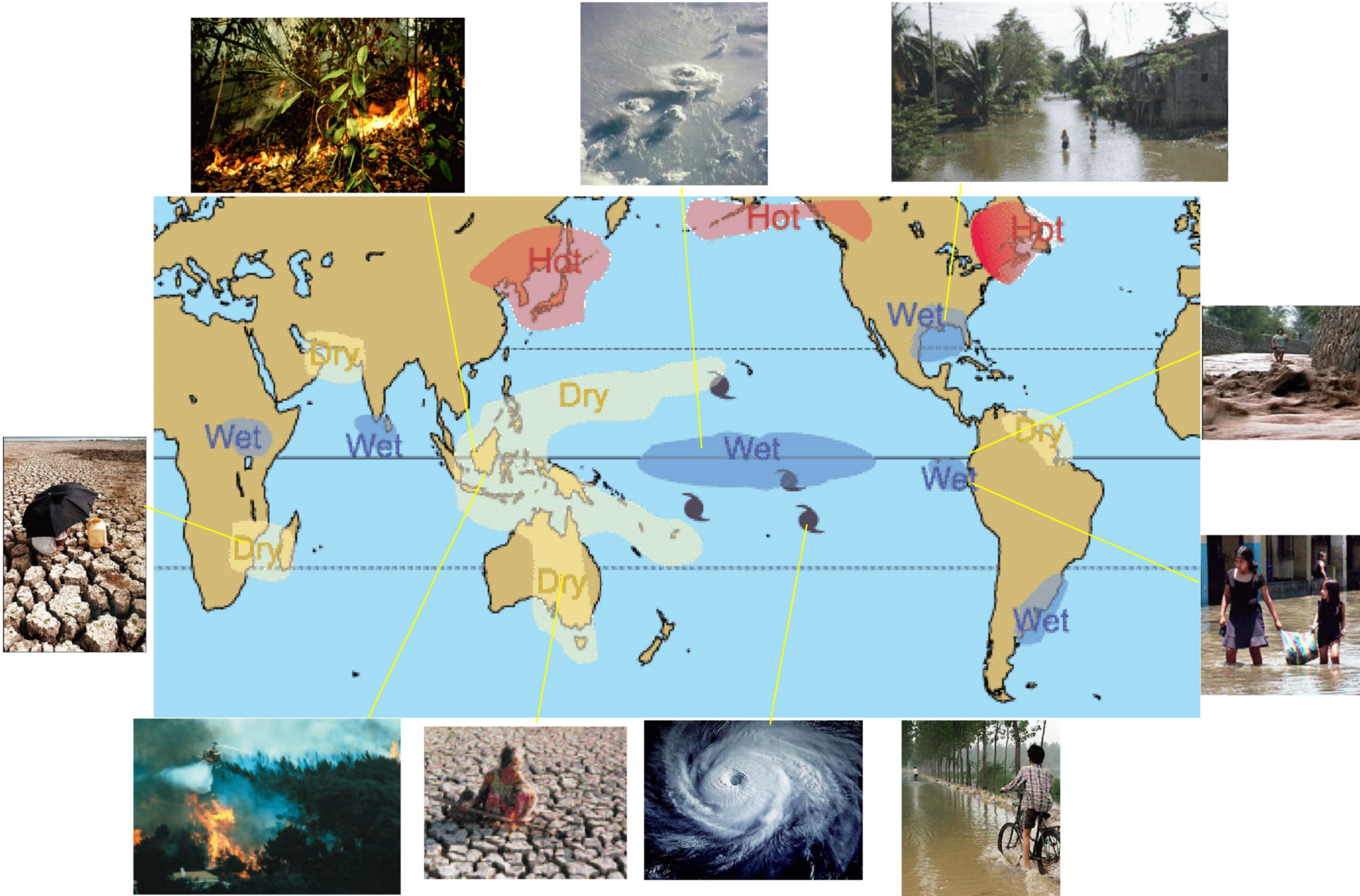
On extended wind stress analyses for ENSO

Dr. Andrew T. Wittenberg

GFDL/NOAA

Global Impacts of ENSO

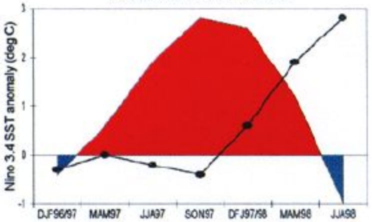


Forecasts of the 1997/98 El Niño

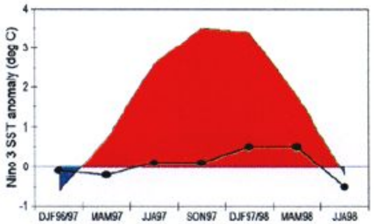
(Landsea & Knaff 2000)

Statistical Models

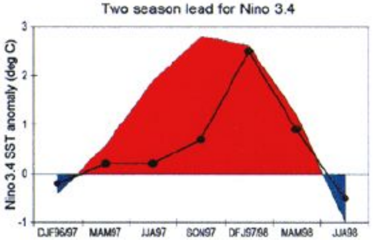
Persistence Forecasts
Two season lead for Nino 3.4



Linear Inverse Forecasts
Two season lead for Nino 3

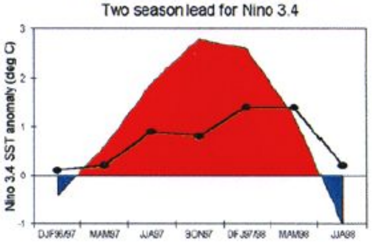


ENSO-CLIPER Forecasts
Two season lead for Nino 3.4



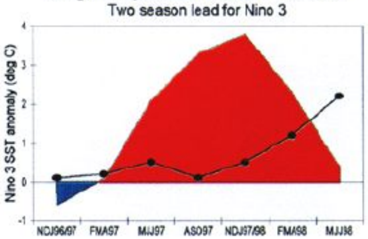
Constructed Analogue Forecasts
Two season lead for Nino 3.4

Canonical Correlation Forecasts
Two season lead for Nino 3.4

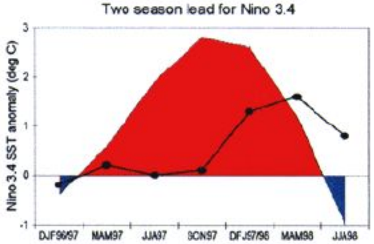


Neural Network Forecasts
Two season lead for Nino 3.4

Singular Spectrum & MEM Forecasts
Two season lead for Nino 3

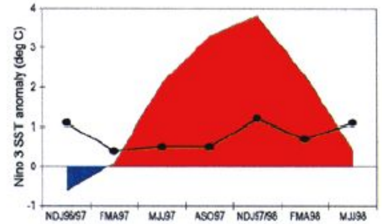


Consolidation Forecasts
Two season lead for Nino 3.4

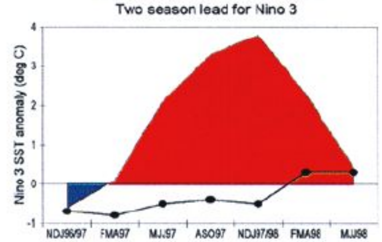


ICMs

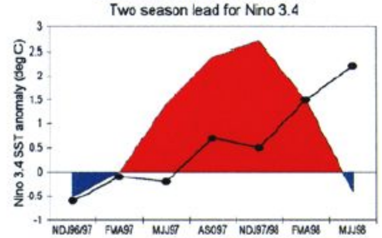
BMRC Forecasts
Two season lead for Nino 3



Lamont-Doherty Forecasts
Two season lead for Nino 3

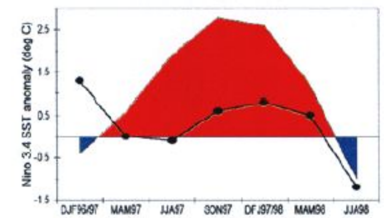


Oxford Coupled Forecasts
Two season lead for Nino 3.4



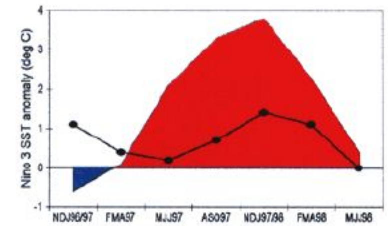
HGCMs

Scripps-Max Planck Forecasts
Two season lead for Nino 3.4

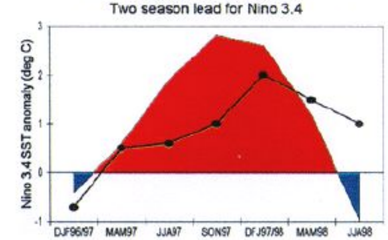


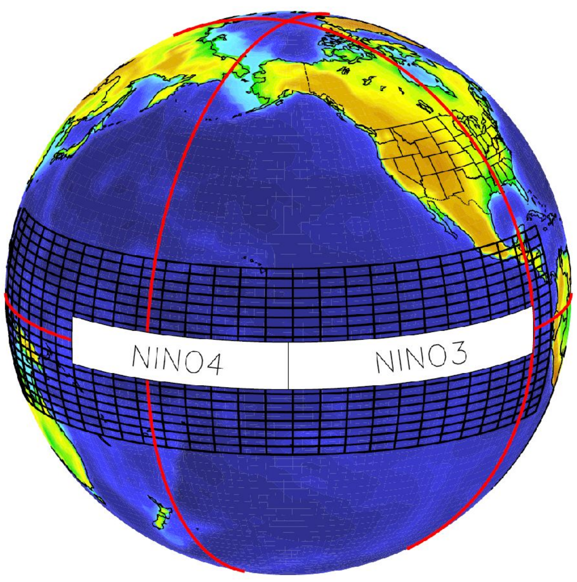
CGCMs

COLA Forecasts
Two season lead for Nino 3



NCEP Coupled Model Forecasts
Two season lead for Nino 3.4





The wind observing network

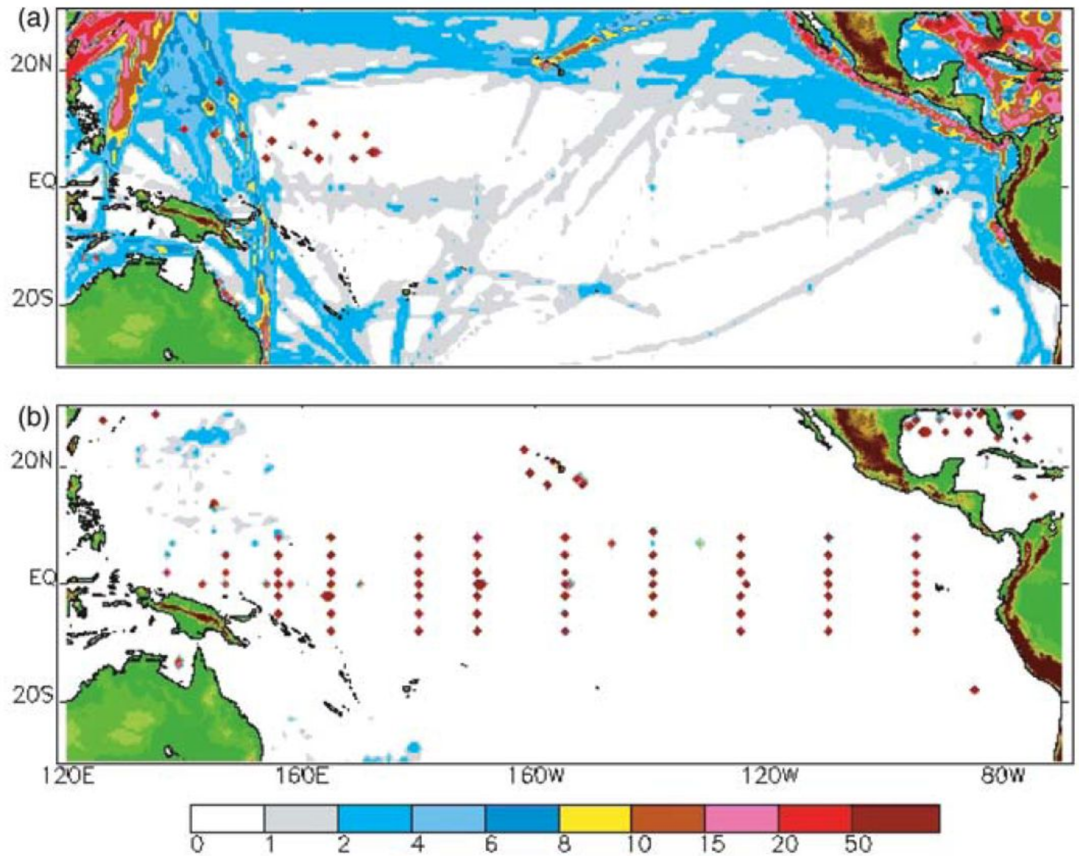
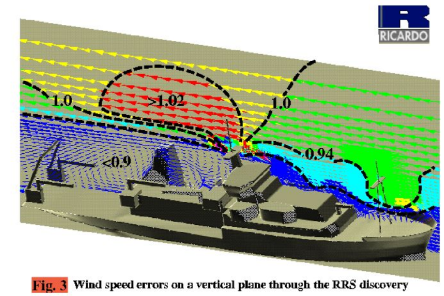


FIG. 2. Mean number of (a) ship and (b) buoy pseudostress values per month for the tropical Pacific Ocean. Averages based on COADS data for the period Jan 1988 through Dec 1997. Means were calculated in 1° bins, then were contoured with magnitudes shown in the color bar. (Smith et al., 2004)

Volunteer Observing Ships (VOS)

