Comparison of representing model uncertainty by multi-stochastic physics and multi-physics approaches in the GRAPES ensemble

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Introduction

To more comprehensively and accurately address model uncertainties in the East Asia monsoon region, a single-physics suite, where each ensemble member uses the same set of physics parameterizations as the control member in combination with multiple stochastic schemes, is developed.

two experiments are performed for a summer monsoon month over China: one with a multiphysics suite and the other with a single-physics suite combined with multistochastic schemes. Three stochastic schemes are applied: the stochastically perturbed parameterizations (SPP) scheme, consisting of temporally and spatially varying perturbations of 18 parameters in the microphysics, convection, boundary layer, and surface layer parameterization schemes; the stochastically perturbed parameterization tendencies (SPPT) scheme; and the stochastic kinetic energy backscatter (SKEB) scheme.

Objectives

This study aims to investigate if the multi-stochastic schemes that combine different stochastic schemes together can be an alternative to a multiphysics suite, where each ensemble member uses a different set of physics parameterizations (e.g., cumulus convection, boundary layer, surface layer, microphysics, and shortwave and longwave radiation).

Methods

The random field $\varphi(\lambda,\phi,t)$, which is described by the first-order Markov chain with spherical harmonics expansion, and has a time–space correlated continuous horizontal structure as in Li et al. (2008), is defined as

$$\varphi(\lambda,\phi,t)=\mu+\sum_{l=1}^{L}\sum_{m=-l}^{l}\alpha_{l,m}(t)Y_{l,m}(\lambda,\phi)$$

The evolution of $\alpha_{l,m}(t)$ is obtained by the first-order Markov chain:

$$\alpha_{l,m}(t+\Delta t)=e^{-\Delta t/\tau}\alpha_{l,m}(t)+\sqrt{\frac{4\pi\sigma^2(1-e^{-2\Delta t/\tau})}{L(L+2)}}R_{l,m}(t)$$

A stretching function $S(\varphi,\mu)$ as in Li et al. (2008) is applied to $\varphi(\lambda,\phi,t)$ to obtain a new random field $\psi(\lambda,\phi,t)$:

$$\psi(\lambda,\phi,t)=\mu+S(\varphi,\mu)[\varphi(\lambda,\phi,t)-\mu],$$

Where the stretching function $S(\varphi,\mu)$ is given by

$$S(\varphi,\mu)=2-\frac{1-\exp\left[\beta\left(\frac{\varphi-\mu}{\psi_{\max}-\mu}\right)^2\right]}{1-\exp(\beta)}$$

Reference

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Results

- **Horizontal distributions of ensemble spread and RMSE for zonal wind**

The horizontal distributions of the ensemble spread and RMSE of the ensemble mean for the MP and SPPT_SPP_SKEB experiments are evaluated. The SPPT_SPP_SKEB experiment is characterized by a larger spread and a similar or slightly higher RMSE of the ensemble mean compared to that of the MP experiment all over the domain.

