ENSO Asymmetry in CMIP5 Models

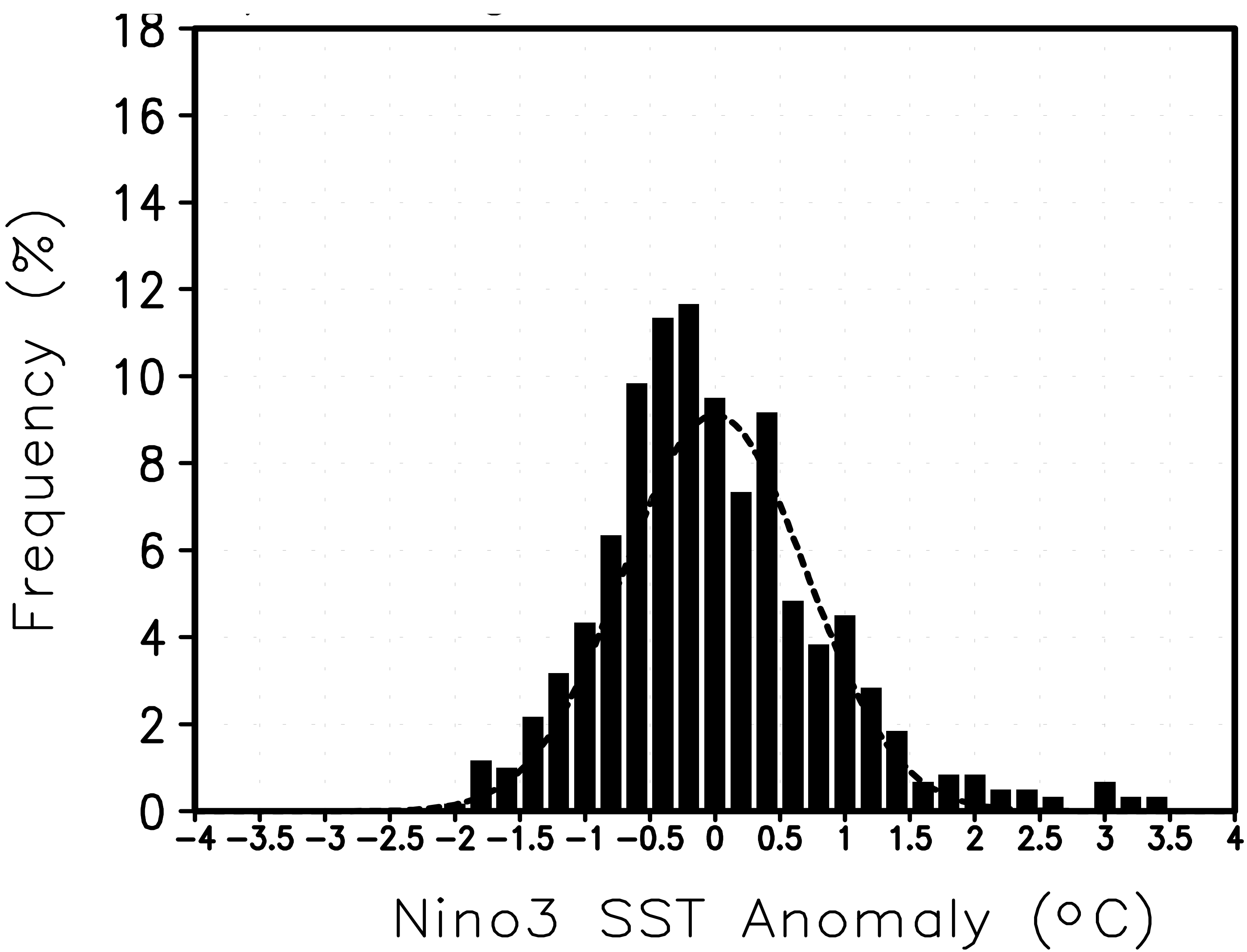
De-Zheng Sun
CIRES, University of Colorado &
Earth System Research Laboratory, NOAA
http://www.noaa.gov/psd/people/dezheng.sun