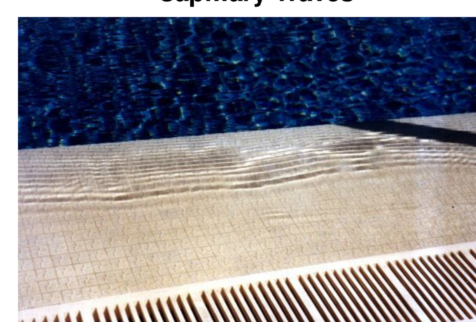


(Yelland et al., 2003)

TAO buoys

ADEOS-II

Capillary Waves



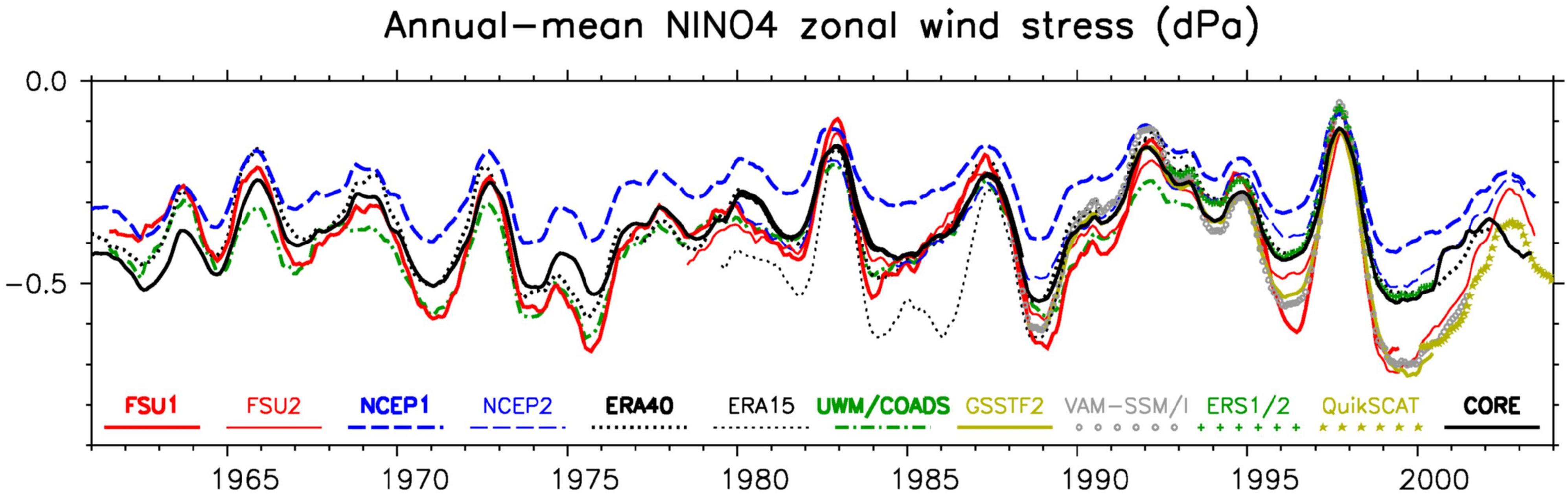
SSM/I

ERS1/2

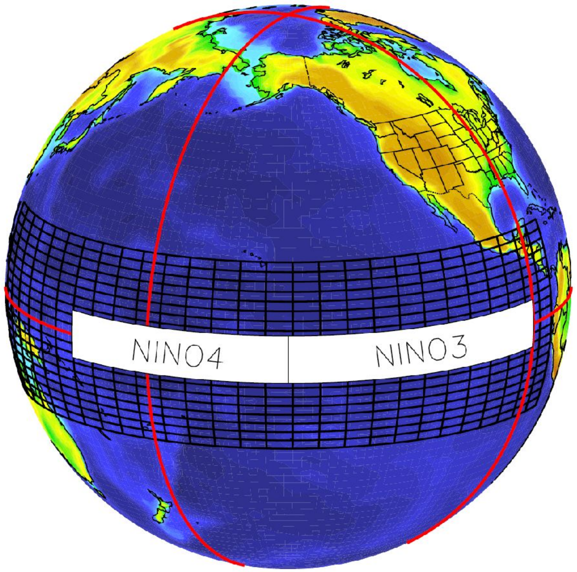
NSCAT

QuikSCAT

A wide variety of products

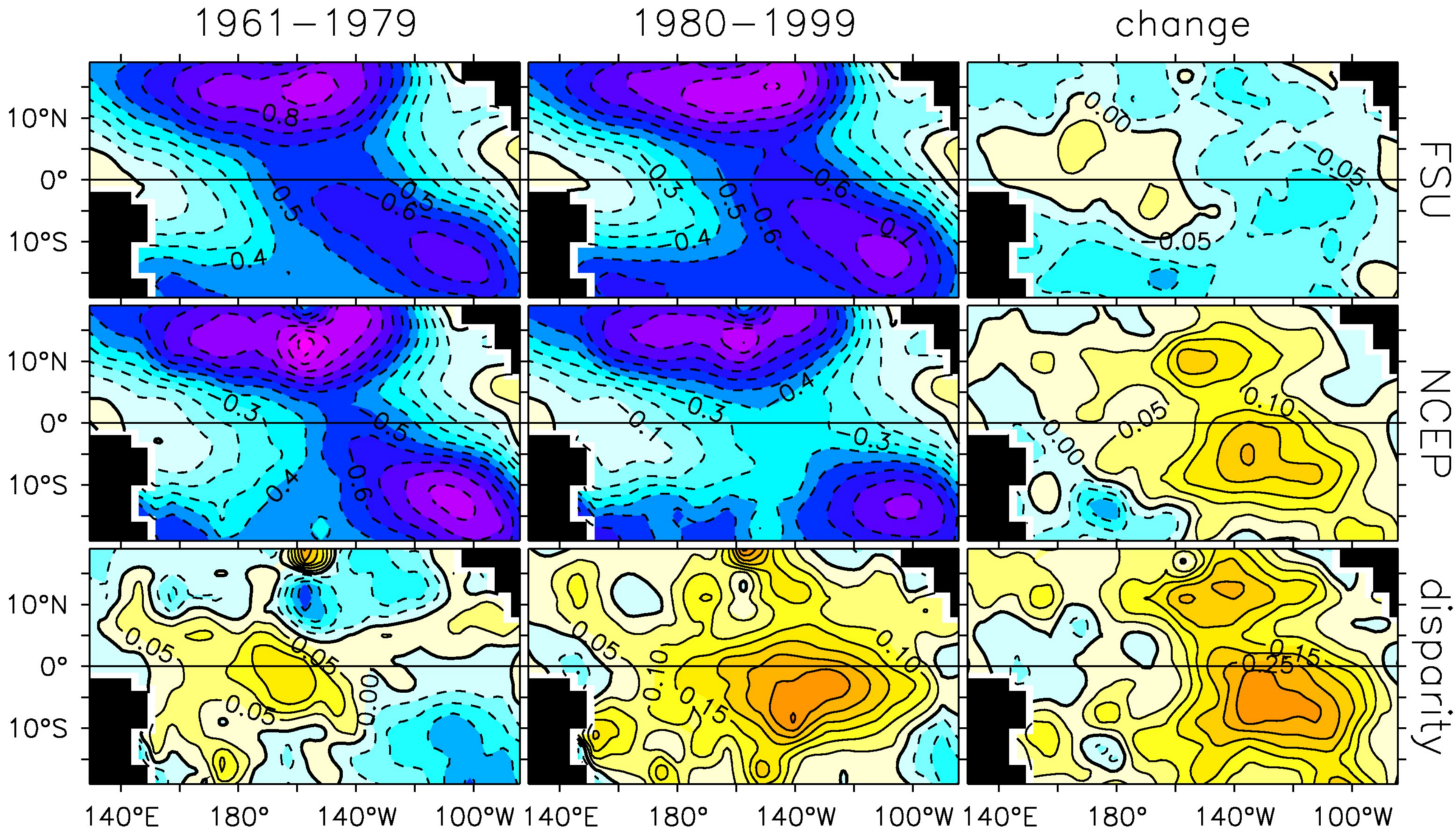


FSU subjective analysis

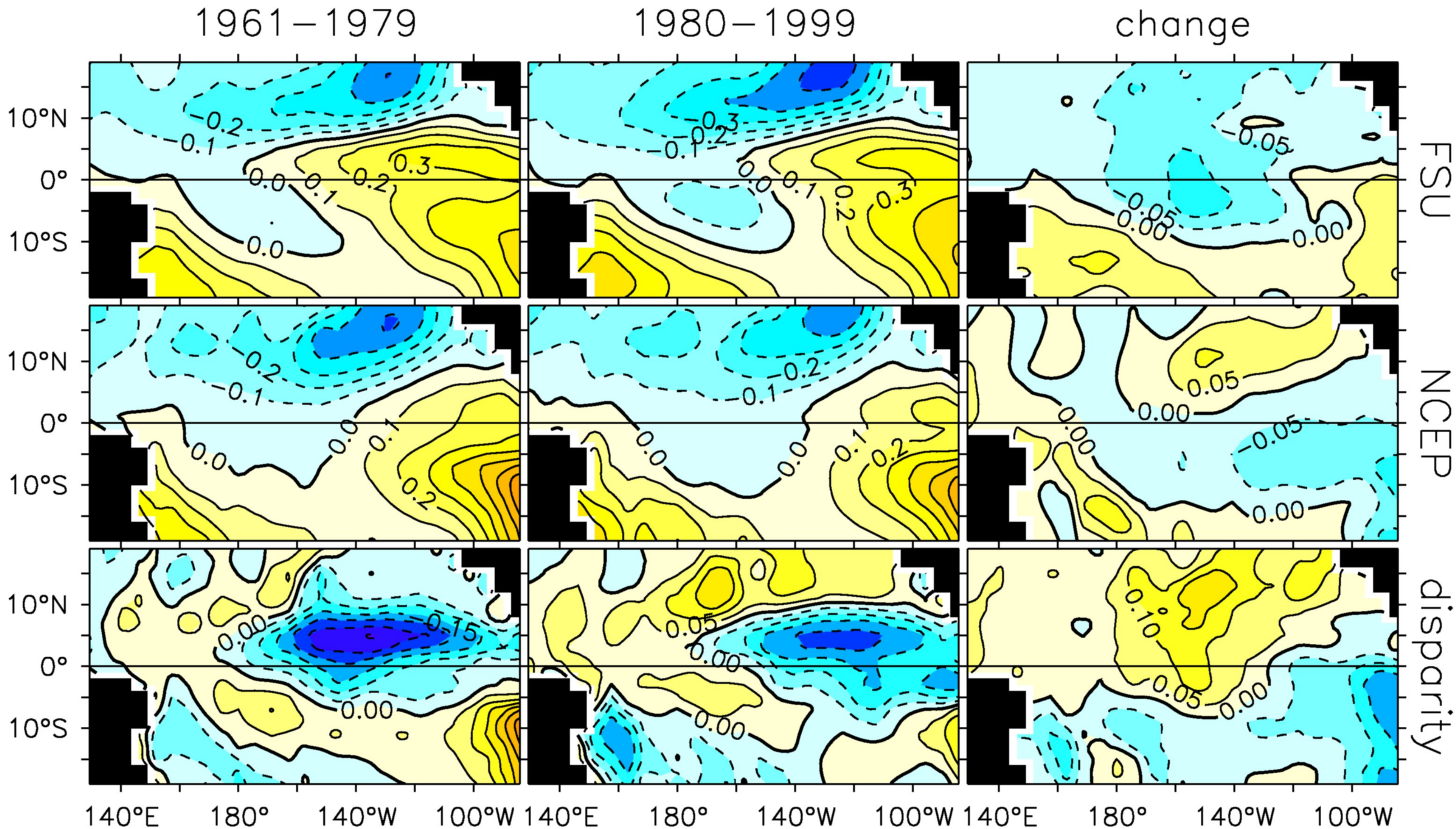


NCEP/NCAR Reanalysis

Annual-mean zonal stress (dPa)



Annual-mean meridional stress (dPa)



Wind stress generates mean oceanic upwelling:

