P4.2

A Baseline Statistical Model for Tropical Pacific Wind Stress Anomalies

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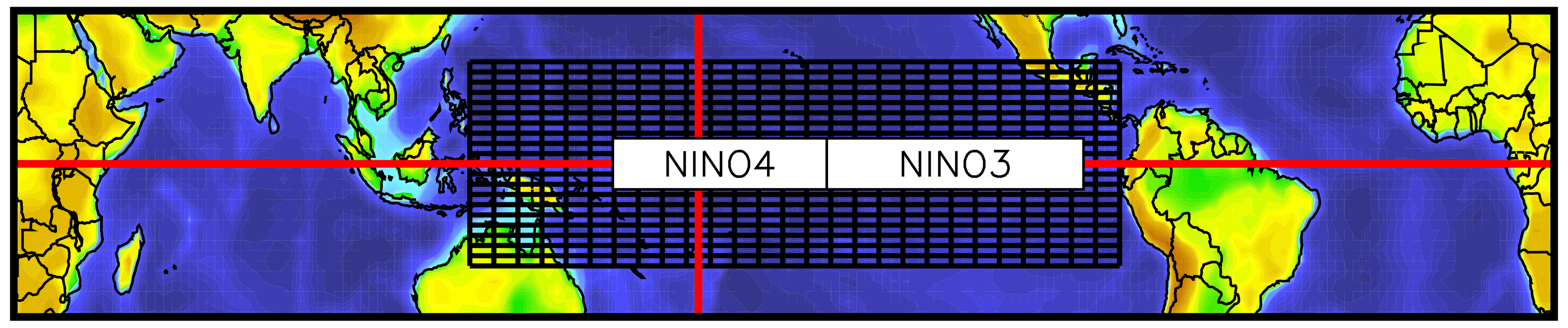
1. Introduction

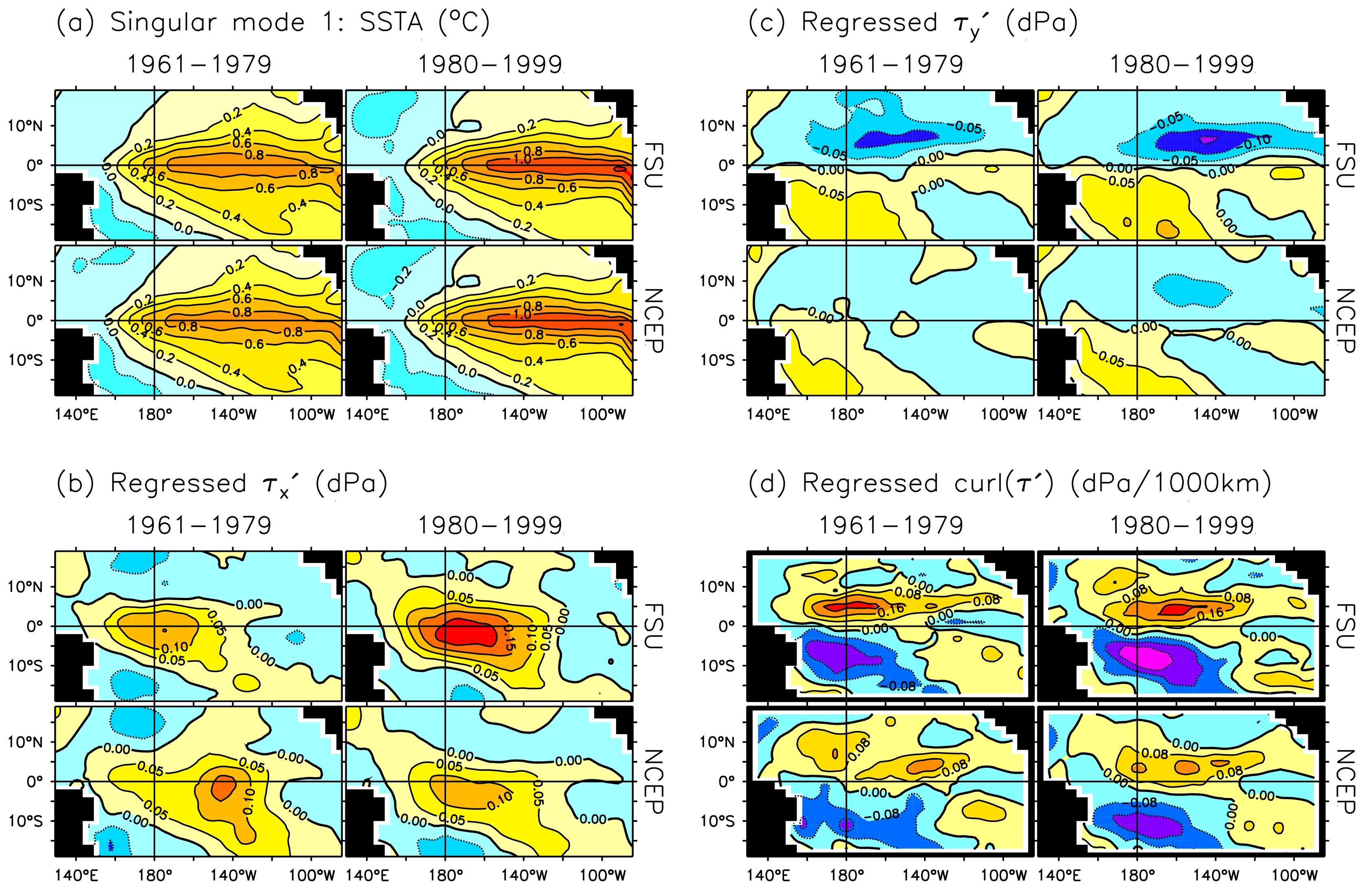
The behavior and predictability of ENSO are largely governed by the structure of the tropical Pacific surface wind stress response to SST anomalies, and by the impact of weather-like disturbances. Both elements remain a challenge for atmospheric GCMs — so how can the stress be modeled realistically?

