

Climate Sensitivities of ENSO

Bridging theory, observations, and modeling

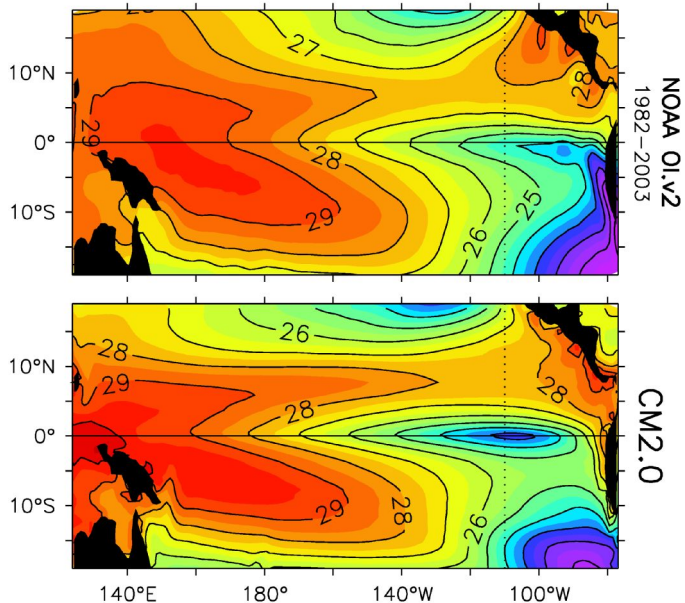
Andrew Wittenberg

GFDL/NOAA, Princeton, New Jersey, USA

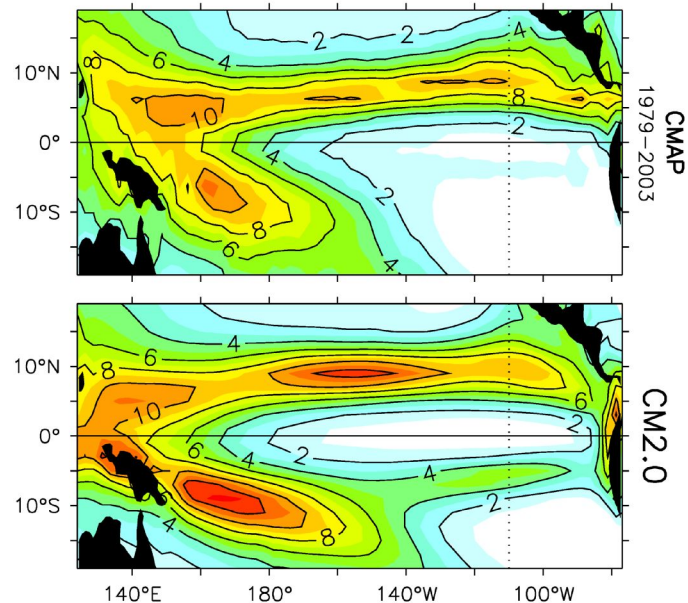
Thanks to: Gabriel Vecchi, Qian Song, and Anthony Rosati

“Other worlds” in CGCMs

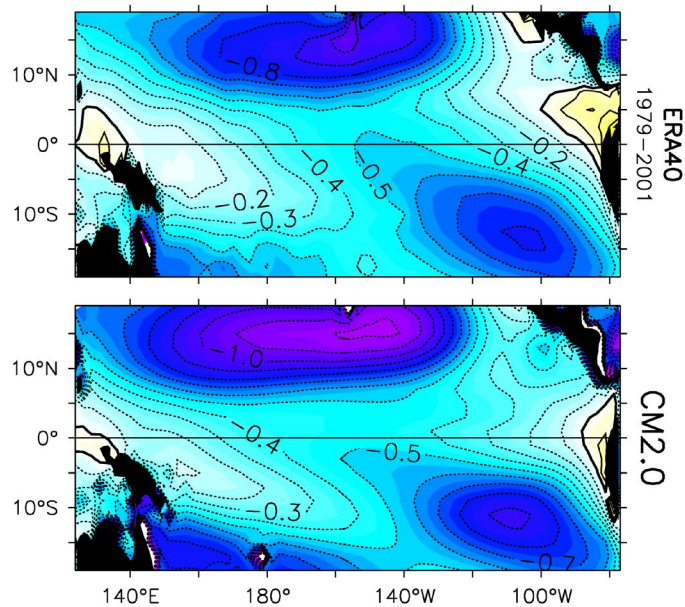
SST (°C)



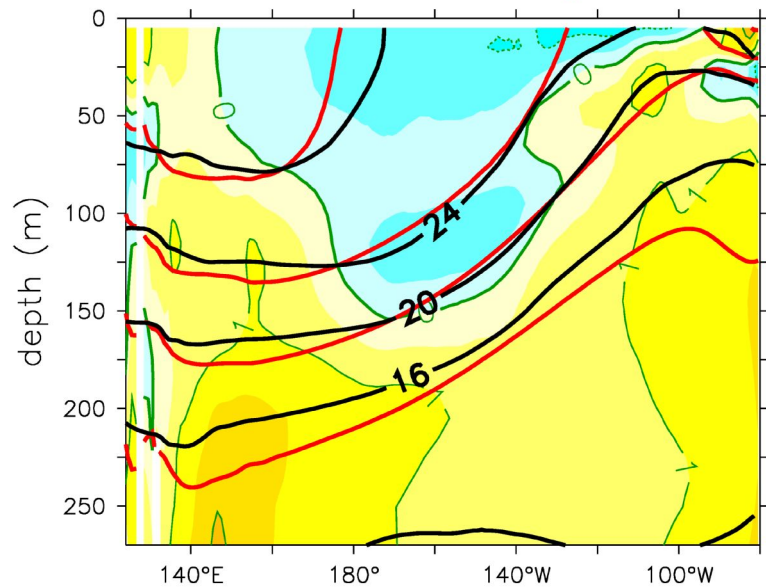
Precip (mm/day)



τ_x (dPa)



Temperature (°C) at Equator
Assim (1980-1999), CM2.0 (bias shaded)



Mixed layer temperature anomaly tendency equation

$$\begin{aligned} T'_t = & -u'\bar{T}_x & -\bar{u}T'_x & -(u'T'_x)' \\ & -v'\bar{T}_y & -\bar{v}T'_y & -(v'T'_y)' \\ & -w'\bar{T}_z & -\bar{w}T'_z & -(w'T'_z)' \\ & +\text{eddy} & +Q'_{\text{sfc}} & \end{aligned}$$

Key to understanding impact of background state on ENSO.

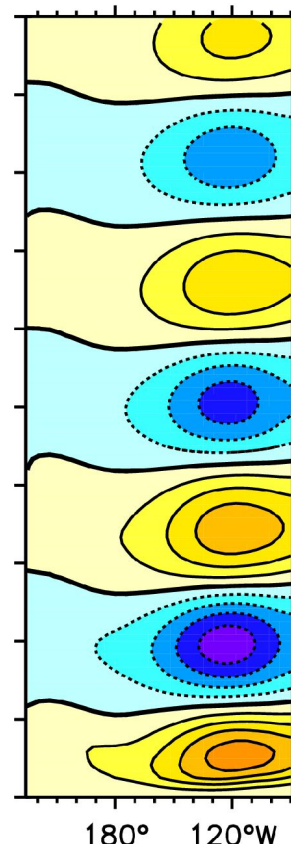
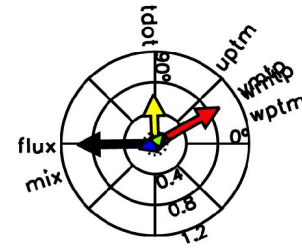
Mixed layer temperature anomaly tendency equation

$$T'_t = \begin{array}{l} \text{---} u' \bar{T}_x \quad \text{---} \bar{u} T'_x \quad \text{---} (u' T'_x)' \\ \text{---} v' \bar{T}_y \quad \text{---} \bar{v} T'_y \quad \text{---} (v' T'_y)' \\ \text{---} w' \bar{T}_z \quad \text{---} \bar{w} T'_z \quad \text{---} (w' T'_z)' \\ \text{+ eddy} \quad \text{+ } Q'_{\text{sfc}} \end{array}$$

Key to understanding impact of background state on ENSO.

