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Revealing the most disturbing tendency error of Zebiak-Cane model associated with El Nino predictions by nonlinear forcing singular vector approach

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The nonlinear forcing singular vector (NFSV) approach is used to identify the most disturbing tendency error of the Zebiak–Cane model associated with El Niño predictions, which is most potential for yielding aggressively large prediction errors of El Niño events. The results show that only one NFSV exists for each of the predictions for the predetermined model El Niño events. These NFSVs cause the largest prediction error for the corresponding El Niño event in perfect initial condition scenario. It is found that the NFSVs often present largescale zonal dipolar structures and are insensitive to the intensities of El Niño events, but are dependent on the prediction periods. In particular, the NFSVs associated with the predictions crossing through the growth phase of El Niño tend to exhibit a zonal dipolar pattern with positive anomalies in the equatorial central-western Pacific and negative anomalies in the equatorial eastern Pacific (denoted as "NFSV1"). Meanwhile, those associated with the predictions through the decaying phase of El Niño are inclined to present another zonal dipolar pattern (denoted as "NFSV2"), which is almost opposite to the NFSV1. Similarly, the linear forcing singular vectors (FSVs), which are computed based on the tangent linear model, can also be classified into two types "FSV1" and "FSV2". We find that both FSV1 and NFSV1 often cause negative prediction errors for Niño-3 SSTA of the El Niño events, while the FSV2 and NFSV2 usually yield positive prediction errors. However, due to the effect of nonlinearities, the NFSVs usually have the western pole of the zonal dipolar pattern much farther west, and covering much broader region. The nonlinearities have a suppression effect on the growth of the prediction errors caused by the FSVs and the particular structure of the NFSVs tends to reduce such suppression effect of nonlinearities, finally making the NFSV-type tendency error yield much large prediction error for Niño-3 SSTA of El Niño events. The NFSVs, compared to the FSVs, are more applicable in describing the most disturbing tendency error of the Zebiak–Cane model since they consider the effect of nonlinearities. The NFSV-type tendency errors may provide information concerning the sensitive areas where the model errors are much more likely to yield large prediction errors for El Niño events. If the simulation skills of the states in the sensitive areas can be improved, the ENSO forecast skill may in turn be greatly increased.