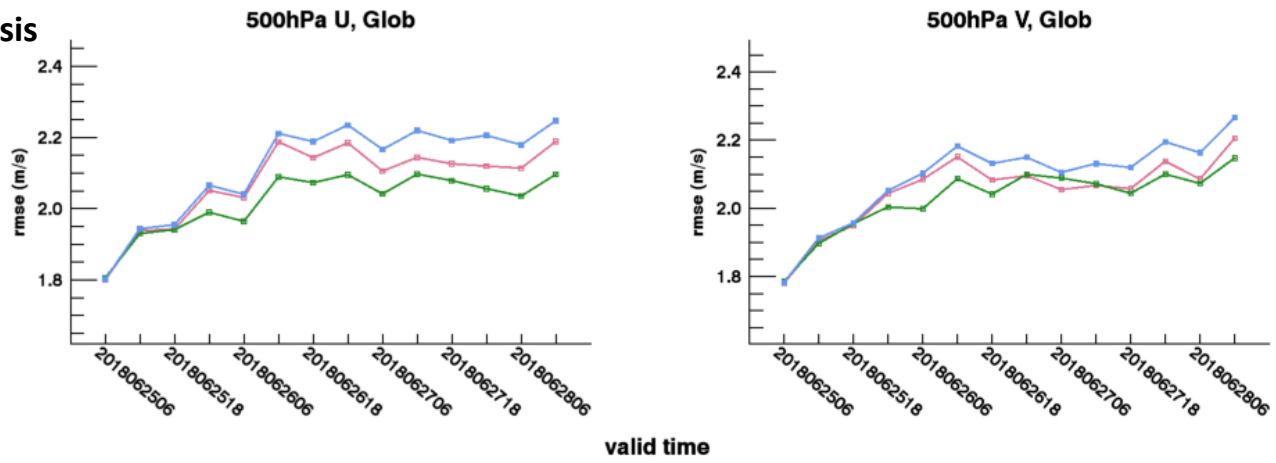
X_{det} Analysis of the deterministic model

s_{ens} 1, but decreased linearly from level 75 to the 0.7 at the top to prevent excessive spread in the upper layers

w_{det} 1.0 for u, v, and t, 0.5 for q, 0 for psfc, but 0.5 for u, v, t in KIM3.5

RMSE against ECMWF analysis

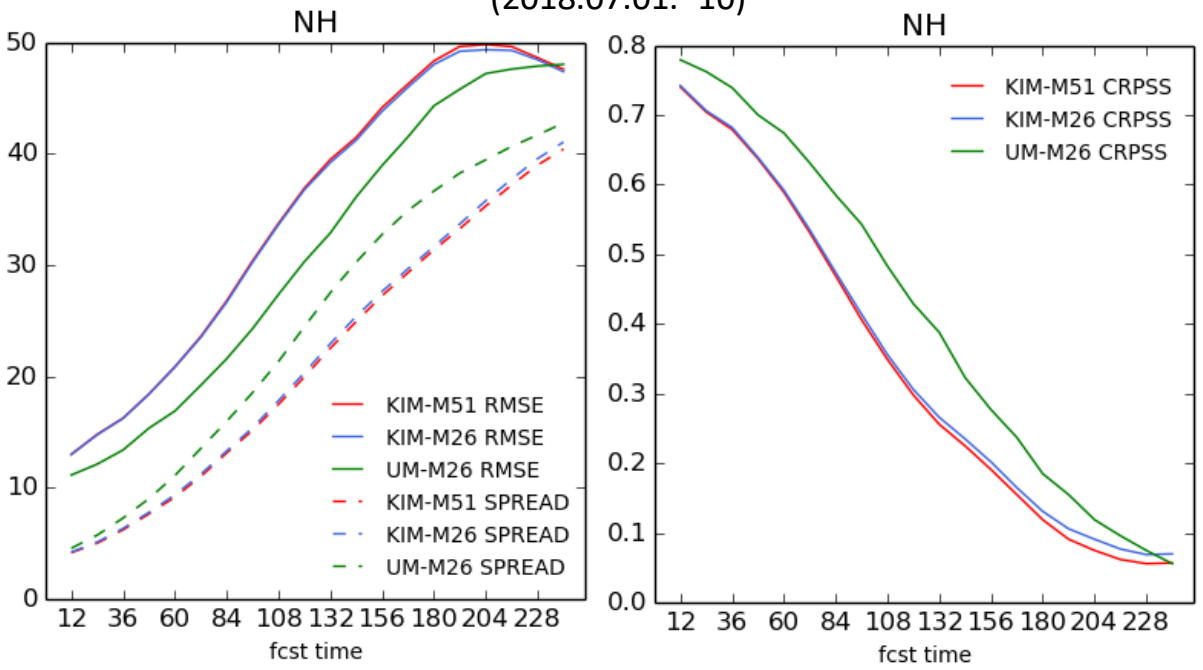
- w_{det}=1 for u, v, and t
- w_{det}=0 for u, v, and t
- w_{det}=1 for u, v, and t without Additive Inflation