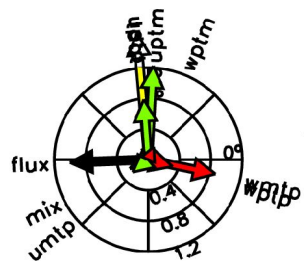
ICM Control Run

(d) $\tau_x=0$
3.1yr at 121°W

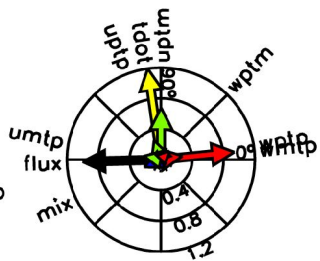


ICM: Impact of trade wind strength

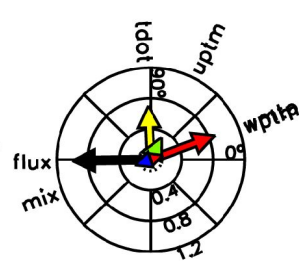
(a) $\tau_x = -0.1$
1.2yr at 142°W



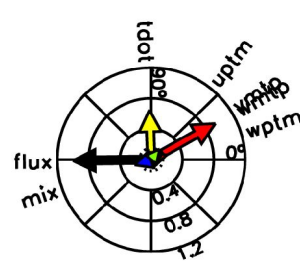
(b) $\tau_x = -0.06$
1.7yr at 137°W



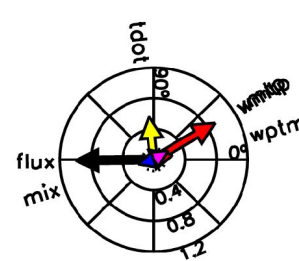
(c) $\tau_x = -0.02$
2.9yr at 127°W



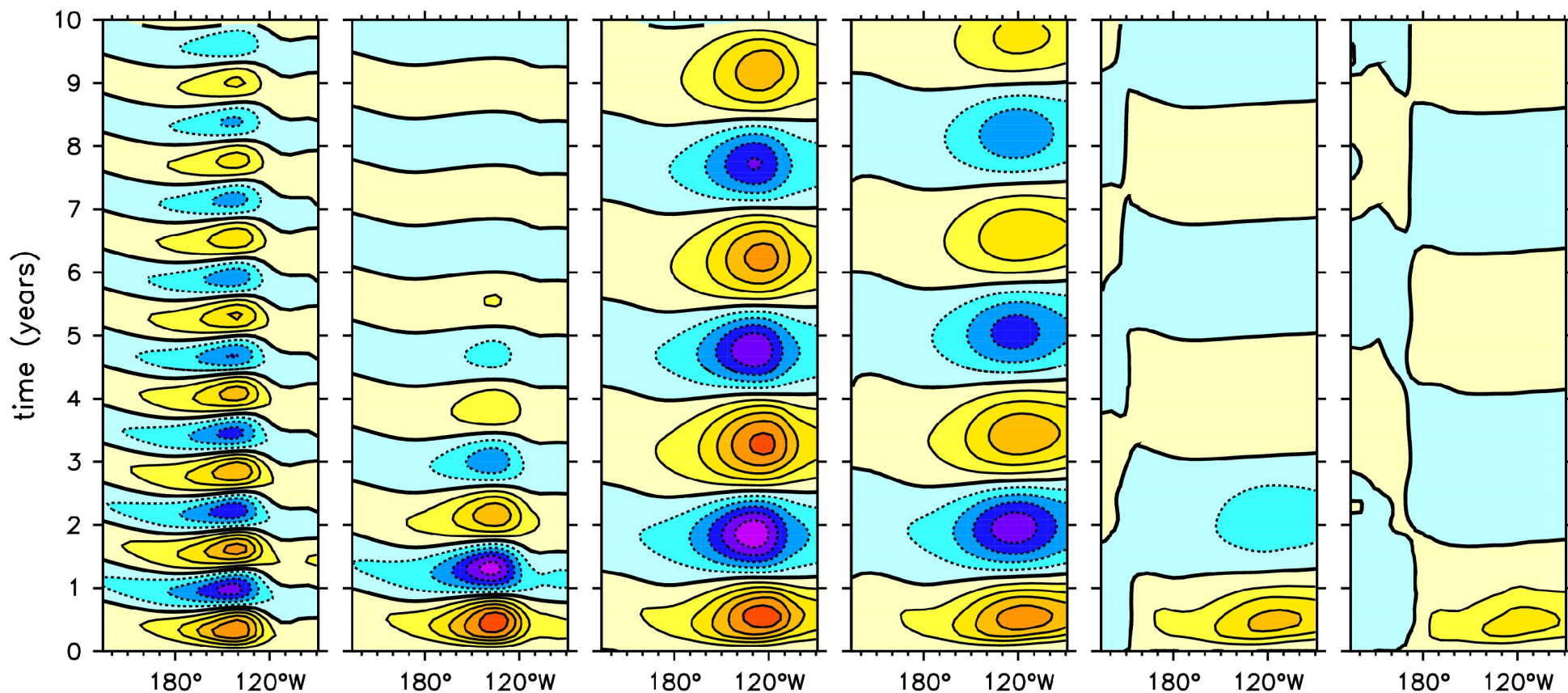
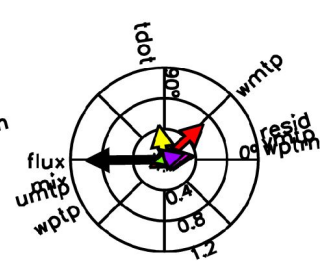
(d) $\tau_x = 0$
3.1yr at 121°W



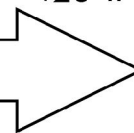
(e) $\tau_x = 0.02$
3.5yr at 119°W



(f) $\tau_x = 0.04$
4.6yr at 119°W

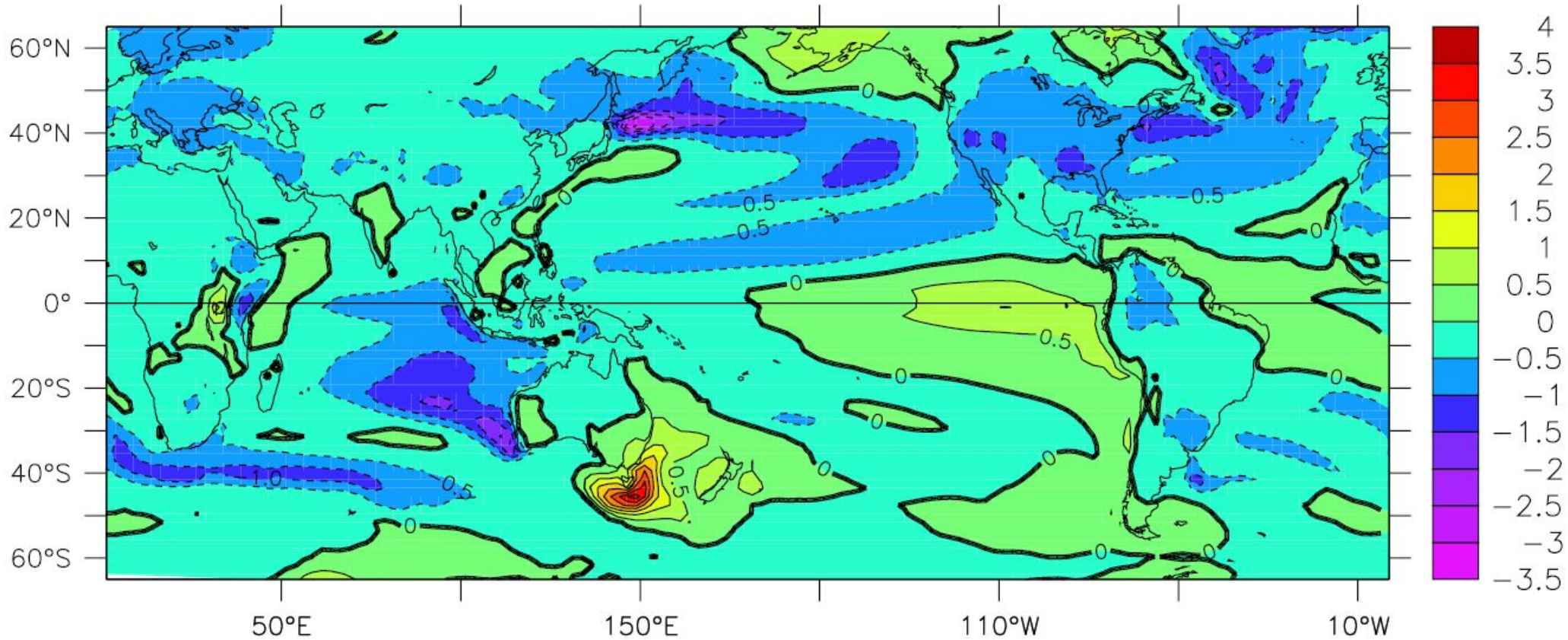


weakening equatorial trades



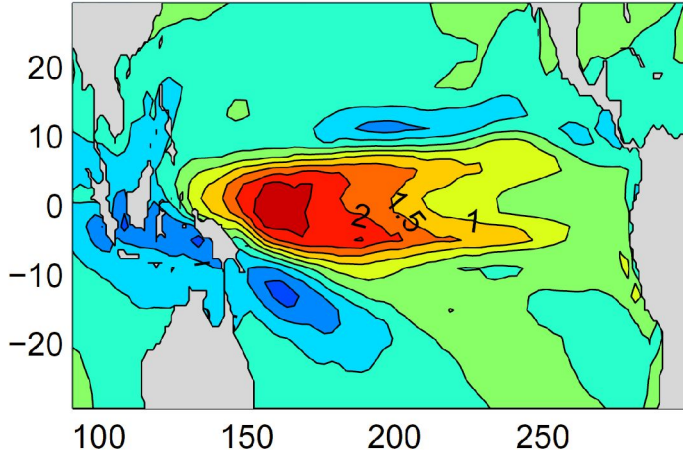
Blocking the Indonesian Throughflow:

Change in mean SST (degC)

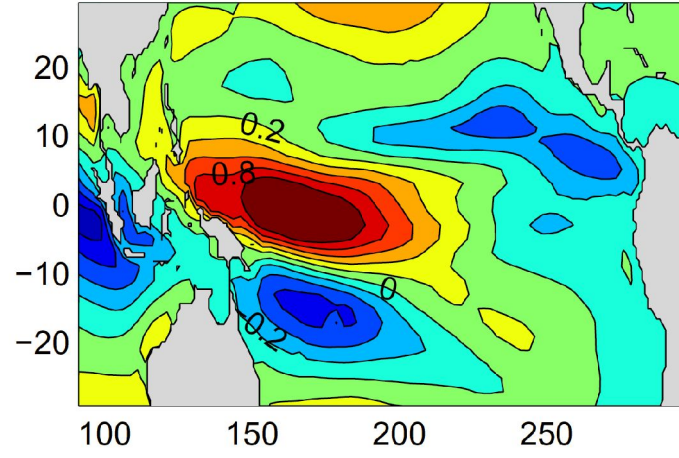


Blocking the Indonesian Throughflow: Anomaly patterns (regressed on NINO3)

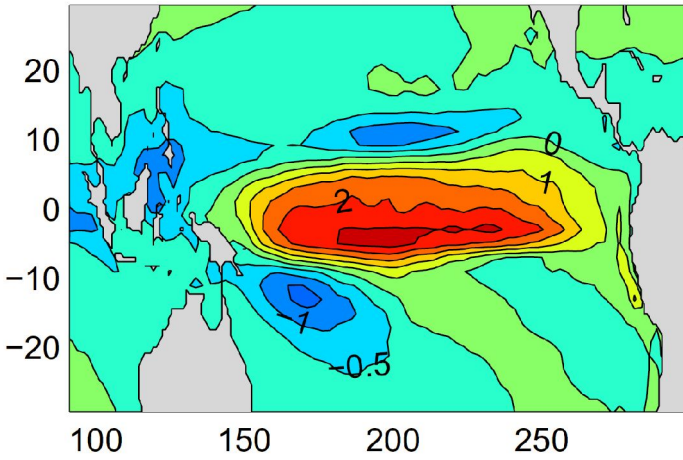
CTRL Precip (mm/day/C)



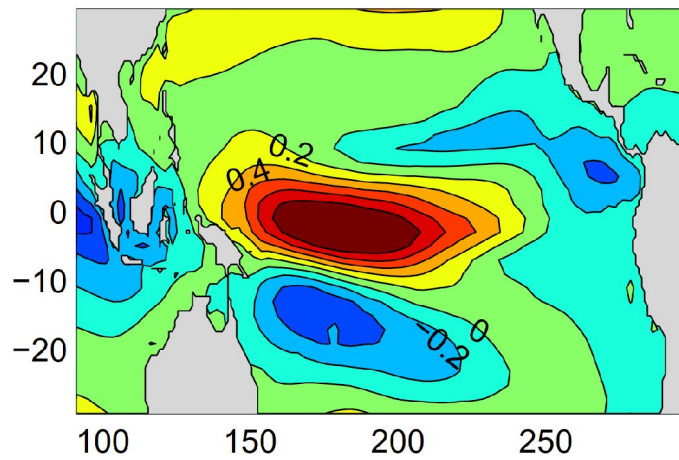
CTRL U_{surface} (m/s/C)



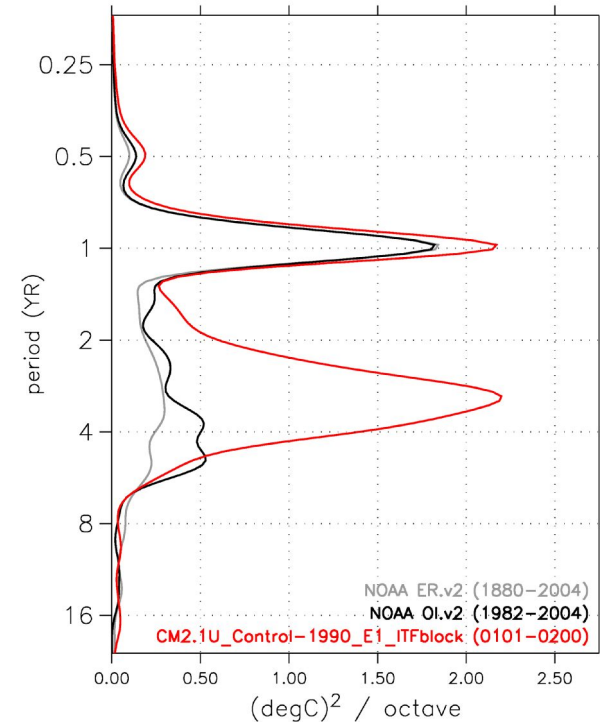
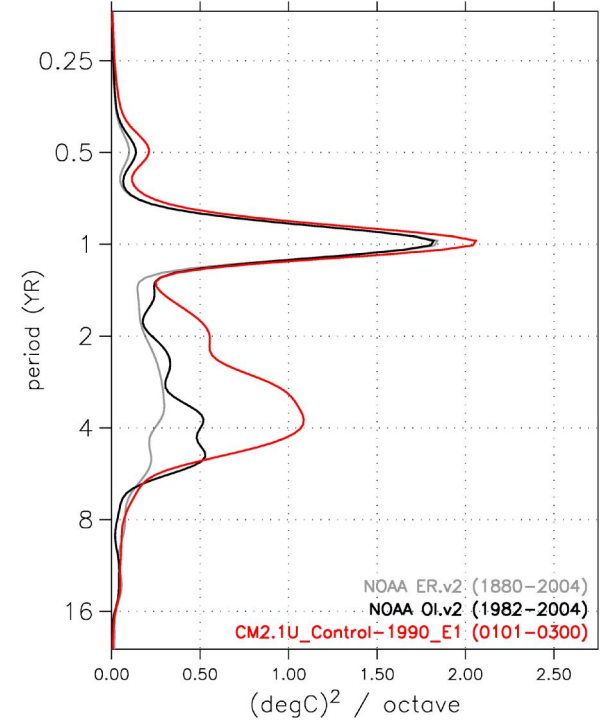
NITF Precip (mm/day/C)



NITF U_{surface} (m/s/C)



