An Empirical Model of Decadal ENSO variability
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Introduction
We have developed an empirical stochastic model for simulating and predicting evolution of the ENSO index $x$ (Fig. 1, red line) computed as the leading normalized principal component (PC) of the tropical Pacific sea-surface temperature (SST) anomalies. The latter anomalies were obtained by subtracting the dominant low-frequency modes $y$ of the global SST variability defined here in terms of the three leading deterministic patterns (Schneider and Held 2001) and their companion time series—canonical variates (CVs); see Figs. 1 a–c. The CVs describe climate modes characterized by maximal ratio of interdecadal to subdecadal SST variance, and were treated as external predictors in the empirical ENSO model (Kravtsov 2012).

Causality of decadal ENSO variations
Is there an apparent connection between multidecadal ENSO STD variations (Fig. 1d, red line) and CVs (Figs. 1a–c, red lines) random (Flügel et al. 2004) and/or the result of ENSO’s midlatitude teleconnections (Vimont 2005)? This question is addressed in Fig. 2.

Model formulation
$x_{t+1} - x_t = \sum_{p=0}^{P-1} a_p(y_{t-p})^2 x_t^p + r_t$,

$\sum_{l=0}^{L-1} b(y_{t-l}) x_{t-l} + c(y_{t})^2 r_t + c(y_{t})^2 r_t$,

Equations (1–2) with $P=3$ and $L=4$ are two-level parametric model for the evolution (with time index $n$) of the seasonal-mean ENSO index $x$; the model parameters linearly depend on external predictors $y$ and on time via harmonic annual predictors (see Fig. 3). The second level models the main-level forcing $r$. The model coefficients are found from data using regularized regression techniques (Kravtsov et al. 2005).

Model performance
Our empirical model captures many aspects of the observed Niño-3 evolution (Fig. 4), including interdecadal modulation of Niño-3 variance largely anti-correlated with the AMO index [cf. Dong et al. (2006); see also Fig. 1d, red line.

Hindcasts of decadal ENSO variability
Cross-validated jack-knife hindcasts of the ENSO STD are presented in Fig. 5 for different choices of external predictors and their extrapolation methodologies. All in all, these results demonstrate the potential for skillful forecasts of the ENSO variance if the external predictors can themselves be forecasted. The results suggest potential long-term ENSO STD predictability if the external predictors can themselves be forecasted.

Discussion
The central result of this paper is that the random variations of ENSO statistics have an insufficient magnitude to rationalize its observed multidecadal behavior (the peak-to-trough variations of the ENSO STD in Fig. 4). Furthermore, the association between the external predictors and ENSO variance is unlikely to be due to random chance (Fig. 2). Hence, the Flügel et al. 2004 and Wittenberg’s (2009) null hypothesis for decadal ENSO modulation is formally rejected, within our empirical model framework, and the effect of the external predictors on ENSO statistics is shown to be quantitatively substantial.

Bibliography

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