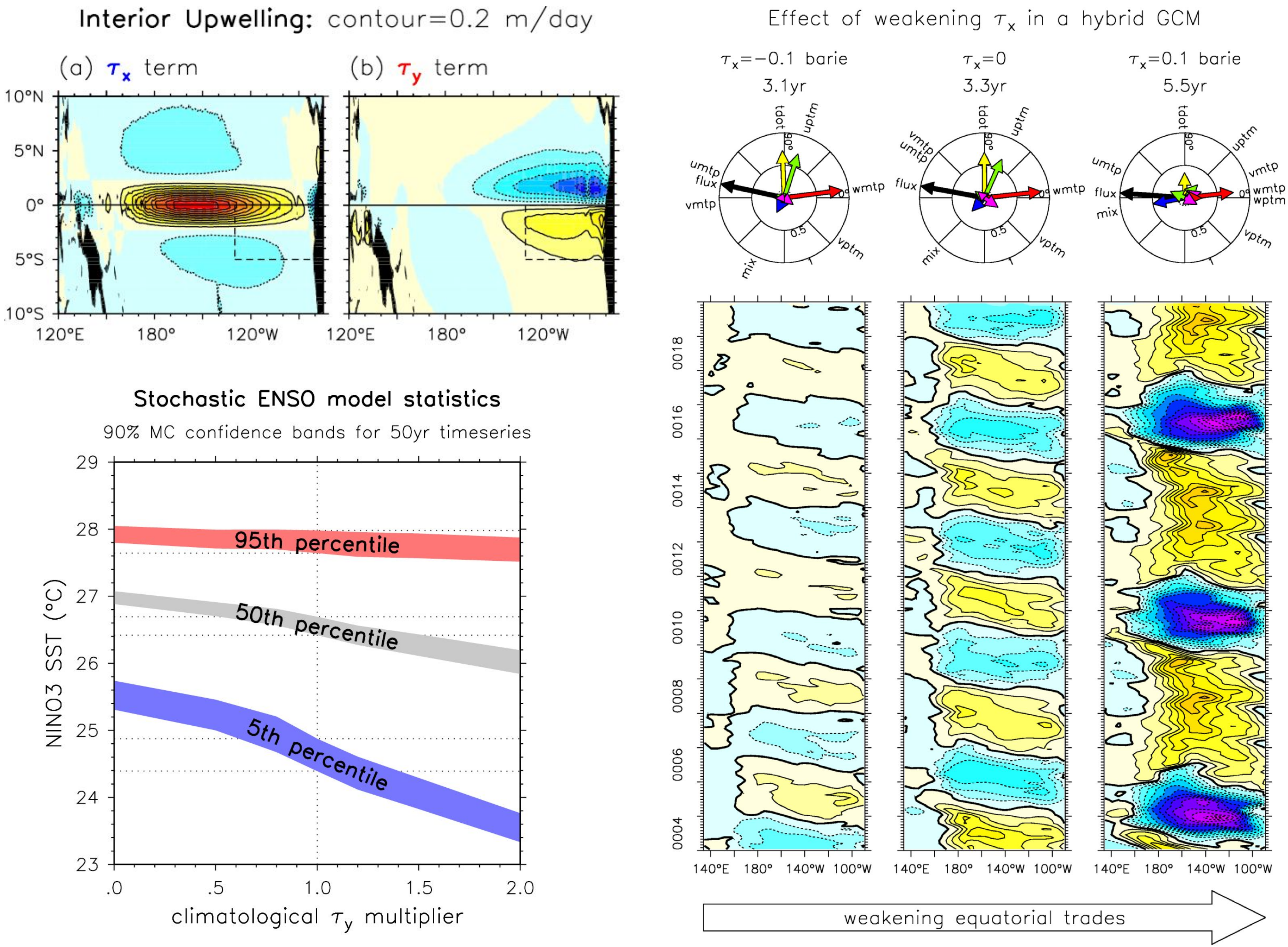
$$w|_{z=H_m} \approx \frac{H - H_m}{\rho H(\tilde{y}^2+1)} \left[\frac{\beta}{r_s^2} \left(\frac{\tilde{y}^2 - 1}{\tilde{y}^2+1} \tau_x - \frac{2\tilde{y}}{\tilde{y}^2+1} \tau_y \right) + \frac{\mathbf{div}(\boldsymbol{\tau})}{r_s} + \frac{\tilde{y}\mathbf{curl}(\boldsymbol{\tau})}{r_s} \right]$$

$$\tilde{y} = \beta y / r_s$$

and a mean thermocline slope:

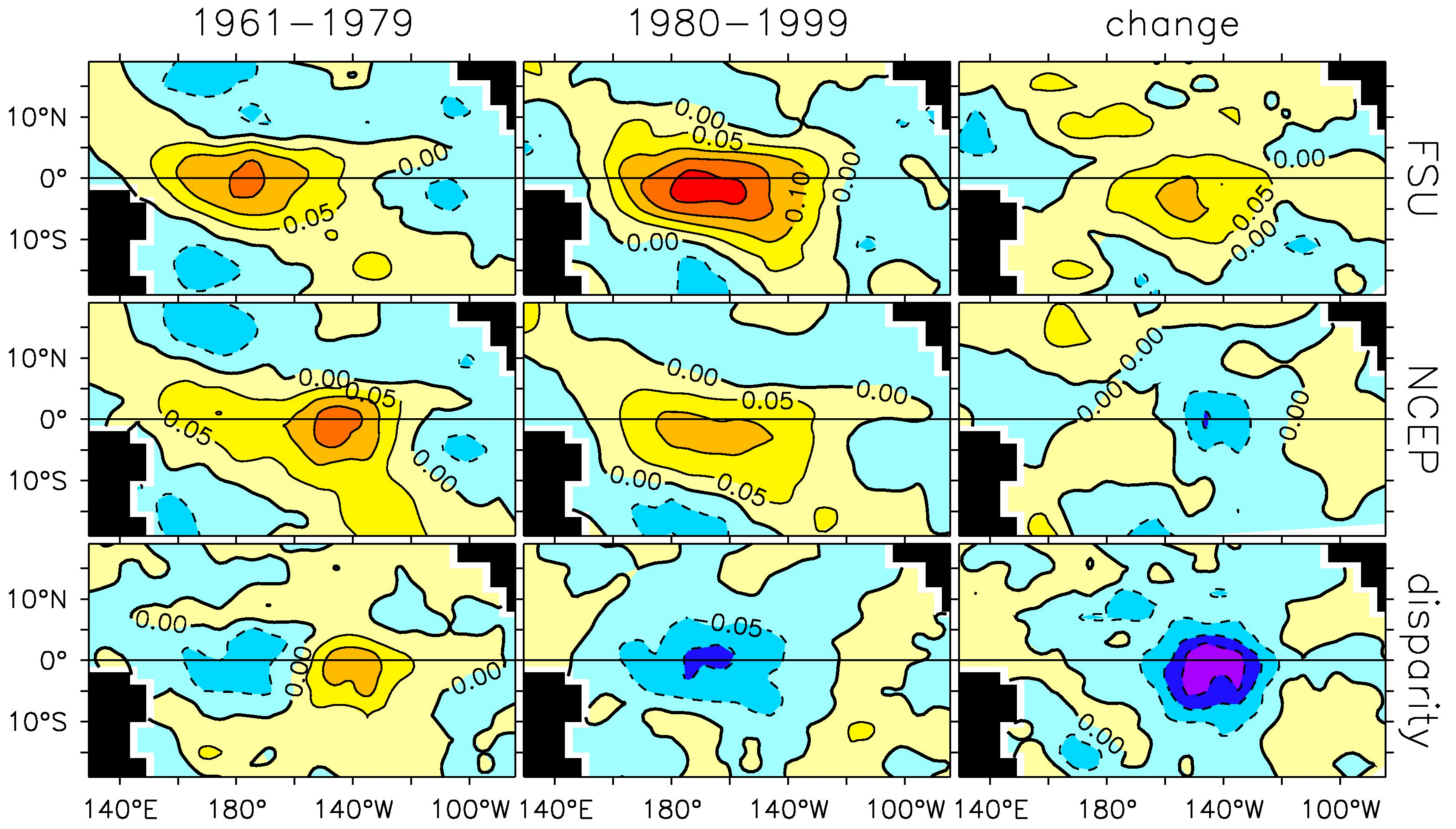
$$\partial_x h \approx \frac{\tau_x}{gH\Delta\rho}$$

Both affect the coupled mean state and ENSO.

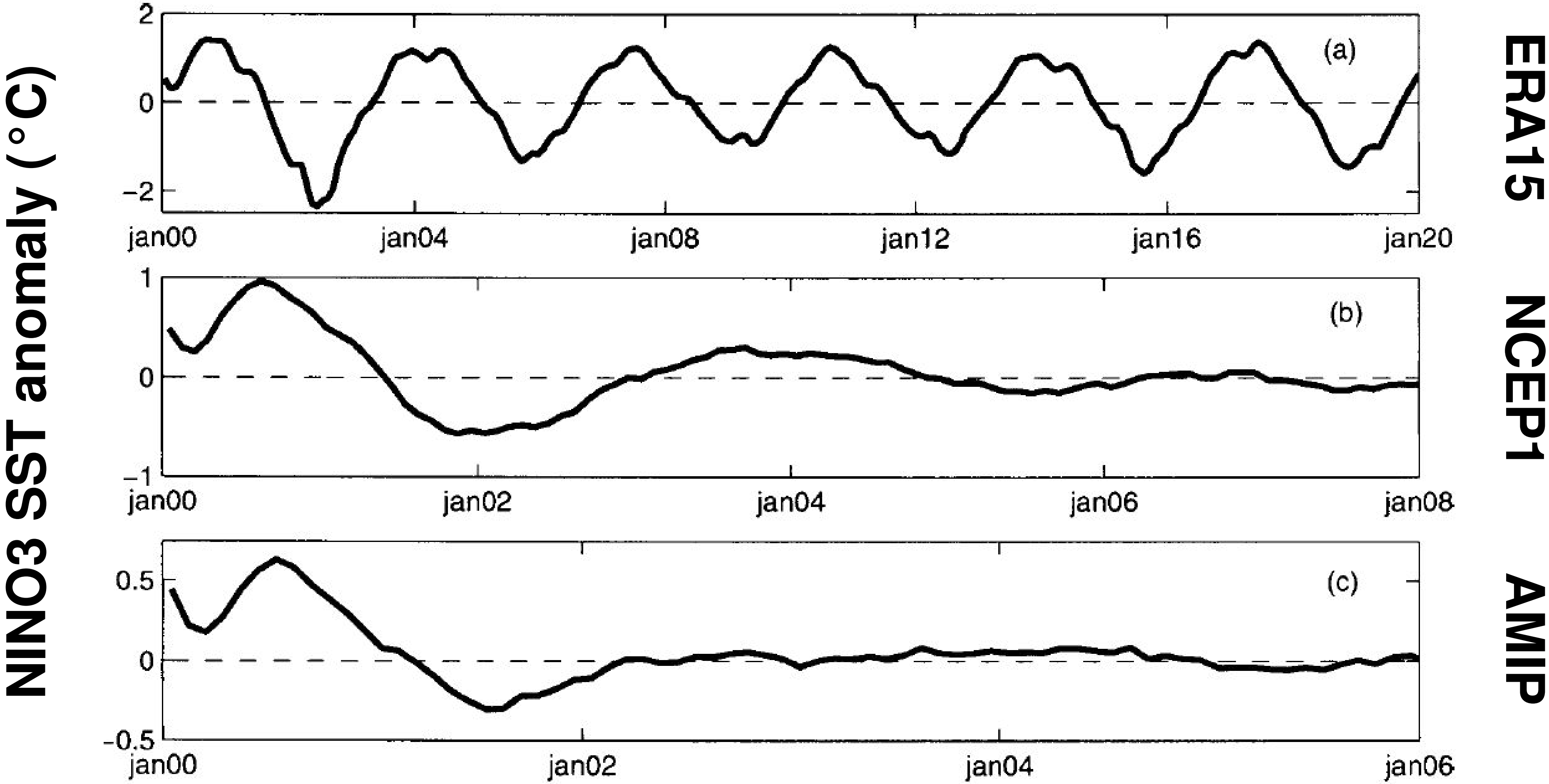


Interior Upwelling: contour=0.2 m/day
(a) τx term
(b) τy term
10°N
5°N
0°
5°S
10°S
120°E
180°
120°W
Stochastic ENSO model statistics
90% MC confidence bands for 50yr timeseries
95th percentile
50th percentile
5th percentile
NINO3 SST (°C)
climatological τy multiplier
29
28
27
26
25
24
23
.0
.5
1.0
1.5
2.0
Effect of weakening τx in a hybrid GCM
τx=−0.1 barie
3.1yr
τx=0
3.3yr
τx=0.1 barie
5.5yr
tdot
uptm
umtp
vmtp
flux
wmtp
wptm
vptm
mix
90°
0°
0.5
1
0004
0006
0008
0010
0012
0014
0016
0018
140°E
180°
140°W
100°W
weakening equatorial trades