Acknowledgement:
Jiabing Shuai, Yan Sun, Tao Zhang

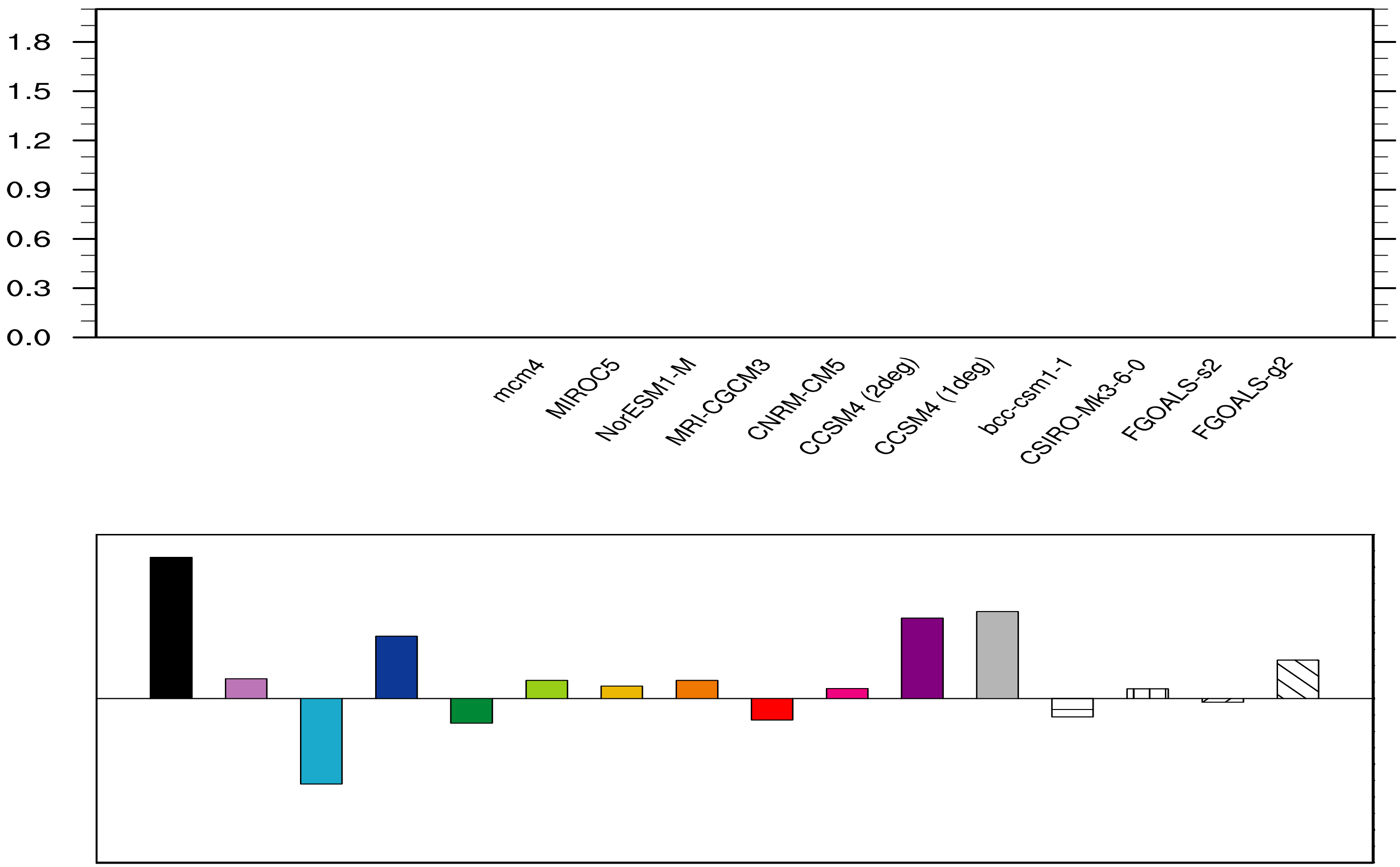
Outline

- ENSO Asymmetry in CMIP5 Models
- The Climatological Equatorial Cold-tongue (Warm-pool) in CMIP5 models
- Excessive cold-tongue (or smaller warm-pool) and Weak ENSO asymmetry: Are They Linked?
- An atmospheric root-cause for the excessive cold-tongue and weak ENSO asymmetry?

