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Two Physics-informed Enso Deep Learning Forecasting Models: ENSO-ASC and ENSO-GTC

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El Niño-Southern Oscillation (ENSO) events have significant impacts on global climate change, and the research on their accurate forecasting and dynamic predictability holds remarkable scientific and engineering values. Recent years, we have constructed two ENSO deep learning forecasting models, ENSO-ASC and ENSO-GTC, which are both incorporated with prior ENSO dynamic mechanisms. Specifically, the former possesses the multivariate air-sea coupler (ASC), which can simulate the occurrence and decay of ENSO events, accompanied by concurrent energy interactions among multiple physical variables in the Pacific Ocean. The latter possesses the global teleconnection coupler (GTC), which can modulate the significant teleconnections of global ocean basins rather than the isolated interactions in the Pacific Ocean. From the perspective of forecasting skill, the Niño 3.4 index correlation skills of these two models can reach 0.78/0.65/0.50 (0.79/0.66/0.51) in 6/12/18 lead-month prediction, which means they exhibit an effective forecasting lead month of more than 18, outperforming the Ham et al.'s Nature-published ENSO forecasting model. The test of the past year's (2022) forecast results shows that the average forecast error of these two models is 0.156, which is less than 10% of the actual ENSO amplitudes. It is worth noting that these two models also encounter the spring presistence barrier (SPB), but indicates a profound improvement compared to the numerical models. From the perspective of ENSO predictability, zonal and meridional winds are two sensitive predictors for ENSO forecasting besides sea surface temperature (SST), which greatly contribute to the Bjerknes positive feedback mechanism and WES mechanism. Walker circulation, acting as the "atmpsphric bridge", induces the teleconnections of the three oceans, which can derive the easterly wind anomalies in the equatorial western Pacific from the Indian Ocean and North Pacific meridional mode in the northeastern Pacific from the Atlantic Ocean, promoting ENSO event development and decay.