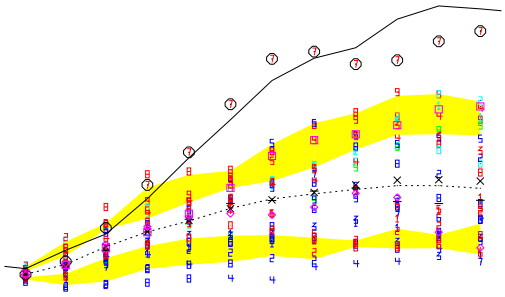
Reassessing the Role of Stochastic Forcing in ENSO Events



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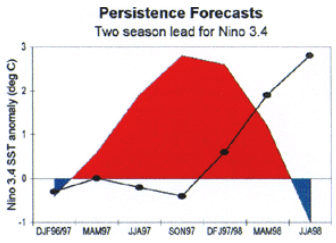
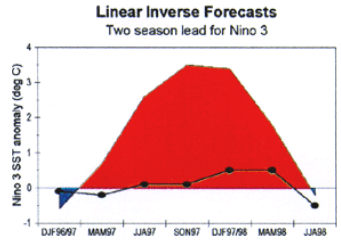
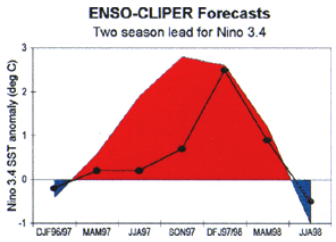
Forecasts of the 1997/98 El Niño

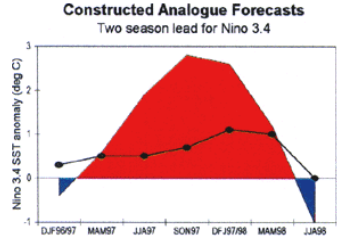
(Landsea & Knaff 2000)

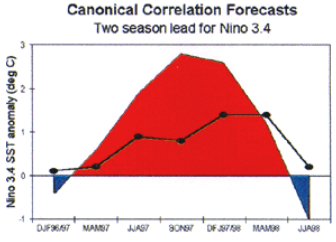
Statistical Models

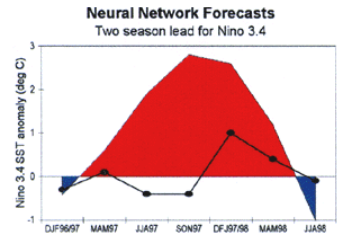


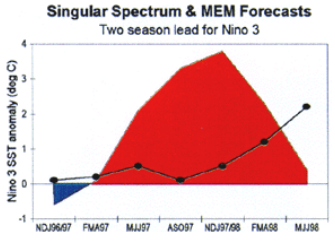


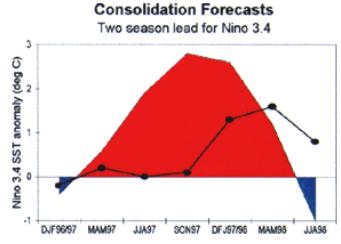




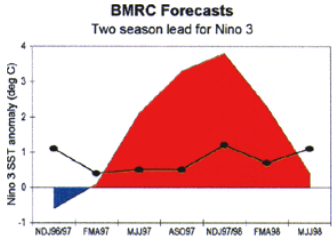


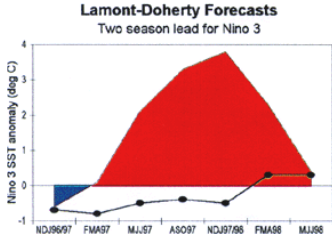


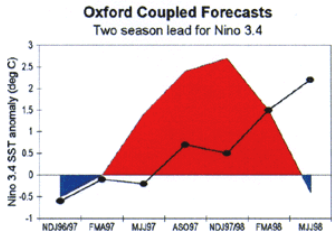




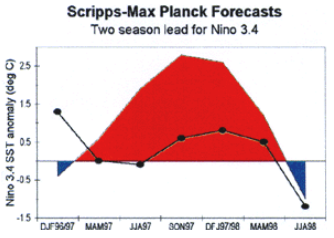
ICMs



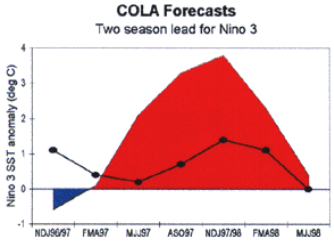


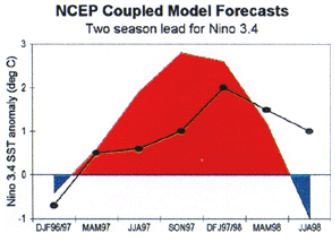


HGCMs



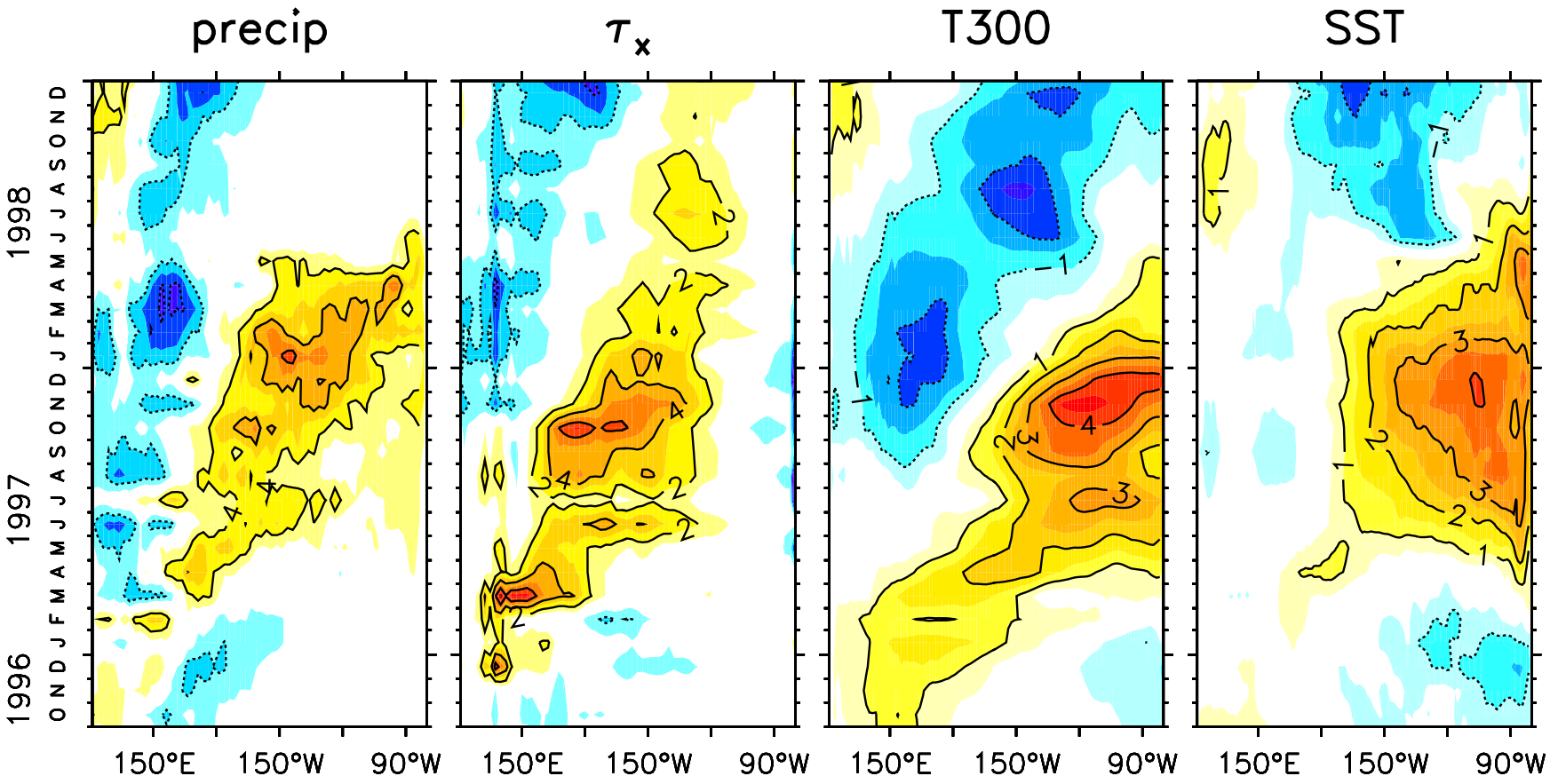
CGCMs





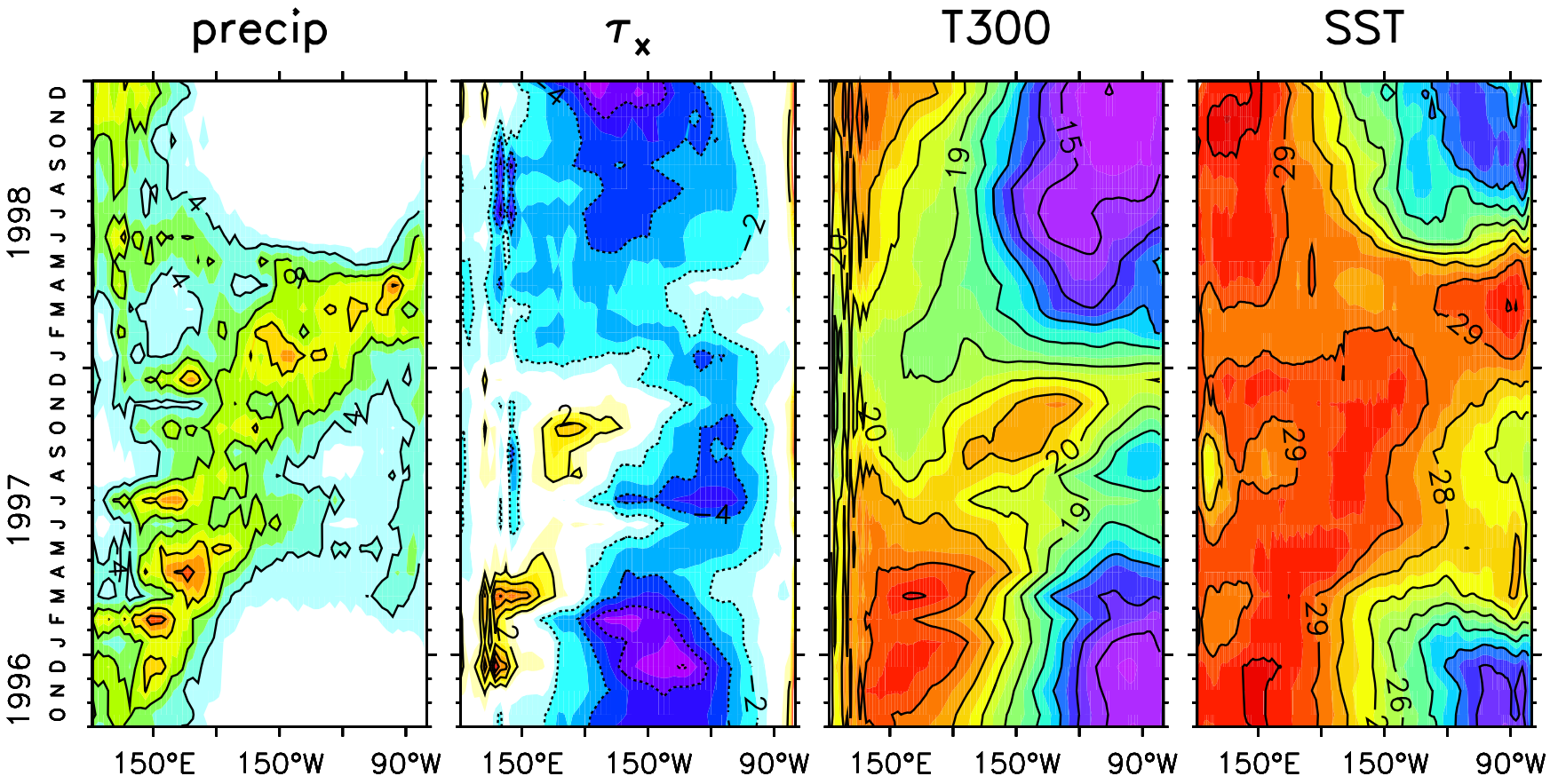
1997/98 El Niño

Equatorial anomalies



1997/98 El Niño

Equatorial totals



Hypothesis:

Unpredictable wind stresses ruined the forecasts.

