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Optimal precursor and optimally growing initial error in the predictability studies of Kuroshio large meander and their nonlinear evolution mechanism

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The optimal precursor (OPR) and optimally growing initial error (OGE) in the predictability studies of Kuroshio large meander (LM) were investigated using the Conditional Nonlinear Optimal Perturbation (CNOP) approach within a 1.5-layer shallow-water model. The OPR is a kind of initial anomaly that is the easiest to cause the occurrence of Kuroshio LM path. The OGE refers to another kind of initial perturbation that has the largest effects on the prediction uncertainty of the LM path. Numerical results showed that the spatial structures of OPR and OGEs are similar and their dominant amplitudes are localized upstream of the occurrence region of Kuroshio LM, i.e. southeast of Kyushu. The nonlinear evolutions of both OPR and OGEs are also similar, which implies that they have a similar development mechanism. Nonlinear physical process has an important effect on their evolutions. The nonlinear advection of momentum tends to enhance the evolution of the perturbations and cause the forecasted Kuroshio LM to be strengthened. We defined sensitive area according to the spatial structures of OPR and OGEs and investigated its usefulness. The results showed that the initial errors in sensitive area have greater impacts on the prediction of the Kuroshio LM path than those in other randomly selected areas. In addition, the prediction is more significantly improved when eliminating the part of initial error in the sensitive area than in other areas. These results provide a theoretical basis for the targeted observation of Kuroshio LM path prediction.