The Role of Physics Perturbation Schemes in Enhancing the Skill of NEPS-G Forecasts

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Introduction: An Ensemble Prediction System (EPS) helps quantify the uncertainty in weather forecasts. However, initial condition errors are not the sole contributors to forecast uncertainty. Errors in numerical models, including their representation of atmospheric processes and numerical integration techniques, also play a significant role. These arises from factors such as the parameterization of unresolved phenomena, challenges in solving partial differential equations (PDEs), and the interactions between the atmosphere, ocean, and land. Understanding the uncertainty in the forecast model and the initial conditions is necessary for developing and operating an EPS (Buizza et al., 1999).

This article explores the impact of model physics perturbations on the spread of significant atmospheric variables, particularly in tropical regions. According to Kalnay (2003), global atmospheric models tend to be less accurate in the tropics due to their limited ability to accurately parameterize sub-grid scale processes, such as convection, which are prevalent in these areas. In contrast, these models are better at numerically representing resolved baroclinic dynamics, which are more significant in the extratropics. There is a lack of studies examining the influence of various schemes on EPS in the tropics, particularly in the Indian region, indicating a need for further exploration in this area.

Methodology: National Centre for Medium-Range Weather Forecasting (NCMRWF), India, runs a global ensemble prediction system (NEPS-G) of 12 km horizontal resolution. Present operational NEPS-G uses the Ensemble Transform Kalman Filter (ETKF) method to generates initial condition perturbations for 22 ensemble members. The model uncertainties are taken care of by the Stochastic Kinetic Energy Backscatter (SKEB) and Random parameters (RP)/Stochastic Perturbation of [Physics] Tendencies (SPT) schemes. The study focuses on understanding the role of model physics perturbations on the spread of important atmospheric variables (temperature at 850hPa, zonal and meridional winds at 200 and 850 hPa, surface temperature at 2 meters, and rainfall). The present study is organized into two experiments. In the first experiment, the same initial condition was used for all ensemble members to study the effects of only RP and SPT physics perturbation schemes ("SKEB + RP" vs. "SKEB + SPT"). In the second experiment, model evaluations using both the initial condition and model physics perturbations were performed ("ETKF + SKEB + RP" vs. "ETKF + SKEB + SPT").

Results: In the first experiment, SKEB + SPT produced a greater spread than SKEB + RP in the tropics at all forecast lead times and for all variables (Figure 1 (a) shown for T850 only).

A similar trend occurred in the northern mid-latitudes, though the increase is less pronounced (Figure 1(b)). Sanchez et. al. 2016 identified that SPT scheme represents the small-scale fluctuations (or sub-grid variability) within the model in a coarse but effective manner (), which enhances the ensemble spread. In the tropics, due to strong convective activity, there is a significant sub-grid variability compared to mid-latitude, which may be the reason why SPT is more effective in the tropics. The greater spread from the SPT scheme led to lower Continuous Ranked Probability Score (CRPS) and Ranked Probability Score (RPS) values in both regions (results not shown).