Zonal stress anomalies regressed onto NINO3 SSTAs

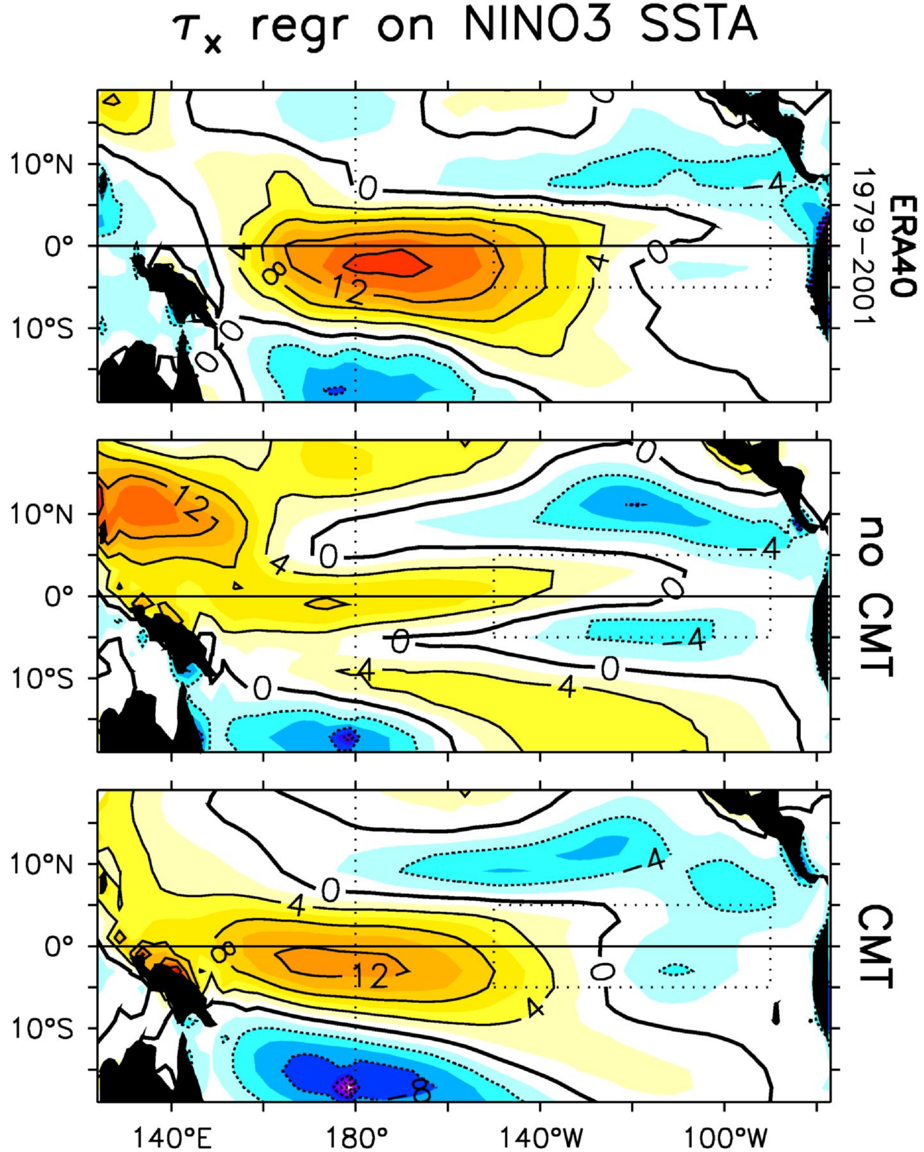


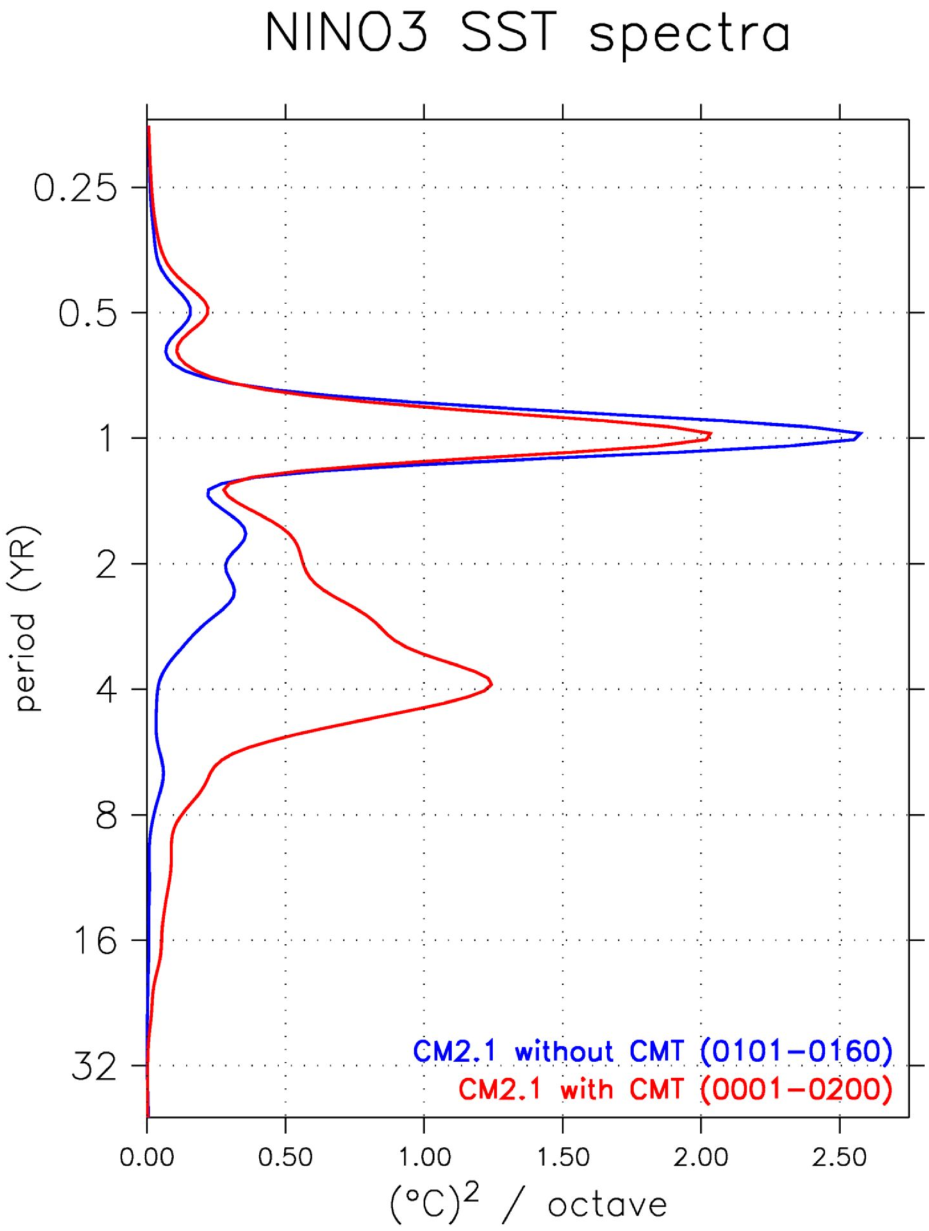
Hybrid coupled model ENSO, using various flux products



Harrison et al. (MWR, 2002)

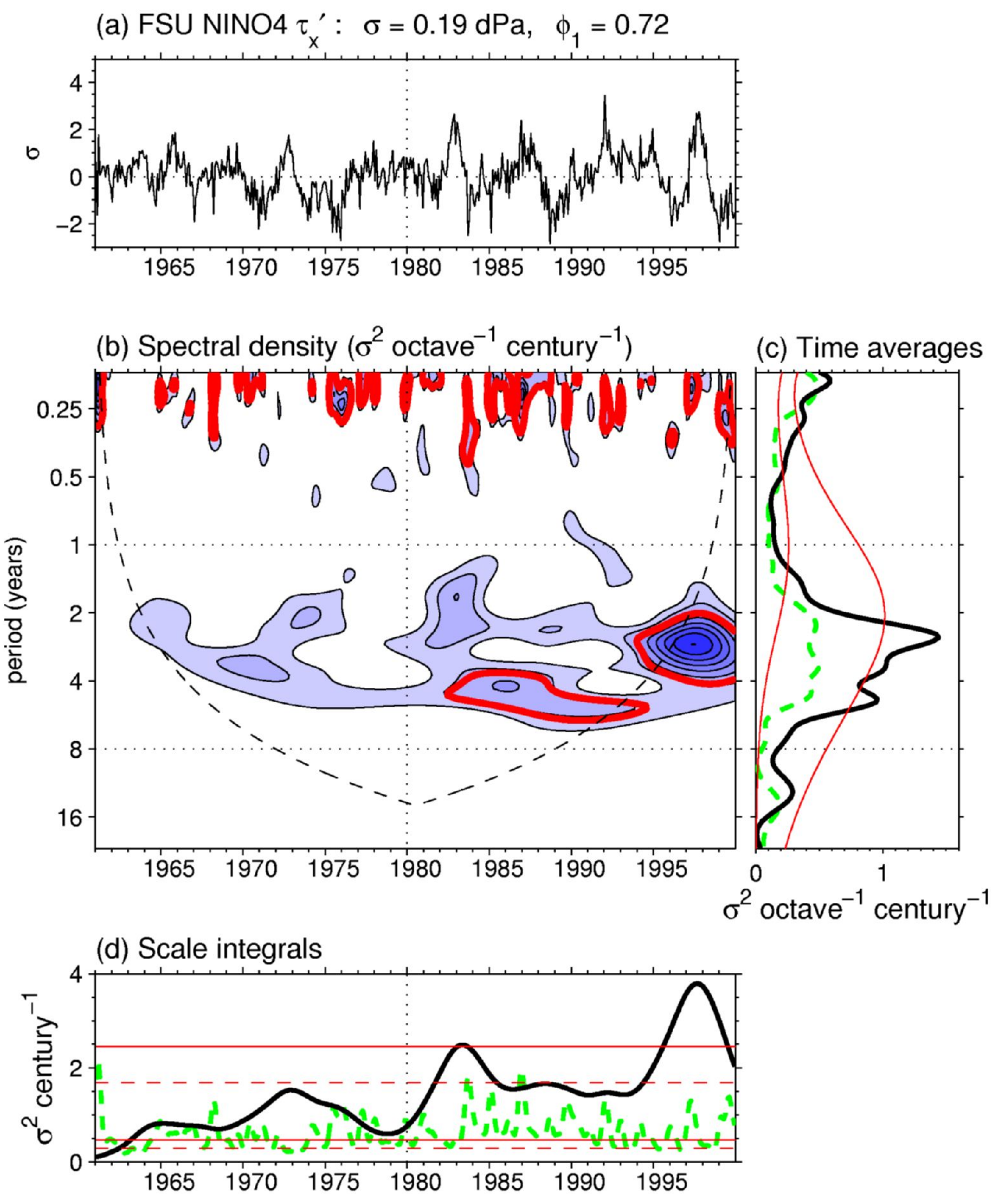
CM2 Sensitivities: Cumulus Momentum Transport



