Interdecadal ENSO modulation: Is it predictable?

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Key findings:

1) A 4000-year control run of GFDL's CM2.1 coupled GCM -- run with unchanging radiative forcings -- exhibits intrinsically-generated, multidecadal swings in the amplitude, spectrum, skewness, spatial pattern, zonal propagation, and seasonal synchronization of ENSO.

2) Ensemble reforecasts, using a perfect model and near-perfect initial conditions, show potential predictability of the control run's ENSO trajectory, sometimes up to four years ahead.

3) However, the reforecast experiments show no clear evidence for predictability of ENSO's *decadal-scale* statistics, in the absence of external forcings.

4) The absence of long-term memory for intrinsic ENSO modulation suggests an efficient, time-saving strategy for evaluating ENSO in models, using large ensembles of short parallel runs.

Relevance to NOAA science, and to society: The El Niño / Southern Oscillation (ENSO) is Earth's strongest interannual climate fluctuation, impacting weather, ecosystems, and economies around the world. Understanding ENSO's modulation and predictability is thus highly relevant to society and to NOAA's mission.

Research overview & goals: Observations and simulations indicate that ENSO behavior is modulated from decade to decade -- leaving open the question of whether the coming decades will bring a barrage of strong ENSO events, or none at all. This study probes the limits of predictability for ENSO, using a model (GFDL-CM2.1) which has been exceptionally successful among coupled GCMs at simulating tropical climate and ENSO.

Unique aspects of the study: GFDL's 4000-year pre-industrial run of CM2.1 is presently the world's longest available control simulation from a coupled GCM at this level of sophistication -- affording a unique opportunity to characterize and reforecast extreme ENSO epochs. In addition, this study's decadal reforecast ensembles are some of the largest ever performed with a coupled GCM, offering a new and detailed look at the long-lead predictability of extreme ENSO epochs.

Methodology: Nine extreme-ENSO decades from the CM2.1 4000-year control run are reforecast using a "perfect model" -- i.e. the same model that generated the control run. The 40-member reforecast ensembles are initialized by adding a tiny temperature perturbation (comparable to round-off error) at a single model grid point. The resulting decadal reforecasts represent the best conceivable predictions of this simulated climate system.

Remaining uncertainties: Future work could analyze a broader range of climate variables (including ocean heat content and extratropical fields), and/or run similar experiments in other models and over a wider range of initial conditions. Work is also needed to establish the relative roles of intrinsic modulation and external forcings in determining ENSO behavior over the next several decades.

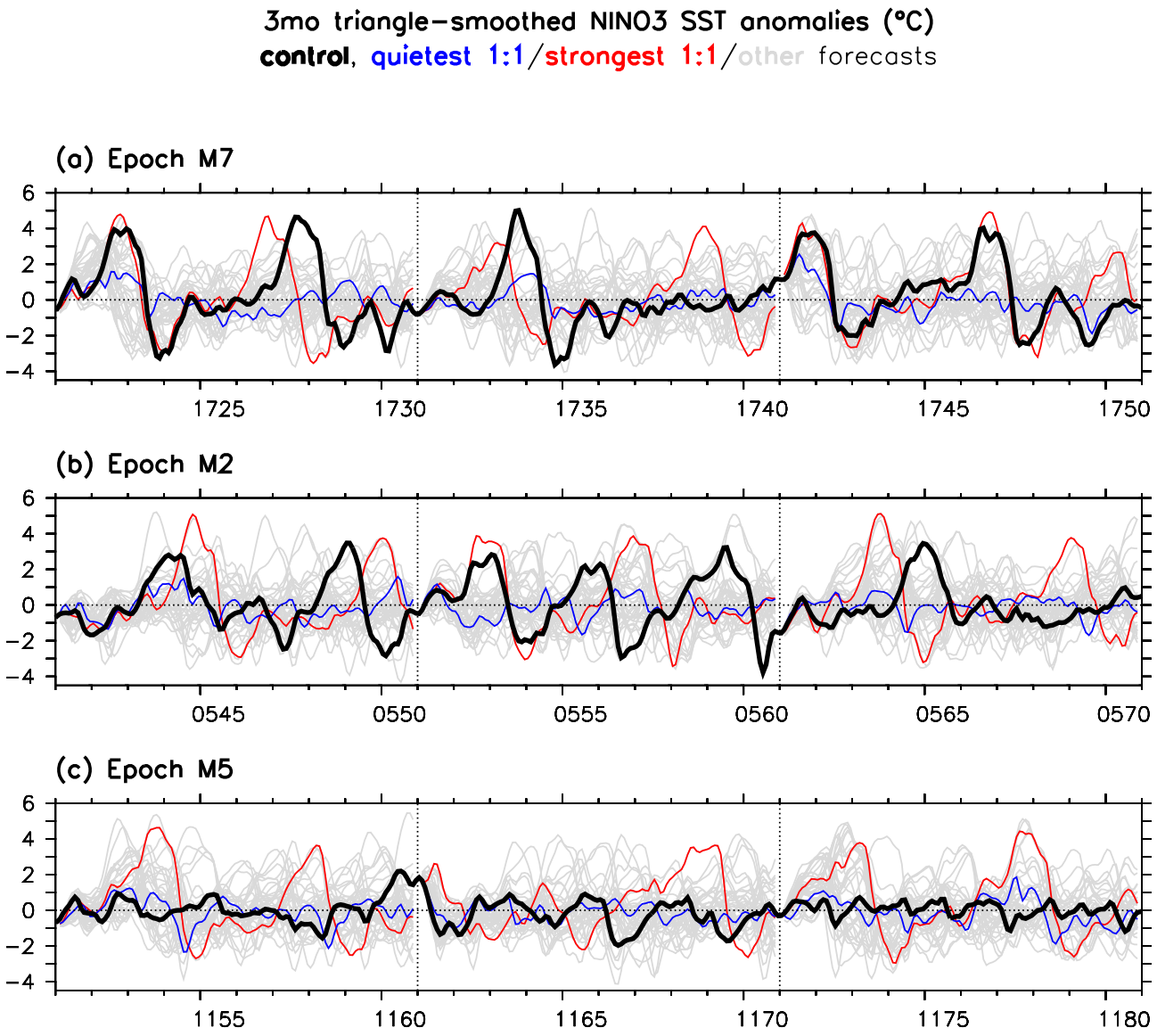

Figure S1: Three 30-year time series of sea surface temperature anomalies (SSTAs, °C) averaged over the eastern equatorial Pacific, during epochs of (a) strong ENSO, (b) moderate and steady ENSO, and (c) weak ENSO from the original 4000-year pre-industrial CM2.1 control run (**black curves**). At the start of each decade (dotted vertical lines), the control run is slightly perturbed to generate an ensemble of 40 reforecasts (gray curves) which evolve forward in time. Red/blue curves indicate the reforecast member with the strongest/weakest ENSO amplitude.