Impact of the stochastically perturbed parameterization tendencies scheme in the Korean Integrated Model

Ja-Young Hong, Taehyoun Shim, Shin-Woo Kim and Kyung-Hee Seol

Korea Institute of Atmospheric Prediction Systems

1 Introduction

- Some forecast error would be due to model imperfections, even if the initial conditions exactly correspond to the true states of atmospheric flows (Leutbecher 2017), and this will limit predictability.
- Ensemble weather forecast is the method of choice in numerical weather prediction to generate probability density of the atmospheric state at some future time (Leutbecher and Palmer 2008; Lock et al. 2019), so it is useful for the representation of uncertainty.
- At the Korea Institute for Atmospheric Prediction Systems (KIAPS), the ensemble system comprises 50 perturbed forecasts. The perturbed forecasts are generated by each starting from a uniquely perturbed set of initial conditions, designed to represent uncertainty in the analysis of the initial state.
- In addition, the forecast model itself includes stochastic perturbations to represent model uncertainties, which arise due to simplifications made necessary by constraints on resolution, efficiency and/or our knowledge of some processes (Lock et al. 2019)
- In this presentation, we examine the sensitivity to stochastically perturbed physical tendencies (SPPT), which aims to account for uncertainties in the forecast model and test a three-scale pattern, which consists of a linear combination of three independent random patterns, each describing a different correlation scale.

2 Method

The formulation of SPPT in the KIM

$$\mathbf{p} = (1 + \mu r)\mathbf{p}_D$$

- $\mathbf{p}$: perturbed tendencies
- $\mathbf{p}_D$: unperturbed net physics tendencies for the four prognostic model variables (temperature (T), specific humidity (q) and wind (u & v) components)
- r : random pattern, which is drawn from a Gaussian distribution with mean of zero and standard deviation
- μ : optional tapering function that depends on the model level only

Details are in Palmer et al. (2009) and Berner et al. (2009)

Summary of the experiments

Table 1. Configurations of random forcing tuning parameters for the experiments using SPPT: τ the time decorrelation scale, L the spatial auto-correlation scale, σ the standard deviation in grid-point space, and μ the tapering function.

Experiments	τ (d)	L (km)	σ	μ	Variables
SPPT1	0.25	500	0.42	on	T, q
SPPT2	3	1,000	0.14	on	T, q
SPPT3	30	2,000	0.048	on	T, q
SPPT1_x3	0.25	500	0.42	off	u, v, T, q
SPPT0	control experiment with perturbations to initial conditions only				

Table 2. Details of the configurations for the ensemble experiments.

	Details	
KIM	V3.7.10	
Coupled to an ocean model	No	
Data Assimilation	No (cold start)	
Resolution	NE090NP3(~50km)L91	
Ensemble size	10	
Forecast range	35 days (extended medium-range)	
Forecast period	10 years (2011-2020)	
Forecast frequency	SPPT0, SPPT1_x3	1st Feb/May/Aug/Nov
	SPPT1 to 3	1st Feb