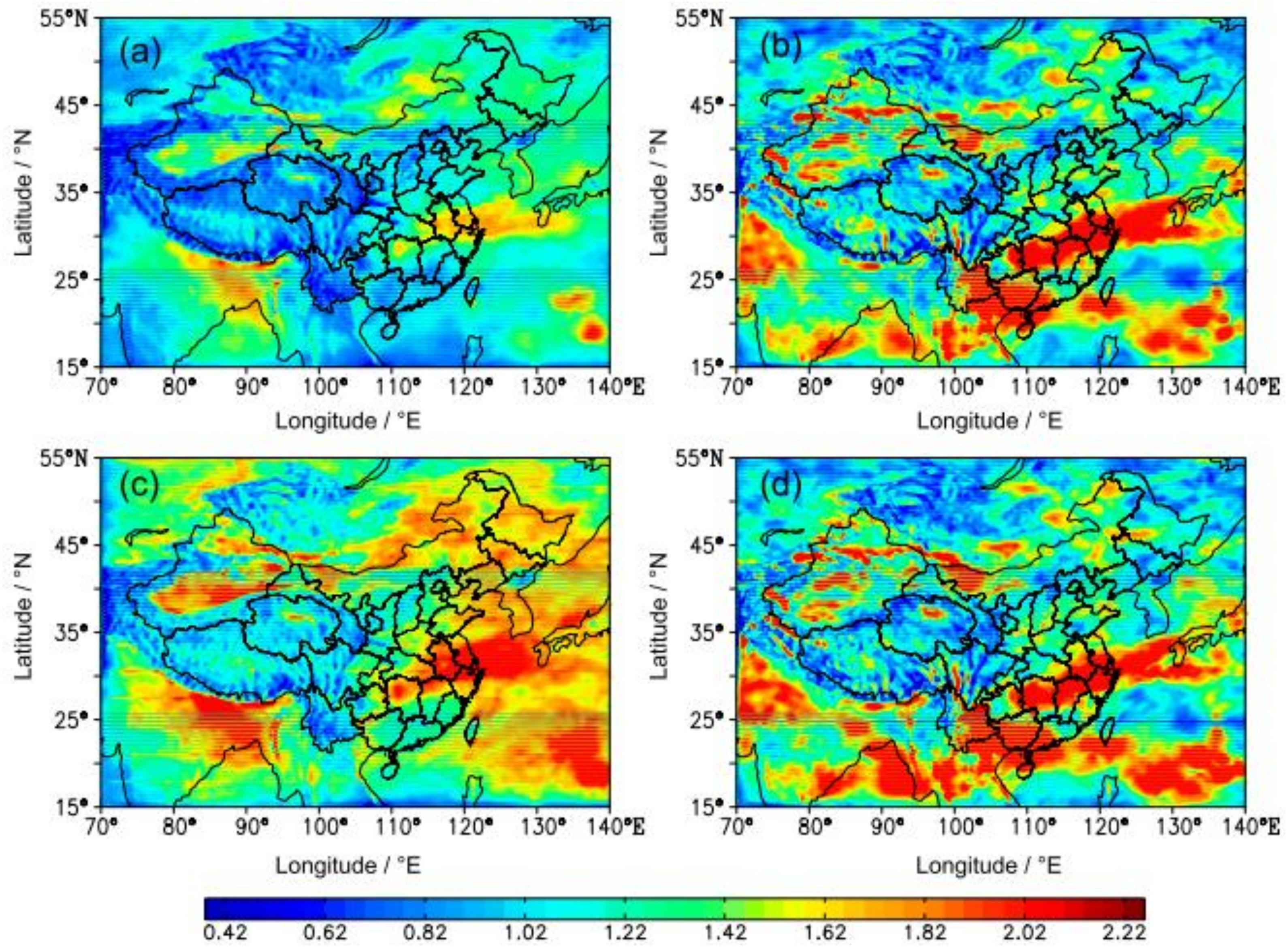

Fig. 1. Horizontal distributions of (a),(c) ensemble spread and (b),(d) RMSE of the ensemble mean for the (top) MP and (bottom) SPPT_SPP_SKEB experiments, for 850-hPa zonal wind at the 48-h forecast lead time

- **Probabilistic and Deterministic verification of precipitation**

- A set of verification measures was employed to assess the precipitation: the area under the relative operating characteristic curve (AROC) score (Mason 1982), the Brier skill score (BSS; Brier 1950; Murphy 1973; Weigel et al. 2007), and probability distribution of precipitation exceeding specific thresholds for probabilistic verification of precipitation; the fractions skill score (FSS; Roberts and Lean 2008; Roberts 2008), the spatial mean correlation coefficient and root-mean-square error (RMSE), as well as the ensemble mean frequency bias (Schaefer 1990) for deterministic verification of precipitation. Overall, all the precipitation verification results shown above indicate that the SPPT_SPP_SKEB experiment is characterized by a generally better performance compared with the MP experiment in both the probabilistic and the deterministic verification of precipitation for most of the lead times and for most of the thresholds.