Performance of KIM3.4 – EPS

Evaluation of ensemble forecasts produced by an early version
KIM3.4: ne090np3 (50km) / no Stochastic Physics / multiplicative & additive inflations

500 hPa GPH in NH against Sondes
(2018.07.01.~10)

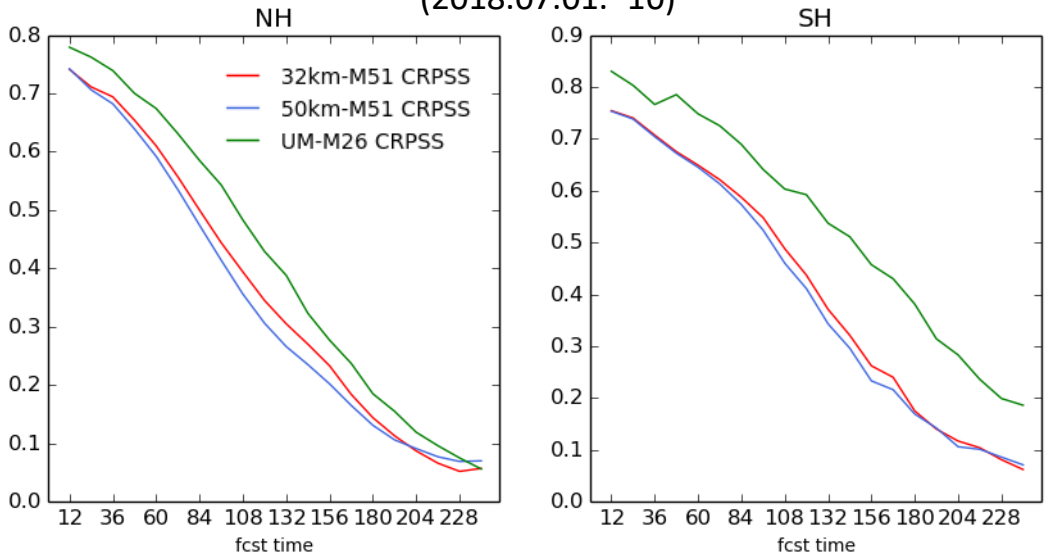


- Small spread relative to MOGREPS-G
- Effect of increasing the ensemble size is not big

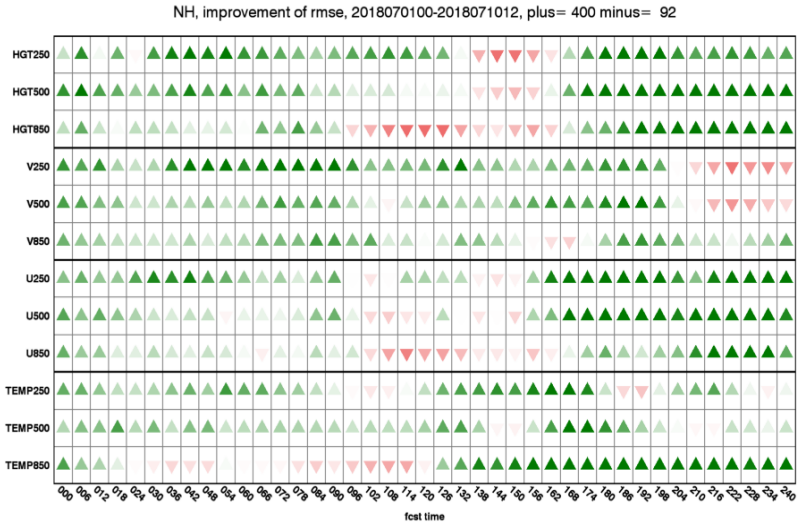
Effect of ensemble resolution

Compare two horizontal resolutions with identical options
KIM3.3b: **ne090np3** (50km) / **ne144np3** (32km)

500 hPa GPH in NH against Sondes
(2018.07.01.~10)



Hinton diagram for Global model



- Higher resolution gives benefit, but performance still not comparable to the operation EPS.
- (In the 4DEnVar system, the high-resolution ensemble improves the performance of the global deterministic analysis.)