Initial test:

Partition the observed stress: $\mathbf{Y} = \mathbf{XW} + \mathbf{E}$

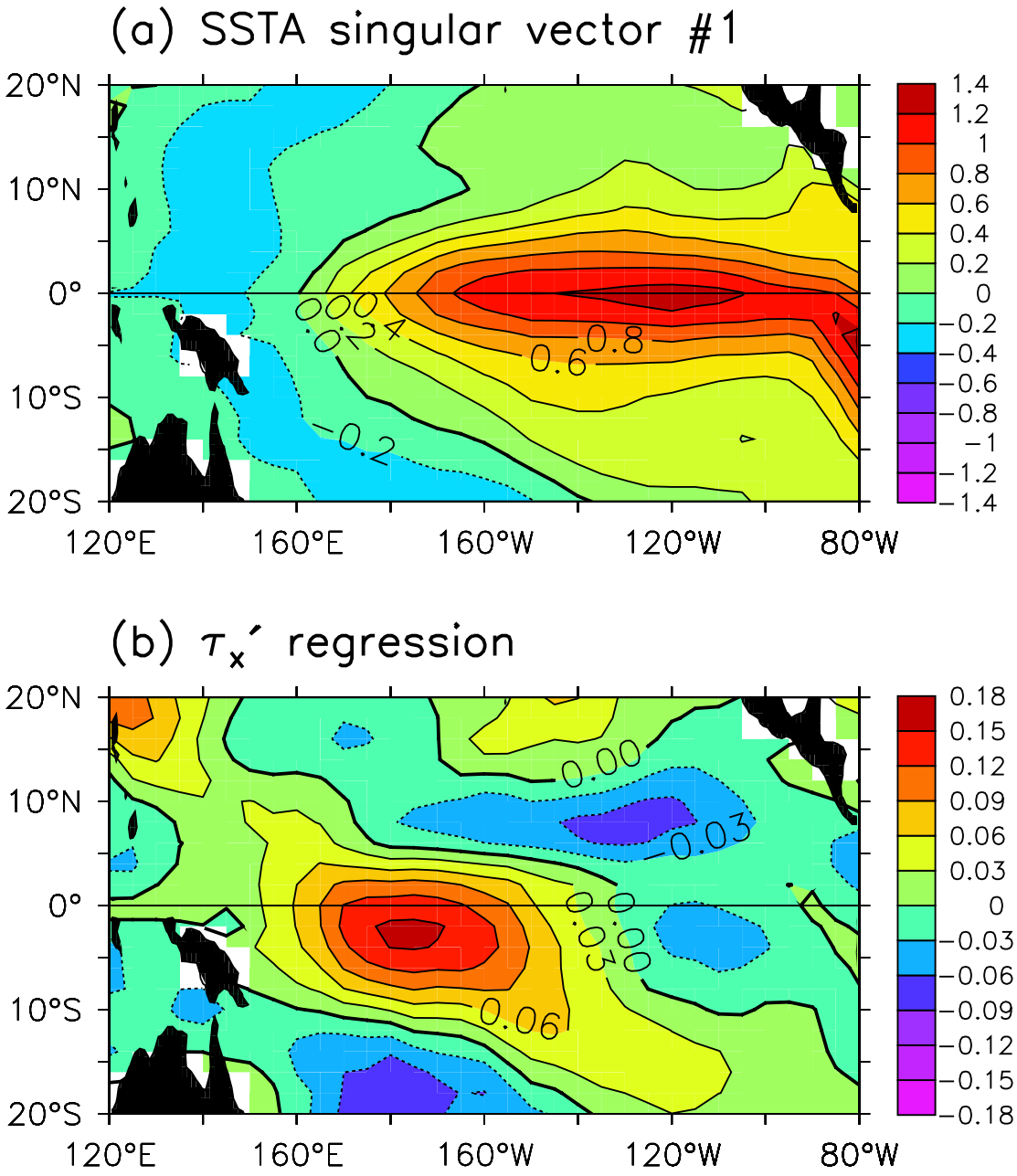
$$
\begin{aligned}
\mathbf{Y}_{n\times q} &= \text{stress anomalies} \\
\mathbf{X}_{n\times p} &= \text{SSTA predictors} \\
\mathbf{W}_{p\times q} &= \text{regression coefficients} \\
\mathbf{E}_{n\times q} &= \text{residual stress}
\end{aligned}
$$

Estimate $\widetilde{\mathbf{W}}$ and $\widetilde{\mathbf{E}}$ from observations.

Investigate how $\widetilde{\mathbf{E}}$ affects coupled forecasts.

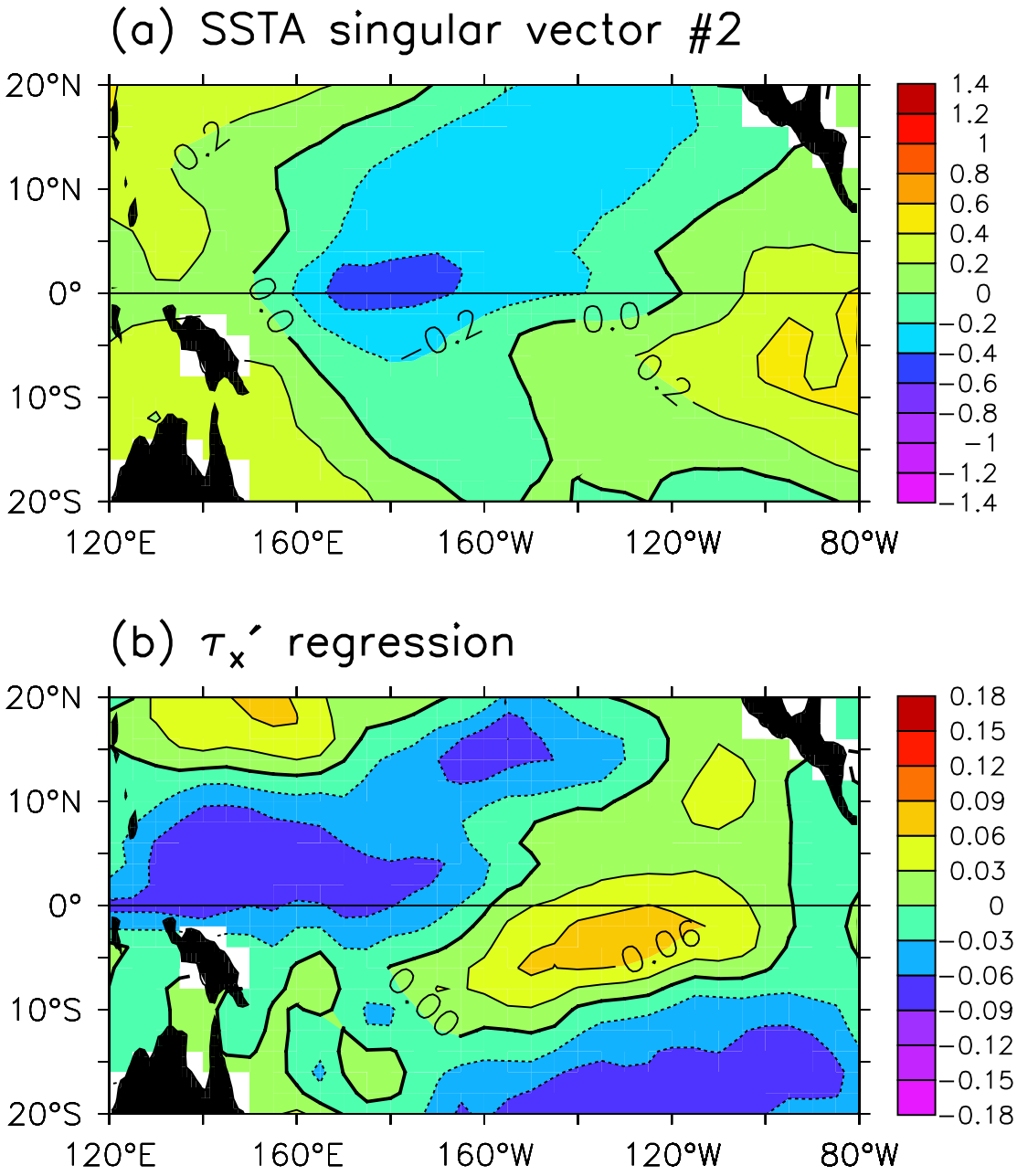
Statistical Atmosphere (Mode 1)

SST and wind stress from NCEP2 (1979–2002)

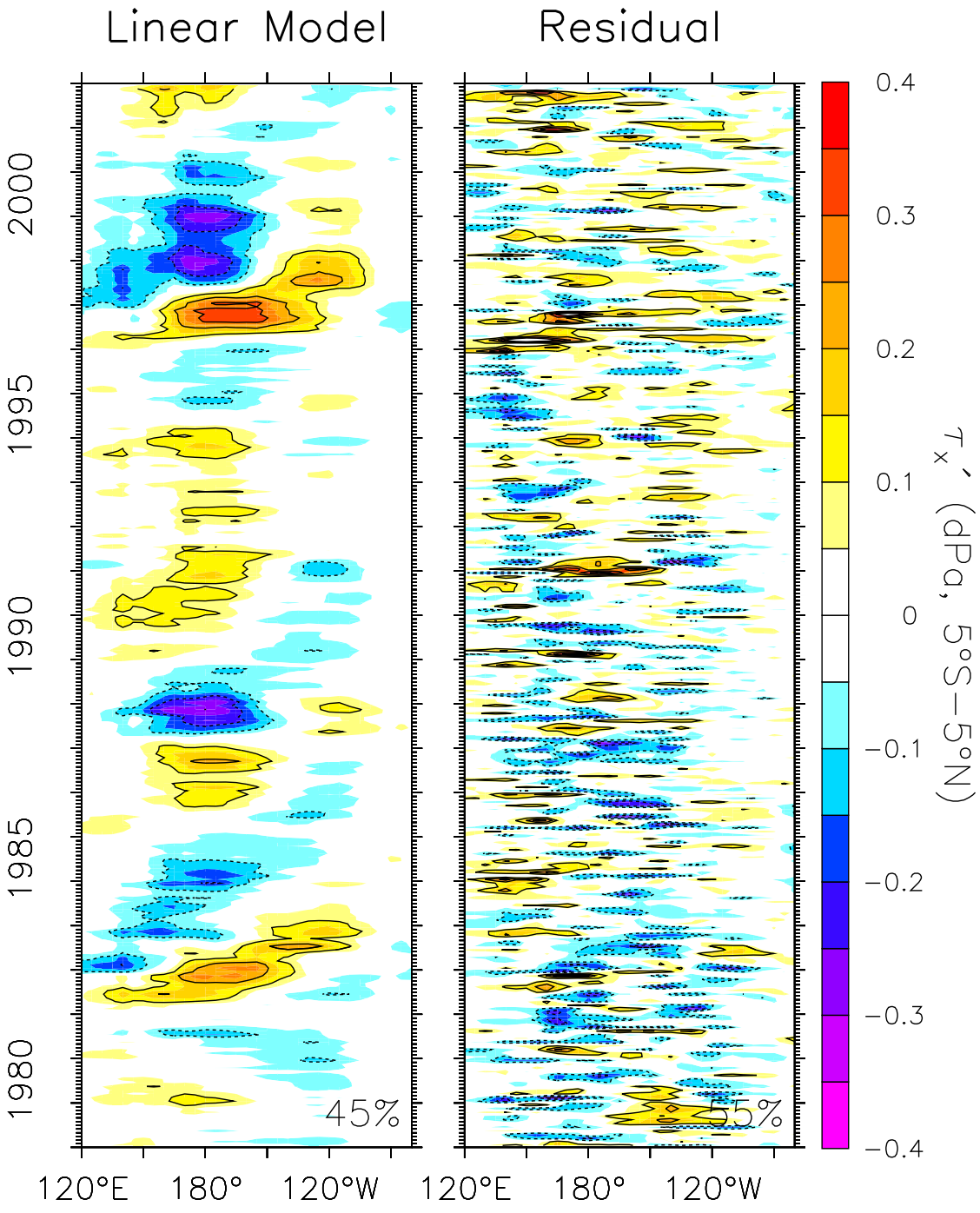


Statistical Atmosphere (Mode 2)

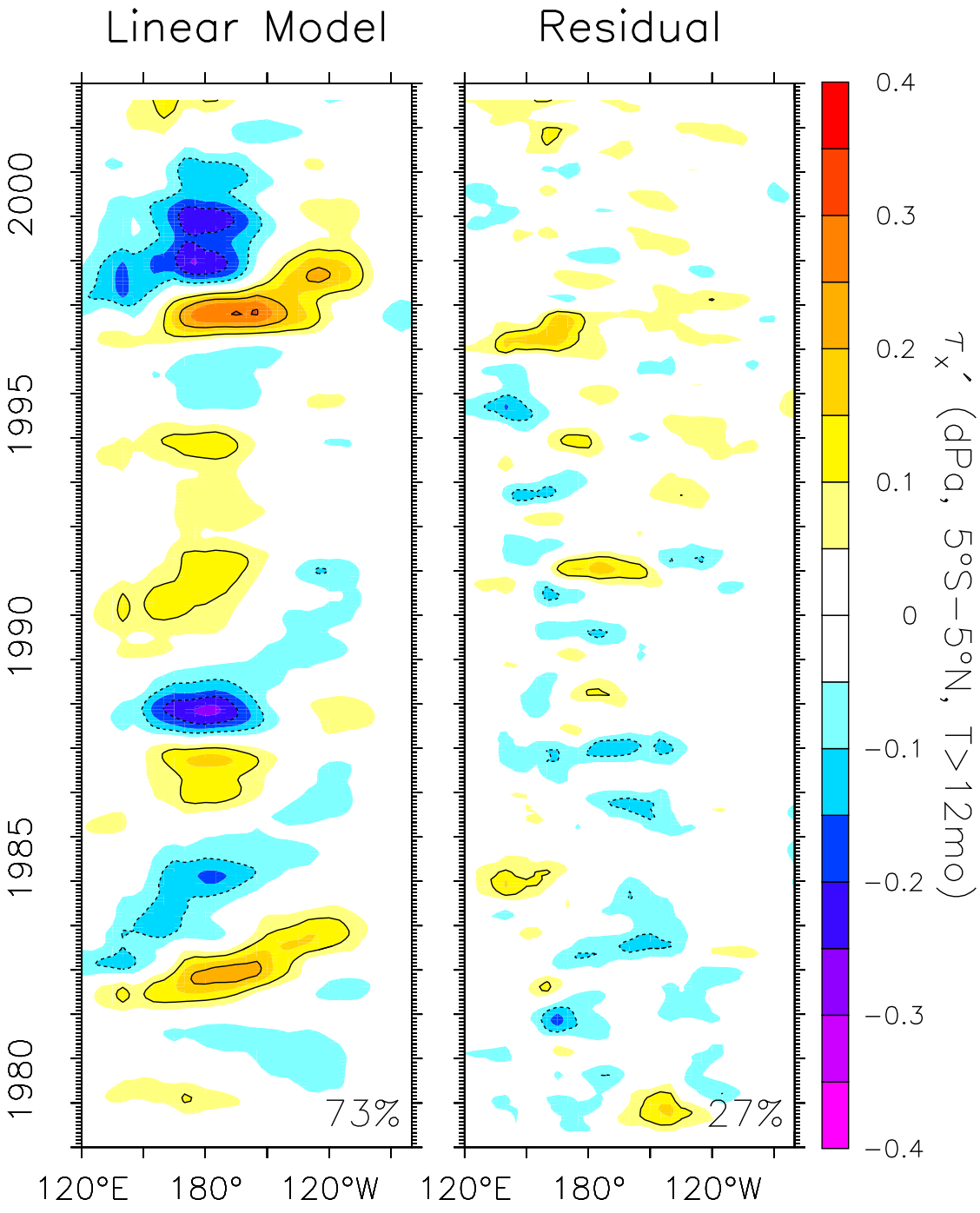
SST and wind stress from NCEP2 (1979–2002)



