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Optimal precursors triggering the Kuroshio Extension state transition obtained by the Conditional Nonlinear Optimal Perturbation approach

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In this study, the initial perturbations that are the easiest to trigger the Kuroshio Extension (KE) transition connecting a basic weak jet state and a strong, fairly stable meandering state, are investigated using a reduced-gravity shallow water ocean model and the conditional nonlinear optimal perturbation (CNOP) approach. This kind of initial perturbation is called optimal precursor (OPR). The spatial structures and evolution processes of the OPRs thus obtained are analyzed in detail. The results show that most of the OPRs are in the form of negative sea surface height (SSH) anomalies mainly located in a narrow band region south of the KE jet, in basic agreement with altimetric observations. These negative SSH anomalies reduce the meridional SSH gradient within the KE, thus weakening the strength of the jet. The KE jet, then, becomes more convoluted, with a high-frequency and large-amplitude variability corresponding to a high eddy kinetic energy level: this gradually strengthens the KE jet through an inverse energy cascade. Eventually, the KE reaches a high-energy state characterized by two well defined and fairly stable anticyclonic meanders. Moreover, sensitivity experiments indicate that the spatial structures of the OPRs are not sensitive to the model parameters and to the optimization times used in the analysis.