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Improved ensemble-mean forecasting of ENSO events by a zero-mean stochastic error model of an intermediate coupled model

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How to design a reliable ensemble prediction strategy with considering the major uncertainties of a forecasting system is a crucial issue for performing an ensemble forecast. In this study, a new stochastic perturbation technique is developed to improve the prediction skills of El Niño–Southern Oscillation (ENSO) through using an intermediate coupled model. We first estimate and analyze the model uncertainties from the ensemble Kalman filter analysis results through assimilating the observed sea surface temperatures. Then, based on the pre-analyzed properties of model errors, we develop a zero-mean stochastic model-error model to characterize the model uncertainties mainly induced by the missed physical processes of the original model (e.g., stochastic atmospheric forcing, extra-tropical effects, Indian Ocean Dipole). Finally, we perturb each member of an ensemble forecast at each step by the developed stochastic model-error model during the 12-month forecasting process, and add the zero-mean perturbations into the physical fields to mimic the presence of missing processes and high-frequency stochastic noises.

The impacts of stochastic model-error perturbations on ENSO deterministic predictions are examined by performing two sets of 21-yr hindcast experiments, which are initialized from the same initial conditions and differentiated by whether they consider the stochastic perturbations. The comparison results show that the stochastic perturbations have a significant effect on improving the ensemble-mean prediction skills during the entire 12-month forecasting process. This improvement occurs mainly because the nonlinear terms in the model can form a positive ensemble-mean from a series of zero-mean perturbations, which reduces the forecasting biases and then corrects the forecast through this nonlinear heating mechanism.