Wind stress decomposition: monthly NCEP2 obs



Wind stress decomposition: low-pass NCEP2 obs



Hybrid Coupled Model

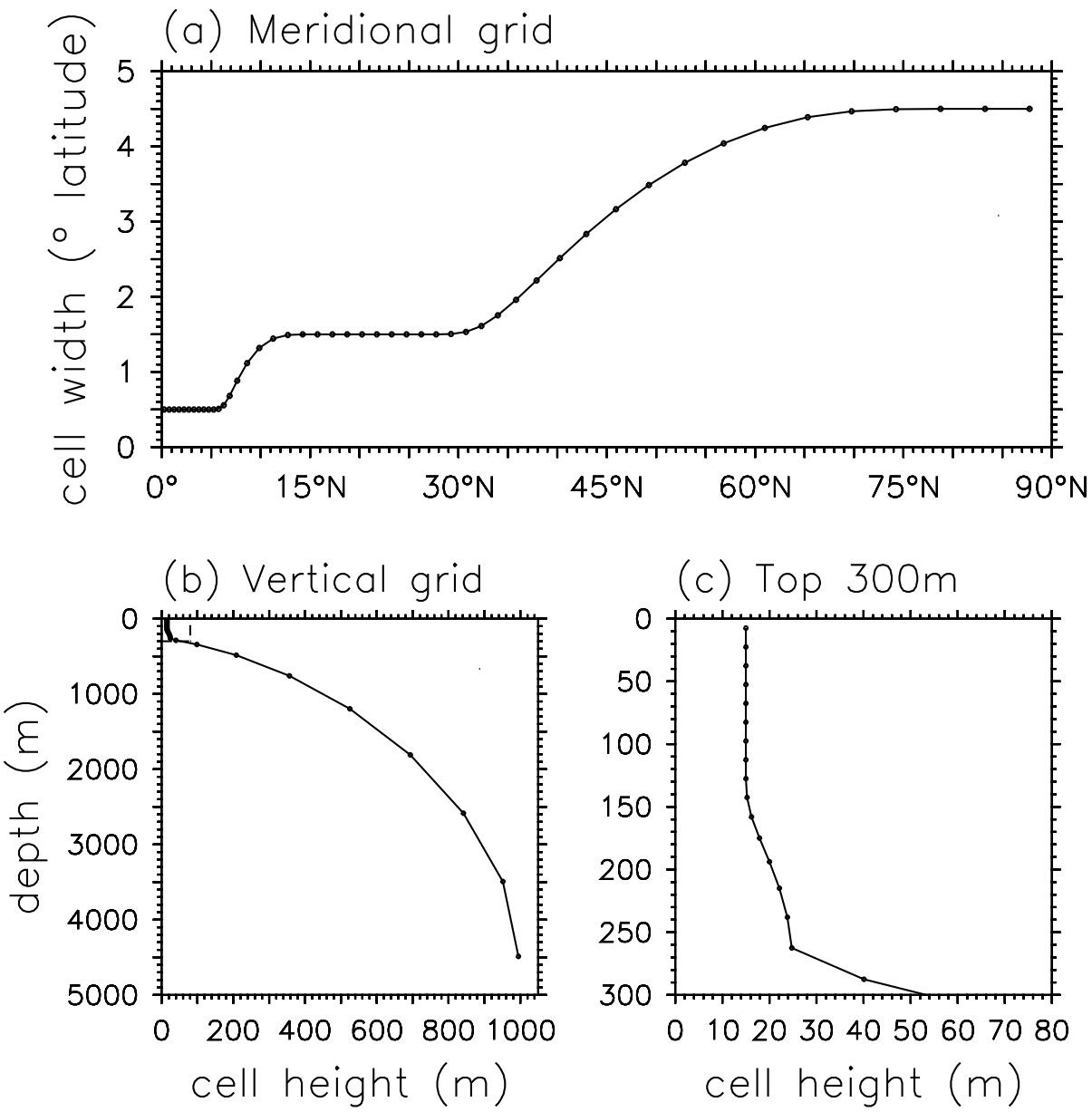
Statistical atmosphere:

- tuned to NCEP2 obs SST/stress (1979–2002)
- 120°E–70°W by 5°; 20°S–20°N by 2°

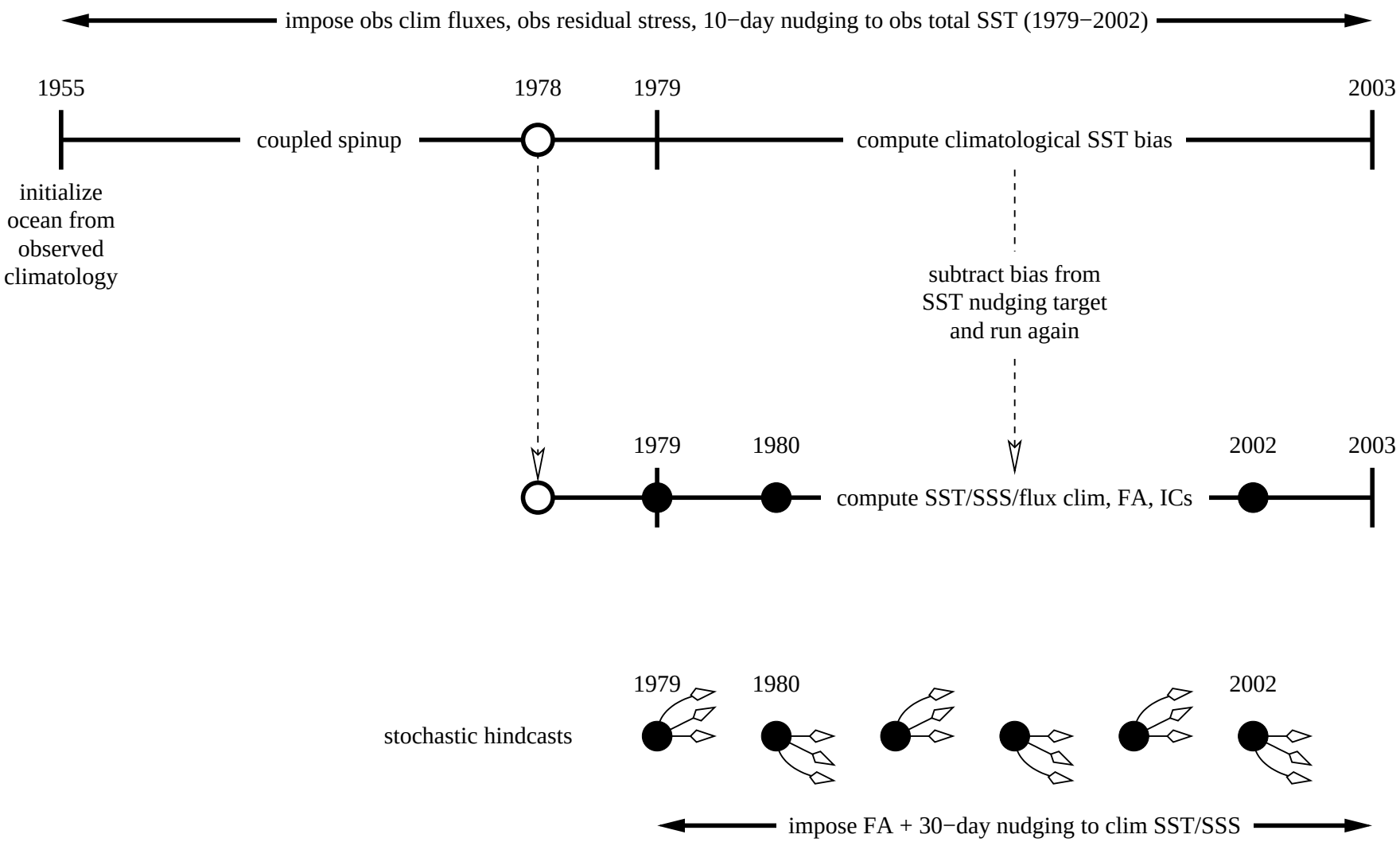
Ocean model (GFDL MOM4):

- 2°lon $\times$ 25 levels; $\triangle y$ = 0.5° $\rightarrow$ 1.5° $\rightarrow$ 4.5°
- global domain, sponge to obs poleward of 45°
- free surface, freshwater fluxes
- KPP vertical mixing
- Laplacian horizontal diffusion & viscosity

