Sensitivities of ENSO: Lessons from the GFDL CM2 Global Coupled GCM

Andrew T. Wittenberg* and **Anthony Rosati**

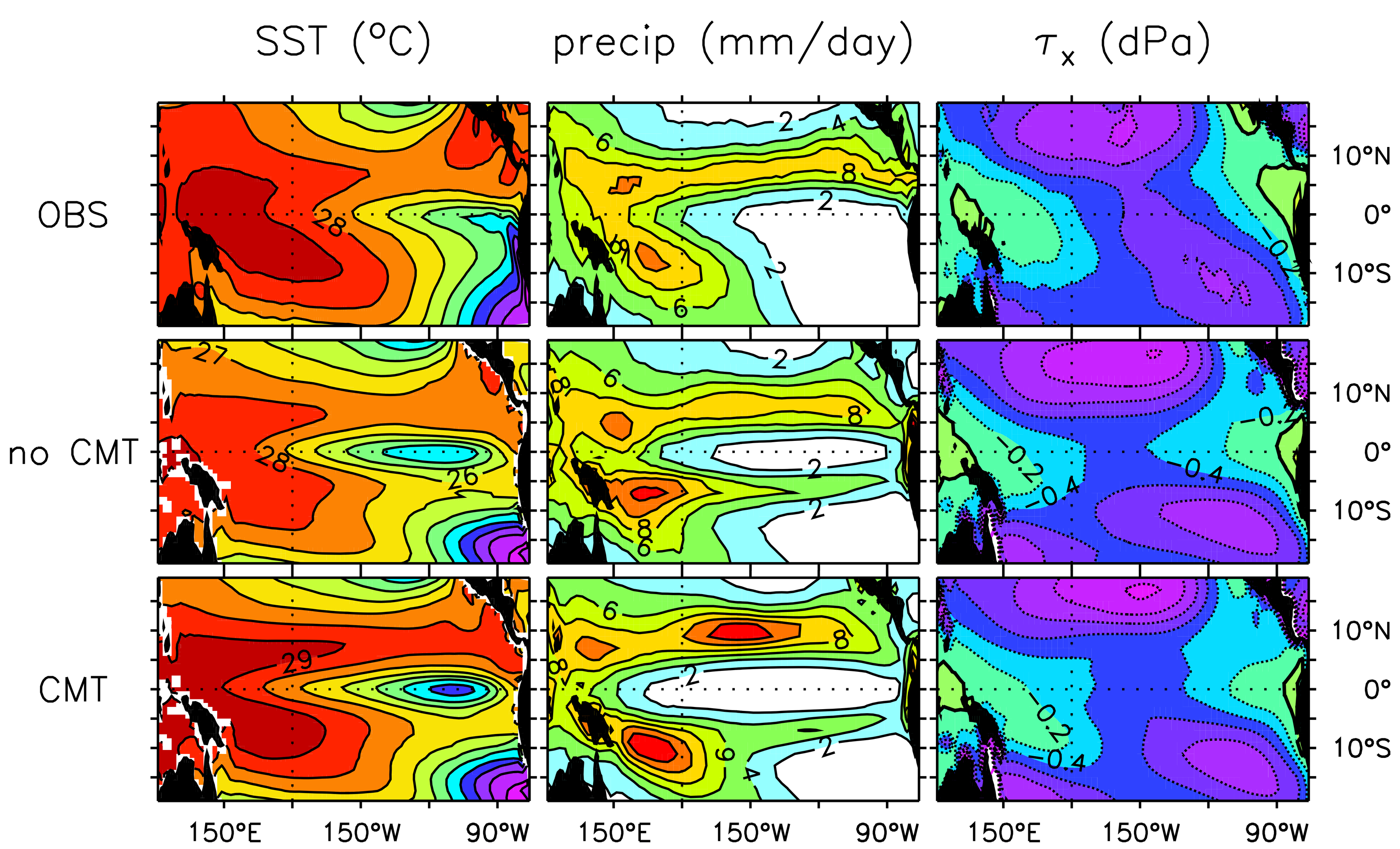
Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey

1. Introduction

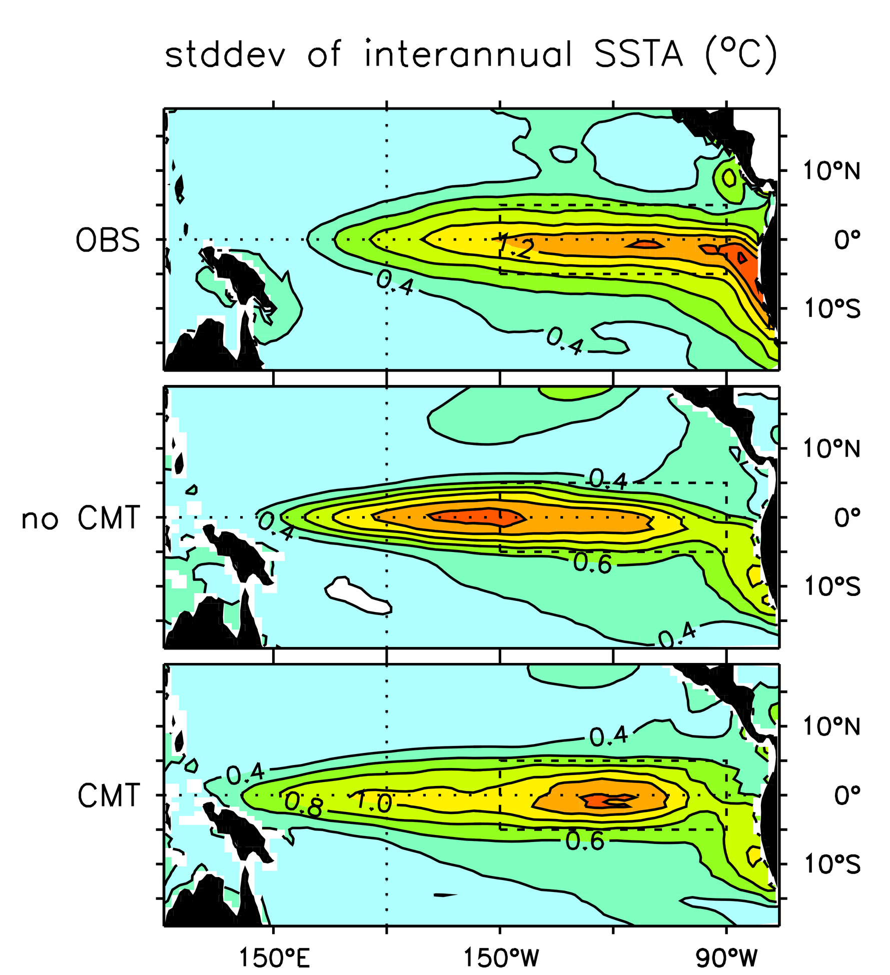
Development of the Geophysical Fluid Dynamics Laboratory (GFDL) coupled GCM has revealed interesting sensitivities of the El Niño/Southern Oscillation (ENSO) to parameterizations of unresolved processes. Understanding these sensitivities may shed light on how ENSO works in nature, and suggest solutions for common problems simulating ENSO in coupled GCMs.

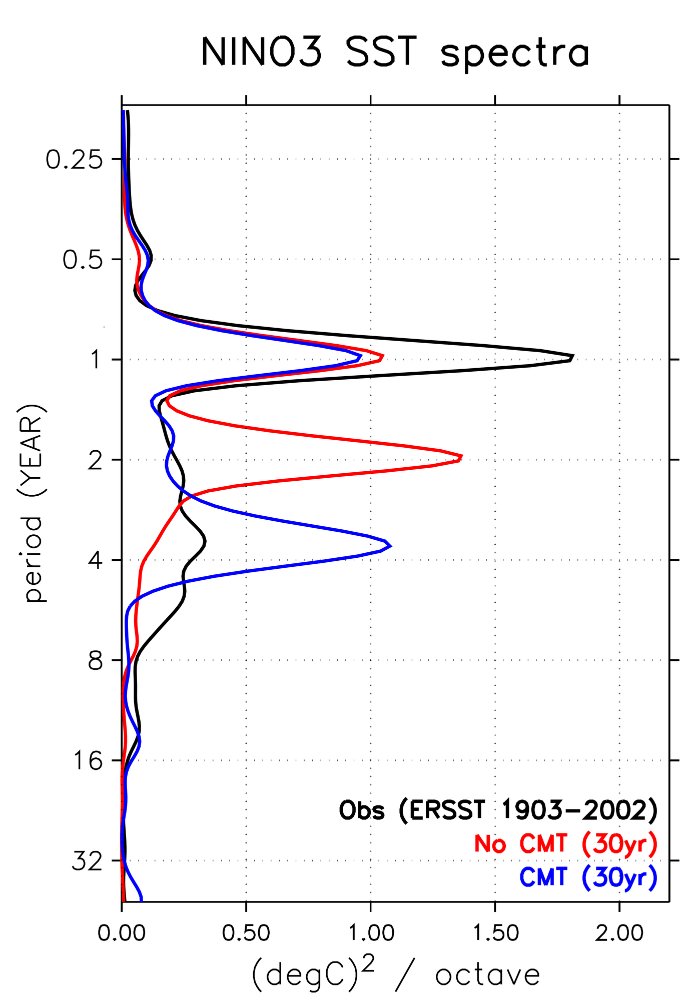
2. Case Study: Cumulus Momentum Transport