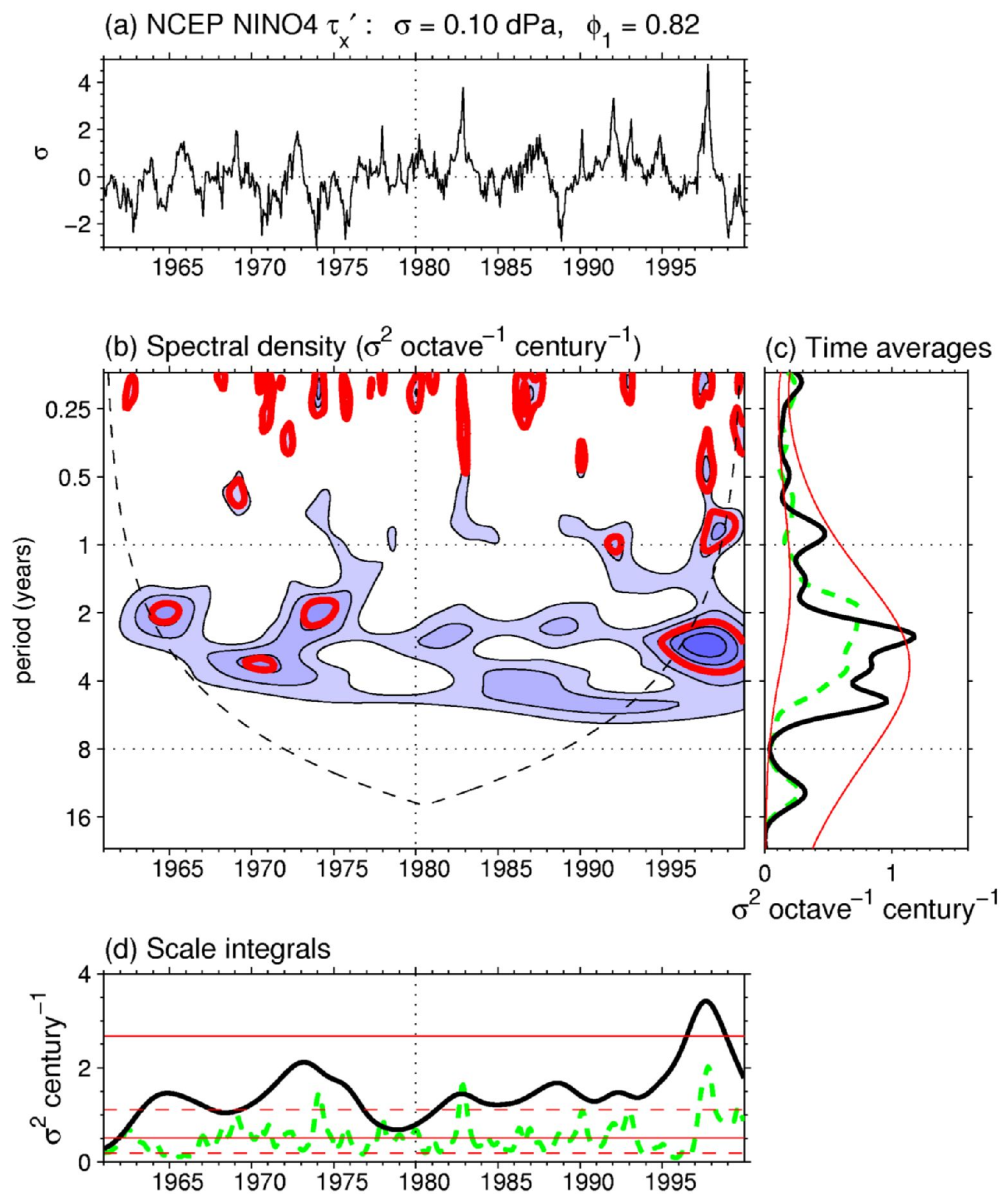


NINO4 zonal stresses

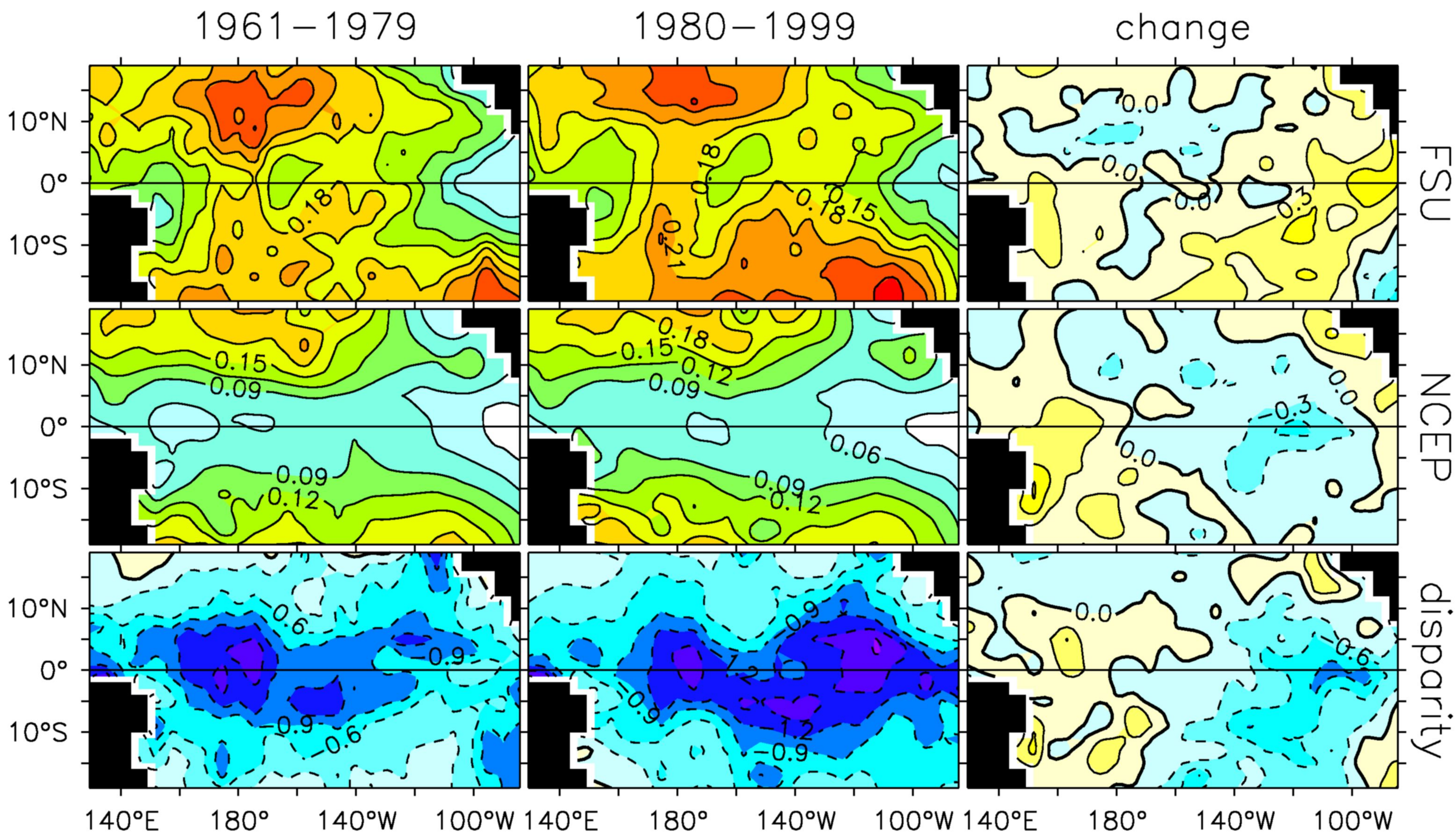
FSU1



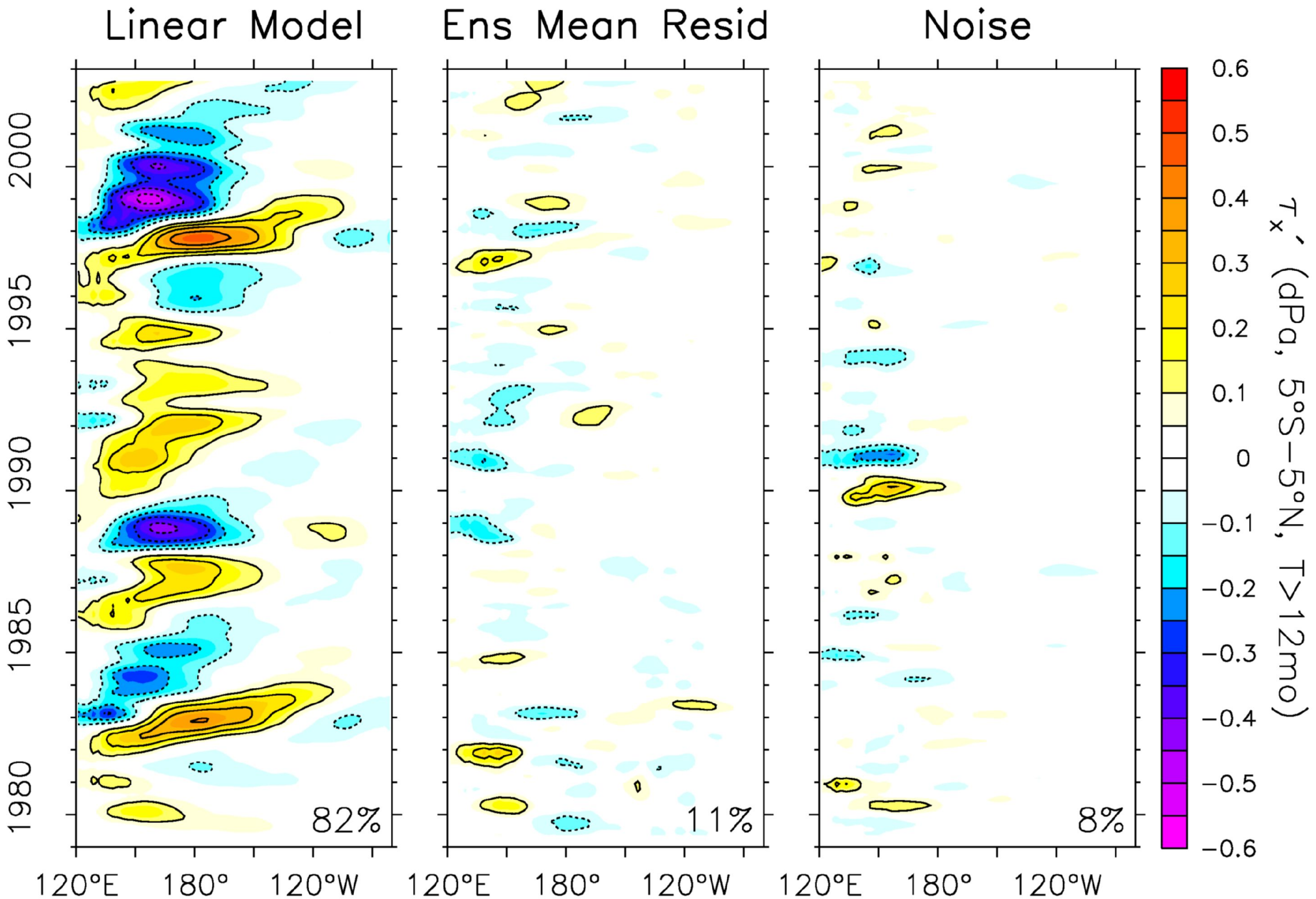
NCEP1



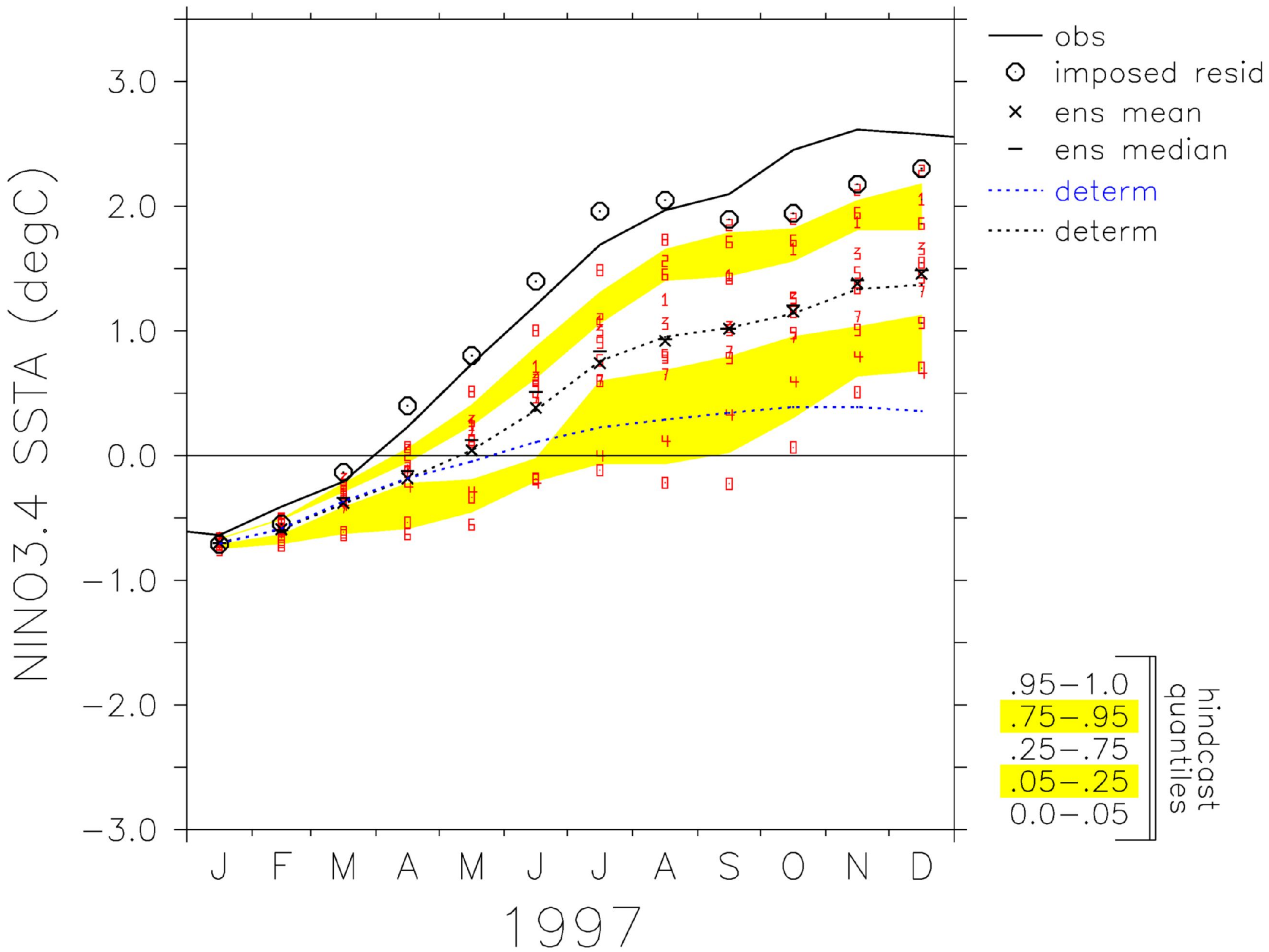
Sub-annual zonal stress anomalies



AGCM wind stress decomposition

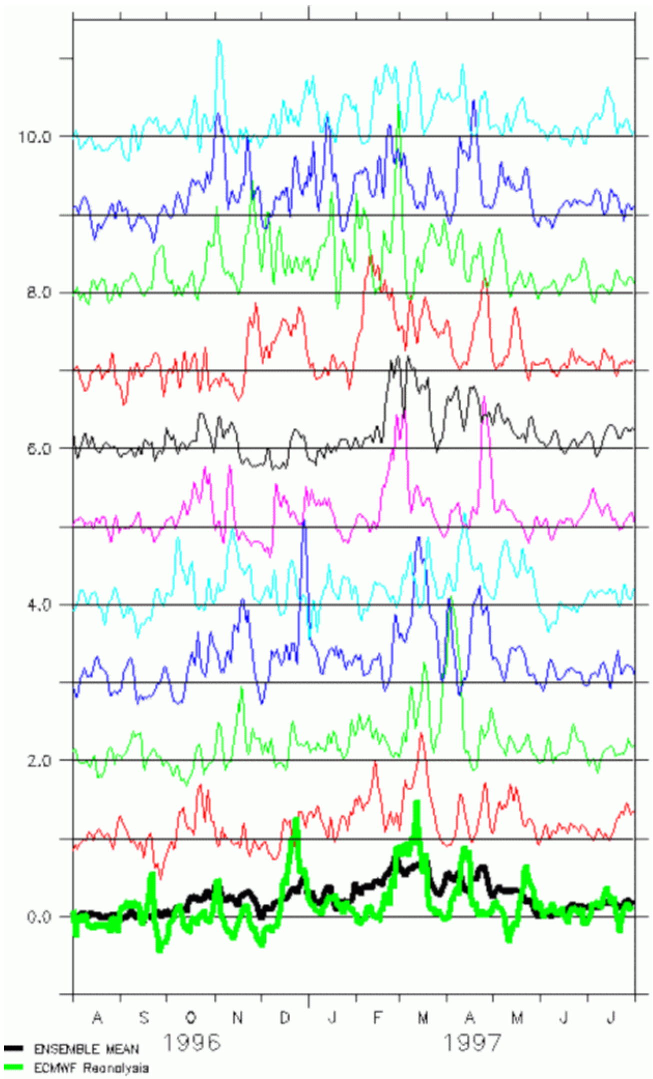


Impact of wind noise & nonlinearity on ENSO forecasts

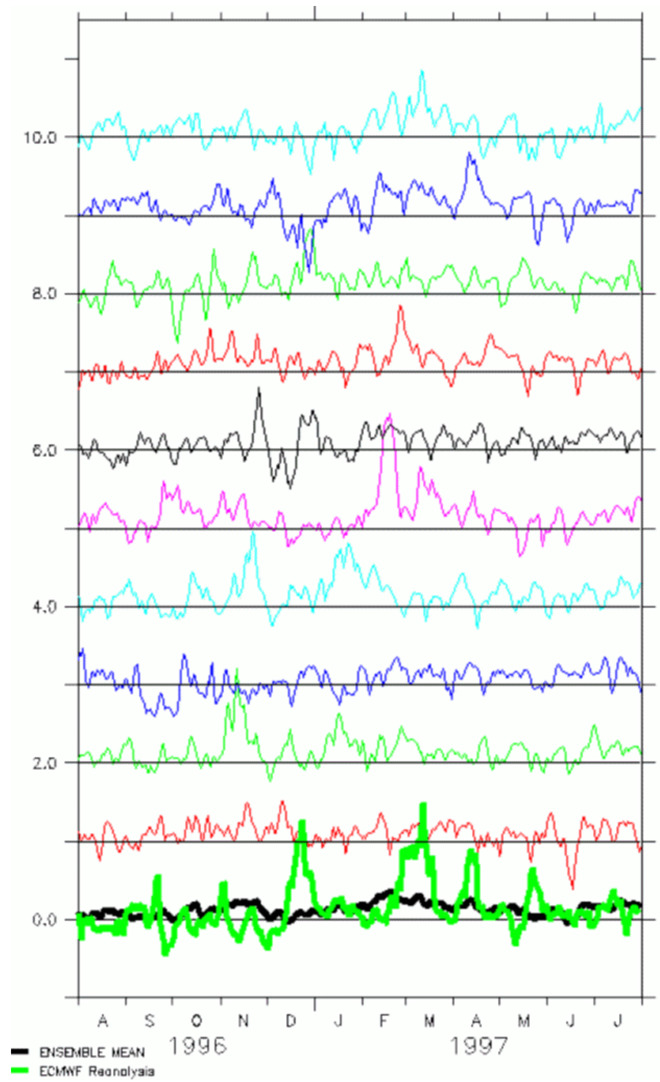


Daily western Pacific zonal stresses, from 10 AMIP runs

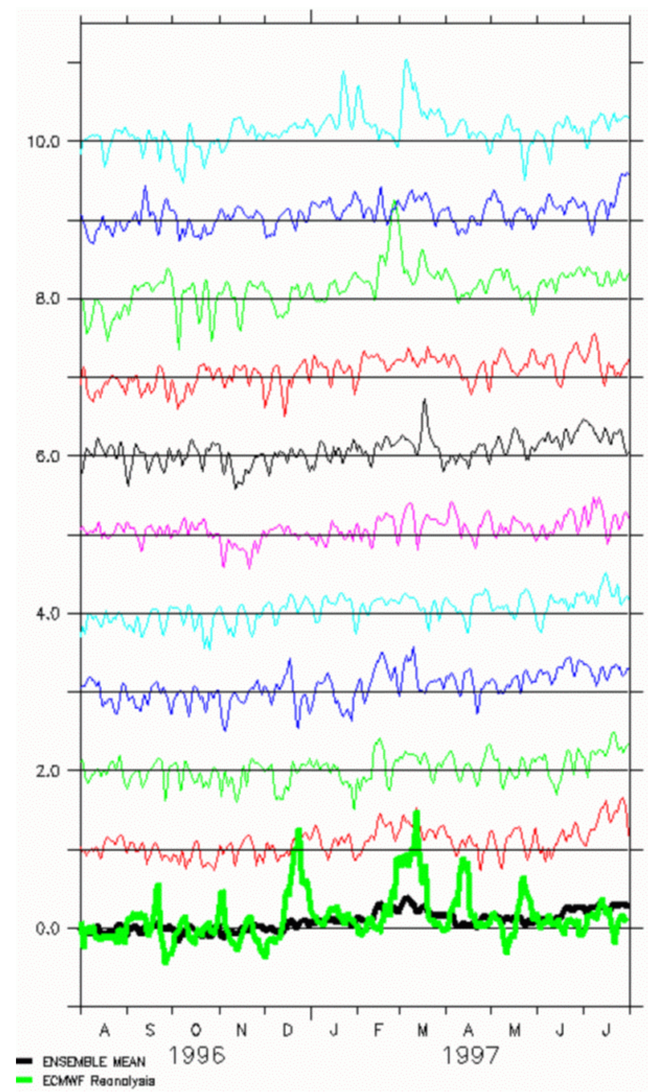
Obs SST forcing



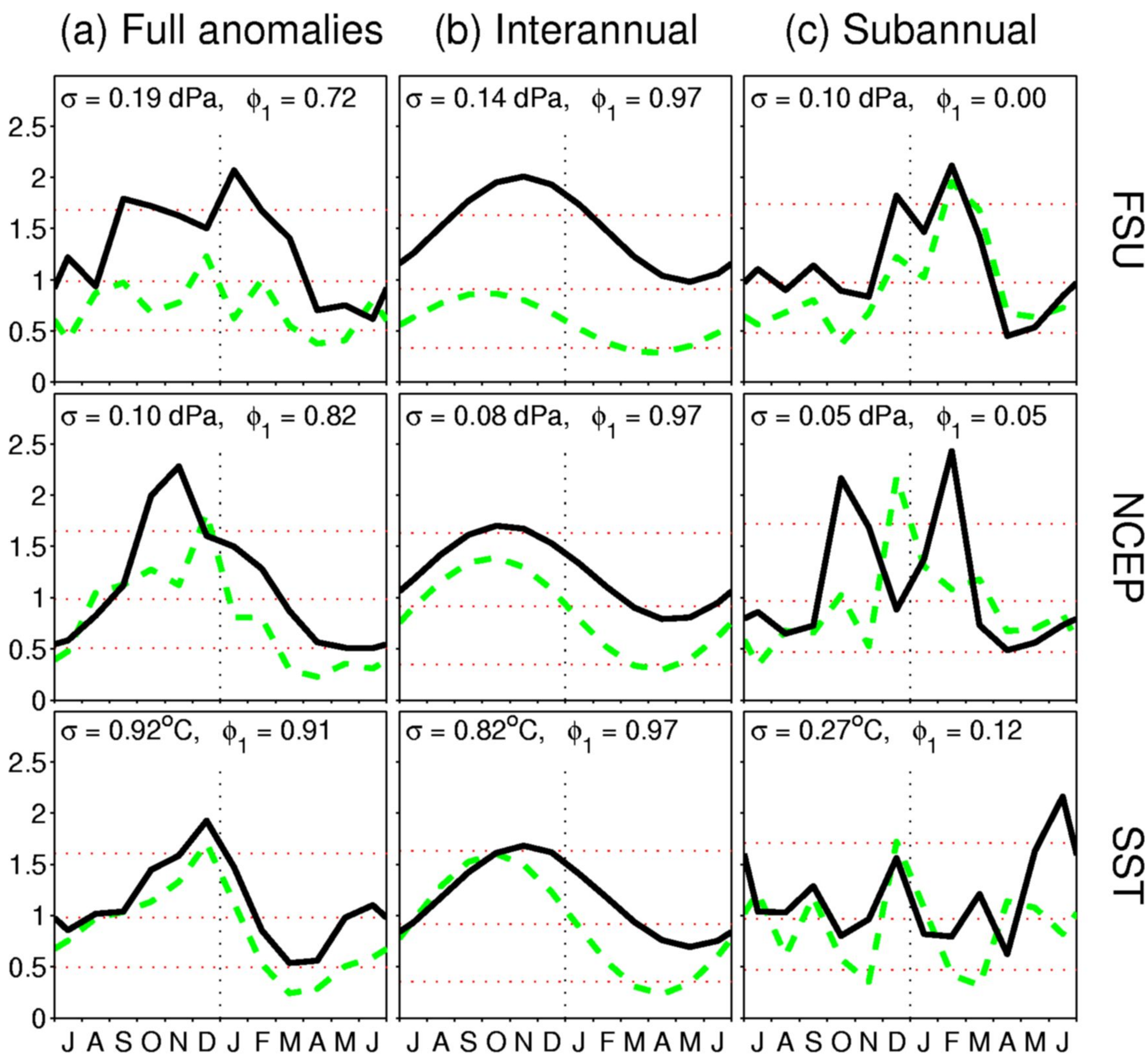
