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Dynamical evolution of ENSO in a warming background: A review of recent trends & future projections

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The wide-spread implications of El Niño–Southern Oscillation (ENSO) on global and regional climate necessitates a better understanding of how the underlying interannual dynamics have changed over recent years. Year-to-year changes in ENSO impact terrestrial and marine habitats, water availability, food security and social stability (Santoso et al., 2017). With abundant evidence of a warming climate, it is imperative to understand how a large-scale climatic oscillation such as ENSO is evolving and influencing changes in large-scale atmospheric circulation patterns (Alizadeh et al., 2022; Cai et al., 2021). Furthermore, quantifying the influence of the ocean on changes in this climatic pattern is an interesting and important question to answer. Evaluating the ability of models to appropriately represent the underlying physics and dynamical changes impacting the spatiotemporal extent and the intensity of ENSO is crucial to understanding ocean-climate teleconnections and changes in climatic extremes. In this study, we review and evaluate the representation of ENSO in several high-resolution CMIP6 and HighResMIP models and forced ocean-only simulations focusing on the ability of current state-of-the-art models to represent central equatorial pacific warming and cooling. This evaluation involves looking at the development and propagation of warm temperature anomalies on surface and sub-surface levels in the equatorial Pacific and understanding the differences in simulating surface heat budget and exchange with the overlying atmosphere and the deeper ocean. Surface and sub-surface (up to 200m depth) temperature anomalies in the Niño 3.4 region were calculated from modelled data and were then compared with anomalies from observational and reanalysis temperature datasets (like EN4, ORAS5). We find good agreement in the timing and vertical structure of surface/sub-surface temperature anomalies in the forced model simulations, particularly during strong ENSO years. Moreover, the genesis of sub-surface anomalies and their further propagation to the surface was well simulated in the forced simulations. The vertical coherence of temperature anomalies was relatively more pronounced in forced ocean-only simulations than in coupled high-resolution model runs. Furthermore, we comment on the shortcomings and suggest potential improvements that can be made in the models that could improve the model's ability to capture ENSO strength and variability.