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The relationship between GCM biases and internal low-frequency variability in the tropical Pacific

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Because the tropical Pacific impacts global climate variability, understanding its response to anthropogenic forcing is pivotal to our ability to forecast climate change. Motivated by Karnauskas et al., (2012), we explore the physical mechanisms for low-frequency internal climate variability in the mean state of the tropical Pacific using preindustrial control runs of 26 Coupled Model Intercomparison Project Phase 5 (CMIP5) models and the Community Earth System Model Large Ensemble Project (CESM LENS). We categorized models as having realistic or unrealistically high interannual Sea Surface Temperature (SST) variance related to the El Niño Southern Oscillation (ENSO) in the western equatorial Pacific Ocean. Results show that the models with ENSO variance that is too strong in the western Pacific have a stronger Pacific Centennial Oscillation (PCO). We argue that the westward extended ENSO pattern in some climate models arises due to mean state biases in these models. In fact, the westward extended cold tongue bias in mean annual SST supports the generation of low-frequency centennial variability. Additionally, analyses of surface zonal winds indicate stronger easterlies and thereby intense westward surface currents in the eastern Pacific in models with these ENSO biases, which has a potential role in advecting cold surface waters westward from the east to the maritime continent. Furthermore, by using a stochastic model of climate variability (Hasselmann, 1976), we show how centennial-scale variability emerge in models with ENSO biases from the ocean-integrating, high-frequency, stochastic atmospheric variability. The Hasselmann model correctly predicts a cold tongue extent of $\sim 210\ ^oE$ in the central Pacific is necessary to achieve significant centennial-scale variability in models; as dictated by the depth of the mixed layer and the magnitude of the ENSO amplitude. This is shown by prescribing the longitudinal profiles of mixed layer depth and amplitude of noise forcing (ENSO variability) to the Hasselmann model. By this method, we are also able to predict the westward extent of the cold tongue that is necessary to produce centennial-scale variability in the real ocean. Our results suggest that caution should be exercised in the use of some climate models having spurious centennial variability, especially while considering a multimodel ensemble mean. It is also likely that the models with a PCO pattern (arising from mean state and ENSO biases) will have issues simulating some climatic processes, including air-sea interaction and multiscale climate variability. In fact, further analysis shows that, due to unforced, internal variability, the ENSO bias becomes more pronounced in historical runs and future projections. The future projections (RCP 4.5 and RCP 8.5) in such biased models show a significantly higher warming trend over the equatorial Pacific and continental Asia ($\sim 1\ ^oC$ /century in RCP 8.5) than the majority of models without a strong PCO, implying potentially serious consequences for models that display the aforementioned ENSO bias.