3 Results

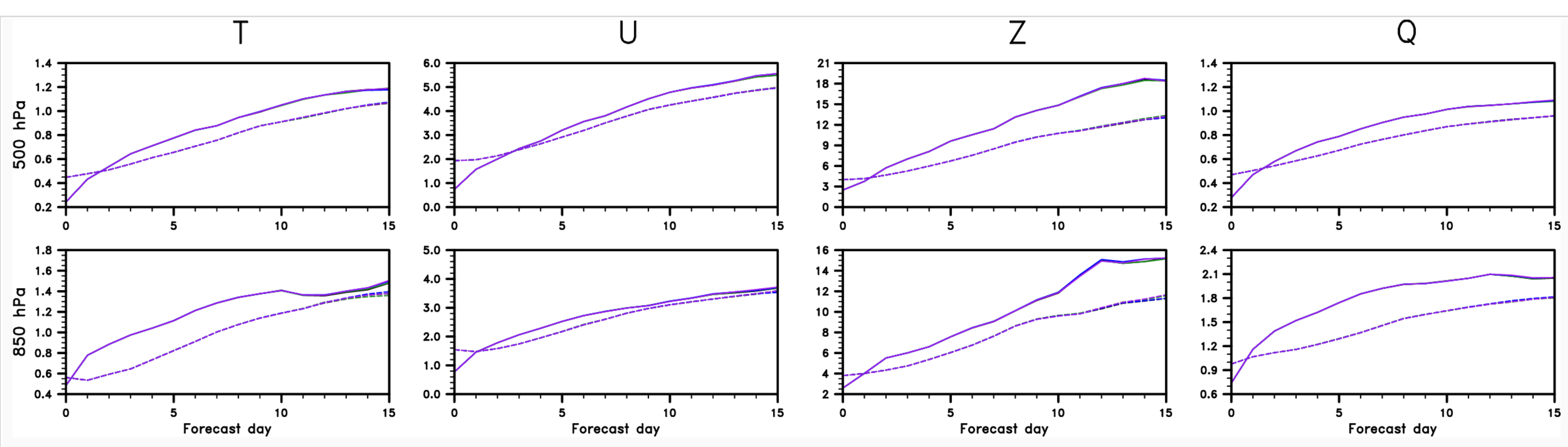

Figure 1. Time series of the experiment for temperature (T), zonal winds (U), geopotential height (Z), and specific humidity (Q) at 500 and 850 hPa to day 15 for ensemble error (solid lines) and ensemble spread (dashed lines) over the Tropics (20˚S–20˚N). Experiments: SPPT0 (black), SPPT1 (green), SPPT2 (blue), SPPT3 (purple). Results are from 10 start dates covering February 2011–2020.

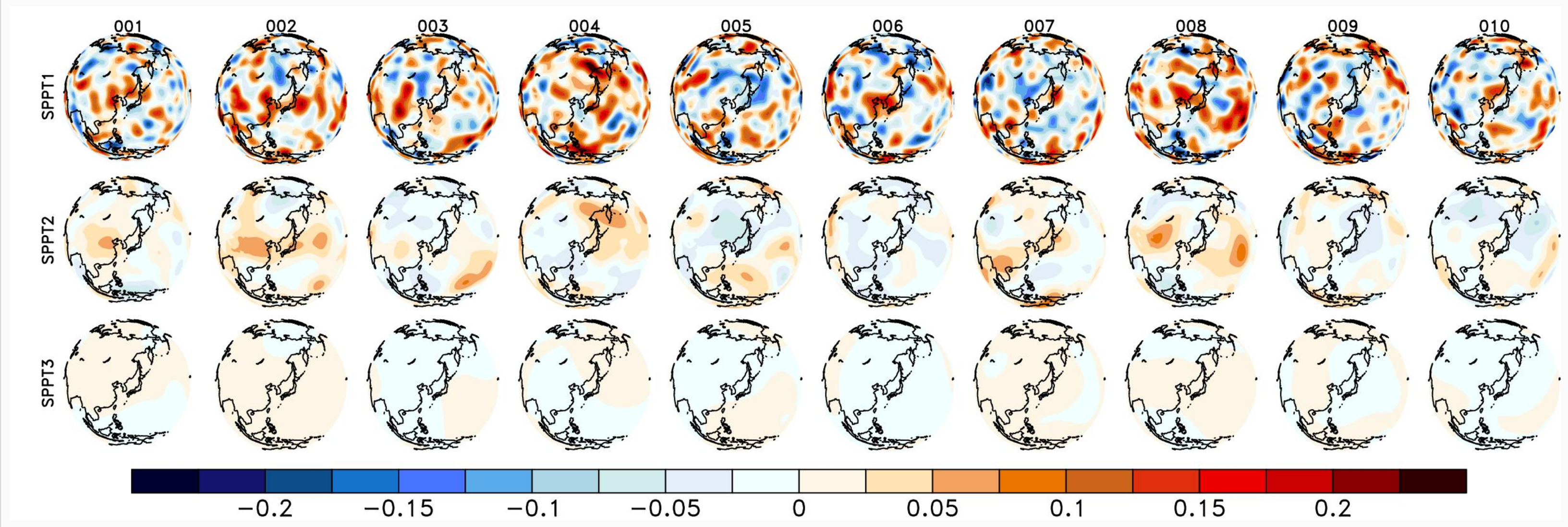

Figure 2. Example random perturbation patterns of ensemble member numbers 1 to 10 from SPPT1 to 3.