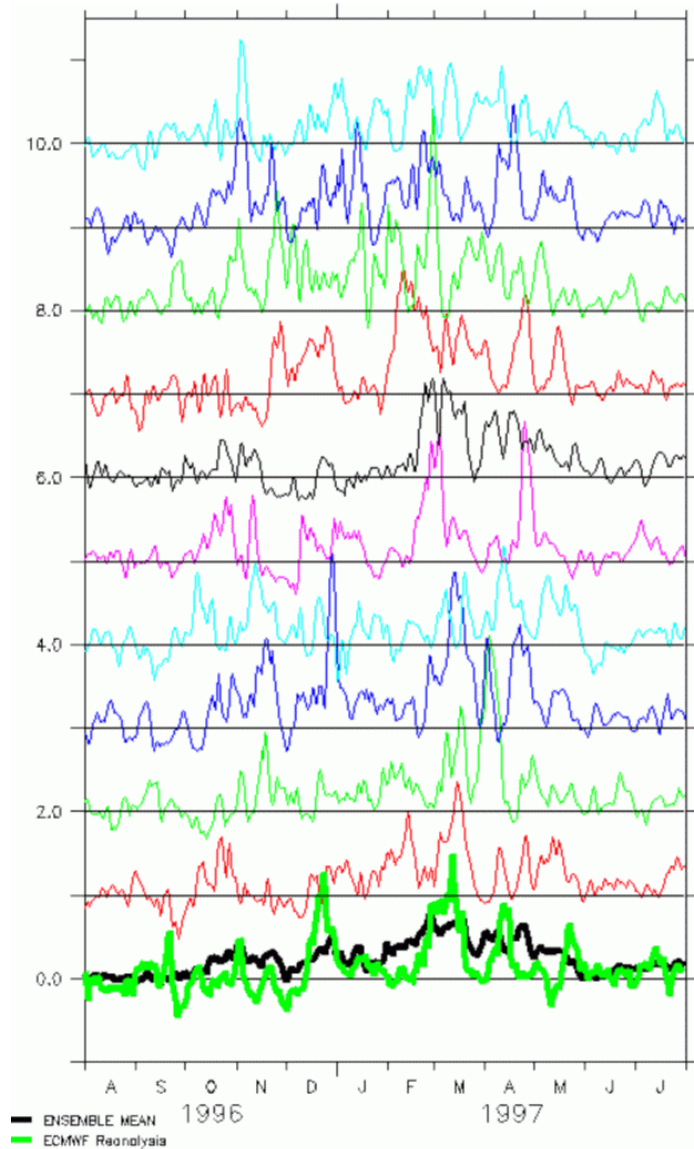
NINO3 SST spectra



Stochastic forcing: A role for the Indian Ocean

Daily west-Pacific zonal stress from 10 AM2 runs

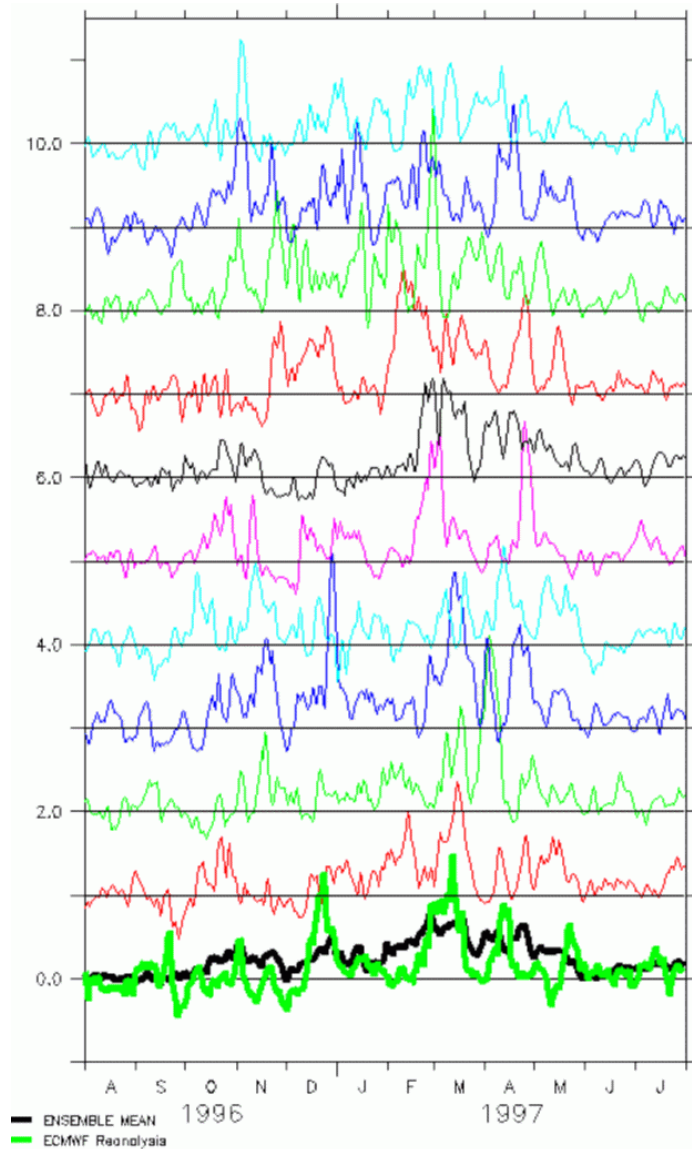
Observed SST forcing



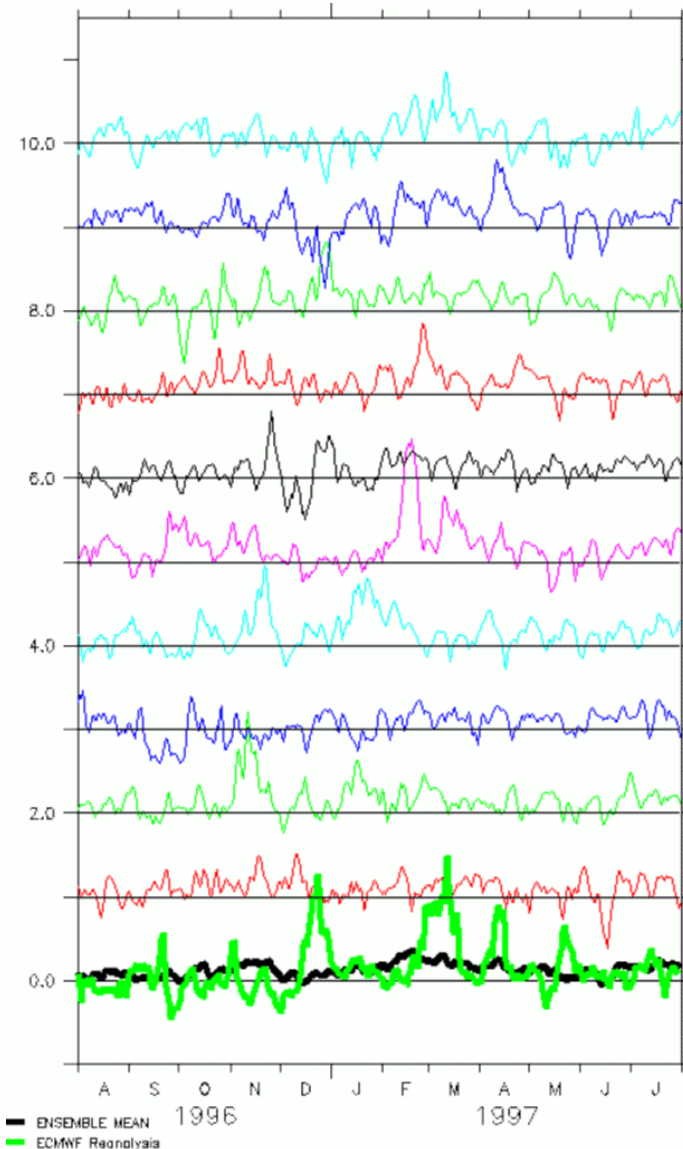
Stochastic forcing: A role for the Indian Ocean

Daily west-Pacific zonal stress from 10 AM2 runs

Observed SST forcing



Warm East Indian



Summary

1) CGCMs: “Other Worlds”

2) Mixed layer heat budget & “frequency budget”

3) ICM: perturbations seed feedbacks, which alter ENSO

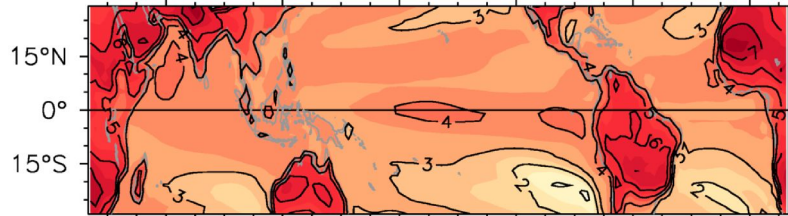
4) CM2: flux anomaly patterns sensitive to background

5) WWBs, nonlinearity, and a role for the Indian Ocean

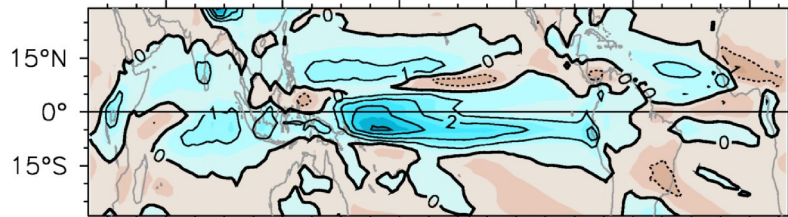
CM2 greenhouse response

Simulated changes: 4xCO2 minus 1860

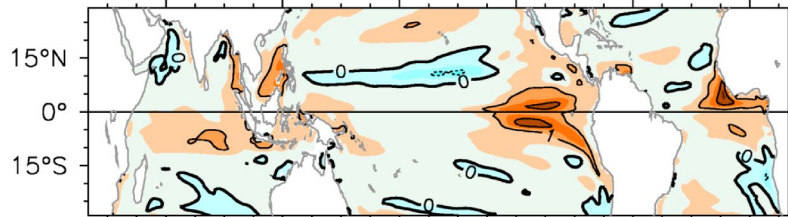
(a) Surface temperature (°C)



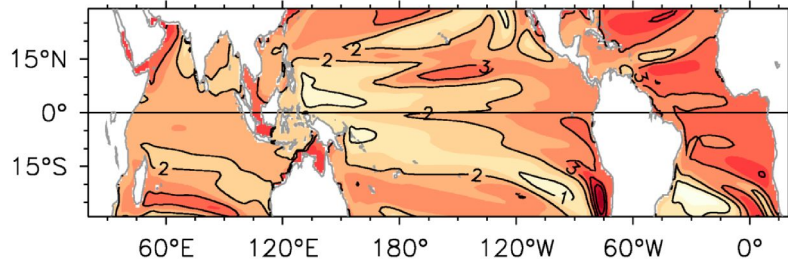
(b) Precipitation (mm/day)



