

A Dual-Core Model for ENSO Diversity: Unifying Model Hierarchies for Realistic Simulations

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Despite advances in climate modeling, simulating the El Niño-Southern Oscillation (ENSO) remains challenging due to its spatiotemporal diversity and complexity. To address this, we build upon existing model hierarchies to develop a new unified modeling platform, which provides practical, scalable, and accurate tools for advancing ENSO research. Within this framework, we introduce a dual-core ENSO model (DCM) that integrates two widely used ENSO modeling approaches: a linear stochastic model confined to the equator and a nonlinear intermediate model extending off-equator. The stochastic model ensures computational efficiency and statistical accuracy. It captures essential ENSO characteristics and reproduces the observed non-Gaussian statistics. Meanwhile, the nonlinear model assimilates pseudo-observations from the stochastic model while resolving key air-sea interactions, such as oceanic feedback balances and spatial patterns of sea surface temperature anomalies (SSTA) during El Niño peaks. The DCM effectively captures the realistic dynamical and statistical features of the ENSO diversity and complexity. The computational efficiency of the DCM also facilitates a rapid generation of extended ENSO datasets, overcoming observational limitations.

Keywords: ENSO, Climate Modeling, Data Assimilation, Complex System, Multi-Core Modeling Framework