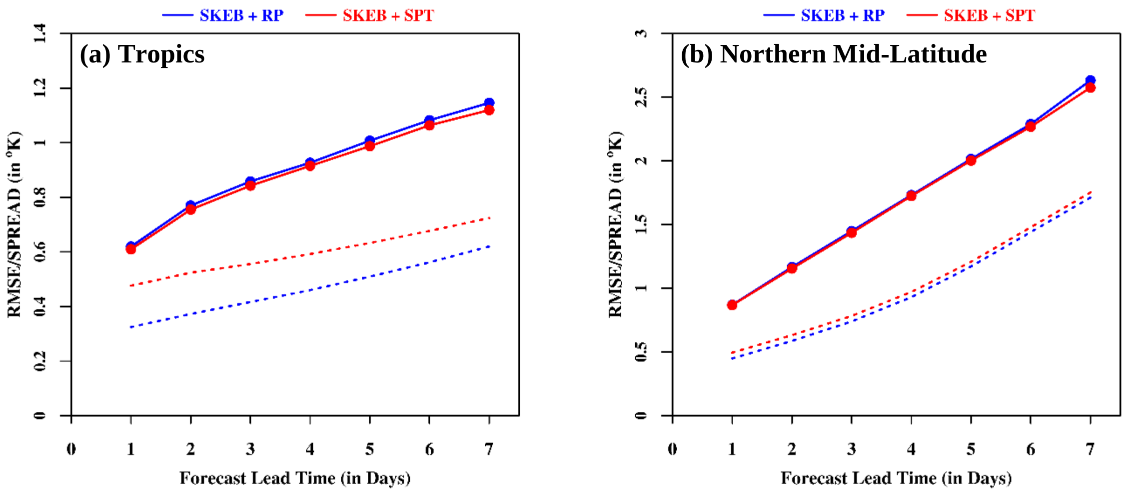

Figure 1. Variation of ensemble mean RMSE (solid lines with round symbol) and ensemble spread (dashed lines) with forecast lead time of T850 for (a) tropics and (b) northern mid-latitude.

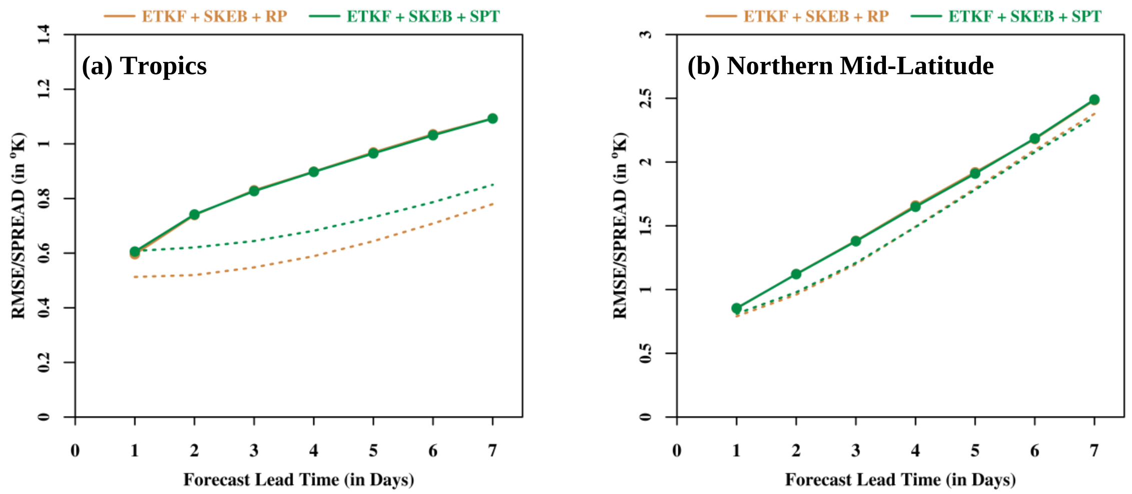

Figure 2. Variation of ensemble mean RMSE (solid lines with round symbol) and ensemble spread (dashed lines) with forecast lead time of T850 (a) tropics and (b) northern mid-latitude.

The second experiment demonstrated that incorporating initial condition perturbations with ETKF further improves the spread of the SPT and RP physics schemes (Figure 2 for T850). The CRPS values for ETKF + SKEB + SPT and ETKF + SKEB + RP are found to be lower than for SKEB + SPT and SKEB + RP (not shown here).

Conclusions: After analyzing both experiments, we concluded that incorporating the SPT scheme into NEPS-G has a more significant impact than the RP scheme, particularly in tropical regions. In the northern mid-latitudes, SPT also demonstrates some positive effects.

References:

https://doi.org/10.1175/1520-0469(1963)020<0130:DNF>2.0.CO;2

1. Kalnay, E., 2003. Atmospheric Modeling, Data Assimilation and Predictability. Cambridge University Press.

2. Buizza, R., Miller, M. and Palmer, T.N. (1999) Stochastic representation of model uncertainties in the ECMWF EPS. Quarterly Journal of the Royal Meteorological Society, 125, 2887–2908. https://doi.org/10.1002/qj.3370

3. Sanchez, C., Williams, K.D. and Collins, M. (2016), Improved stochastic physics schemes for global weather and climate models. Quarterly Journal of the Royal Meteorological Society, 142: 147-159. https://doi.org/10.1002/qj.2640