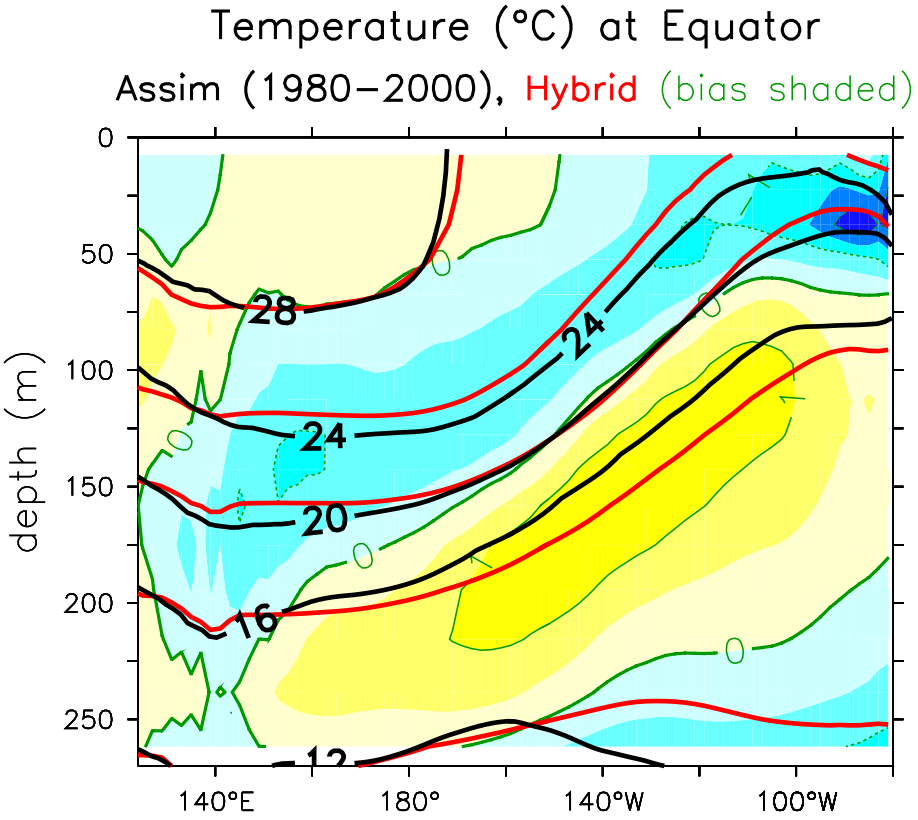
Hybrid Model Ocean Grid

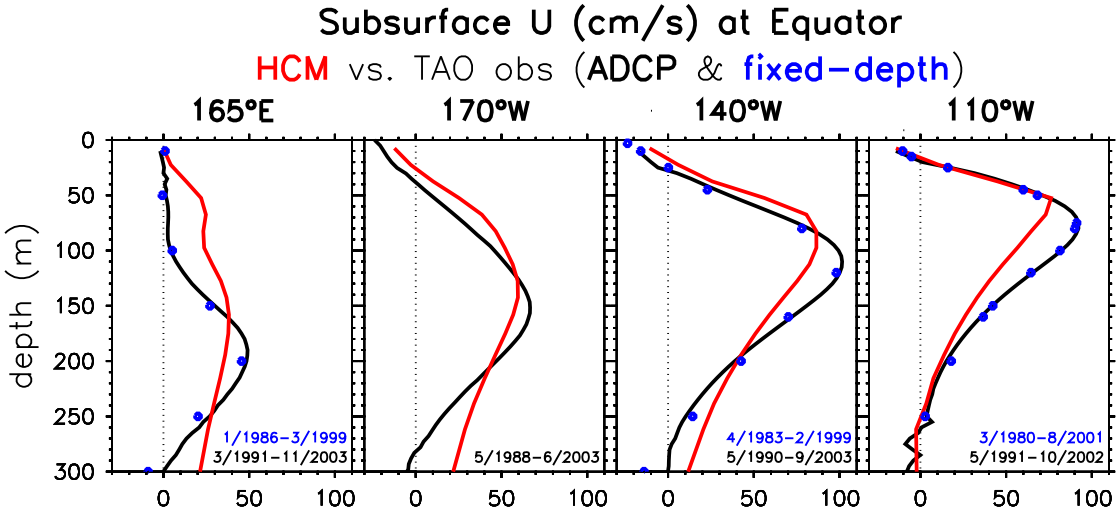


Spinup of the hybrid coupled model

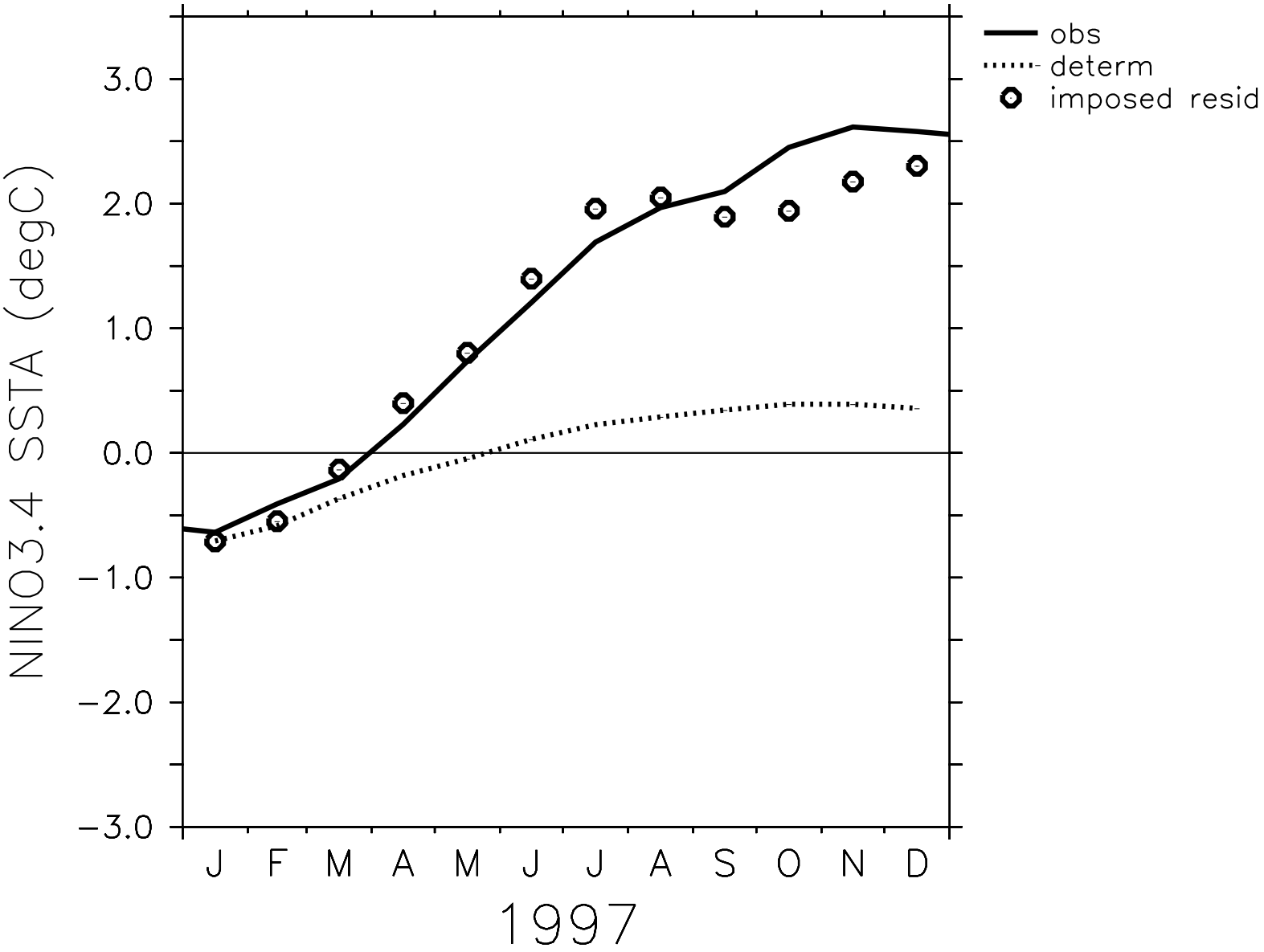


Mean state from flux-adjusted HCM

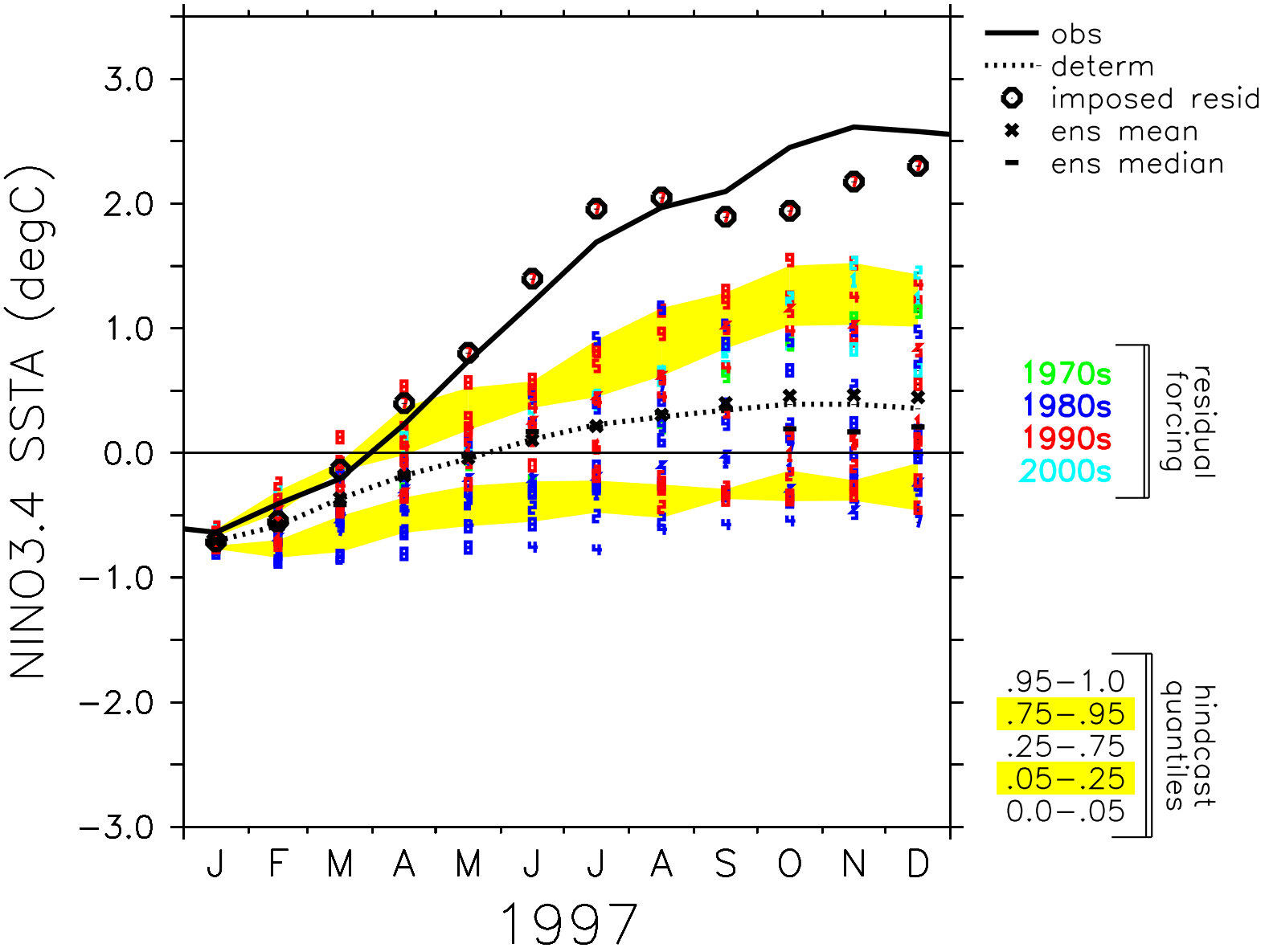




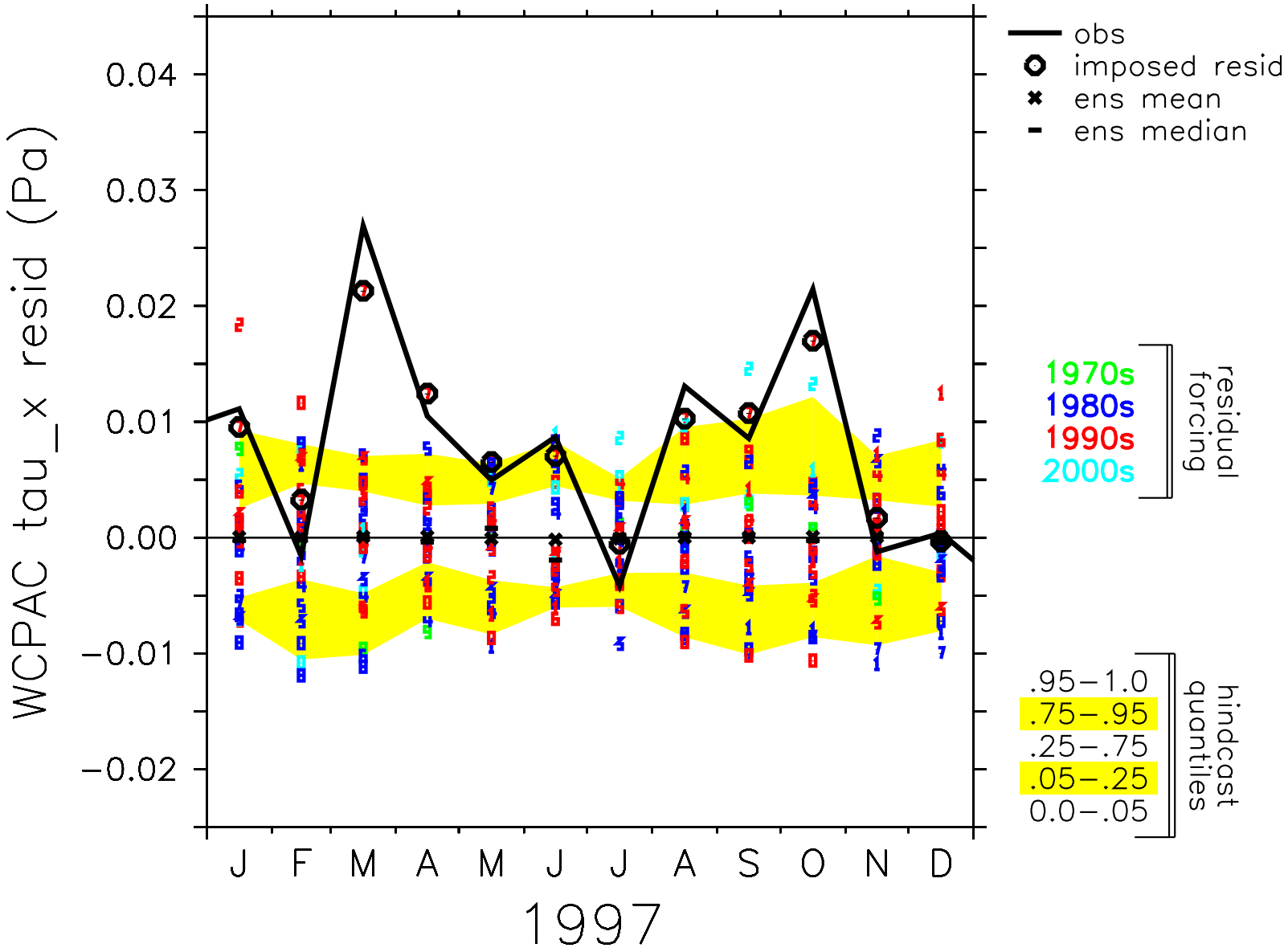
Deterministic forecasts of east Pacific SST anomalies



