Sensitivity of stochastic perturbation schemes to the data assimilation in ensemble forecast system

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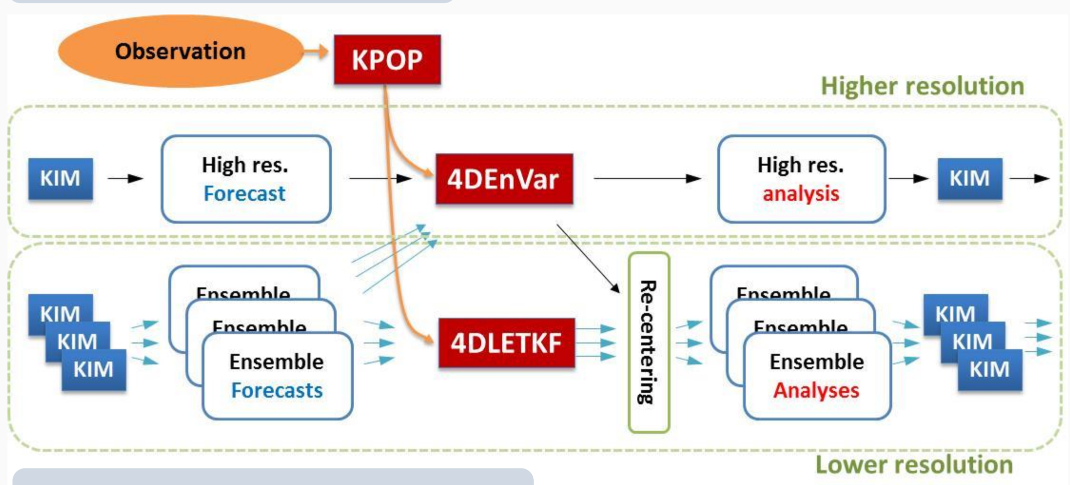
1 Background and objectives

The Korea Institute for Atmospheric Prediction Systems (KIAPS) was established in 2011 with a mission to develop a global atmosphere-only numerical weather prediction system for operational use at the Korea Meteorological Administration (KMA). This system was completed on schedule, and made operational at KMA in April 2020, immediately giving a world-class performance. The system is based on a new atmospheric model called the "Korean Integrated Model" (KIM), which is based on a cubed-sphere grid and uses the spectral element method within its dynamical core. Deterministic data assimilation (DA) is based on a hybrid-4DEnVar algorithm, and forecast uncertainties are modelled by a 50-member Ensemble Prediction System (EPS). The EPS is based on a local ensemble transform Kalman filter (LETKF) DA algorithm, and further schemes are included to account for deficiencies and uncertainties in the DA process and the forecast model.

2 KIM and experimental design

KPOP and DA



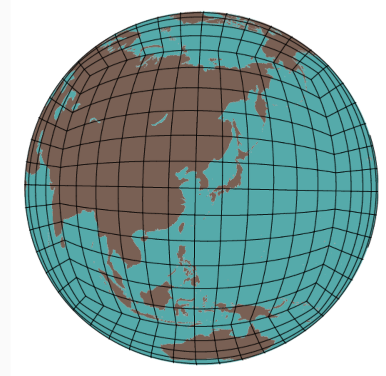
Observation pre-processing: KIAPS Package for Observation Processing (KPOP) [Kang et al., 2018]

Data assimilation: Hybrid-4DEnVar System (50 ensemble members) [Kwon et al., 2018]

