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Two ENSO modes in the forced tropical coupled model

Lingjiang Tao and Wansuo Duan

Institute of Atmospheric Physics, State Key Laboratory of Numerical modeling for Atmospheric Sciences and Geophysical Fluid Dynamics, Beijing, China (taolj1992@foxmail.com)

Evidence shows that the tropical Pacific has two dominant interanual modes with different spatial patterns and temporal evolutions: eastern-Pacific (EP) type and central-Pacific (CP) type ENSO. However, most of current models fail to depict such diversity of ENSO. In the present study, a nonlinear forcing singular vector (NFSV) approach is applied to force an intermediate ENSO model and obtain the two dominant modes of ENSO. The NFSVs represent the combined effect of missing or simplified processes in the model simulations. As a result, the ENSO model with NFSVs can capture the realistic evolutions of ENSO. To examine ENSO-related NFSV, the predetermined-NFSVs are classified into two categories in terms of the ENSO type. It is found that the both EP and CP-related NFSV shows quasi-biennial oscillation but differ in spatial patterns. Thus, to separate two kinds of ENSO, the type-dependent NFSVs with two-year cycle are constructed to force the ENSO model and formulate the CP and EP ENSO model.

The EP ENSO model that is forced by the EP-related NFSV can successfully depict a dominant four-year oscillation period of SST variability centered in the eastern tropical Pacific. The simulated EP El Niño is followed by a double-year cooling event due to the strong discharge effect, the phenomenon of which is also found in observations. Different from the EP ENSO model, the CP ENSO model is forced by the CP-related NFSV. As observations, CP ENSO has two significant spectral peaks around the four- and two-year bands. The modeled CP El Niño is centered in the central Pacific triggered by the local air-sea coupling involved local thermocline variability. The zonal position of the CP El Niño is sensitive to the wind and thermocline effect. An enhanced thermocline effect can directly warm the central Pacific through ocean mixing since the thermocline fluctuation is confined in the central Pacific during the development of CP El Niño. While, a strong wind effect not only induce a warming trend in the central Pacific but also cool down the eastern tropical Pacific by the strengthened trade wind. The heat budget analyses further demonstrate dynamics in different stage of CP El Niño. The zonal advection plays prominent role in the initial warming in the central-western Pacific. As a response, westerly wind prevails in the western Pacific, which in turn triggers deepened Kevin waves. Therefore, the thermocline feedback dominants the rapid development of SST during summer and fall. In the mature phase of CP El Niño, the thermocline feedback shows identical role with zonal advection. For the eastern tropical Pacific, cross-equator (southeast) wind is significant so as to cause a strong south equatorial current (SEC) enhancing the eastern Pacific cold tongue. In general, the zonal advection, thermocline feedback and SEC cooling effect dominant the horizontal and evolution of CP El Niño. Note that the ENSO model with NFSV can depict the realistic ENSO diversities, the forced ENSO model may provide a plausible platform to study the ENSO diversities.