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A Study on the Precursors of ENSO Events in Zebiak and Cane Model by Using Conditional Nonlinear Optimal Perturbation

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With a coupled ocean-atmosphere ENSO model, Zebiak and Cane model (1987), the problem of optimal precursors for ENSO is explored by using conditional nonlinear optimal perturbation (CNOP). For different optimization time intervals, CNOPs of a predetermined annual cycle of climate mean stable are obtained. It is shown that CNOPs and local CNOPs have respectively the robust patterns qualitatively, which are quite different from those of linear singular vector (LSV) quantitatively. Extensive numerical experiments demonstrate that the nonlinear evolutions of CNOPs (local CNOPs) are significantly larger than those of the corresponding LSVs for the same amplitudes of initial perturbations. Compared with LSV, CNOPs (local CNOPs) tend to be the optimal initial patterns that evolve into El Nino (La Nina) events most probably. These facts therefore inspire us to regard CNOPs (local CNOPs) of annual cycle as the optimal precursors for El Nino (La Nina). The amplitudes of the nonlinear development of CNOPs (local CNOPs) are highly dependent on the phase of the annual cycle of climate mean state at which perturbations are applied and on the duration over which perturbations evolve. However, the spatial structure of the optimal precursors is remarkably insensitive to these factors. The positive (negative) equatorial thermocline depth anomaly is a notable character of the optimal precursor of an El Nino (La Nina) event. A mechanism that explains why optimal precursors develop into ENSO events is given based on the positive feedback of tropical ocean-atmosphere interaction and Delayed Oscillator negative feedback.