Dynamical core

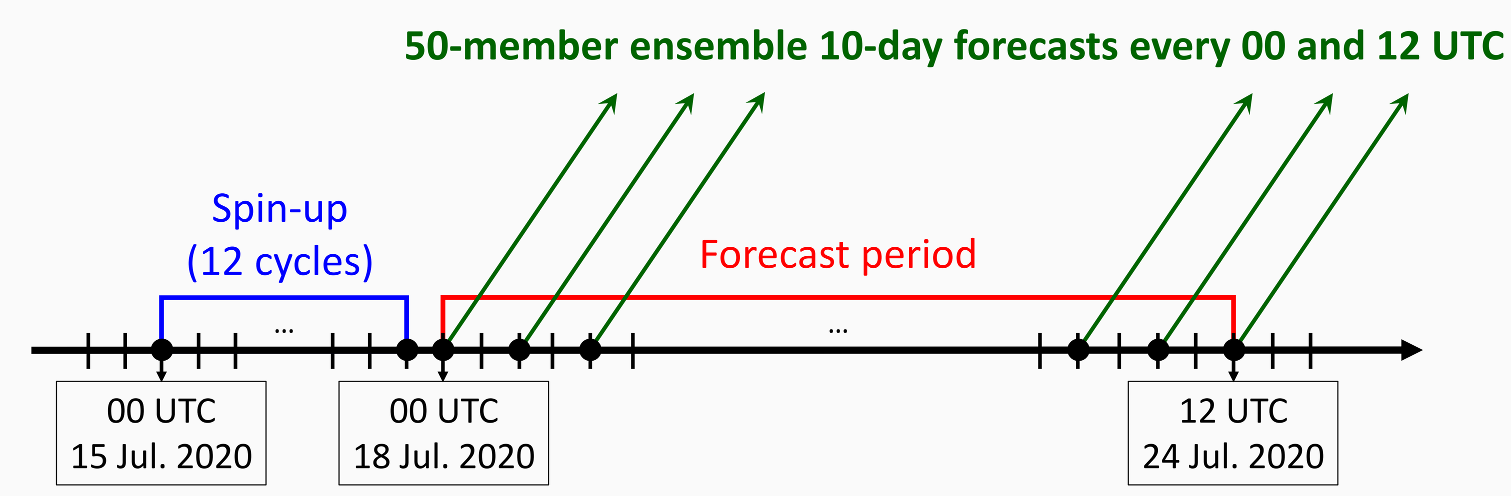
[Choi et al., 2014; Choi and Hong, 2016]

Equation	Non-hydrostatic (perturbation variables)
Spherical grid	Cubed-sphere
Horizontal resolution	~100km (NE45NP3)
Vertical levels	91 (~80km)
Temporal approximation	split-explicit 3rd Runge-Kutta