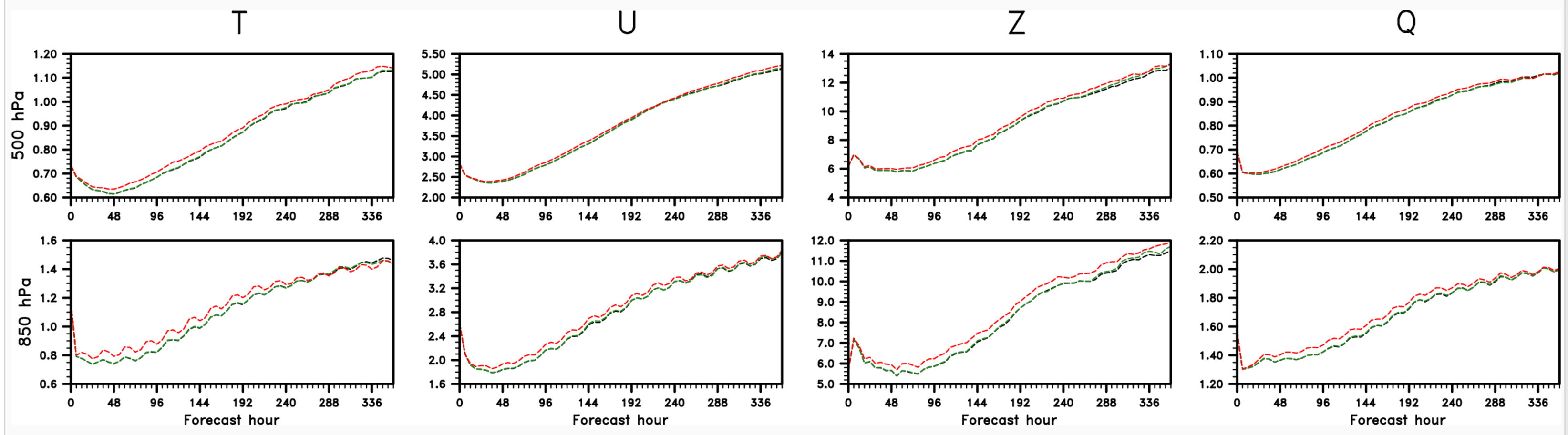

Figure 3. Time series of the experiment for T, U, Z, and Q at 500 and 850 hPa to hour 360 for ensemble spread over the Tropics (20˚S–20˚N). Experiments: SPPT0 (black), SPPT1 (green), SPPT3_x3 (red). Results are from 10 start dates covering February 2011–2020.

Table 3. Differences (%) relative to the experiment with perturbations to initial conditions only (SPPT0) for T, U, Z and Q at 850 hPa to hour 360 for ensemble spread over the Tropics (20˚S–20˚N). Experiments: SPPT1 , SPPT1_x3.

Experiments	T		U		Z		Q	
	min	max	min	max	min	max	min	max
SPPT1	-1.34	0.86	-0.50	0.86	-0.50	1.83	-0.15	0.43
SPPT1_x3	-2.99	9.94	0.00	5.43	0.00	7.42	0.00	3.93

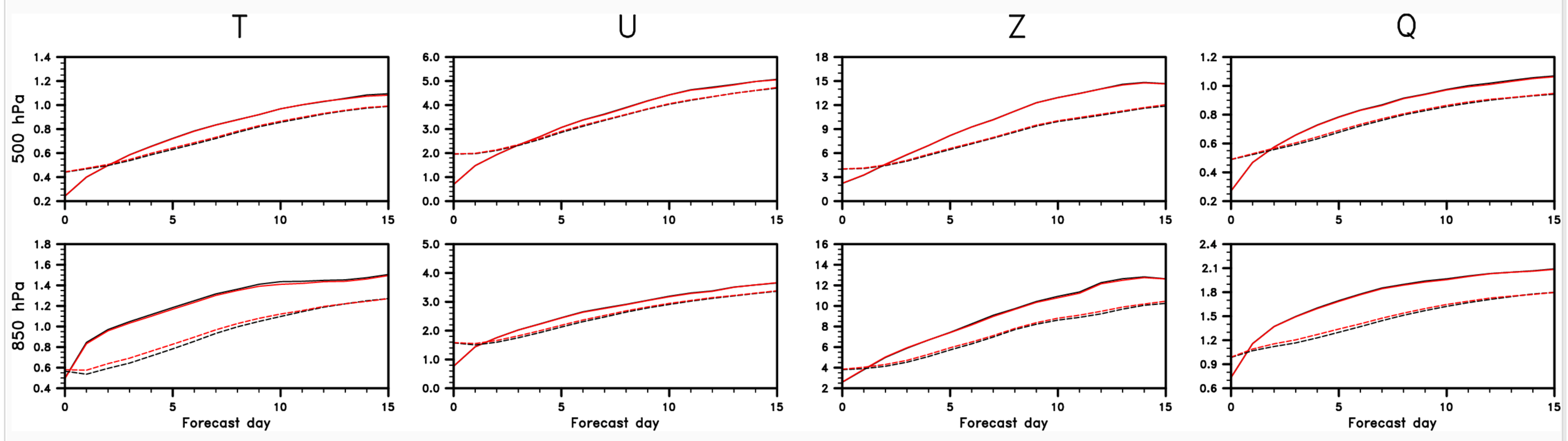

Figure 4. Time series of the experiment for T, U, Z, and Q at 500 and 850 hPa to day 15 for ensemble error (solid lines) ensemble spread (dashed lines) over the Tropics. Experiments: SPPT0 (black), SPPT0 (black), SPPT3_x3 (red). Results are from 40 start dates covering February, May, August, November 2011–2020.