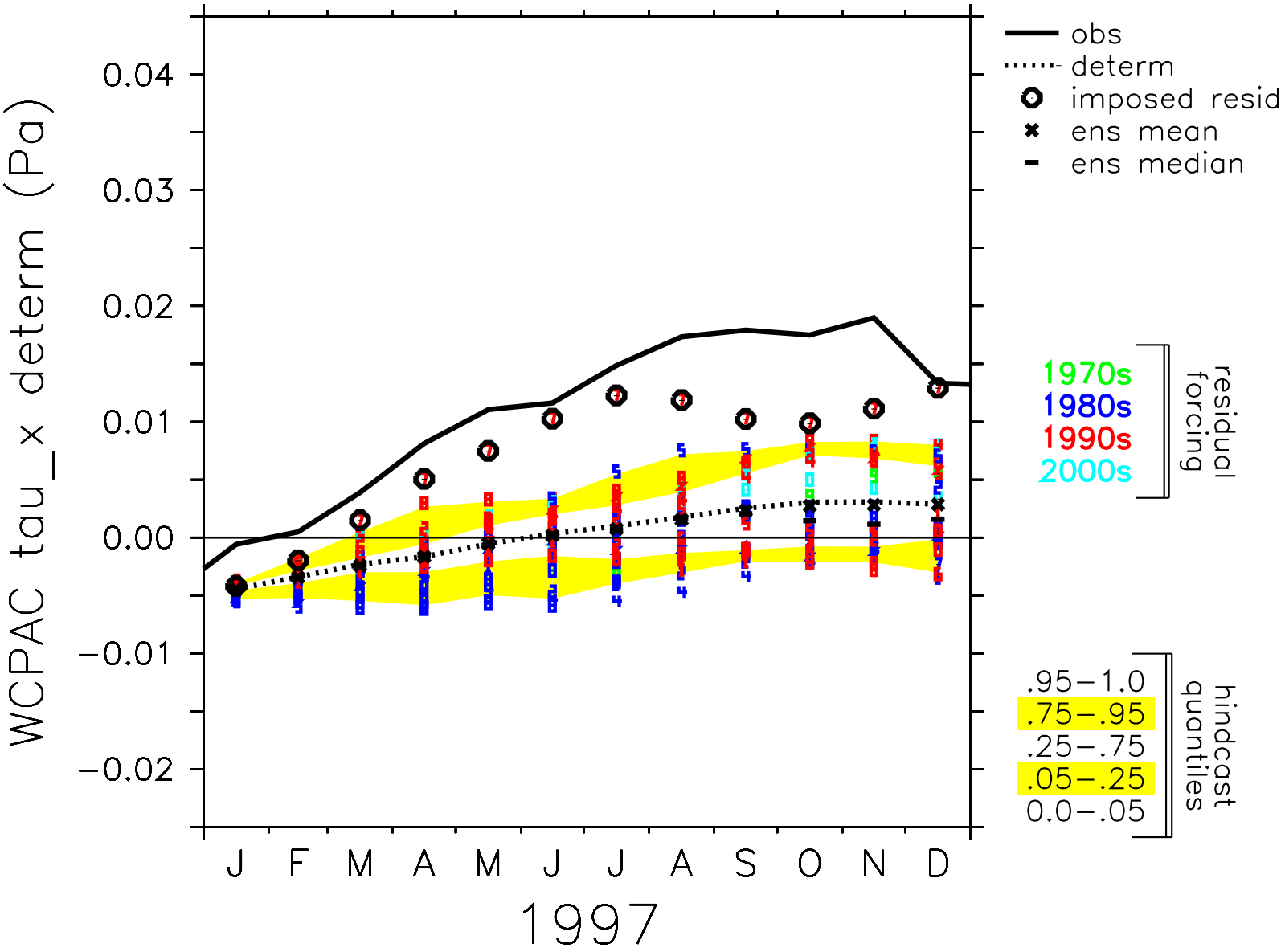
Stochastic forecasts of east Pacific SST anomalies



NCEP2 residual zonal wind stress

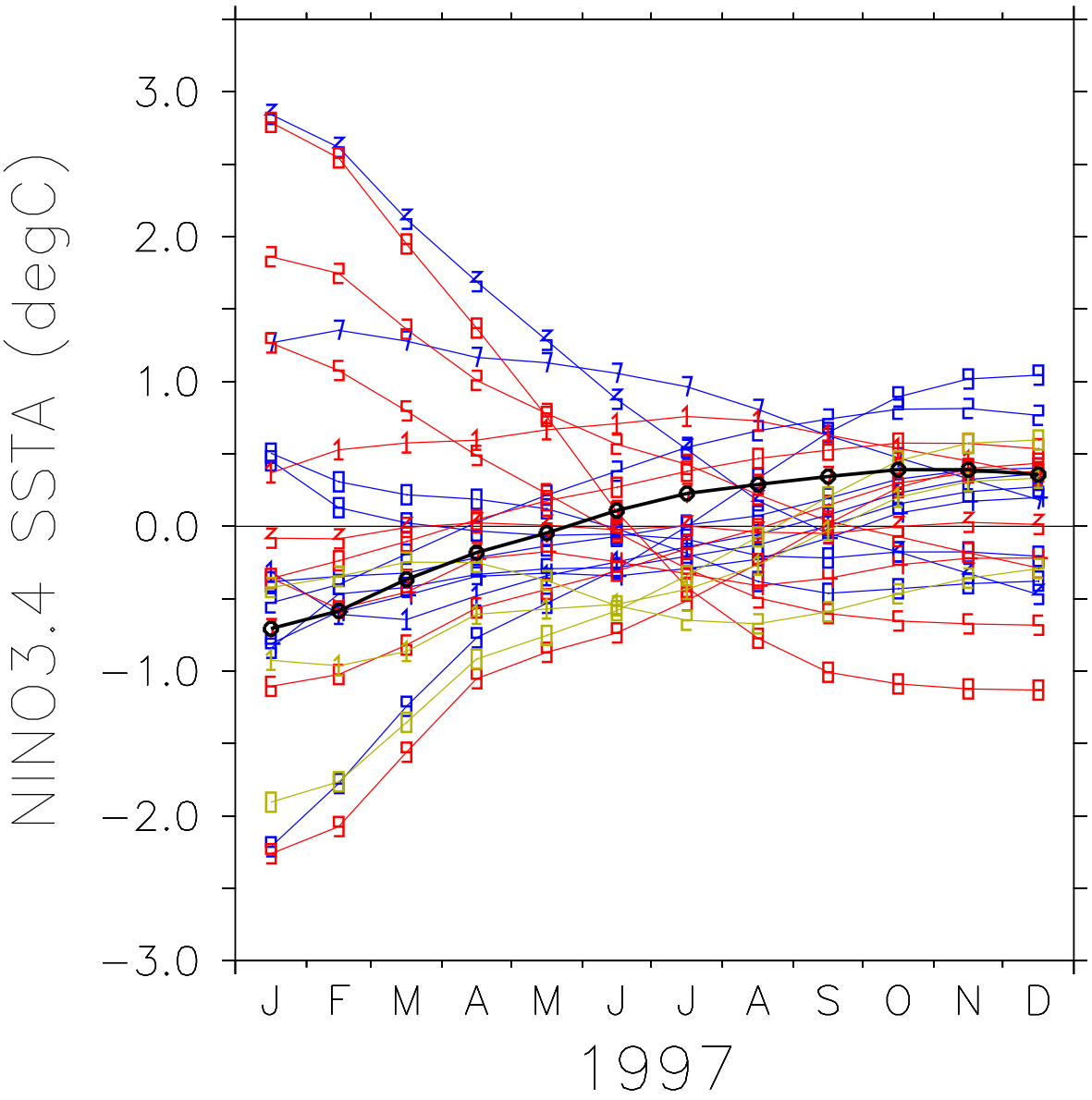


NCEP2 deterministic zonal stress anomaly



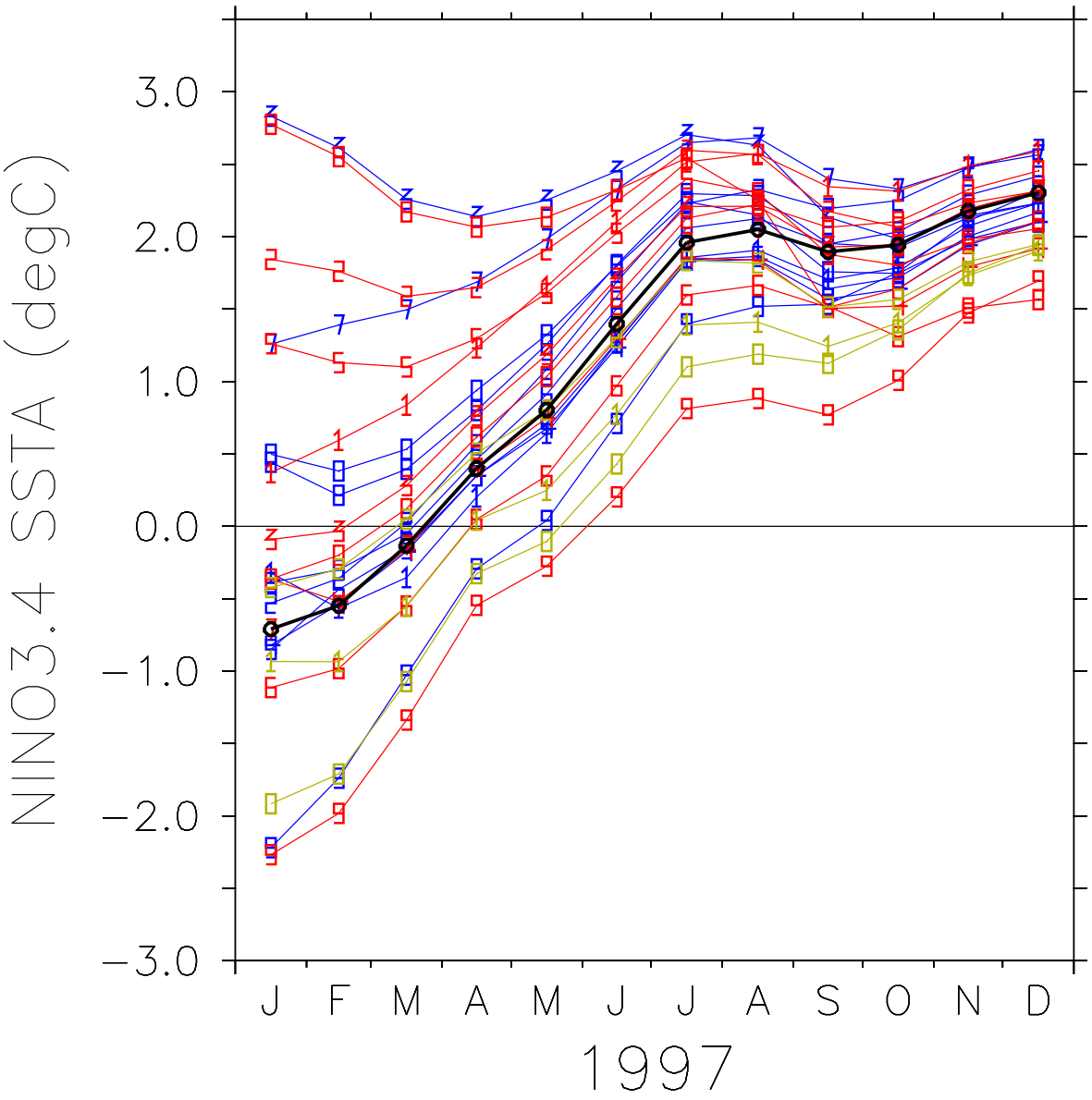
Random initial conditions

no residual forcing

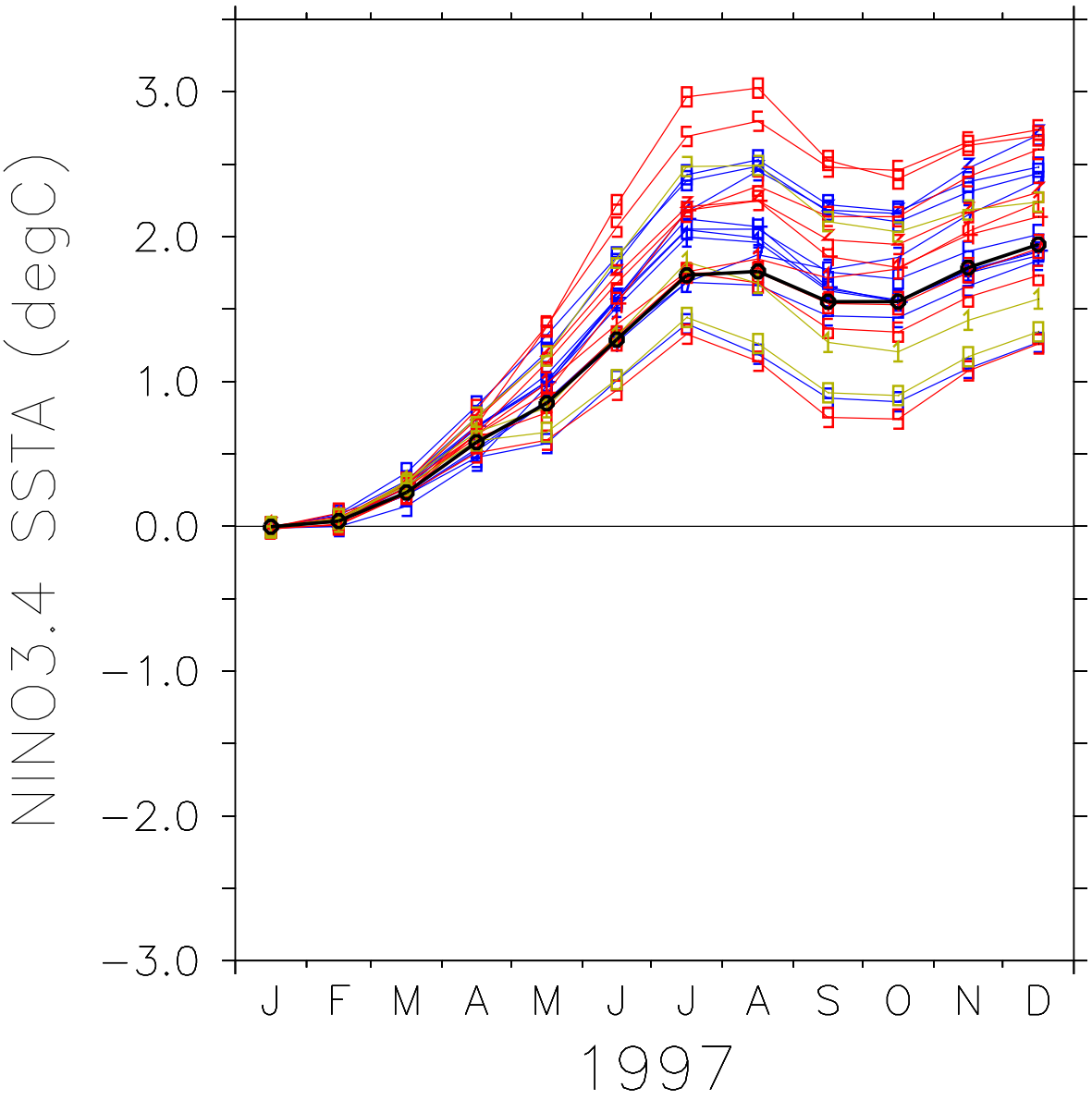


Random initial conditions

forced by 1997 stress residual



SST change induced by 1997 residual



Are the residual stresses random?