Recent developments by KIAPS By Seoleun Shin

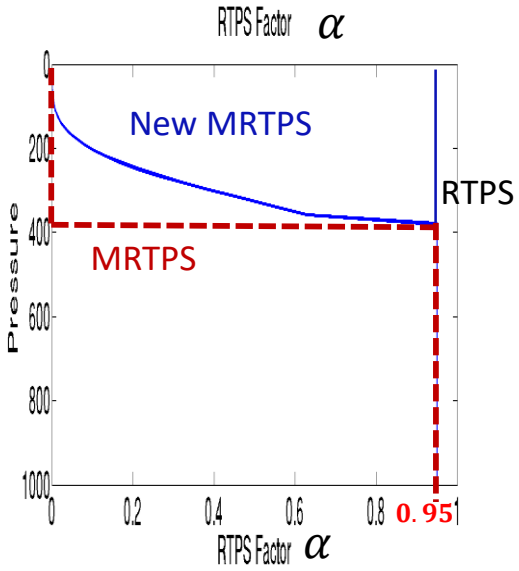
Relaxation-to-prior spread (RTPS) Inflation (Whitaker and Hamill, 2012)

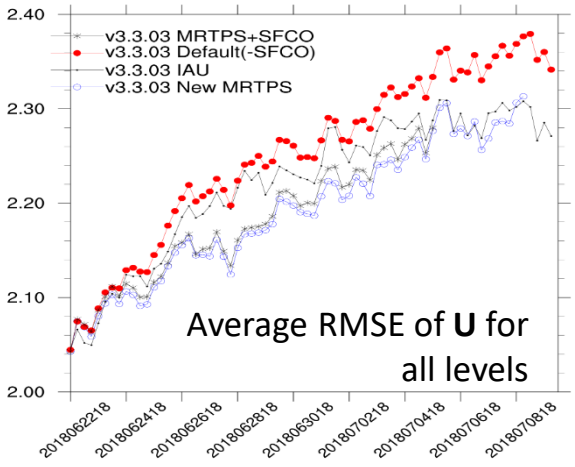
$$\mathbf{x}_i'^a \leftarrow \mathbf{x}_i'^a \left(\alpha \frac{\sigma^b - \sigma^a}{\sigma^a} + 1 \right)$$

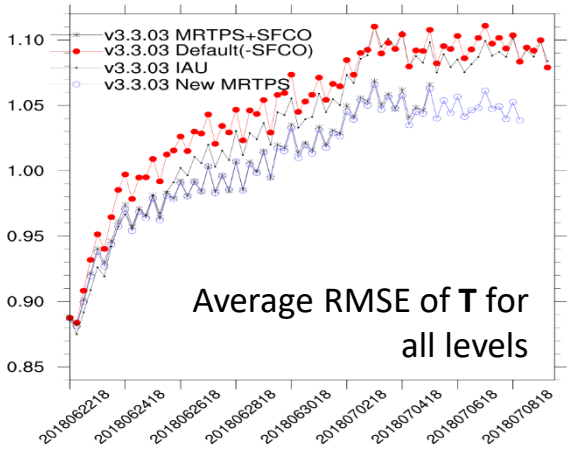
Spread of background

RTPS factor

Spread of analysis







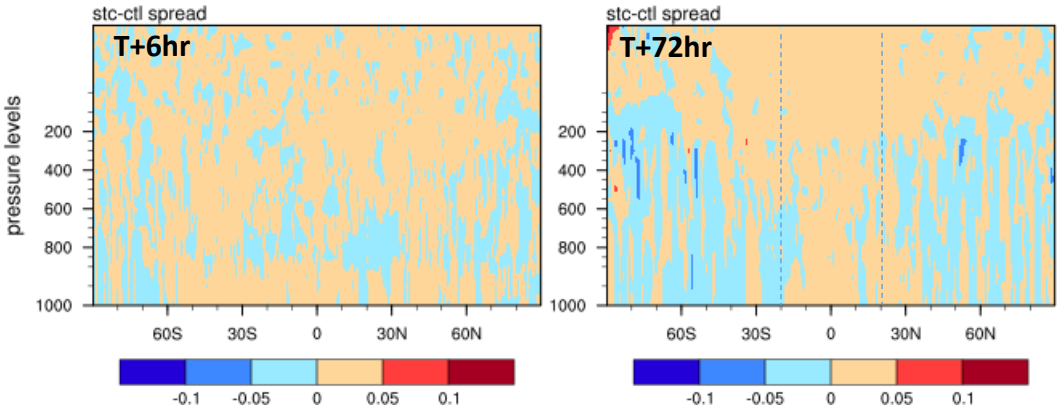
- RTPS is applied instead of the adaptive multiplicative inflation
- Tested different vertical profiles of the RTPS factor α: "RTPS", "MRTPS", and "New MRTPS".
- RMSE is better in order of New MRTPS > MRTPS > RTPS > adaptive multiplicative inflation
- Spread is also improved (not shown)