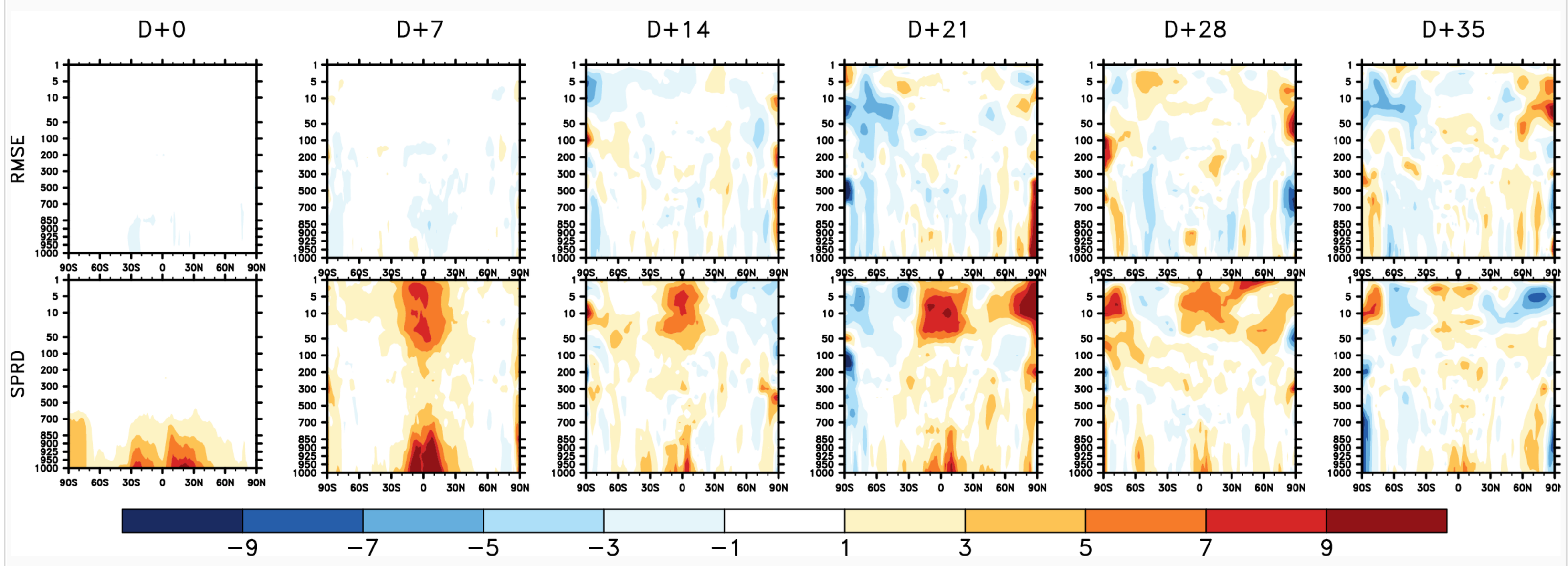

Figure 5. Zonally averaged cross-sections of ensemble error (upper panels) and ensemble spread (lower panels) of SPPT1_x3 as the relative change (%) with respect to SPPT0 for T from day 0 to 35. Results are from 40 start dates covering February, May, August, November 2011–2020.

5 Summary and discussions

- This presentation focuses on the sensitivity to the stochastic perturbation method (e.g. SPPT), which is formulated to generate ensemble spread that reflects the relative uncertainties due to the atmospheric physics parameterizations (Lock et al. 2019). This is done in the forecast model, KIM by adjusting the tuning parameters such as length scale, time scale, and amplitude.
- However, it is difficult to discern individual ensemble spread in the experiments SPPT0 to 3 due to the relatively small perturbations in comparison to the cutoff values (-1,1).
- A revised formulation of SPPT has been proposed, in which the perturbations (r) from SPPT1 are multiplied by a constant value within a dynamically stable range and changed the tapering limits in the boundary and stratospheric layers.
- A comparison of the revised results with the control (SPPT0) and original (SPPT1) results shows that ensemble spread has slightly increased, while ensemble error has remained similar to or below that of SPPT0 and SPPT1.
- A few aspects remain to be addressed in the revisions of the design SPPT in the KIM and the evaluations of alternative model uncertainty schemes.

Workshop on Diagnostics for Global Weather Prediction, 9 to 12 September 2024