A parameterization of atmospheric cumulus momentum transport (CMT) has strong impacts on ENSO in the coupled model. The CMT scheme generates a vertical diffusion of horizontal momentum in regions of convection, with diffusivity proportional to the mass flux generated by the RAS convection scheme. Coupled simulations with CMT show dramatically weaker transient eddies, and a change in the time mean climate of the tropical Pacific:



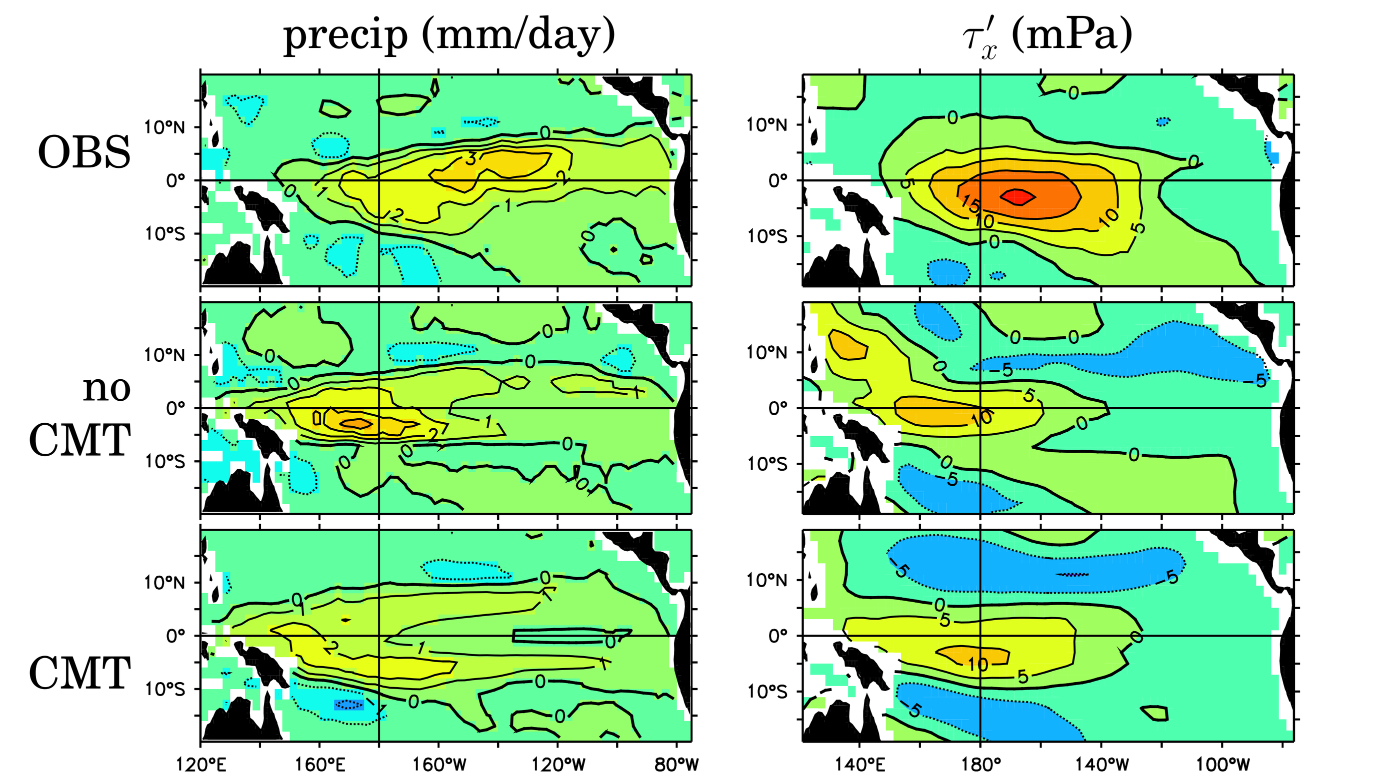
CMT also affects the simulated ENSO: sea surface temperature anomalies shift eastward, and the oscillation period increases from 2.0 to 3.6 years:





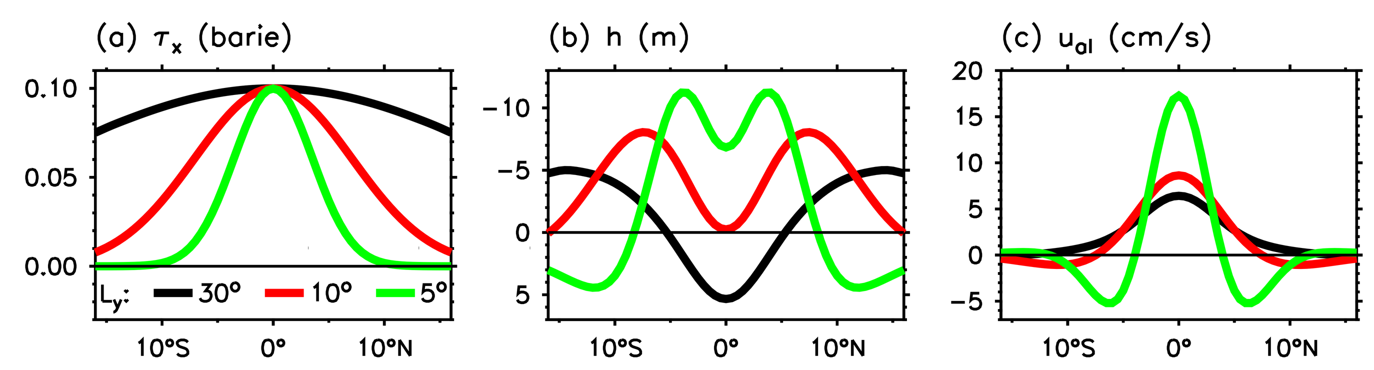
3. Why Does CMT Affect ENSO?

Coupled simulations show a change in the atmospheric response to SST anomalies when CMT is present. The precipitation and zonal wind stress (τ_x) anomalies—shown below regressed onto eastern equatorial Pacific (NINO3) SST anomalies—spread southeastward and widen meridionally.