2. Data



Most available estimates of tropical Pacific wind stress anomalies (τ') cover only a fraction of the past four decades (see timeseries at bottom). The exceptions are FSU (Stricherz et al. 1997), the NCEP/NCAR Reanalysis-1 (NCEP, Kalnay et al. 1996), and UWM/COADS. We focus on FSU and NCEP here, since UWM/COADS gives results very similar to FSU. SSTs are taken from the reconstruction of Smith et al. (1996). Monthly-mean data are averaged onto the grid above, and anomalies are computed by subtracting 12-month climatologies separately for 1961–79 and 1980–99.

3. Stress Response to SST Anomalies



The stress response to SSTAs is estimated by regressing τ' onto the leading singular vectors of SSTA/τ' covariance. The large differences between products (Wittenberg 2003) motivate the use of multiple datasets for diagnostic studies and ocean simulations, since the stability and period of ENSO depend strongly on the amplitude, position, and structure of the stress response (Kirtman 1997; Harrison et al. 2002). Even the secular changes in the response, which have been linked to decadal changes in ENSO (An and Wang 2000), differ between analyses.

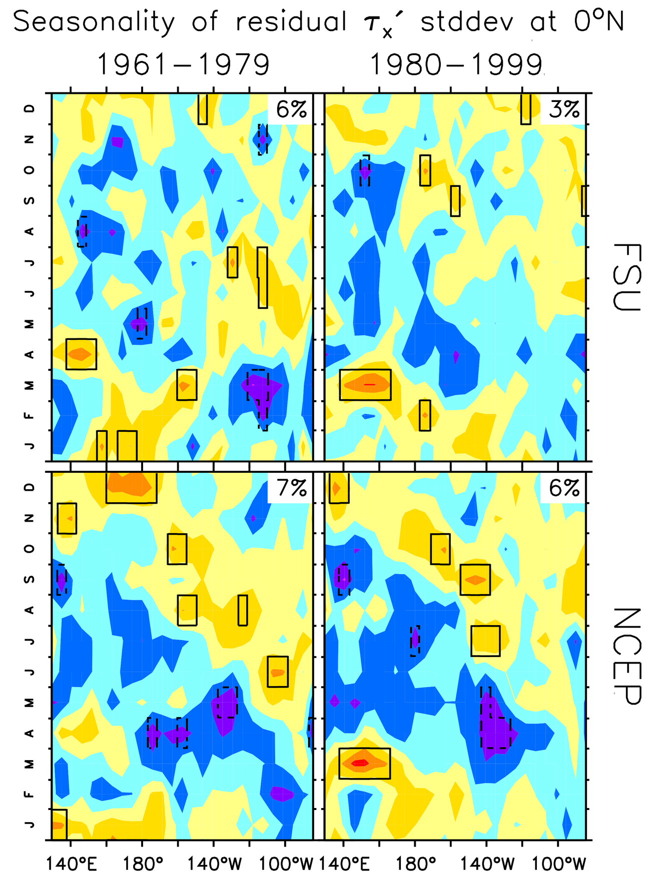
4. Signal vs. Noise

To capture propagating features without overfitting, the SST-dependent part of the model incorporates predictors if and only if they significantly improve the stress simulation. There is a large residual: over three quarters of the monthly τ' variance is *not* linearly related to large-scale SSTAs.