Recent developments by KIAPS By Myung-Seo Koo

Stochastic Perturbed Parameterization Tendencies (SPPT) & Stochastic Perturbed Dynamic tendencies (SPDT)

- SPPT perturbs the total parameterized tendencies with a random number sampled from the Gaussian distribution with a spatial and temporal autocorrelation.
- One random number for each vertical column. Random numbers uncorrelated horizontally.
- The tendency is applied only to temperature and humidity now, because of model stability.
- SPDT is similar to SPPT, but for dynamic tendency

Spread difference for U between w/o ST and with ST



- The stochastic tendency methods generally improve spread at early forecast times for every variable, even if only applied to T and Q.
- But as the forecast time gets longer, the middle and polar latitudes below 200 hPa show reduced spread.

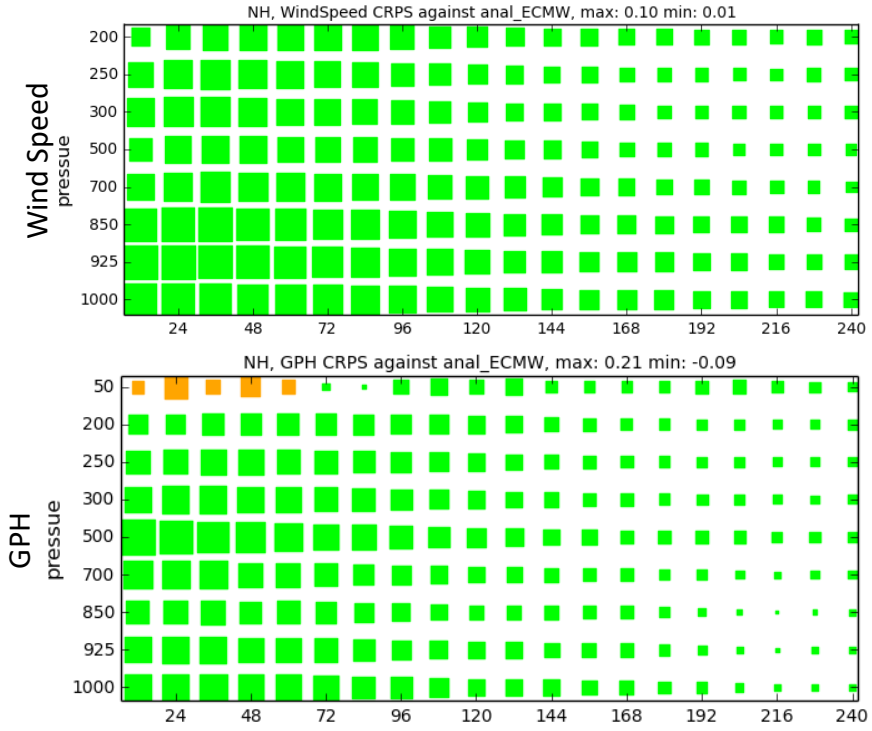
The current KIM-EPS

Compare two versions

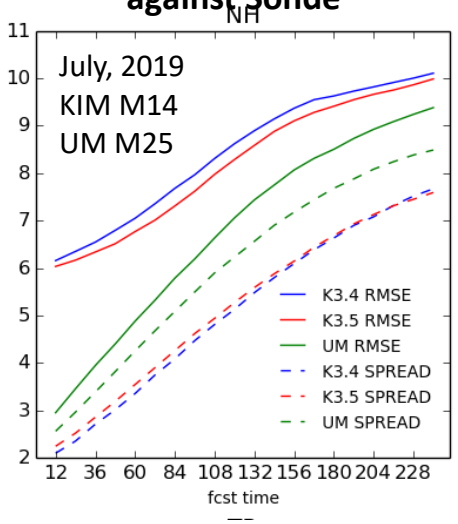
KIM3.4: ne090np3 (50km) / no Stochastic tendency / multiplicative & additive inflations
Recentering: w_2 = 1.0 (u, v, t), 0.5(q) / ensemble size 14