Only one realization of the obs!

Invoke an atmospheric GCM:

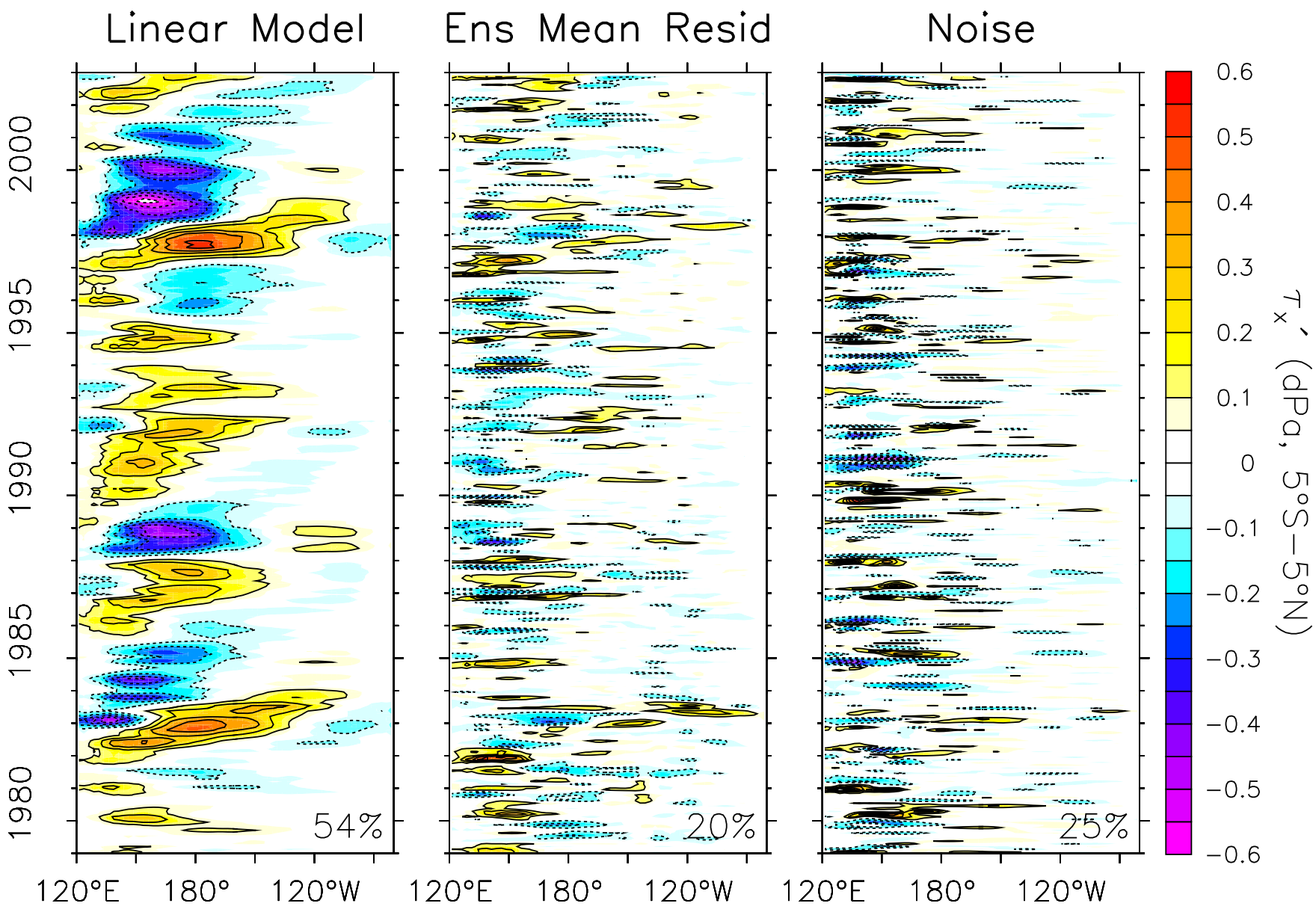
1. Force an AGCM ensemble with obs SSTs.

2. Fit a linear stress model to each run.

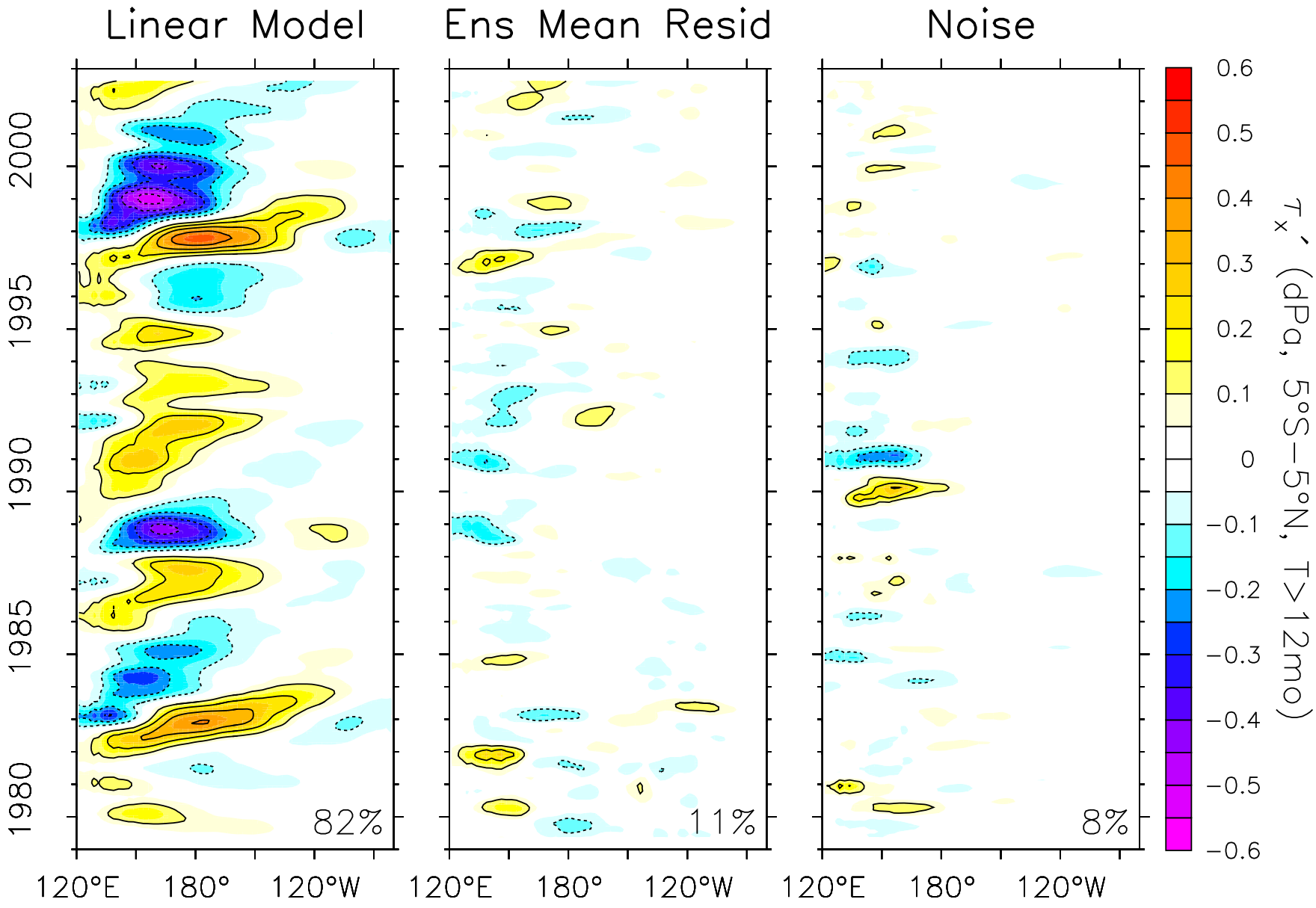
$\Rightarrow$ Ensemble mean should vanish if residual is noise.

GFDL AM2p12
2.5°lon $\times$ 2°lat $\times$ 24 levels
10 members

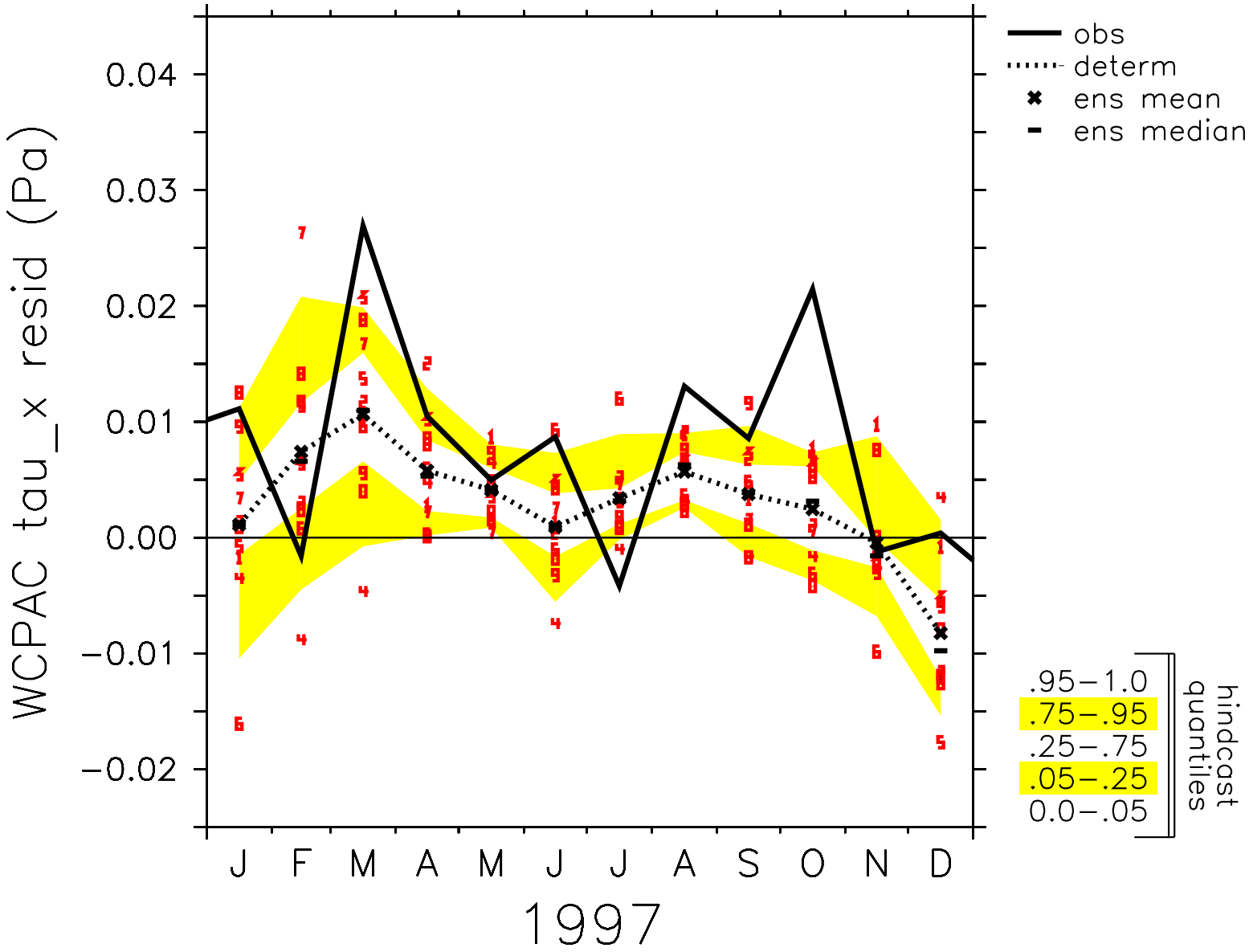
AGCM wind stress decomposition: monthly mean



