Diagnosing Externally-forced Changes in ENSO Dynamics and Predictability within a CGCM Large Ensemble

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We constructed Linear Inverse Models (LIMs) from oceanic and atmospheric data from the NCAR-CESM1 large ensemble (CESM-LE) to diagnose potential anthropogenically-forced changes in tropical climate dynamics and ENSO predictability. Separate LIMs were constructed from sea surface temperature (SST) and height (SSH) anomalies drawn from the 40-member ensemble of each 20-yr period from 1950-2069, where first the anomalies were determined from the time-evolving base state (i.e., including effects from changing radiative forcing).

It can be shown that for any unbiased model, forecast skill is related to the “signal-to-noise” ratio of the predictable signal to unpredictable noise. In the LIM these terms are easily determined. Additionally, the “maximum amplification” curve determined from the LIM shows the maximum possible predictable anomaly growth (under a norm of interest) as a function of the forecast lead time, where the initial condition or “optimal perturbation” leading to maximum anomaly growth (and therefore maximum potential predictability) for a time interval is determined from an SVD of the system propagator. This calculation was made from the LIMs from each 20-yr period.

One clear result is that, as the external forcing drives a long-term base state change (including global SST warming), maximum potential ENSO growth both significantly increases and peaks at slightly shorter lead times. This is related to optimal initial conditions where the SSH portion of the anomaly becomes increasingly important for ENSO development, suggesting a pronounced change in the balance of processes responsible for ENSO in the model. This change in the dynamics is evident in tropical SST variability, which increases over this period. That is, using LIMs constructed from CESM-LE output shows that the model projects ENSO itself will become more predictable.