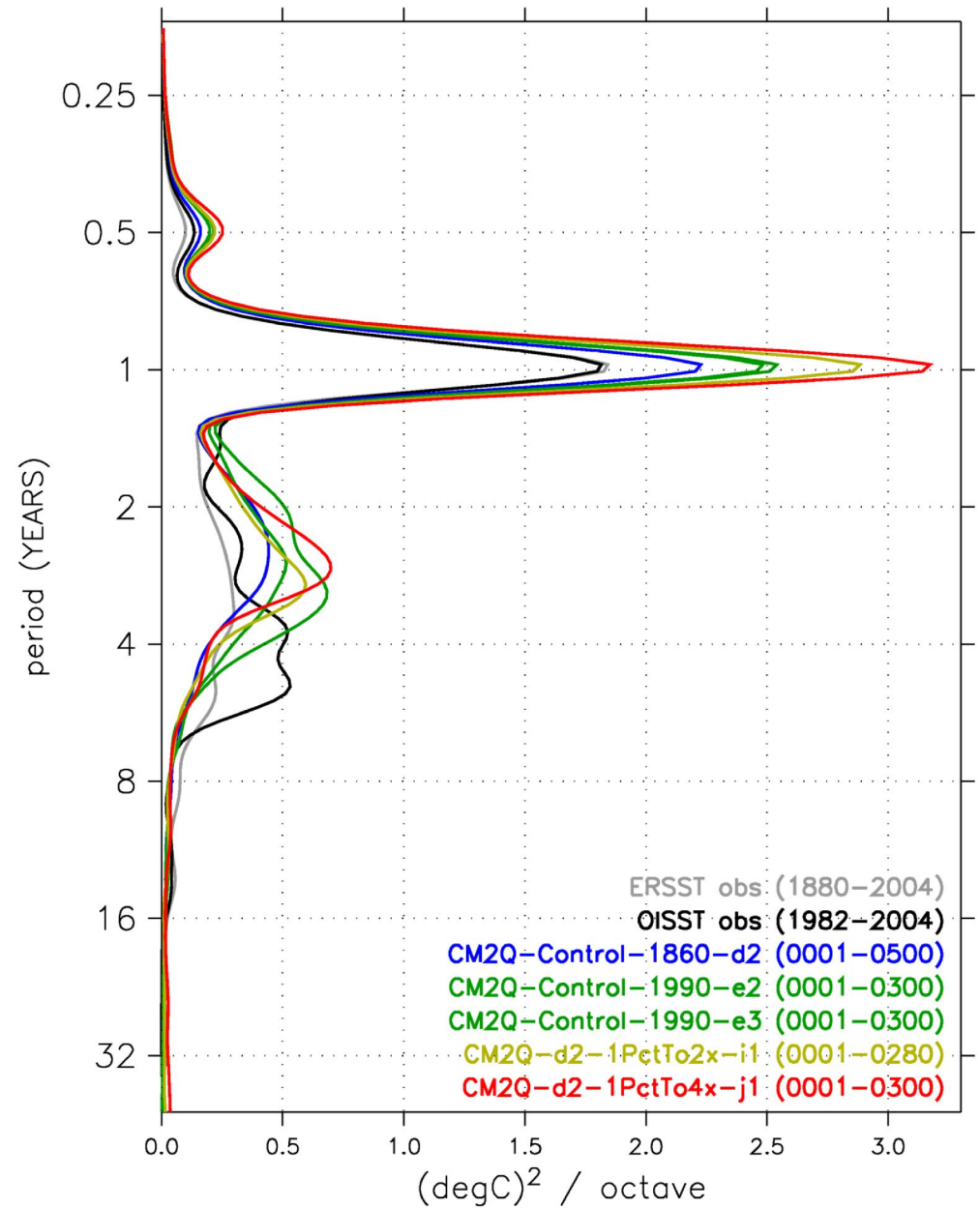
(c) SST minus 50m temperature (°C)



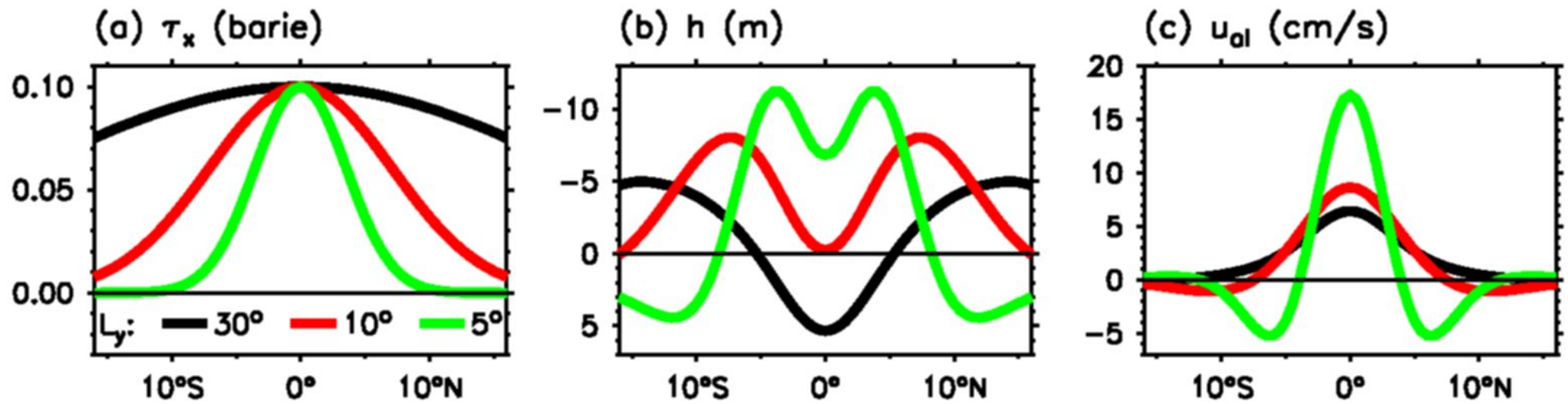
(d) Temperature of top 300m (°C)