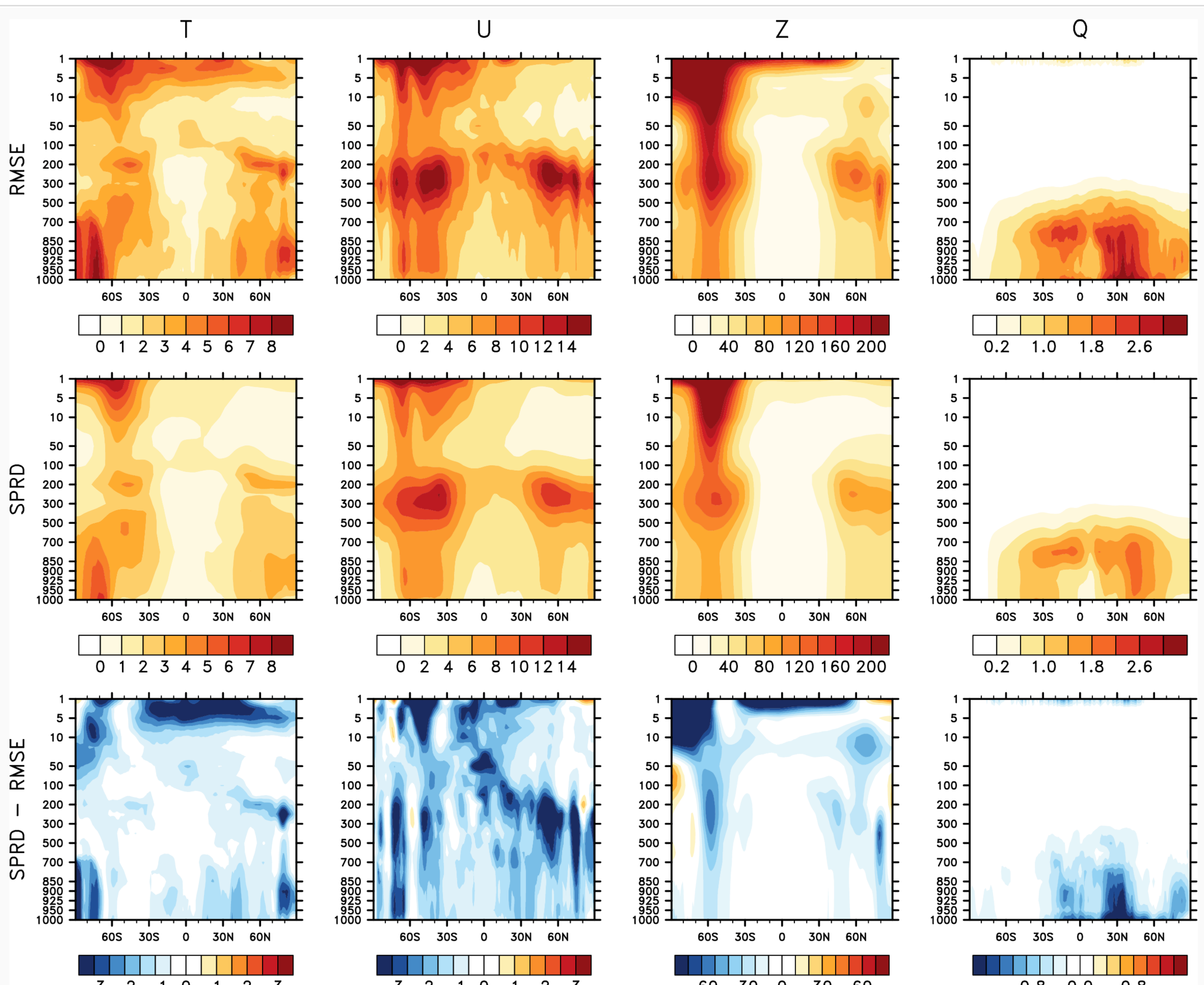


Experimental design

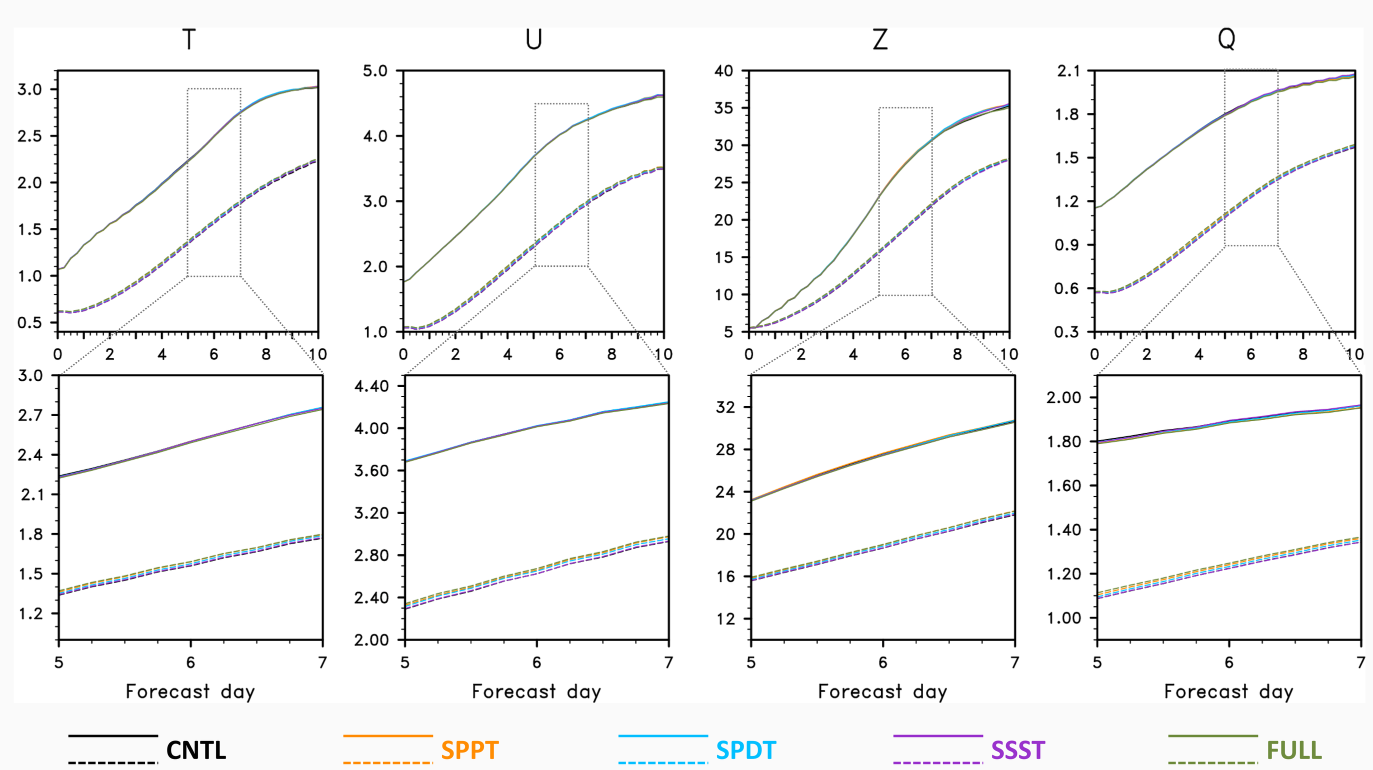
Stochastic Perturbation schemes	L (km) & t (h) scales	Control CNTL	ON Experiments SPPT	SPDT	SSST	FULL
stochastically perturbed physical tendencies (SPPT)	500 / 6	X	O	X	X	O
stochastically perturbed dynamical tendencies (SPDT)	500 / 3	X	X	O	X	O
stochastically perturbed initial sea surface temperatures (SSST)	1,000 / 6	X	X	X	O	O