4. Clues From Intermediate Models

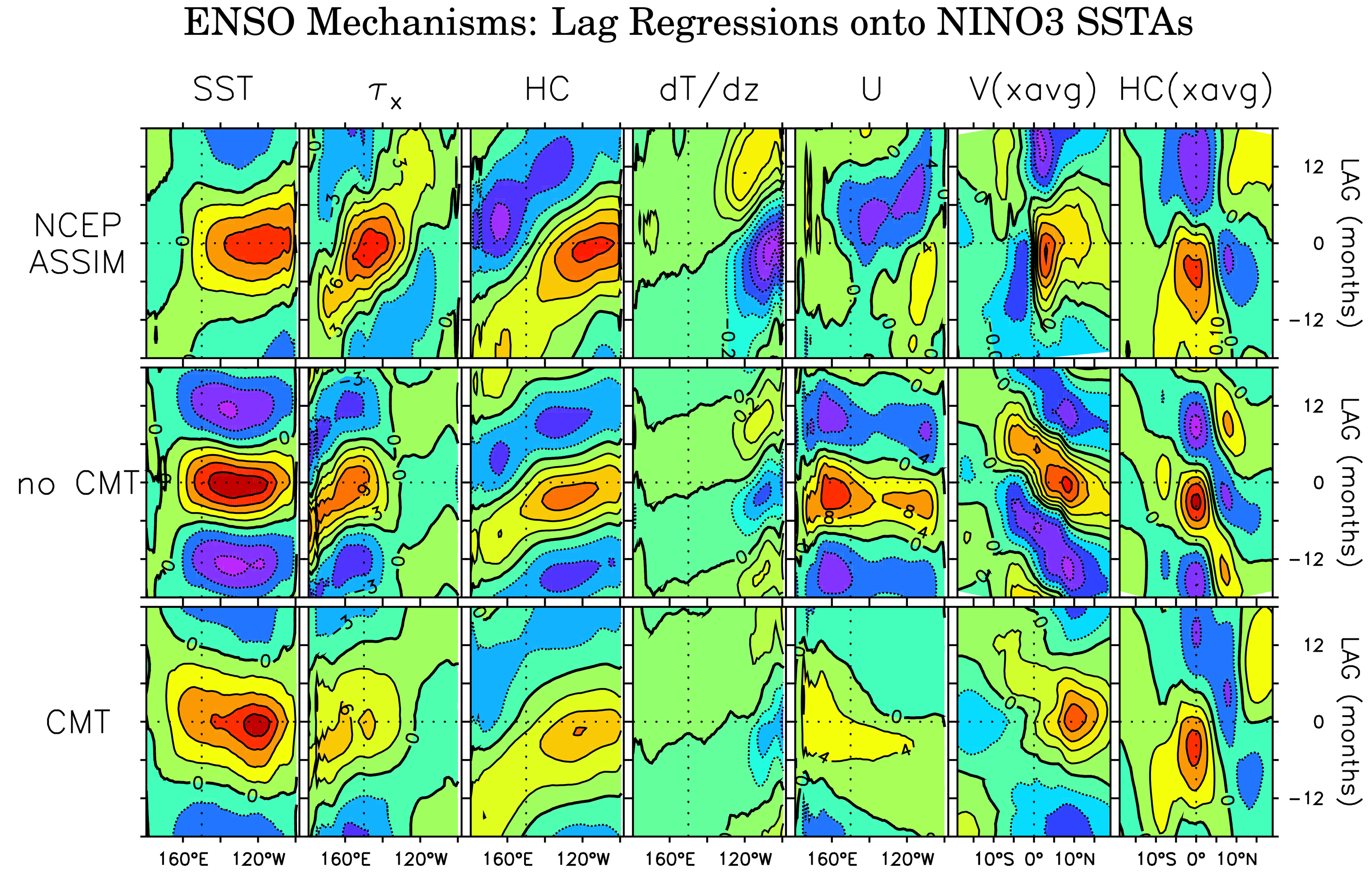
The meridional structure of the wind stress affects the delayed adjustment of the equatorial thermocline depth (h) and zonal currents (u):



Intermediate model studies (Kirtman 1997; An and Wang 2000; Wittenberg 2002) suggest that

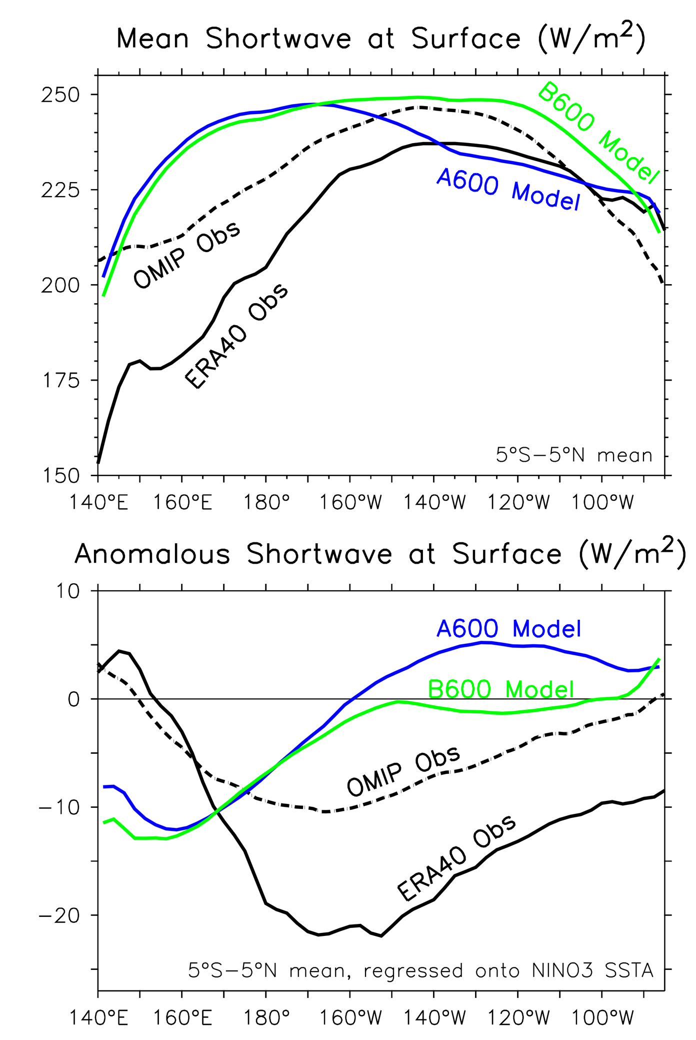
as τ_x' widens ⇒ weaker discharge, weaker u' ⇒ longer period
as τ_x' shifts east ⇒ u' less of a transitioner ⇒ longer period