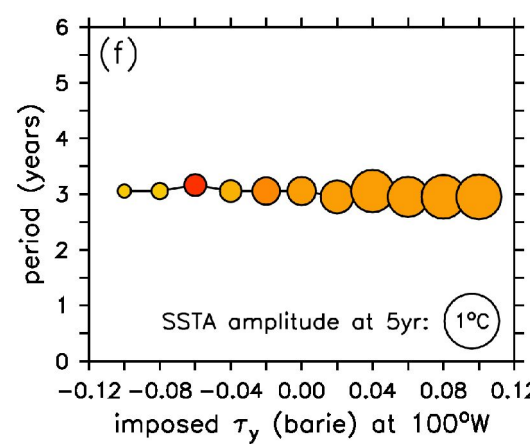
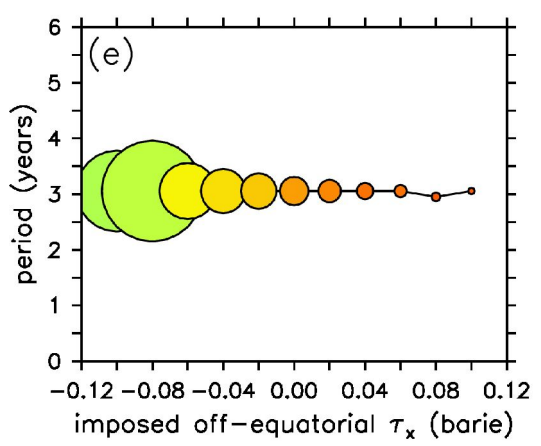
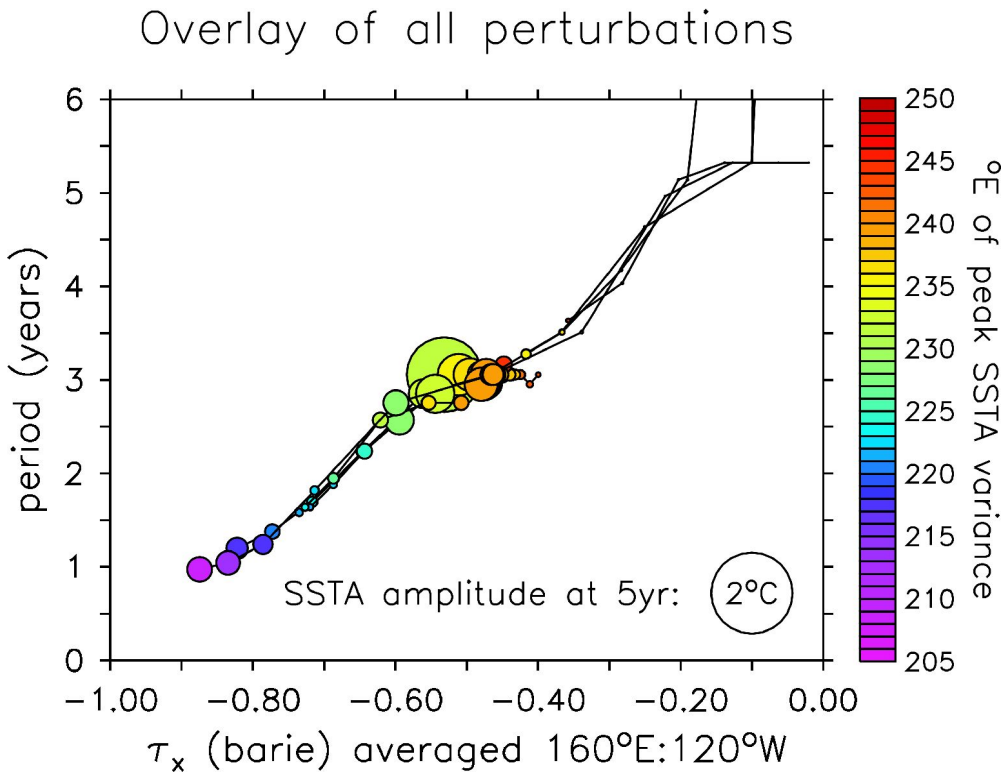
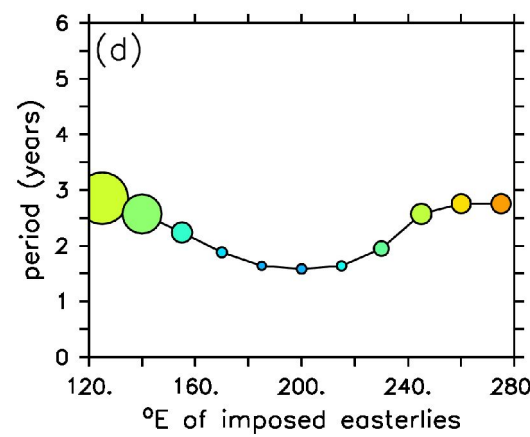
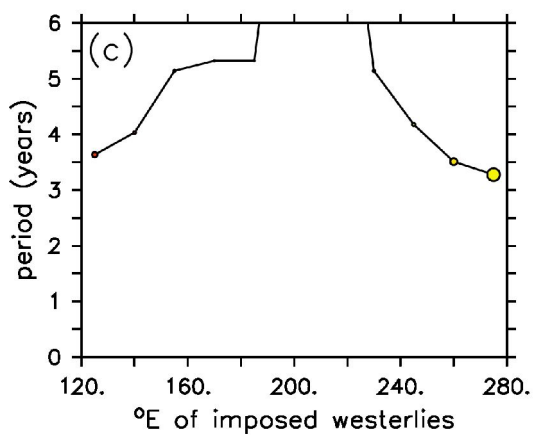
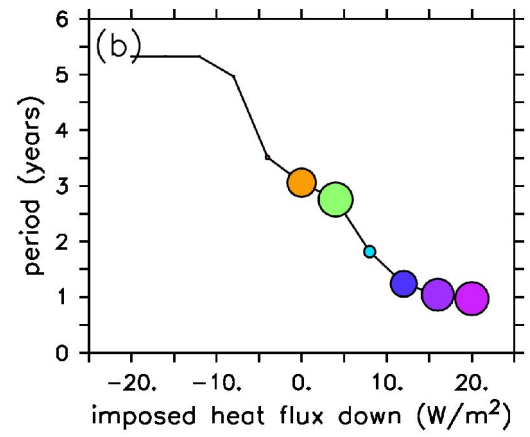
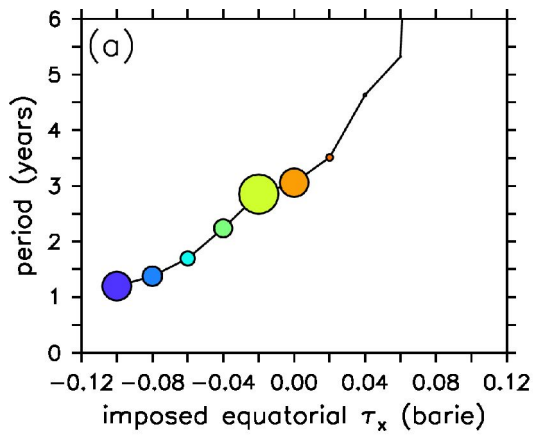
NINO3 SST spectra



