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Applications of conditional nonlinear optimal perturbations to adaptive observations

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In this study, conditional nonlinear optimal perturbation (CNOP), which is a natural extension of linear singular vector (LSV) into the nonlinear regime, is applied to the determination of sensitive area in adaptive observations. The 5th generation Pen-State University/National Center for Atmosphere Research mesoscale Model (MM5) and its adjoint system are utilized to study the effects of initial errors on the forecast of precipitations and tropical cyclones. The spectral projected gradient 2 (SPG2), which calculates the least value of a function of several variables subject to box or ball constraints, is employed as the optimization algorithm.

Using the metric of total dry energy, the authors compare the differences between the spacial structures of CNOPs and the first singular vectors (FSVs), as well as their nonlinear evolutions. The developments of CNOPsąŕ and FSVsąŕ energies are also checked. Both the precipitation and the tropical cyclone cases come to a consistent result. That is, the structures of CNOPs differ much from those of FSVs as well as their nonlinear evolutions. Besides, at the end time, the total energies of CNOPs are larger than those of FSVs. The results of sensitivity experiments indicate that the forecasts are more sensitive to the CNOP-type initial errors than the FSV-type ones in terms of total energy. Considering that LSVs are obtained under the linear approximation and CNOPs are for the nonlinear model, our results suggest that it is feasible to use CNOP to identify the sensitive region in adaptive observations.