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Behaviors of nonlinearities modulating the El Nino events induced by optimal precursory disturbances

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In the present paper, we explore the manner in which nonlinearities modulate El Nino events by investigating the optimal precursory disturbance for El Nino events in the Zebiak-Cane model. The initial anomalies of conditional nonlinear optimal perturbation (CNOP) and linear singular vector (LSV) are studied. The CNOPs evolve into stronger El Nino events than the LSVs and act as the optimal precursor for El Nino events. By examining the role of nonlinearities in El Nino events induced by CNOPs and LSVs, we find that the nonlinearities enhance CNOP-El Nino events but suppress LSV-El Nino events. Nonlinearities in the Zebiak-Cane model arise from nonlinear temperature advection (NTA), sub-surface temperature parameterization (STP), and wind stress anomaly (WSA). With these types of nonlinearities, we trace the approach of the nonlinearities modulating the CNOP- and LSV-El Nino events. The results demonstrate that nonlinearities of the NTA enhance both CNOP-El Nino events and LSV-El Nino events, while nonlinearities of the STP and WSA suppress these events. For the CNOP-El Nino events, the enhancement effect of the NTA is considerably larger than the suppression effect of the STP and WSA, resulting in the combined effect of the nonlinearities in the Zebiak-Cane model enhancing the CNOP-El Nino events. However, for the LSV-El Nino events, the enhancement effect of the NTA is smaller than the suppression effect of the WSA and STP. Consequently, the combined effects of the nonlinearities in the Zebiak-Cane model suppress the LSV-El Nino events.