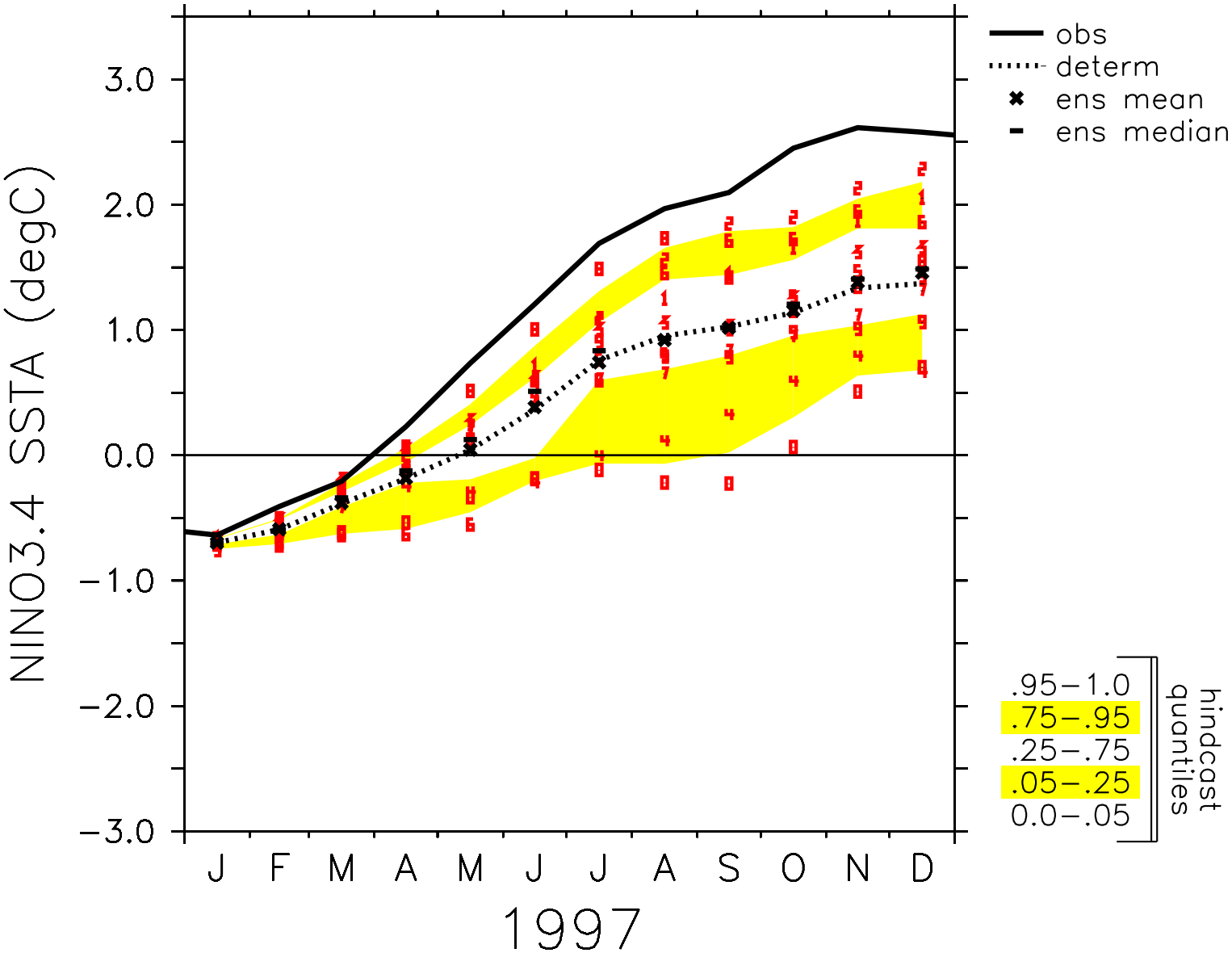
AGCM wind stress decomposition: low-pass



AGCM residual zonal wind stress

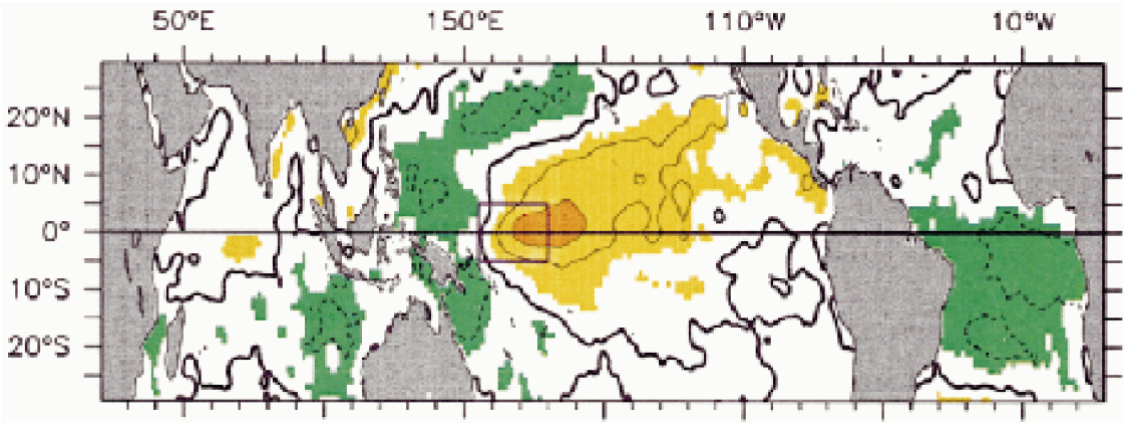


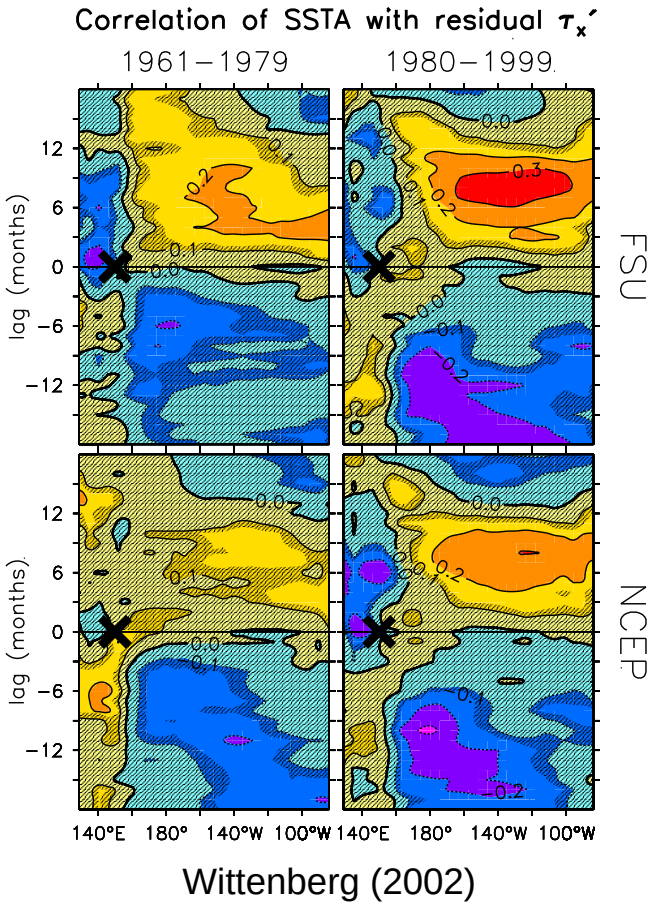
“Cheatcasts” forced by AGCM stress residuals



What drives the WWEs?

non-ENSO composite of WWE SSTAs (Vecchi & Harrison 2000)



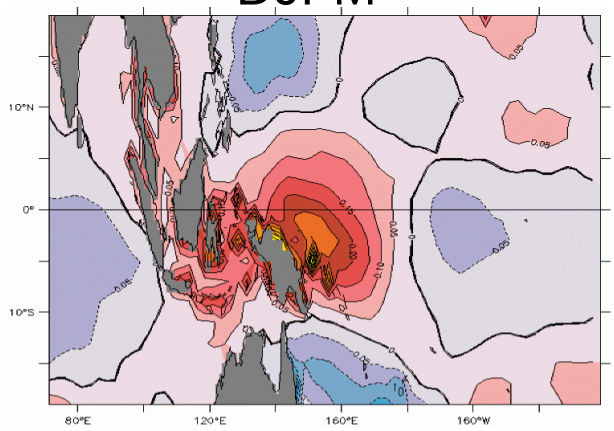


Wittenberg (2002)

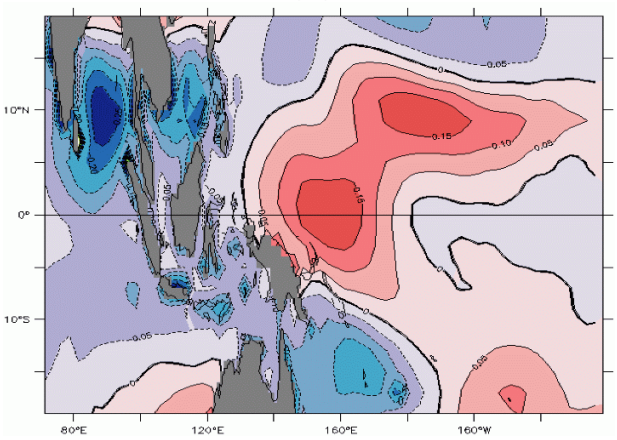
- linked to eastward SSTA gradients in west
- connected with large-scale warming

