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El Nino-Southern Oscillation: Mid-Holocene, Present and Future

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Proxy data of sea surface temperature (SST) and precipitation in the tropical Pacific suggests the variance in ENSO was greatly reduced in the mid-Holocene compared to the modern climate. Recent studies report that full-physics climate models (e.g., those used in the recent IPCC assessment) with realistic ENSOs in their modern day climate simulations also show reduced ENSO variance when the models are forced by mid-Holocene insolation and greenhouse gas concentration. In most of these studies the reduction in variance is thought to be due to changes to the climatological mean state and – although the climate models simulate similar mean state changes – authors have offered different hypotheses for which mean state changes are important for the changes in ENSO. None of the hypothesis put forward have been tested, however, presumably because of the difficultly of designing a set of experiments with the full physics models that would illuminating which of the mean state changes were important, and the extraordinary computational resources that would be required to perform the experiments.

Here we introduce a new tool for evaluating the physics responsible for the ENSO – in nature and in full-physics climate models (such as those used in IPCC). The tool is a linear version of the Zebiak/Cane model with updated parameters estimated from observations and theory and with the climatological mean fields determined from observations or from the full-physics climate models. We demonstrate the tool can be used to determine the spatial and temporal characteristics of ENSO in nature. We also demonstrate how to use the tool to unambiguously determine how and why ENSO changes in the full-physics climate models when the mean state changes due to external forcing, such as Milankovitch or anthropogenic climate change. Applying the tool to the output of the NCAR CCSM, for example, shows that ENSO variance is reduced in the mid-Holocene in this model because the tropical Pacific SST is reduced, weakening the Bjerknes Feedback (ocean mean state changes destabilize ENSO, but not enough to compensate for the stabilization due to reduced SST). In contrast, applying the tool to the identical experiments using the HADCM3 shows that ENSO is reduce in that model because of a weaker thermocline that stabilizes the ENSO mode.

Finally, we show how the tool can be used to quantitatively estimate the influence of mean state biases in the present generation full-physics climate models on the ENSO biases simulated by these models. We also we outline a method for side-stepping the mean state biases to obtain better projections of how anthropogenic climate change will impact the spatio-temporal structure of ENSO and its teleconnections.