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# Nonlinear forcing singular vector -type tendency errors of the Zebiak-Cane model and its effect on ENSO predictability

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Within the framework of the Zebiak–Cane model, the nonlinear forcing singular vector (NFSV) approach is used to explore the constant tendency error that has the largest effect on prediction uncertainties for El Niño events. The results showed only one NFSV to exist for each of the predictions for the predetermined model El Niño events. It was found that the NFSVs often present large-scale zonal dipolar structures and are insensitive to the intensities of El Niño events, but are dependent on the prediction period. 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 “type-1 NFSVs”). Meanwhile, those associated with the predictions through the decaying phase of El Niño are inclined to present another zonal dipolar pattern (denoted as “type-2 NFSVs”), which is almost opposite to the type-1 NFSVs. The FSVs, i.e. the linear counterpart of the NFSVs, can also be classified into two types, which are of almost the same signs as in type-1 NFSVs and type-2 NFSVs, and which we similarly denoted as “type-1 FSVs” and “type-2 FSVs”, respectively. We found that both type-1 FSVs and type-1 NFSVs often cause negative prediction errors for Niño-3 SSTA of the El Niño events, while the type-2 FSVs and type-2 NFSVs 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. Correspondingly, the NFSVs cause much larger prediction errors than the FSVs and show themselves to be much more applicable in describing the optimal tendency errors in the nonlinear Zebiak–Cane model. Our results also show that the nonlinearities have a suppression effect on the growth of the prediction errors caused by the FSVs. Furthermore, the particular structure of the NFSVs tends to reduce the suppression effect of nonlinearities on prediction errors for Niño-3 SSTA of El Niño events. It is clear that the effect of nonlinearities on ENSO predictability is significant and cannot be neglected. The NFSV-type tendency errors, compared to the FSV-type tendency errors, is much potential for revealing the effect of nonlinearity. The NFSV-type tendency errors may also provide information concerning the sensitive areas in which the model errors, compared to those in other areas, are much more likely to yield large prediction errors for El Niño events. Therefore, if we improve the ability of the model simulating the states in the sensitive areas, the ENSO forecast skill may in turn be greatly improved.