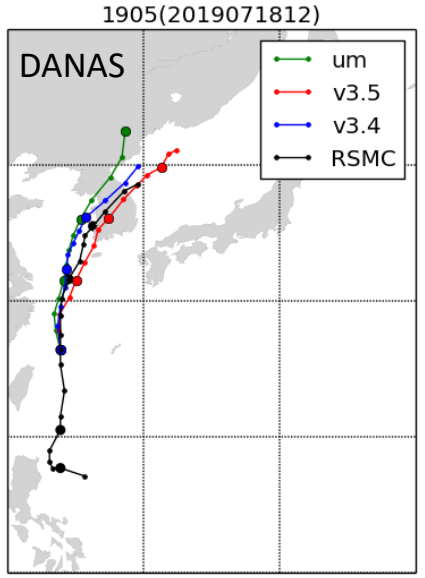
KIM3.5: ne144np3 (32km) / SPPT & SPDT / new MRTPS & additive inflations
Recentering: w_2 = 0.5 (u, v, t, q) (+ Upgrade of DA and Physics) / ensemble size 14

Hinton diagram for CRPS against ECMWF in NH



500 hPa GPH in NH against Sonde

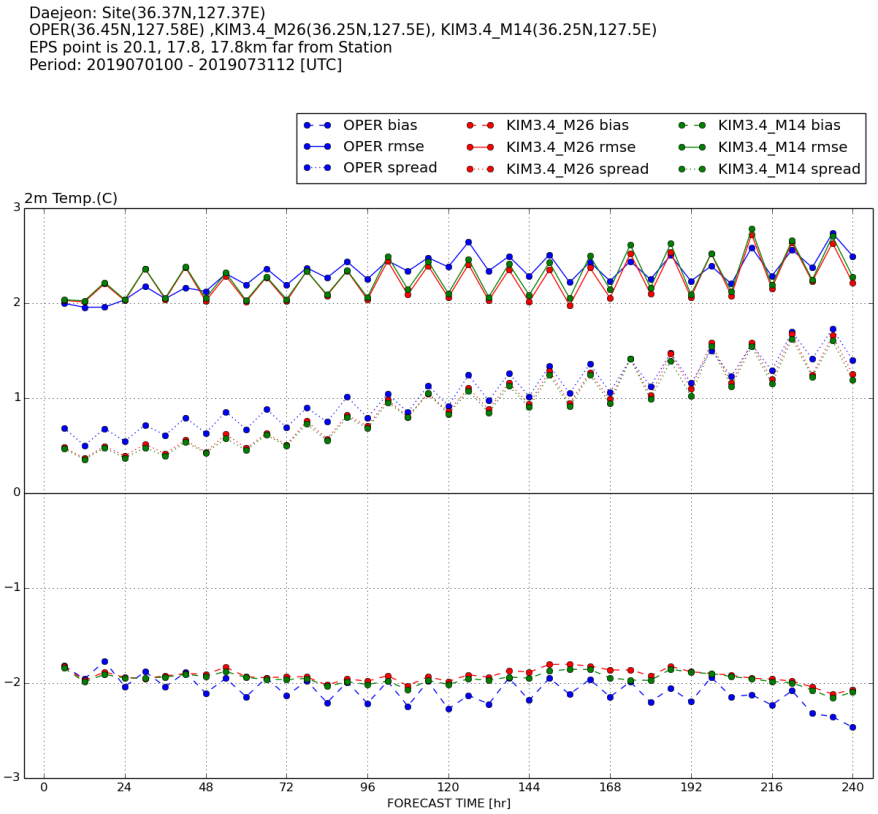




- New version of KIM-EPS shows improvement compared to the previous version for almost all variables.
- The operational MOGREPS-G EPS is still much better
- Typhoon track of ensemble mean is comparable to UM

Future plan

Test initial SST perturbations, as used already in MOGREPS-G



- The spread of surface variables is too low, especially for the early forecast times.
- In addition, there's no big difference for RMSE and spread between ensemble sizes of 26 and 14
- So we need to add surface perturbations

Experiments

1. **SSST**: stochastic tendency like SPPT in 3 layer sea-ice model
   * ocean-mixed layer model
1. **Initial SST perturbations**: perturbations around OSTIA analysis, as in MOGREPS-G

Future plan

Operational Plan

	April, 2020	April, 2021
Status	Semi-operational	Operational
HPC	5th initial machine (416 nodes/39,936 cores)	5th Final machine (7,200 nodes/691,200 cores)
Cycle	Late cycle	Early cycle
resolution	Ne144np3(32km) L91 M50	Ne144np3(32km) L91 M50
Ensemble size for fcst	Control + 13 perturbations	Control + 25 perturbations
fcst length	10 days (00, 12 UTC)	12 days (00, 12 UTC)