Warm East Indian



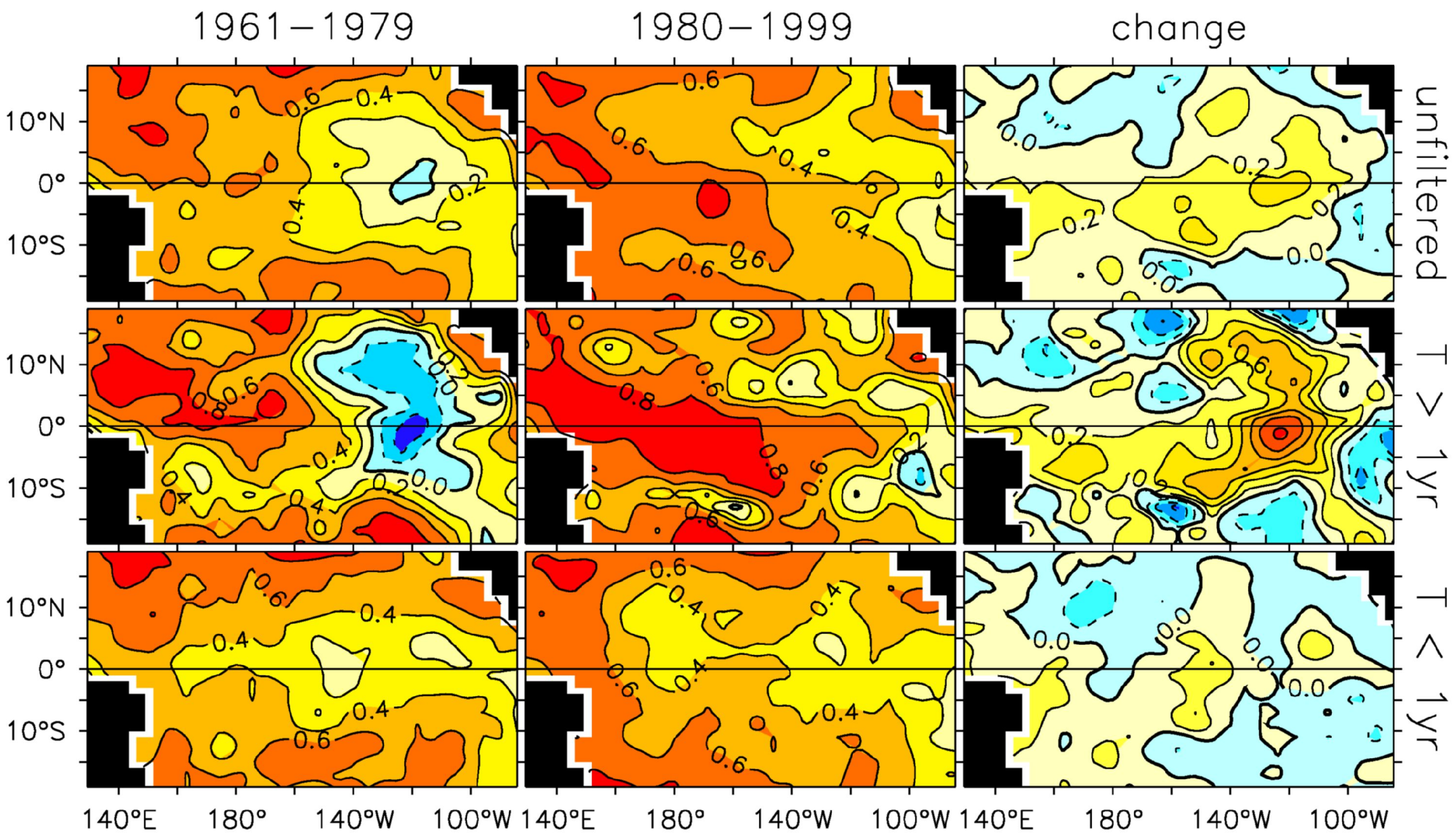
Cool West Pacific



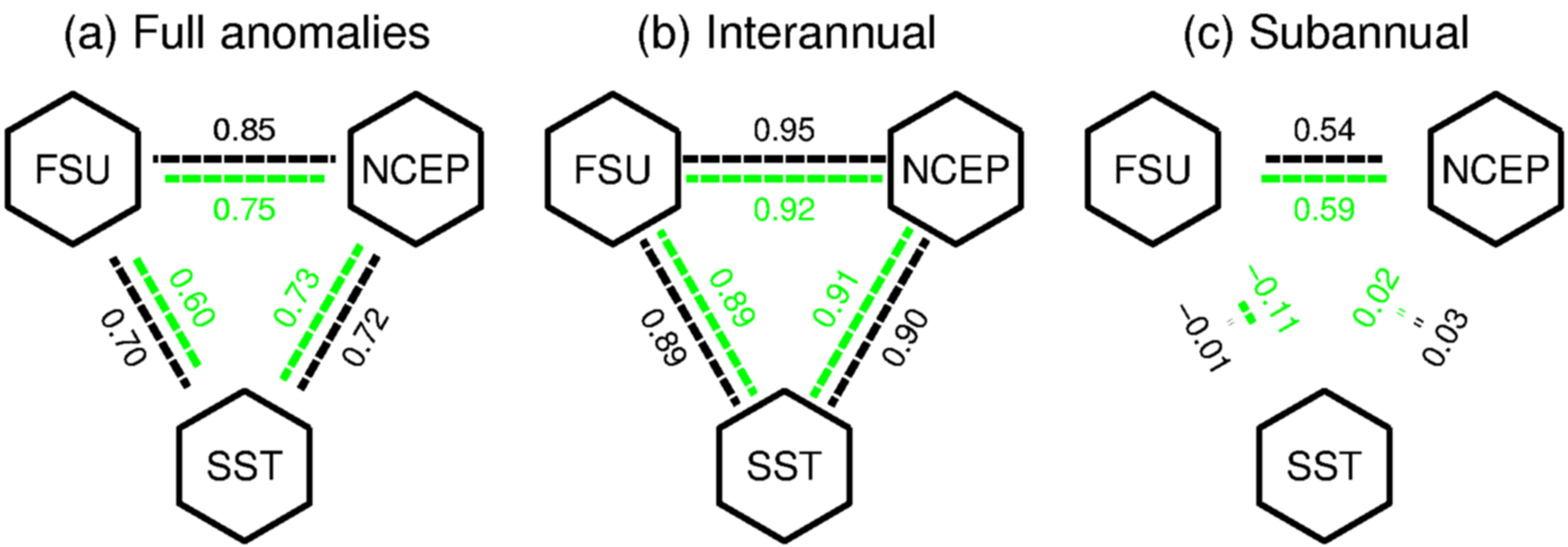
Annual cycle of variance



Correlation of FSU1 and NCEP1 zonal stress anomalies



Anomaly correlation of NINO4 zonal stress and NINO3 SST



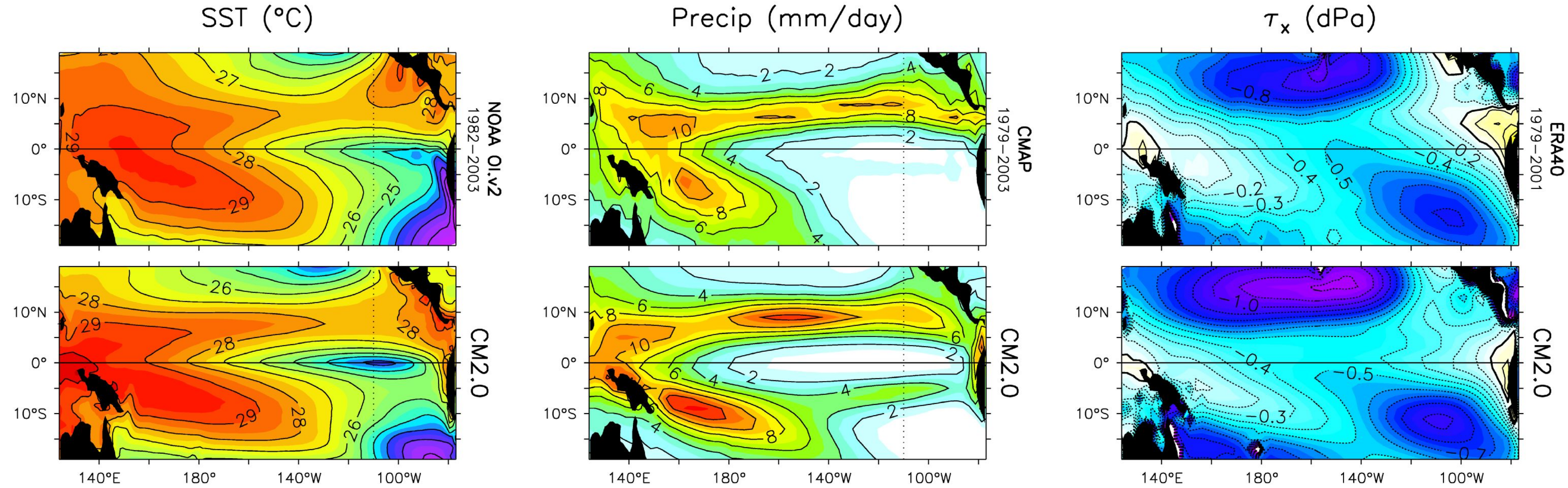
Conclusions

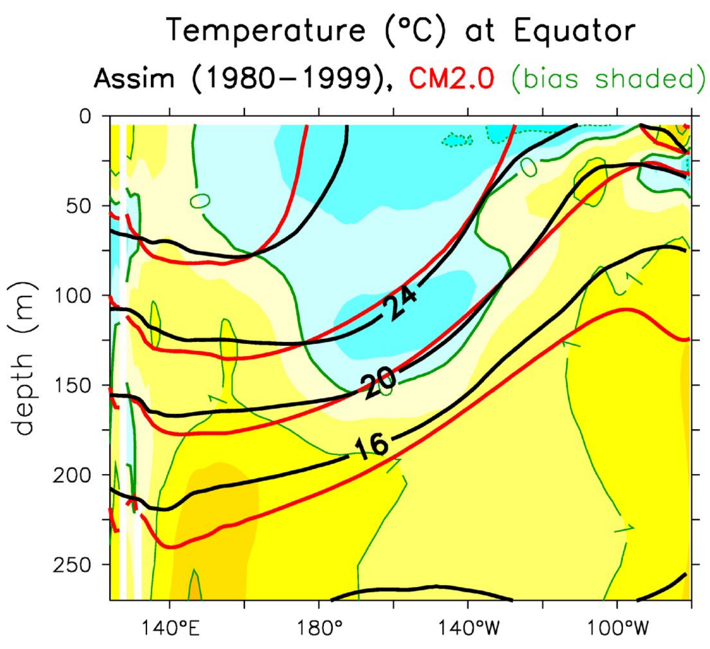
- **Wind stress is critical to ENSO**
  - Mean, anomalies, & noise
- **“True” stresses are hard to estimate**
  - Nonlinearity & sparse historical obs
- **Popular analyses disagree substantially**