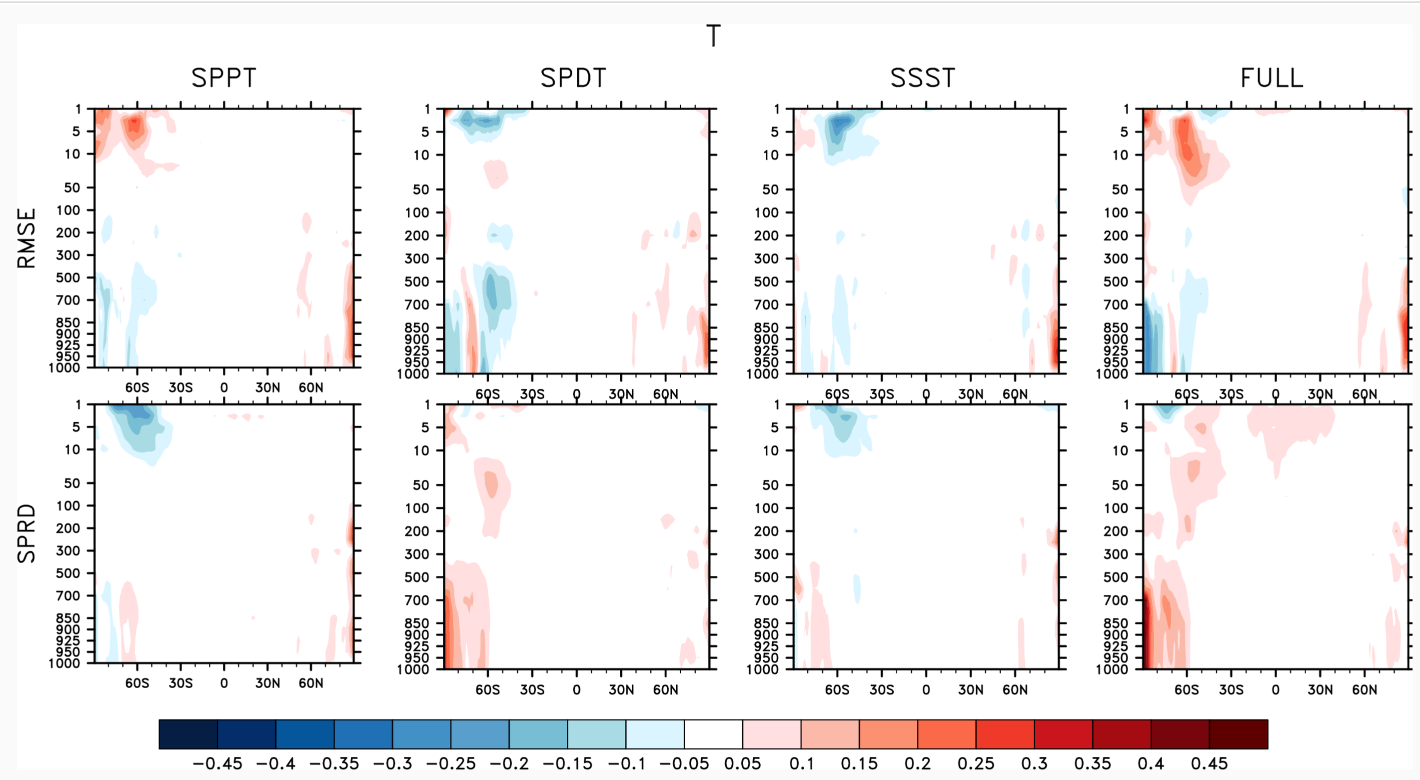
3 Results

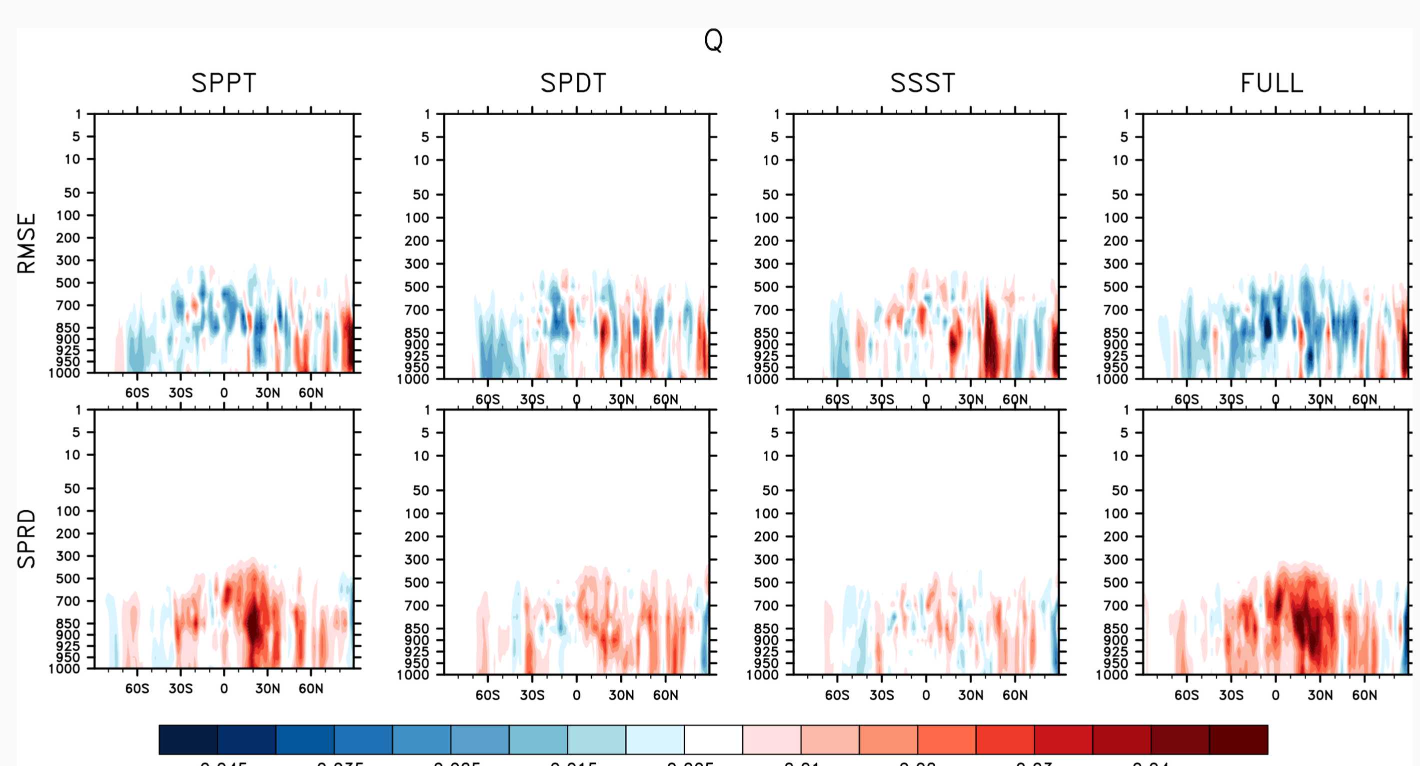


◀ The zonal mean ensemble mean error calculated by the root mean square error (RMSE) against the Integrated Forecast System (IFS) analysis (upper panels), ensemble spread (SPRD) (middle panels), and differences between SPRD and RMSE (lower panels) after 240-hr forecast time of the control run for temperature (T), zonal wind (U), geopotential height (Z), and specific humidity (Q).



◀ The RMSE of the ensemble mean (solid lines) and ensemble spread (dashed lines) versus forecast time (in days) for 850 hPa T, U, Z, and Q in the northern extra-tropics (20°–90°N) for various representations of model error: CNTL, SPPT, SPDT, SSST, and FULL.





▲ The zonal mean differences between ON experiments (e.g. SPPT, SPDT, SSST, and FULL) and CNTL of the RMSE (upper panels) and the SPRD (lower panels) against the IFS analysis after the 240-hr forecast for T (in K) and Q (in g/kg). Results are represented with a composite of the 14 forecasts from 00:00 UTC on 18 to 12:00 UTC on 24 July 2020.

4 Summary and conclusions

- **We examine the sensitivity to three stochastic perturbation methods, which aim to account for uncertainties in the forecast model and at the lower boundary: SPPT, SPDT, and SSST. To reduce computational costs, the sensitivity tests were carried out within a low-resolution framework, and we analyzed the effect of the schemes on the ensemble mean error and spread in temperature, zonal wind, geopotential height and specific humidity in a 10-day forecast. However, it is difficult to characterize sources of model uncertainty due to their small scales.**
- **It is necessary to find the optimal combination by changing the tuning parameters (e.g. length scale, time scale, and amplitude) of the three perturbation schemes.**

ECMWF workshop on model uncertainty, 9–12 May 2022