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A new method, based on Offline Slab Ocean SST, to quantify the error compensation of ENSO atmospheric feedbacks in climate models

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Common problems in state-of-the-art climate models are a cold sea surface temperature (SST) bias in the equatorial Pacific and an underestimation of the two most important atmospheric feedbacks operating in the El Niño/Southern Oscillation (ENSO): the positive, i.e. amplifying wind-SST feedback and the negative, i.e. damping heat flux-SST feedback (Bellenger et al. 2014). To a large extent, the underestimation of those feedbacks can be explained by the cold equatorial SST bias, which shifts the rising branch of the Pacific Walker Circulation (PWC) too far to the west by up to 30°, resulting in an erroneous convective response during ENSO events (Bayr et al. 2018a). Based on simulations from the Kiel Climate Model (KCM) and the 5th phase of Coupled Model Intercomparison Project (CMIP5), we investigate how well ENSO dynamics are simulated in case of underestimated ENSO atmospheric feedbacks (EAF), with a special focus on ocean–atmosphere coupling over the equatorial Pacific. We present a new method based on an offline slab ocean SST that gives a quantitative measure about the error compensation between the wind-SST and the heat flux-SST feedbacks. We show by means of this method that ENSO is not predominantly wind-driven in many models, as observed; instead, and in contrast to observations, ENSO is significantly driven by a positive shortwave radiation feedback. Thus, although these models simulate ENSO, which in terms of simple indices is consistent with observations, it originates from very different dynamics. A too weak wind-driven oceanic forcing on the SST is compensated by weaker atmospheric heat flux damping. The latter is mainly caused by a biased shortwave-SST feedback that erroneously is positive in most climate models. In the most biased models, the shortwave-SST feedback contributes to the SST anomaly growth to a similar degree as the ocean circulation (Bayr et al. 2018b). Our results suggest that a broad continuum of ENSO dynamics exists in state-of-the-art climate models and explain why models with less than a half of the observed EAF strength can still exhibit realistic ENSO amplitude.

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