	1961–1979 FSU	1961–1979 NCEP	1980–1999 FSU	1980–1999 NCEP
number of modes	4	5	3	5
% square covariance	98	99	98	98
% SSTA variance	81	85	76	81
% τ' variance:				
singular vectors	23	44	25	39
regression	13	23	14	20

Number of modes retained in each stress model, with the percent squared covariance, SSTA variance, and τ' variance that project onto the singular vectors, and the percent τ' variance captured by the regression model.

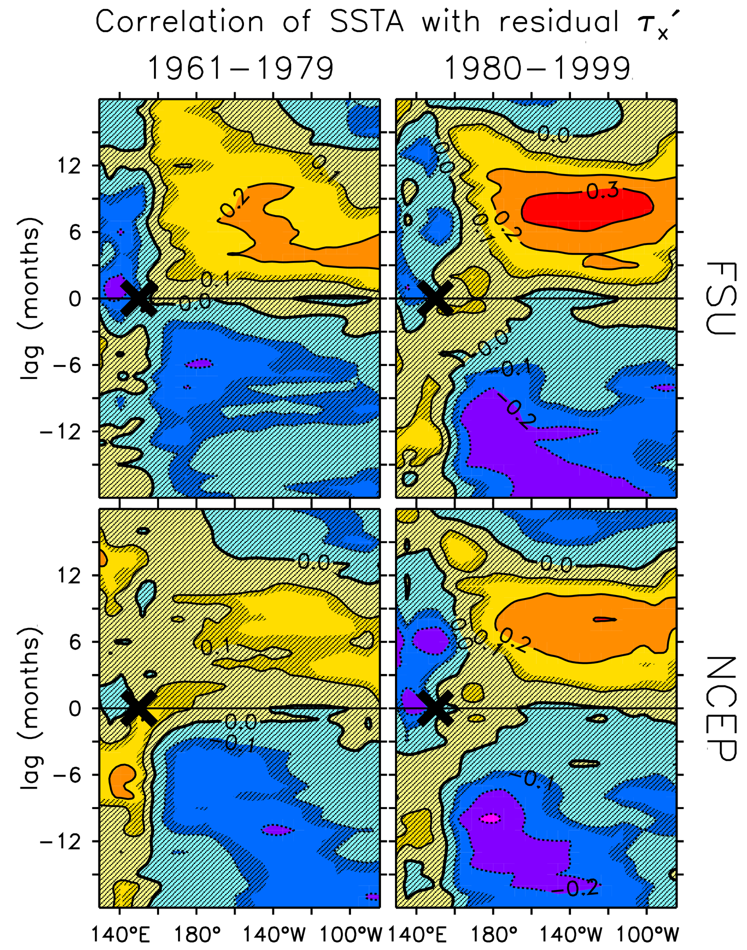
5. Structure in the Residual



The noisy residual stresses do retain some structure. They are most active off-equator and in the western Pacific, and exhibit distinct seasonality. The figure at left shows the annual cycle of τ_x' noise along the equator, expressed as a standard deviation for each month divided by that of all months. Warm colors show increased activity, and contours indicate points where an F-test rejects stationarity with 99% confidence. The noise in the west tends to peak in boreal spring, and in recent decades has grown stronger and shifted later in the calendar year.

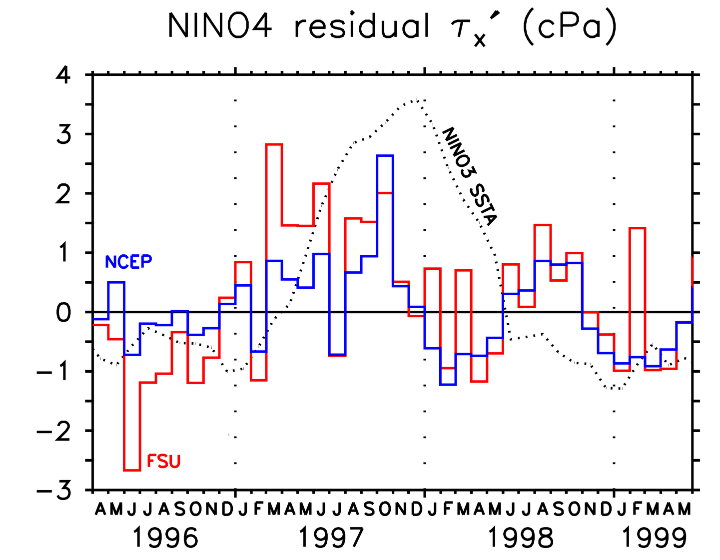
6. Is the Noise Linked with ENSO?

The residual stresses in the western equatorial Pacific are linked with large-scale changes in equatorial SST (at right, unmasked values exceed 95% of correlations between the SSTAs and white noise). Westerly residuals are followed months later by significant warming, which would seem to indicate a coupled air-sea response to a quasi-random part of the stress. Yet this "noise" is not entirely independent of ENSO: in fact, westerly residuals are significantly correlated with *prior* cooling in the east. Thus ENSO may modulate the noise and vice versa.



