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ENSO change in climate projections: forced response or internal variability?

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There is little consensus in the literature as to how the El Niño Southern Oscillation (ENSO) may change under future greenhouse gas warming, with climate models showing a large range of future projections. This project utilises the grand ensemble of the MPI-ESM-LR climate model to quantify the extent to which internal variability can contribute to long term changes in ENSO characteristics. Such quantification enables us to diagnose the changes in ENSO that are externally forced and furthermore to distinguish between multi-model simulation results that differ by chance and those that differ due to different model physics.

Unlike previous studies, the grand ensemble allows us to evaluate how the ENSO pattern changes over time. Here, an EOF analysis is applied over the ensemble dimension to identify the ENSO pattern. We find that the pattern can change under a strong warming scenario, but is much more robust under weaker warming.

ENSO events are classified in both the grand ensemble and the CESM Large Ensemble Project to assess the frequency of Modoki, canonical and strong El Niño events. The classification system is based on three factors: the sea surface temperature pattern, ENSO evolution between May and January and the Niño3.4 index. When the classification is applied to observations, we are able to automatically classify the majority of ENSO events correctly. The variability in the frequency of each type of ENSO event is higher over a short time period, in agreement with previous studies which indicate that the recent increase in Modoki Niño events is likely due to internal variability. When we consider multiple future scenarios, we find no change in the frequency of each type of ENSO event.

Finally, the Grand Ensemble allows the identification of the influence of internal variations on future projections. When we compare projections from CMIP5 to the strongest and weakest members of the grand ensemble, we find that the disparity between CMIP5 model projections can largely be explained by internal variations simulated in the model in both weak and moderate forcing scenarios. However, in a strong warming scenario differences in ENSO projections found in CMIP5 are likely to be due to a combination of internal variability and model differences. The sign of future ENSO amplitude change in our simulations depends on internal variations. Approximately 30-40 ensemble members of a single model are needed to robustly assess changes over a 30 year period, demonstrating that single model simulations cannot be used to investigate future projections of ENSO.