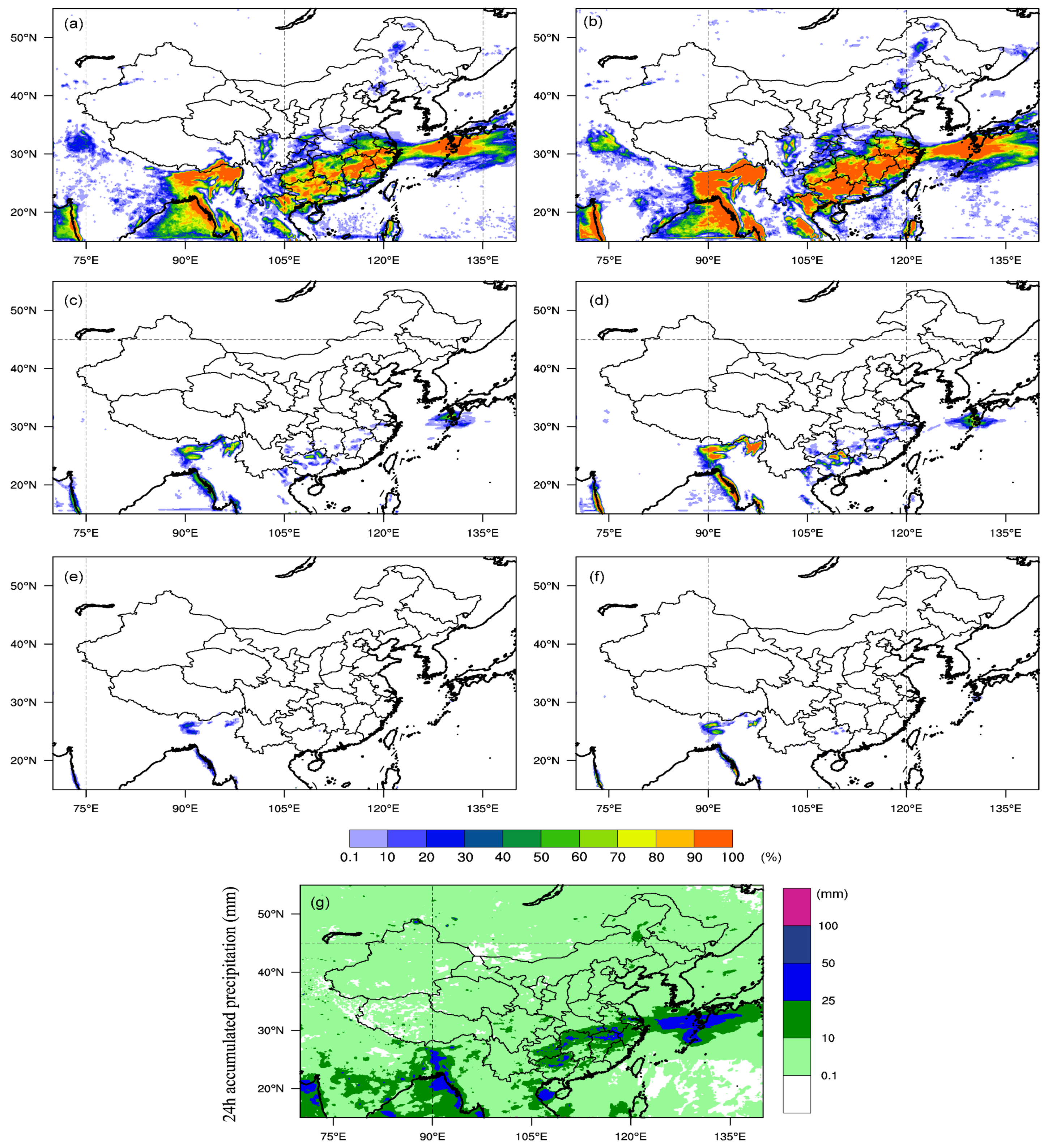

Fig. 2. Probability distribution of precipitation exceeding (a, b) 10-mm, (c, d) 25-mm and (e, f) 50-mm thresholds for monthly mean 24-h accumulated precipitation for (a, c, e) MP and (b, d, f) SPPT_SPP_SKEB; and (g) the corresponding observation field for monthly mean 24-h accumulated precipitation. The results are the monthly averages for the 0000 UTC cycle during June 2015.

Conclusion

- The SPPT_SPP_SKEB experiment produces generally more skillful precipitation forecasts than the MP experiment for precipitation, especially for heavier precipitation thresholds (above 10 mm).
- For upper-air temperature and 2-m temperature, the SPPT_SPP_SKEB experiment generally yields a slight improvement compared to the MP experiment.
- In summary, the above verification results indicate that a single-physics suite combining SPP, SPPT, and SKEB is characterized by an overall better performance compared with the multiphysics suite in precipitation verification and verification for upper-air variables, 10-m zonal wind, and 2-m temperature in the East Asian monsoon region. Our results are consistent with the previous findings of Berner et al. (2011, 2017) and Hacker et al. (2011a,b) in that model error can be better represented by a combination of model-error schemes than a single scheme alone.