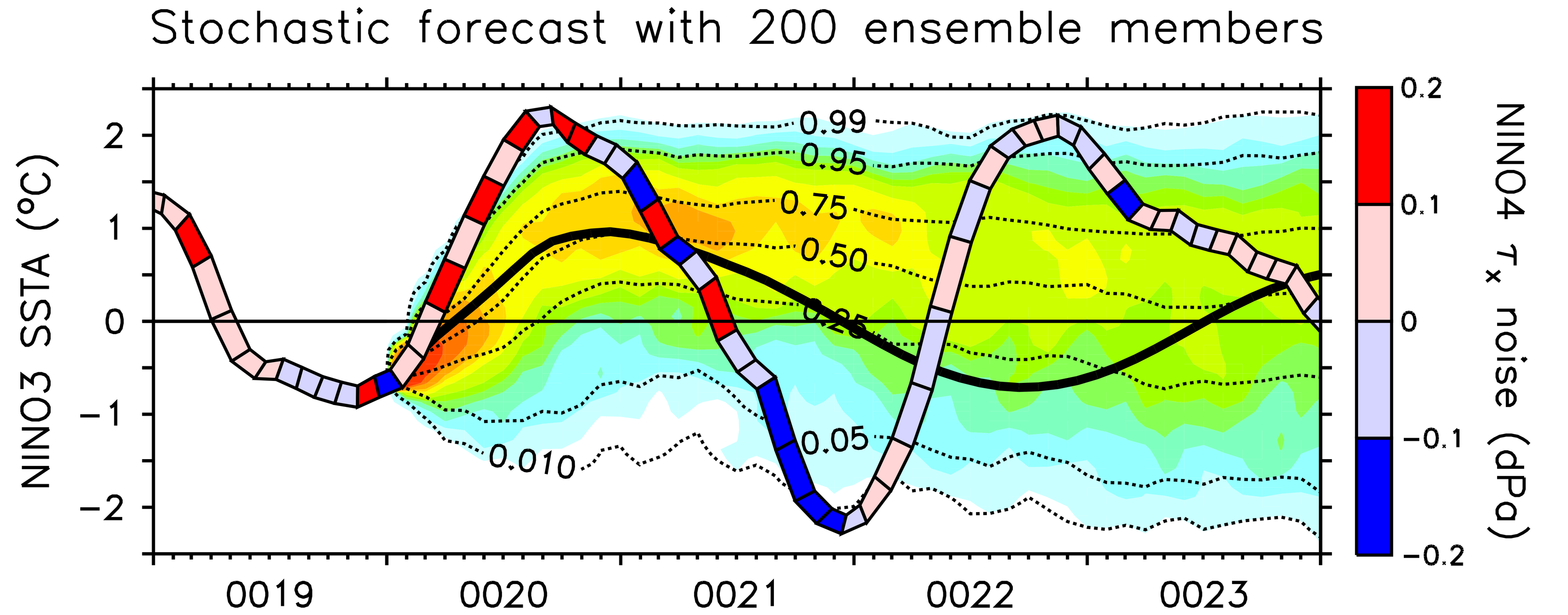
7. A Forecast Surprise

Operational forecasts of the 1997–98 El Niño failed to anticipate its intensity and sudden demise. What went wrong? Perhaps random disturbances were to blame: the FSU and NCEP residuals show strong equatorial westerly bursts prior to the event, and easterly bursts during the decay. This particular sequence of wind bursts was unusual and possibly unpredictable (Fedorov et al. 2003).



8. Stochastic Ensemble Forecasting

Given an ENSO model and the noise statistics, one can forecast the risk of such surprises. Below, a particular noise-forced hybrid coupled model run (banded tube) serves as the "truth" to be predicted. Following a mild cold event, two types of forecasts are issued using the same ("perfect") model and perfect initial conditions. The forecast without noise (solid line) enters an El Niño, but underestimates the severity and rapid decay of the true event. The stochastic ensemble forecasts (quantiles dotted) show the full range of possibilities. Clearly the true event was an exceptional case: by chance it received a series of westerly wind bursts during its onset, and easterly bursts during its decay.



The stress model developed here has been used to assess the ENSO sensitivity to climate changes (Wittenberg 2002), and our current work aims at understanding ENSO/noise interactions, improving the baseline statistical model, and implementing stochastic ensembles for operational forecasts.

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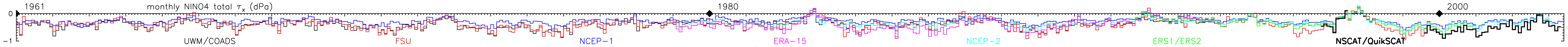

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