Equatorial adjustment to off-equatorial stress

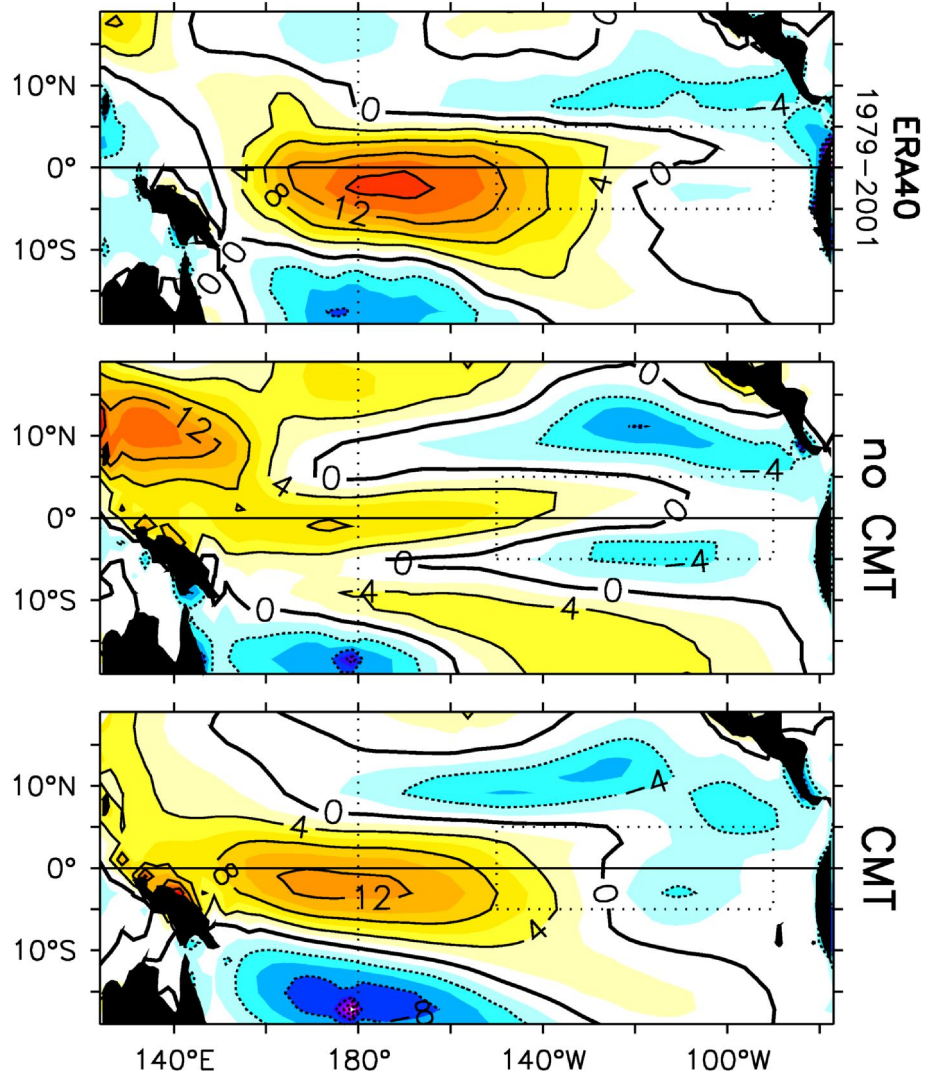


ICM: Different climate perturbations, similar effects

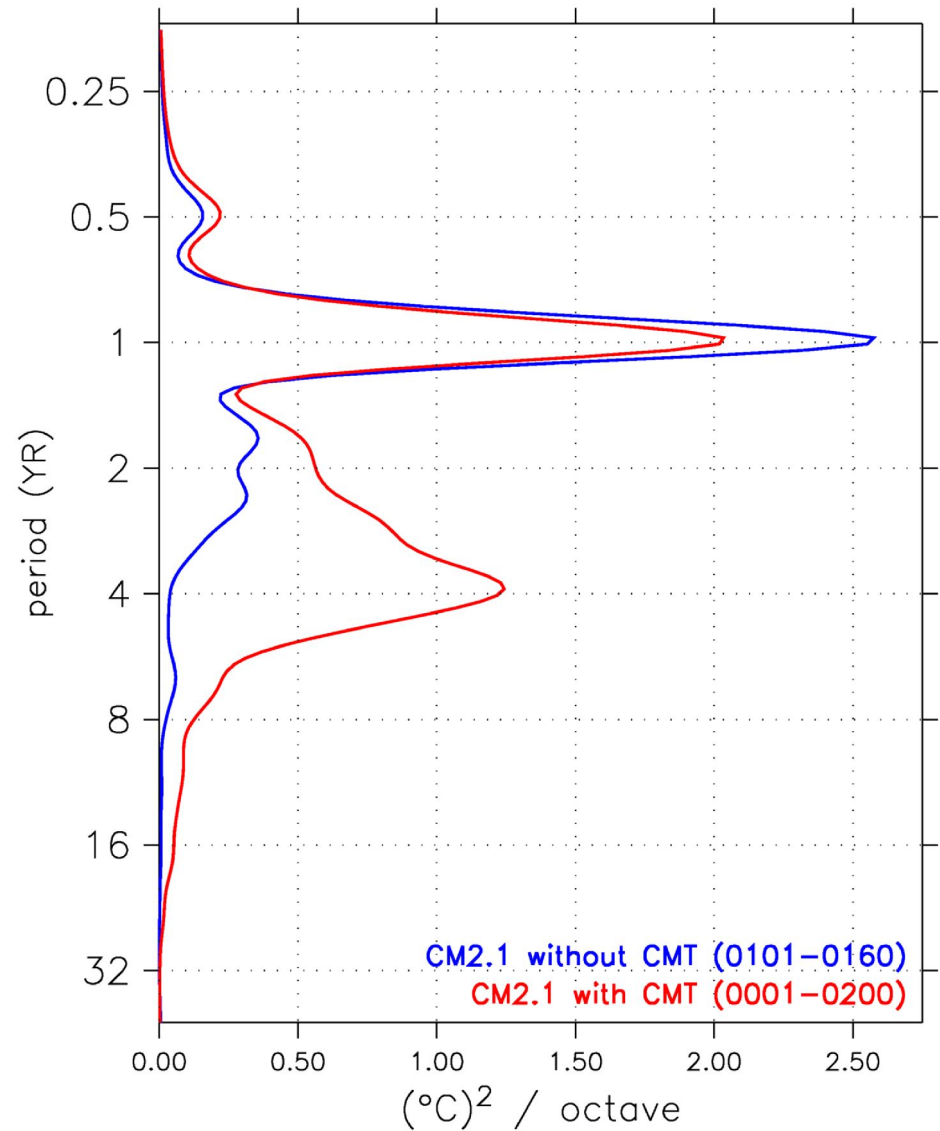


CM2 anomaly patterns: Wind stress

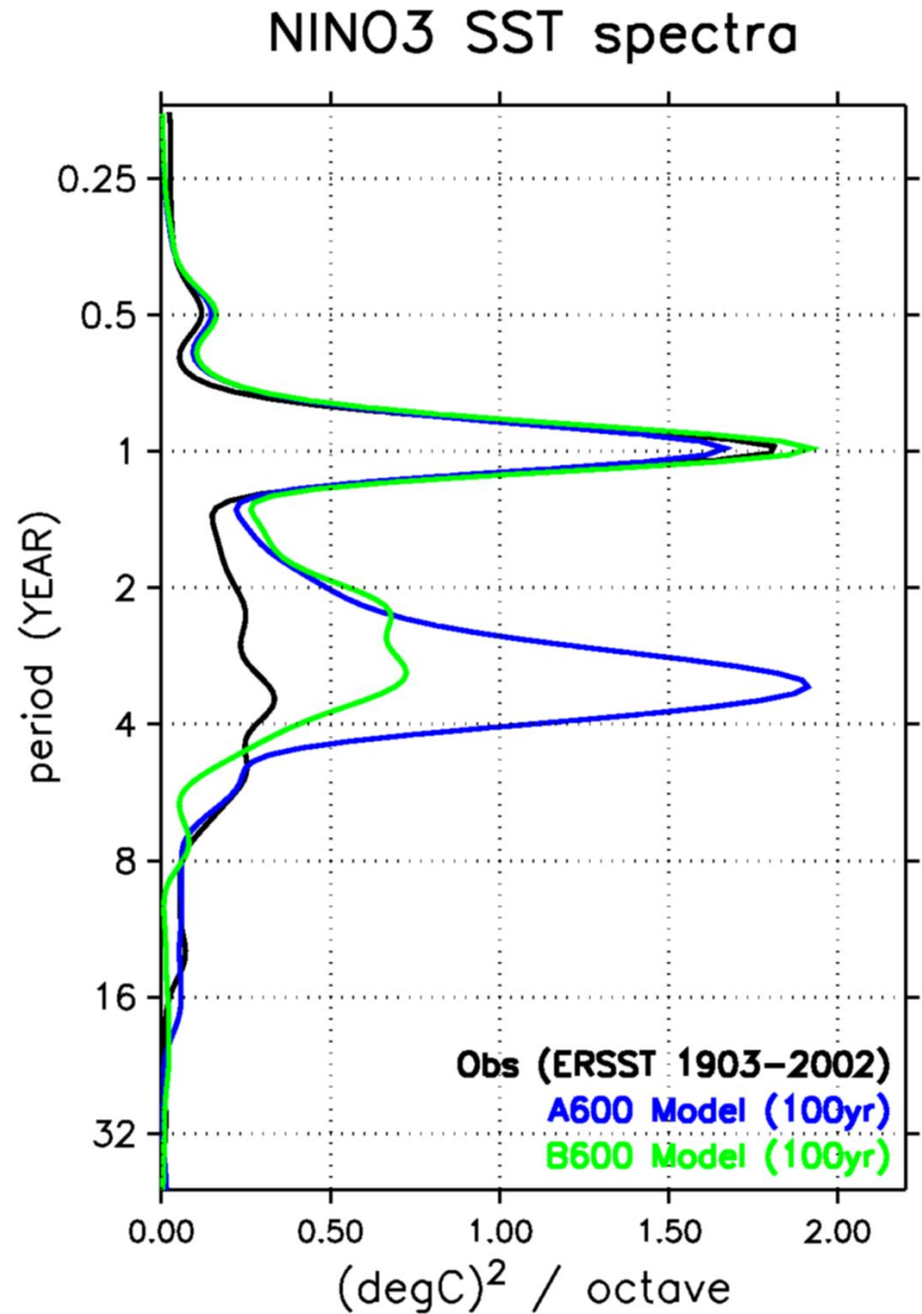
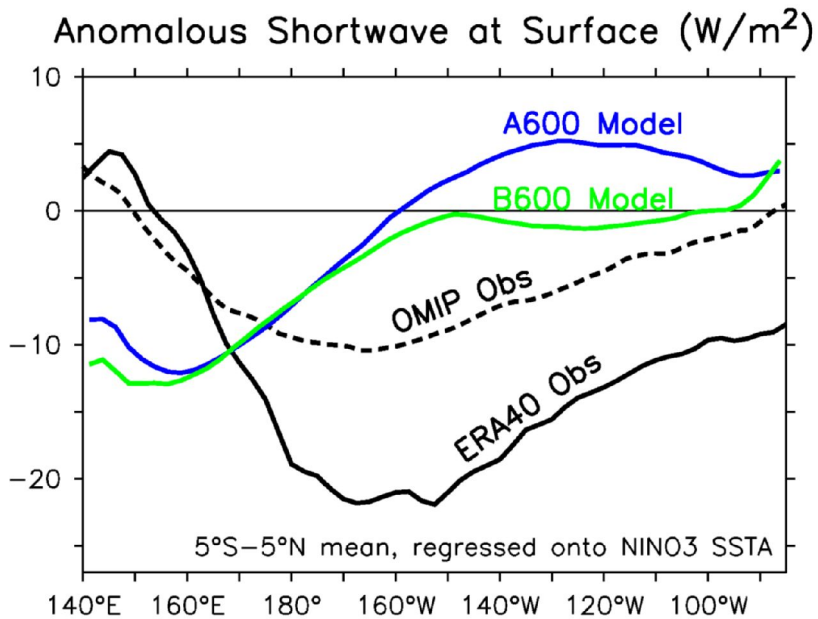
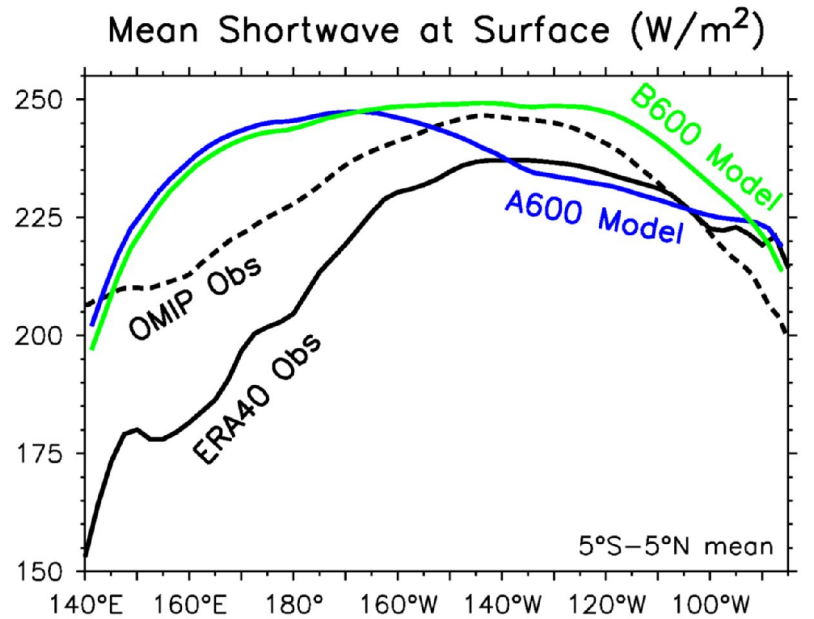
τ_x regr on NINO3 SSTA