AGCM τ_x' driven by precursive SSTA

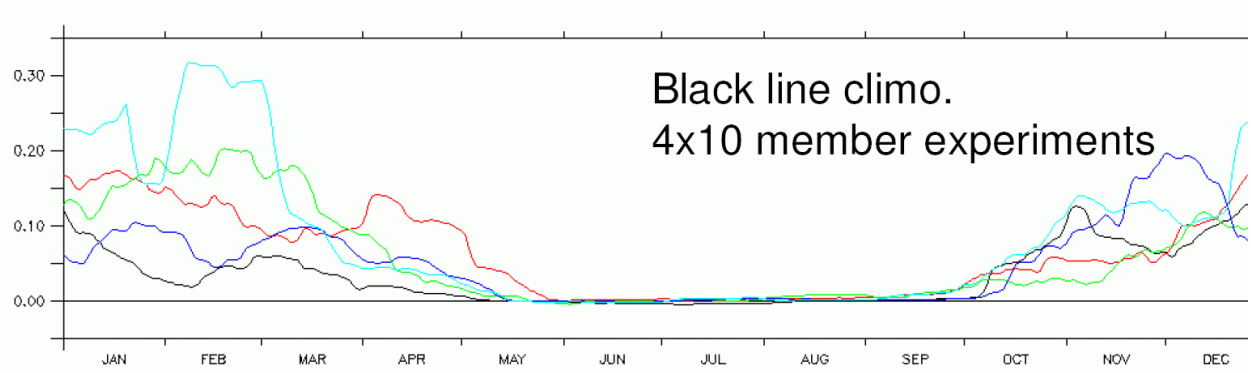
DJFM



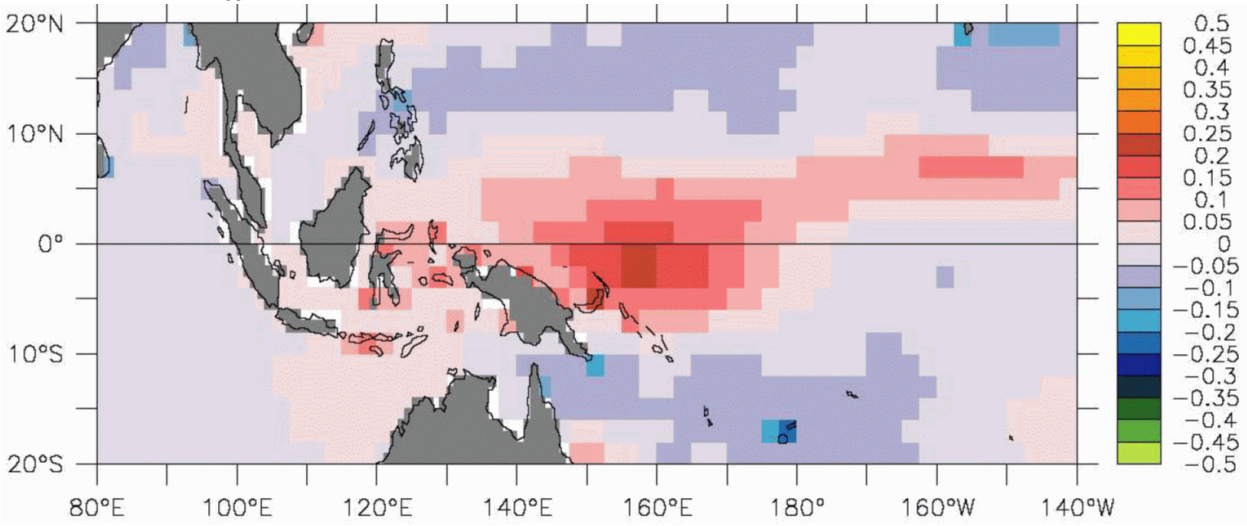
MJJA



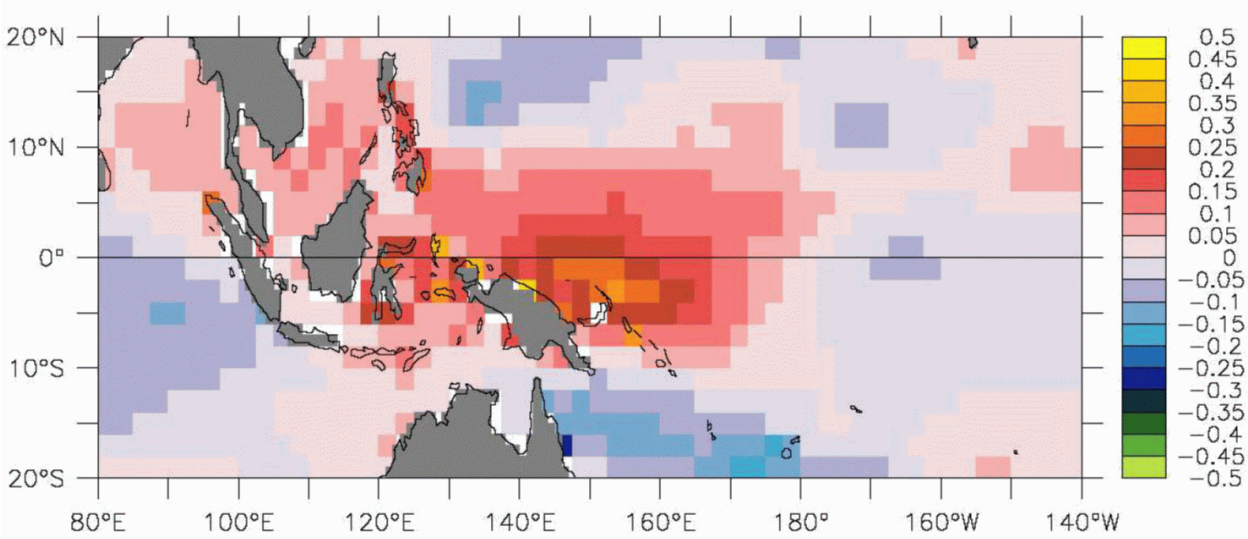
Skewness of AGCM τ_x' noise



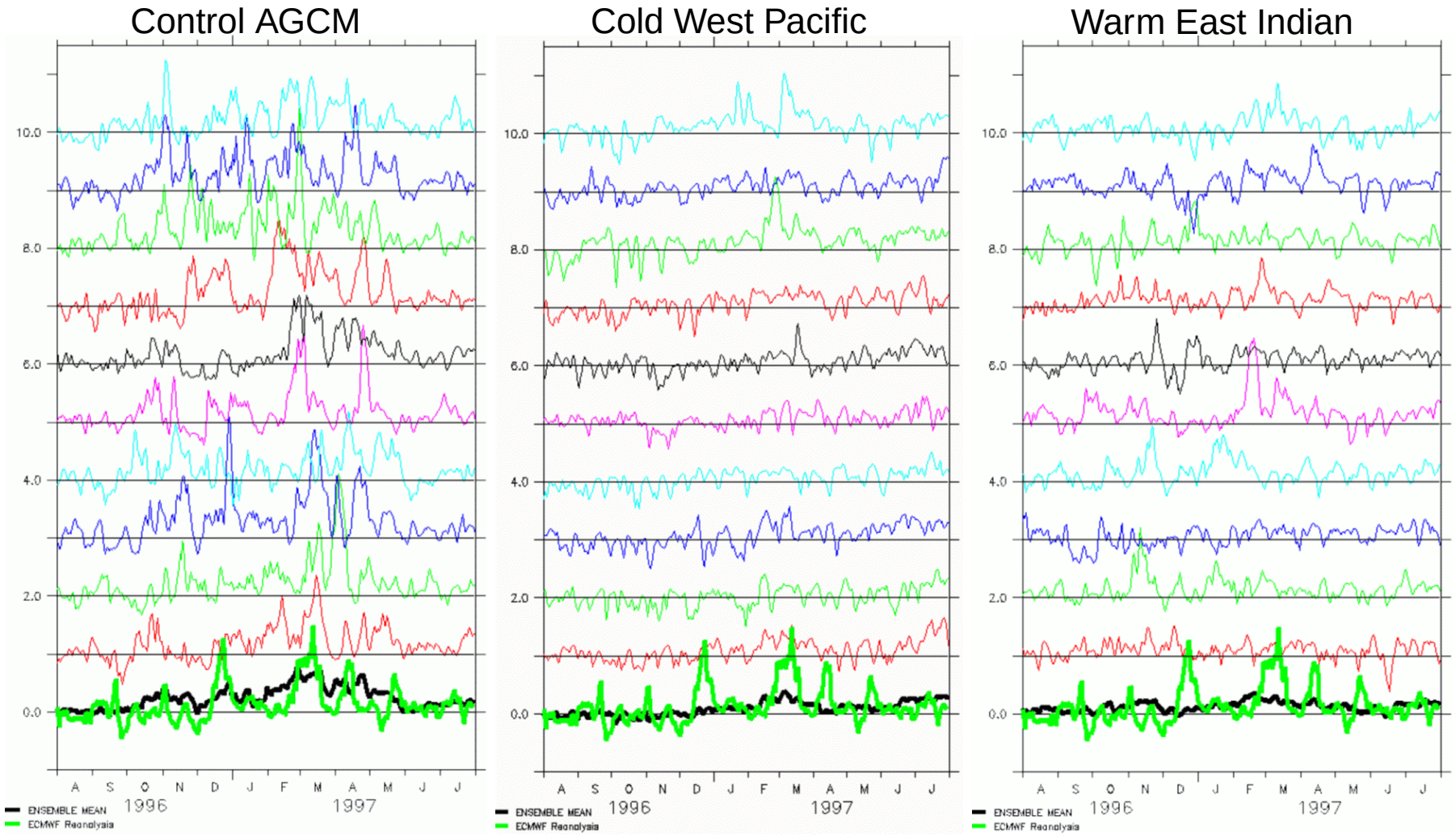
τ_x' driven by Pacific precursive SSTA



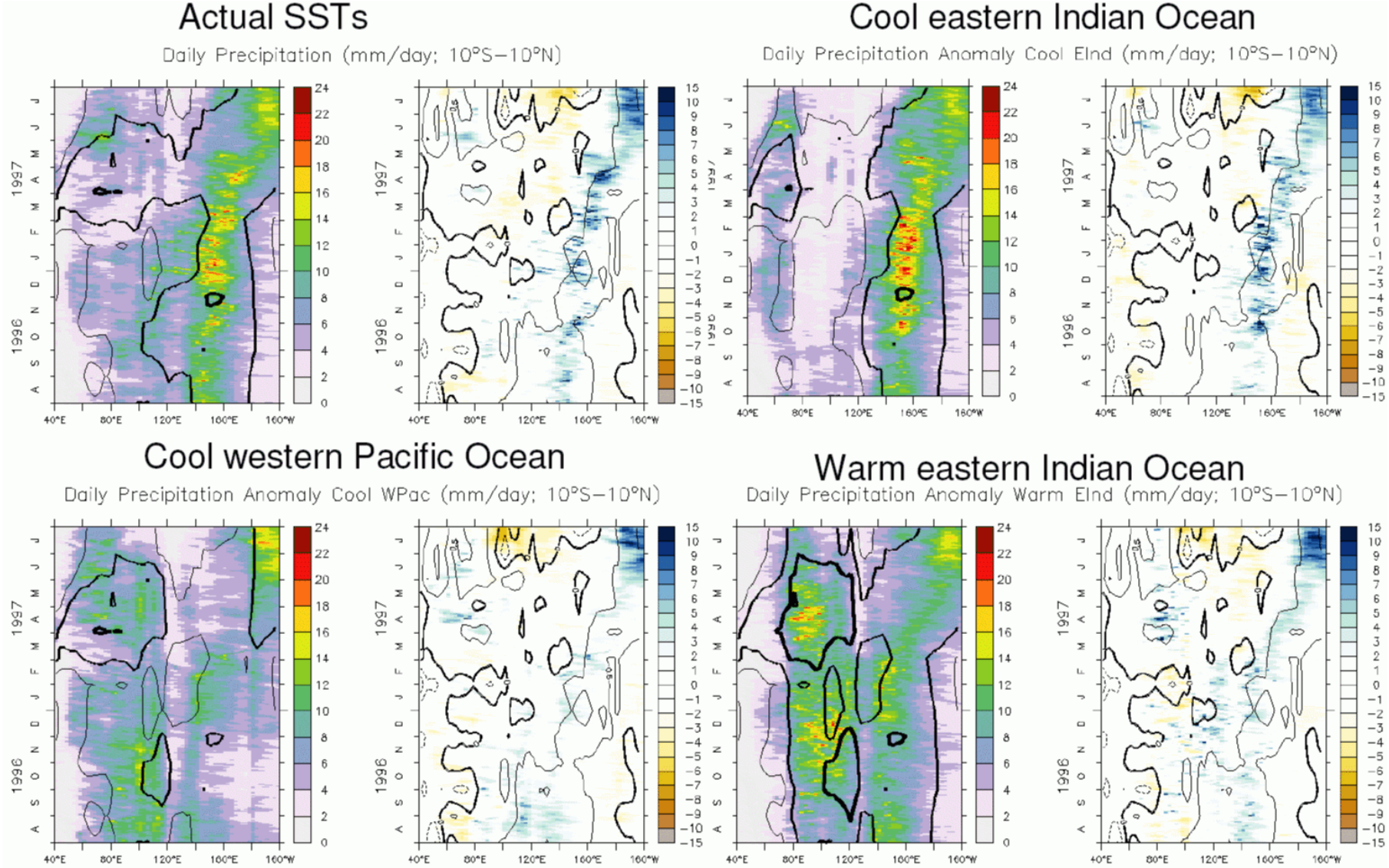
τ_x' driven by IndoPacific precursive SSTA



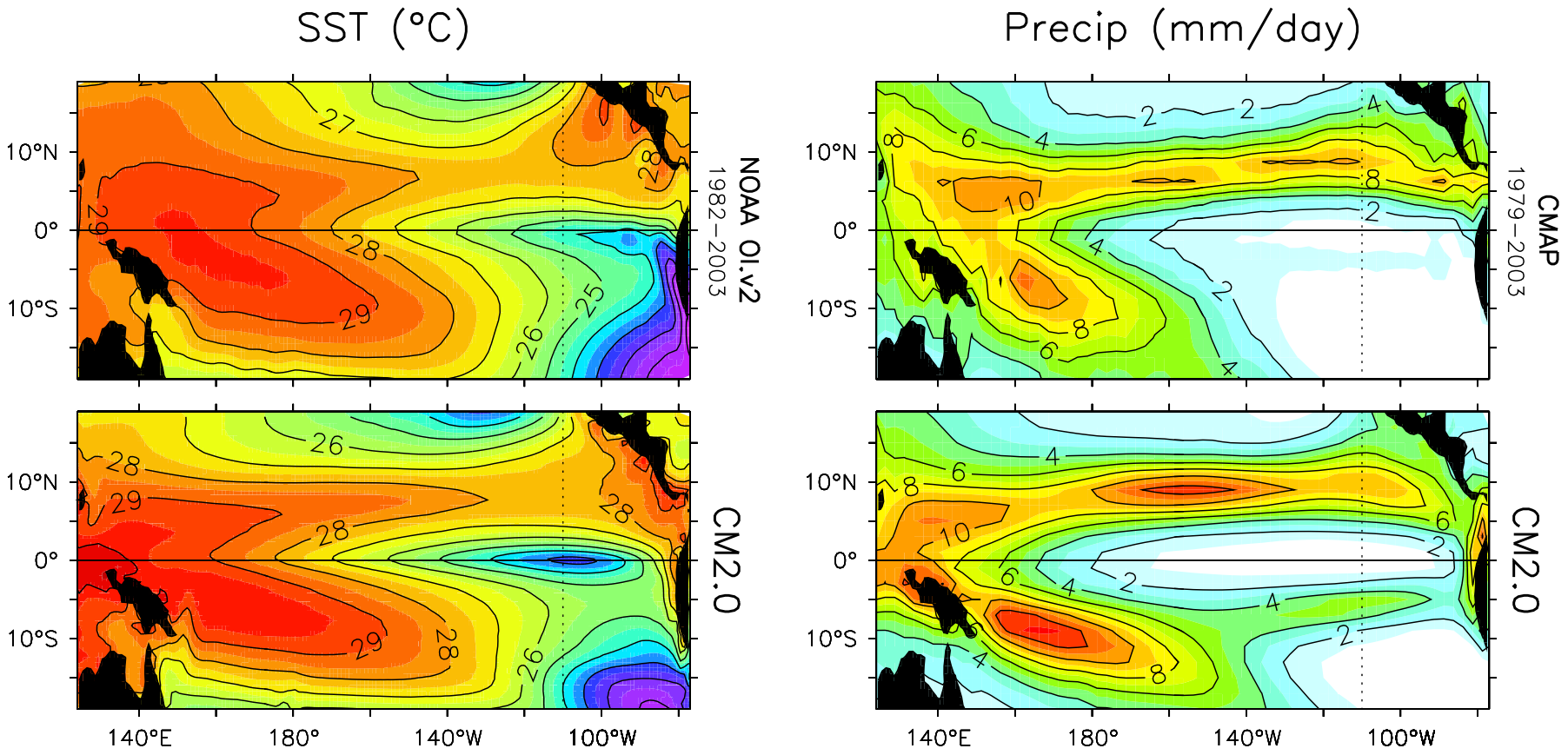
Background SST affects the WWEs



Background SST affects the convection



CGCM biases


SST (°C)
Precip (mm/day)
NOAA OI.v2
1982–2003
CMAP
1979–2003
CM2.0
CM2.0
10°N
0°
10°S
140°E
180°
140°W
100°W

Summary

1. Regression onto tropical Pacific SST captures most interannual variance of equatorial Pacific τ_x'.

2. But the residual stress matters. It induces strong dispersion of ENSO forecasts.

3. Pacific was preconditioned for warming in 1997. But unusually intense residual westerlies greatly amplified the warming.

4. The residual is not completely independent of SST.

5. Convective nonlinearity $\Rightarrow$
   - role for background SST, Indian Ocean
   - challenge for CGCMs (climate drift)