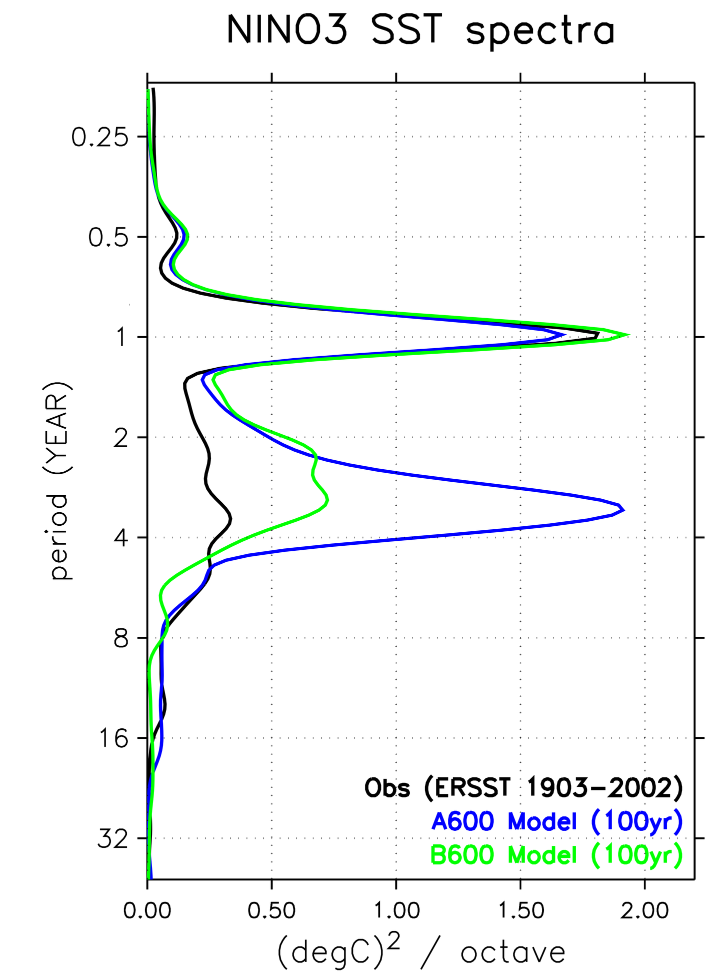
ENSO Mechanisms: Lag Regressions onto NINO3 SSTAs



5. ENSO Sensitivity to Cloud Feedbacks

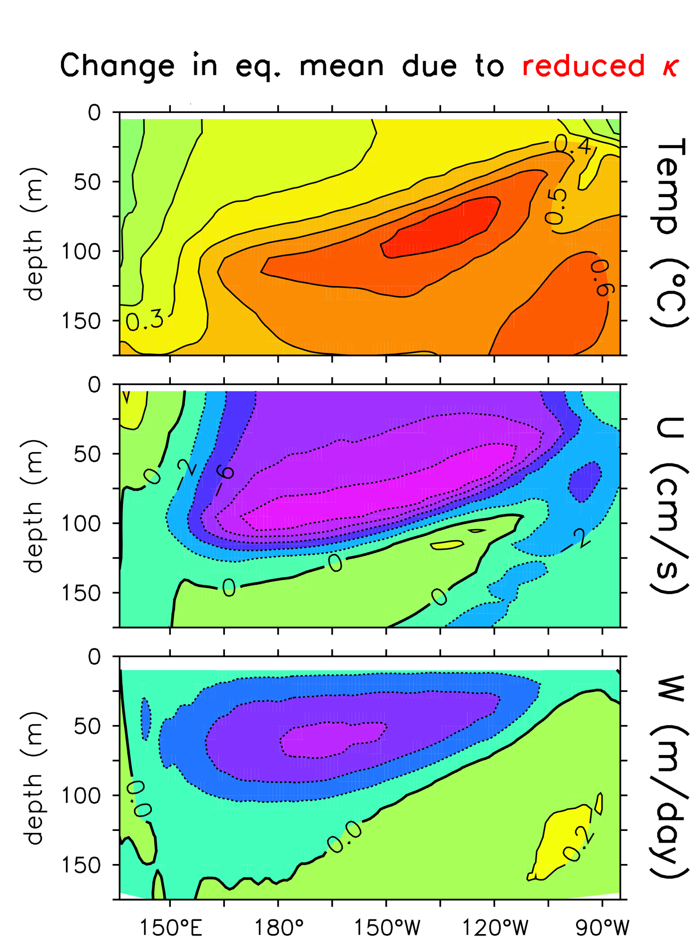
Changes in the AGCM boundary layer and cloud schemes, which were aimed at reducing excessive cloudiness over the equatorial cold tongue, also tamed the model ENSO by increasing the heat flux damping of SSTAs:

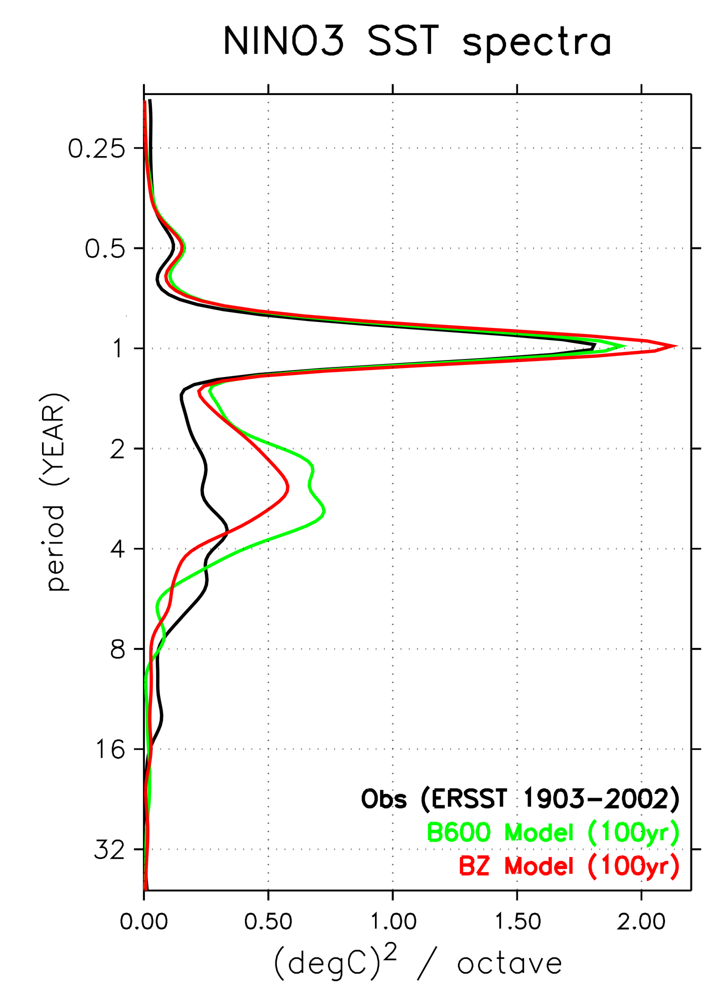




6. ENSO Sensitivity to Ocean Mixing

To reflect the observed spatial inhomogeneity of oceanic mesoscale eddies, a variable diffusivity κ was included in the Gent-McWilliams (GM) mixing scheme. Compared to a run with constant $\kappa = 600\ \mathrm{m}^2\ \mathrm{s}^{-1}$, the variable scheme (with $\kappa = 100\ \mathrm{m}^2\ \mathrm{s}^{-1}$ at the equator) acts to weaken the climatological cold tongue, the mean equatorial upwelling, and ENSO.





References

An, S.-I., and B. Wang, 2000: Interdecadal change of the structure of the ENSO mode and its impact on the ENSO frequency. *J. Climate*, **13**, 2044–2055.

Kirtman, B. P., 1997: Oceanic Rossby wave dynamics and the ENSO period in a coupled model. *J. Climate*, **10**, 1690–1704.

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*Address for correspondence: Dr. Andrew T. Wittenberg, US DOC/GFDL, Princeton University Forrestal Campus, US Route 1, Princeton, NJ 08542. Email: Andrew.Wittenberg@noaa.gov