NINO3 SST spectra

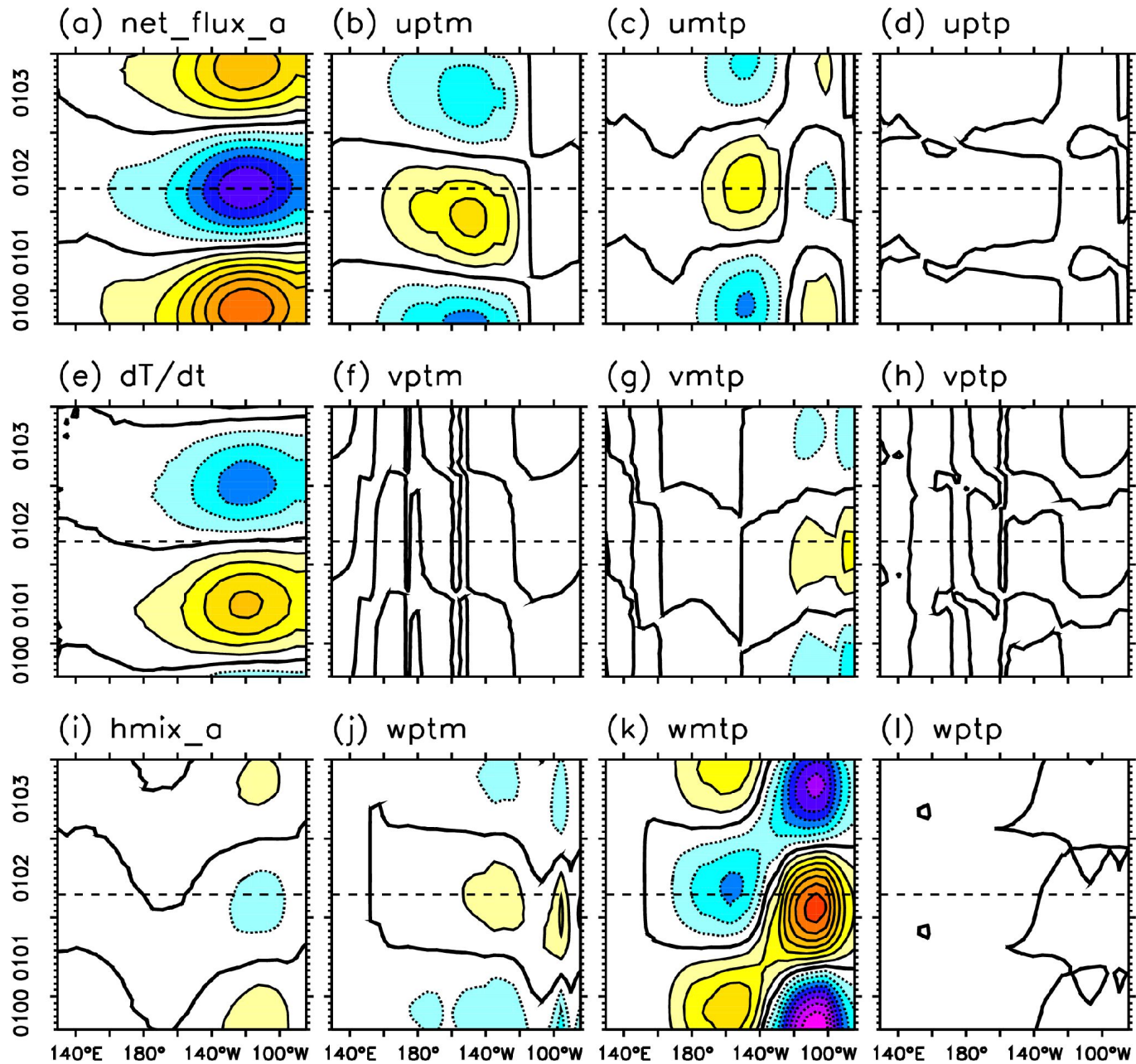


CM2 anomaly patterns: Surface heat flux



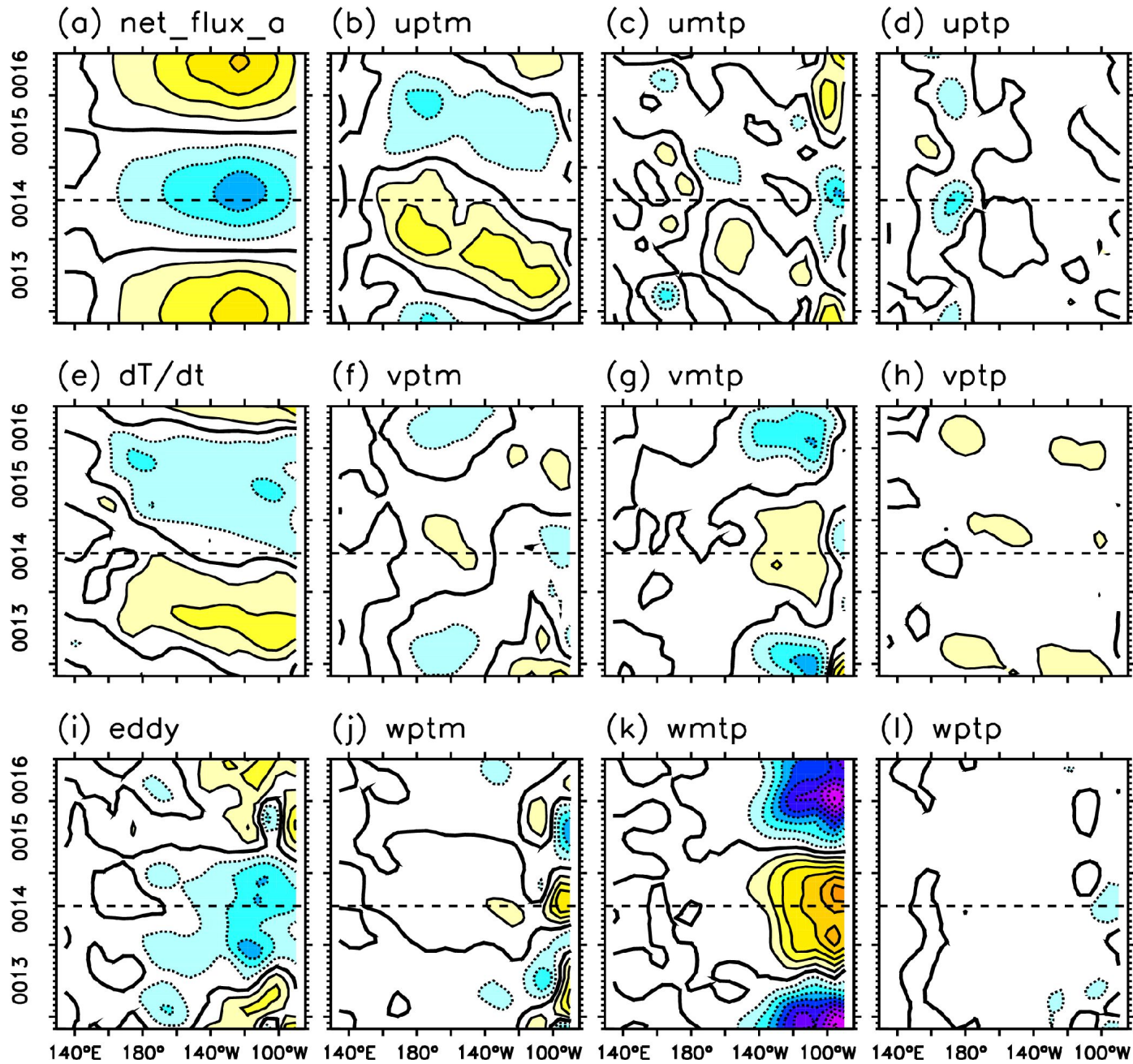
ICM: Mixed layer heat budget

Least damped mode: $2^{\circ}\text{S}-2^{\circ}\text{N}$



Hybrid CGCM mixed layer heat budget

HGCM ENSO: 2°S–2°N



Impact of weakening equatorial zonal stress

Effect of weakening τ_x in a hybrid GCM

