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The application of Nonlinear Local Lyapunov Vectors to the Zebiak-Cane Model and their performance in the Ensemble Prediction

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Nonlinear local Lyapunov vectors (NLLVs) have been developed to indicate orthogonal directions in phase space with different error growth rates. Comparing to the breeding vectors (BVs), NLLVs can span the fast-growing perturbation subspace efficiently and may gasp more components in analysis errors than the BVs in the nonlinear dynamical system. Here, NLLVs are employed in the Zebiak-Cane (ZC) atmosphere-ocean coupled model and represent a nonlinear, finite-time extension of the local Lyapunov vectors of the ZC model. The statistical properties of NLLVs is not very sensitive to the choice of the breeding parameter. However, the non-leading NLLVs have some randomness, which increase the diversity of NLLVs. Not only the leading NLLV but also the non-leading NLLVs are flow-dependent and related to the background ENSO evolution of the ZC model in the aspect of spatial structure and error growth rate. the non-leading NLLVs also are the instability direction related to the ENSO process in the ZC model. Due to the non-leading NLLVs, the subspace of the first few NLLVs can describe better the analysis error than that of the same number BVs in the ZC model. NLLVs as initial ensemble perturbations are applied to the ensemble prediction of ENSO and the performance are systematically compared to those of the random perturbation (RP) technique, and the BV method in the prefect environment. The results demonstrate that the RP technique has the worst performance and the NLLVs method is the best in the ensemble forecasts. In particular, the NLLV technique can reduce the “spring barrier” for ENSO prediction further than the other ensemble method.