  - Mean, trend, ENSO patterns, spectra, seasonality
- **Things are gradually improving**
  - Satellites, bulk formulae, reanalyses, merged products

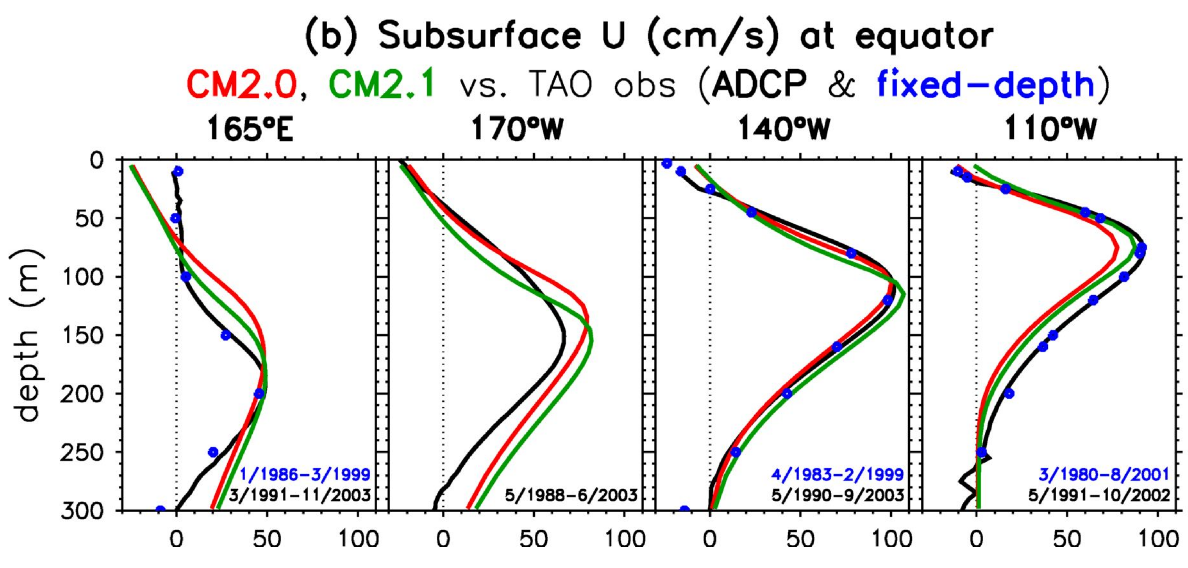
References

- **Wittenberg et al. (2005, submitted to JC)**
  - **www.gfdl.noaa.gov/~atw/2005/cm2_tropac.pdf**
- **Zhang et al. (2005, submitted to MWR)**
  - **www.gfdl.noaa.gov/~atw/2005/ptwsupdt_cov.pdf**
- **Wittenberg (2004, J. Climate 17, 2526-2540)**
  - **www.gfdl.noaa.gov/~atw/2004/stress.pdf**
- **Wittenberg (2002, Ph.D. thesis)**
  - **www.gfdl.noaa.gov/~atw/research/thesis**

