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The role of model errors represented by nonlinear forcing singular vector tendency error in causing the "spring predictability barrier" within ENSO predictions

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Within the Zebiak–Cane model, the nonlinear forcing singular vector (NFSV) approach is used to investigate the role of model errors in the "Spring Predictability Barrier" (SPB) phenomenon within ENSO predictions. NFSV-related errors have the largest negative effect on the uncertainties of El Niño predictions. NFSV errors can be classified into two types: the first is characterized by a zonal dipolar pattern of SST anomalies (SSTA), with the western poles centered in the equatorial central-western Pacific exhibiting positive anomalies and the eastern poles in the equatorial eastern Pacific exhibiting negative anomalies; and the second is characterized by a pattern almost opposite the first type. The first type of error tends to have the worst effects on El Niño growth-phase predictions, whereas the latter often yields the largest negative effects on decaying-phase predictions. The evolution of prediction errors caused by NFSV-related errors exhibits prominent seasonality, with the fastest error growth in the spring and/or summer seasons; hence, these errors result in a significant SPB related to El Niño events. The linear counterpart of NFSVs, the (linear) forcing singular vector (FSV), induces a less significant SPB because it contains smaller prediction errors. Random errors cannot generate a SPB for El Niño events. These results show that the occurrence of an SPB is related to the spatial patterns of tendency errors. The NFSV tendency errors cause the most significant SPB for El Niño events. In addition, NFSVs often concentrate these large value errors in a few areas within the equatorial eastern and central-western Pacific, which likely represent those areas sensitive to El Niño predictions associated with model errors. Meanwhile, these areas are also exactly consistent with the sensitive areas related to initial errors determined by previous studies. This implies that additional observations in the sensitive areas would not only improve the accuracy of the initial field but also promote the reduction of model errors to greatly improve ENSO forecasts.