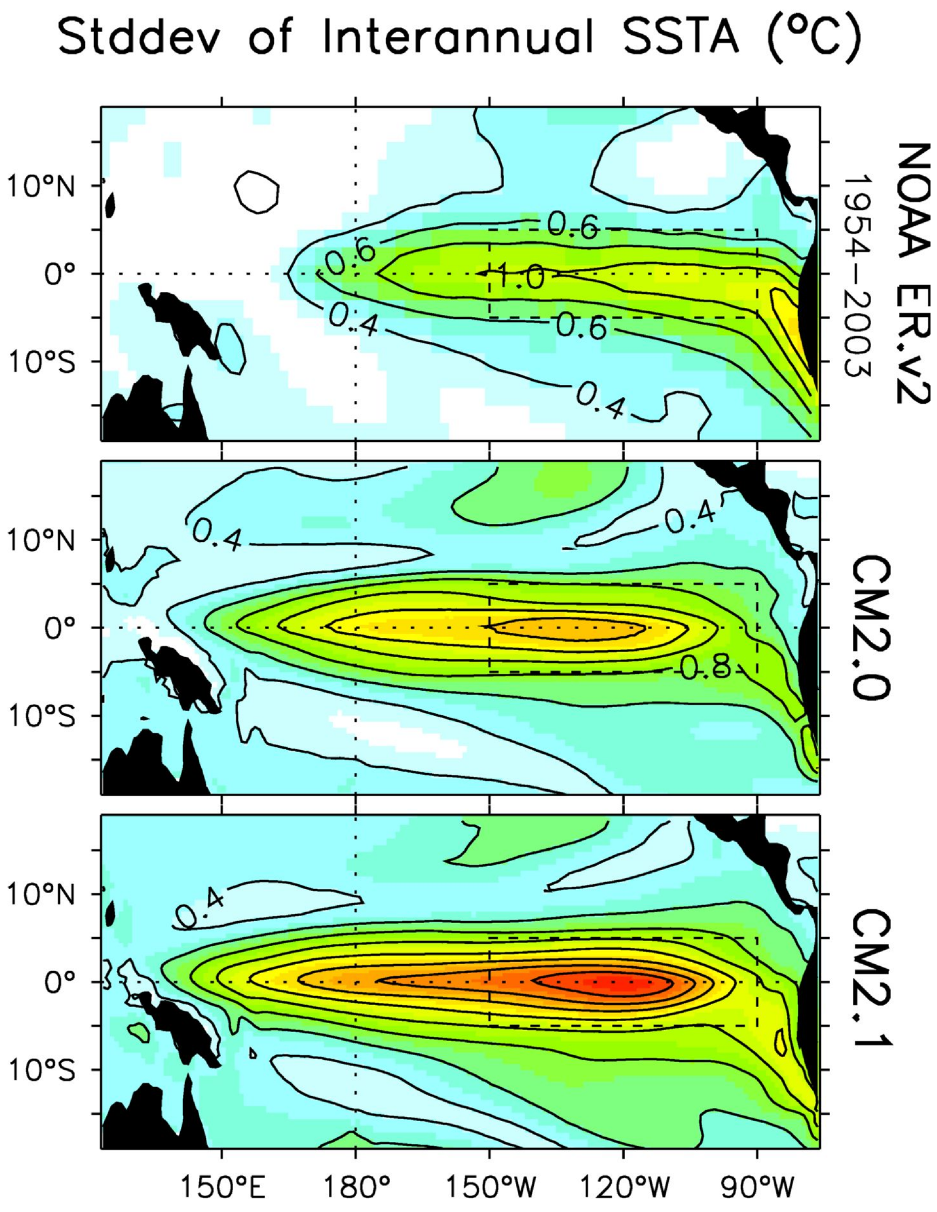
Simulated annual-mean climate

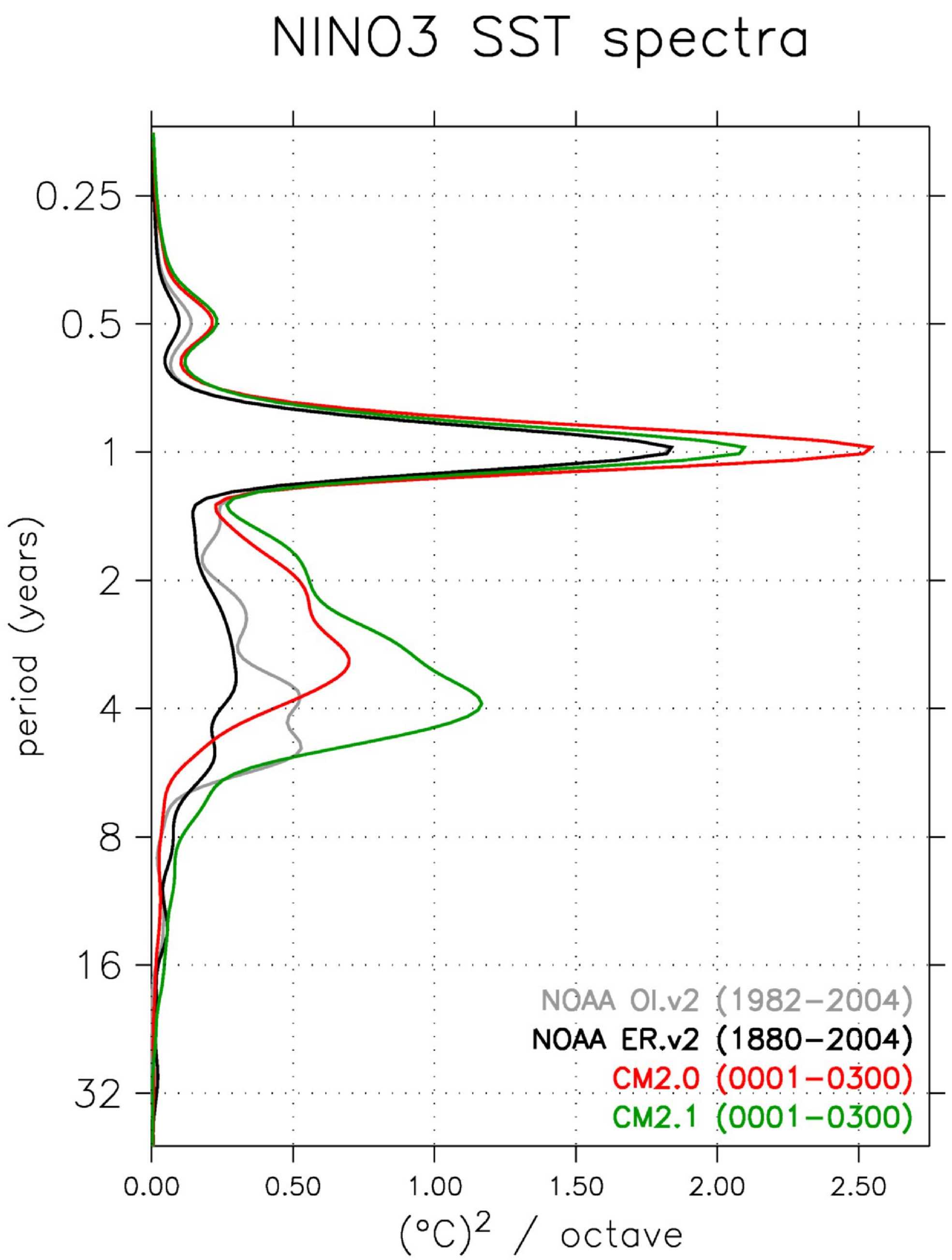




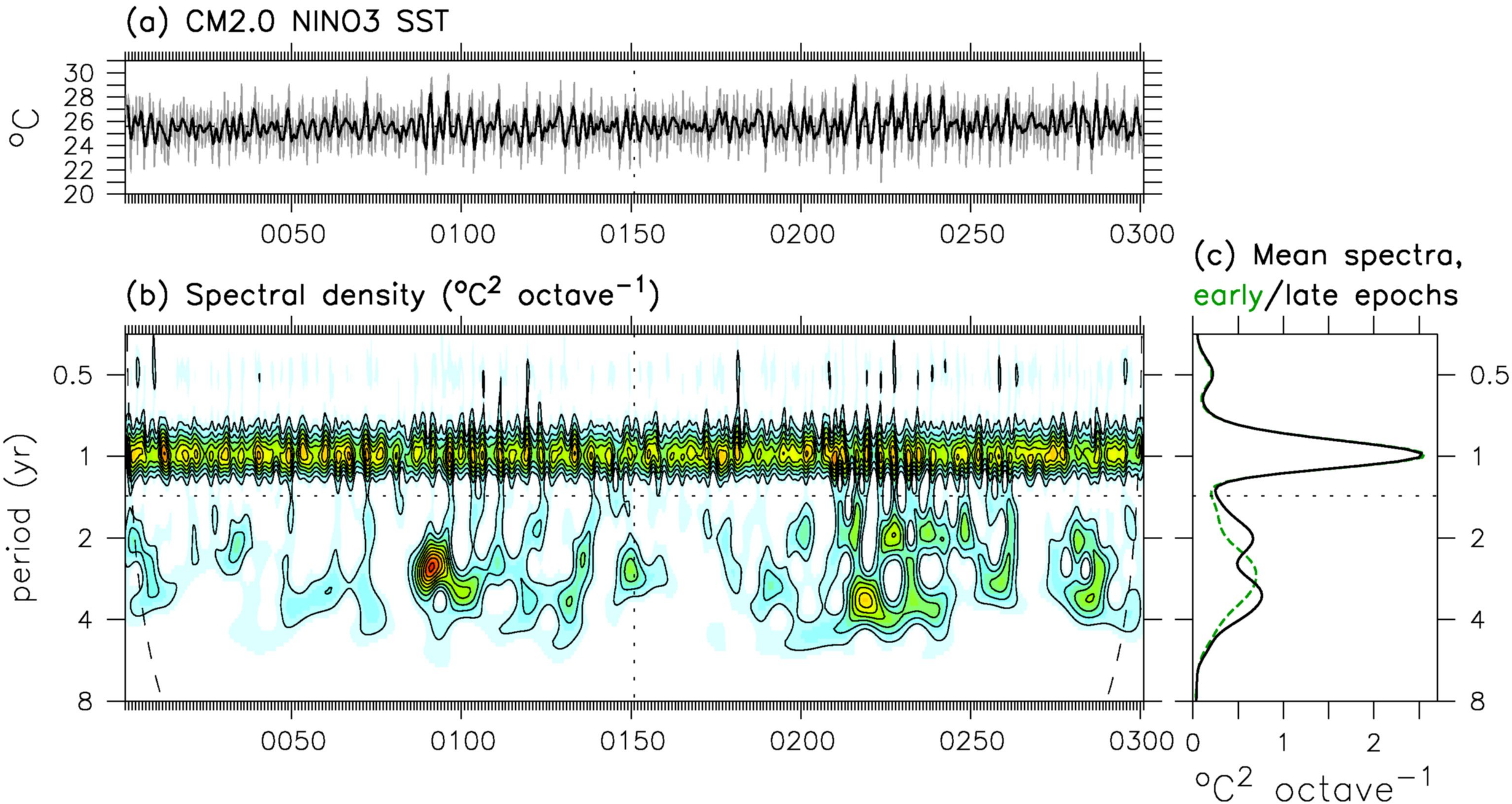


Simulated ENSO

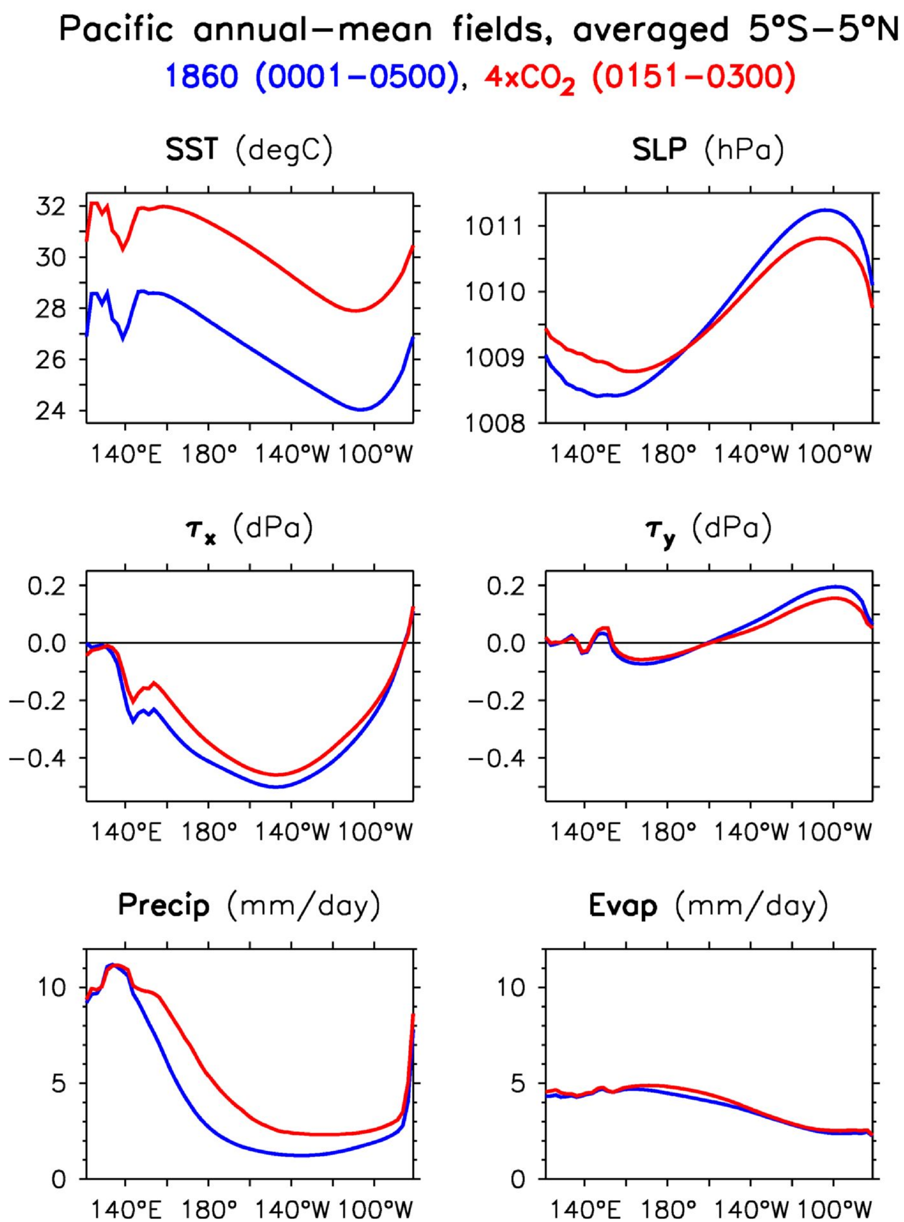


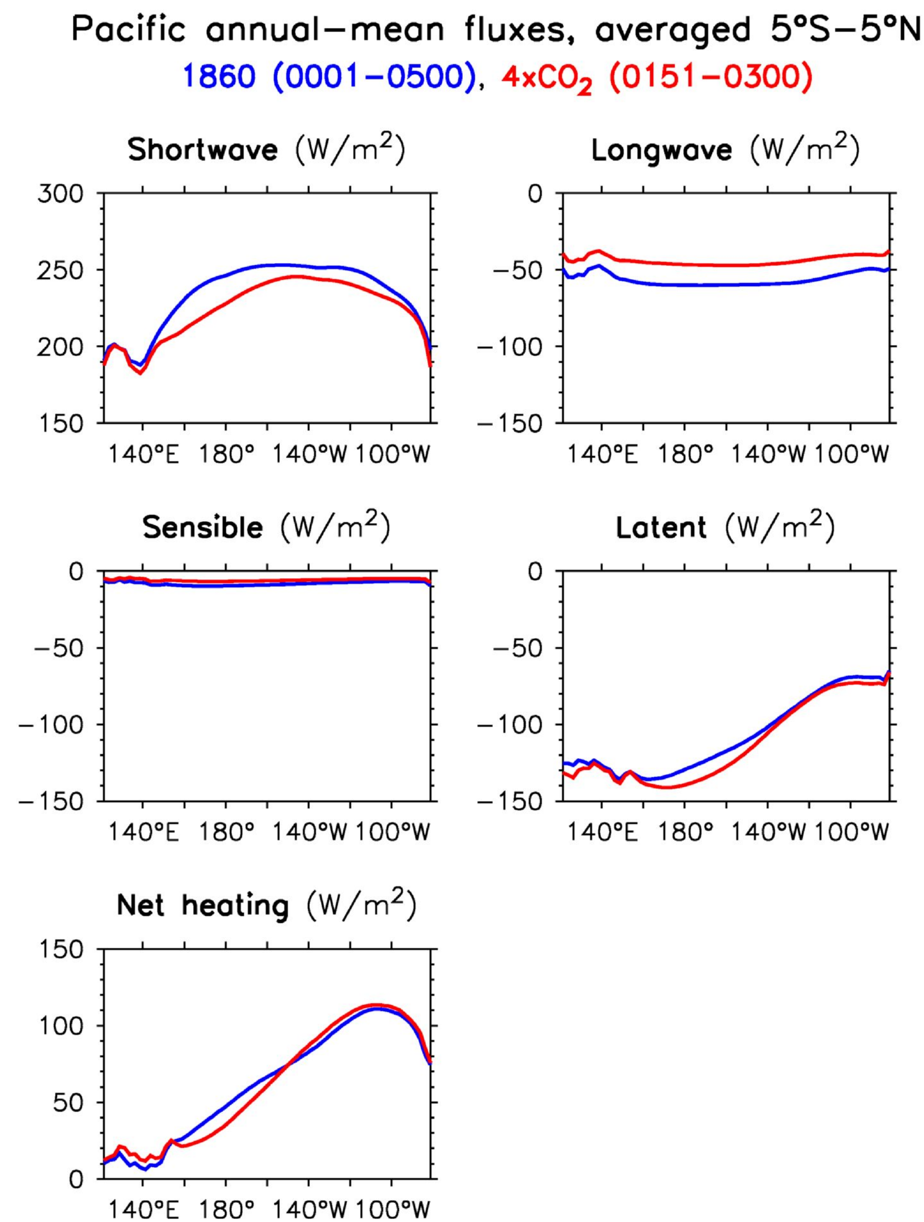


Modulation of ENSO



CM2.0 response to increasing CO_2





Greenhouse response