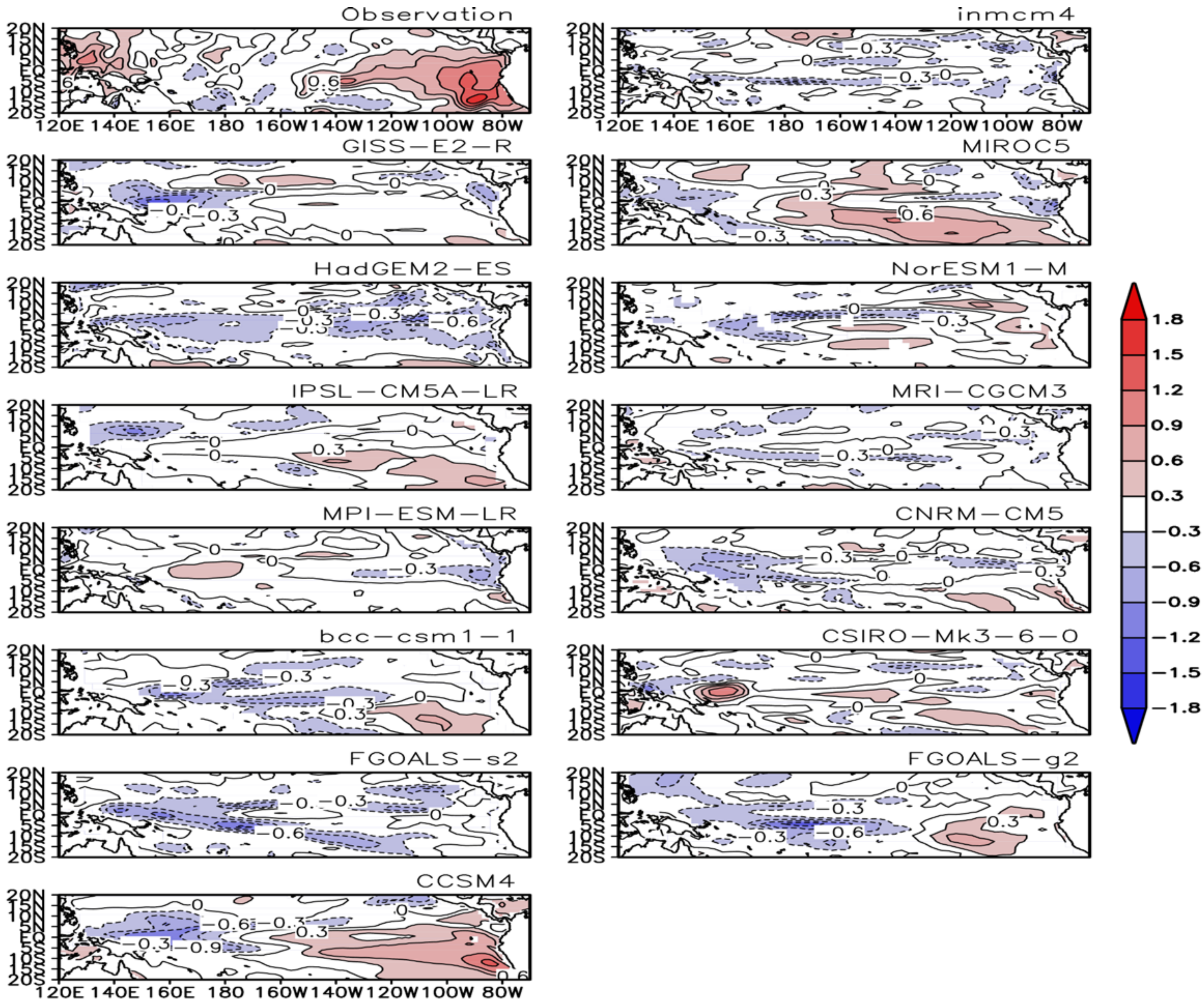
What is ENSO asymmetry?



ENSO Amplitude & Asymmetry in CMIP5 Models

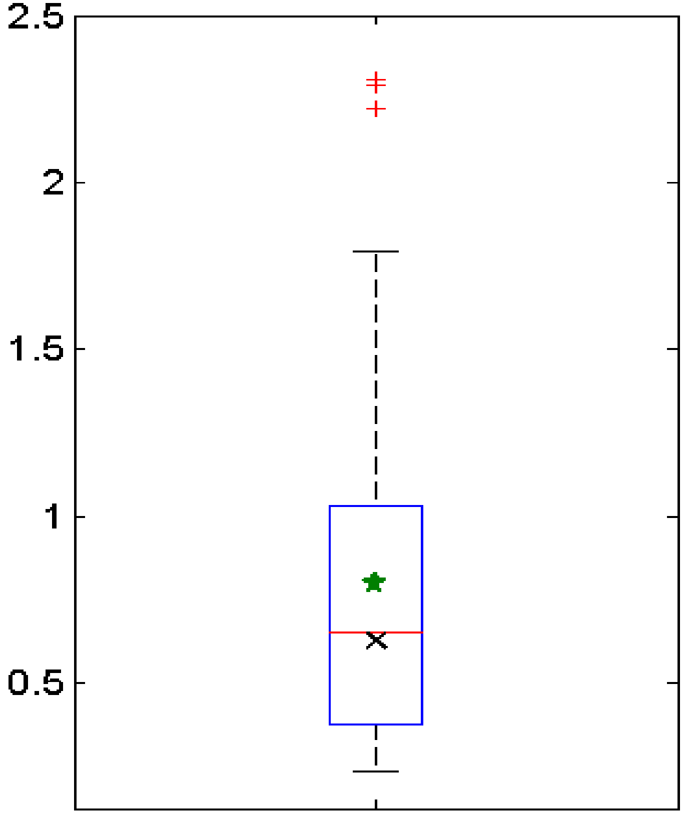


SST skewness pattern from CMIP5 coupled models

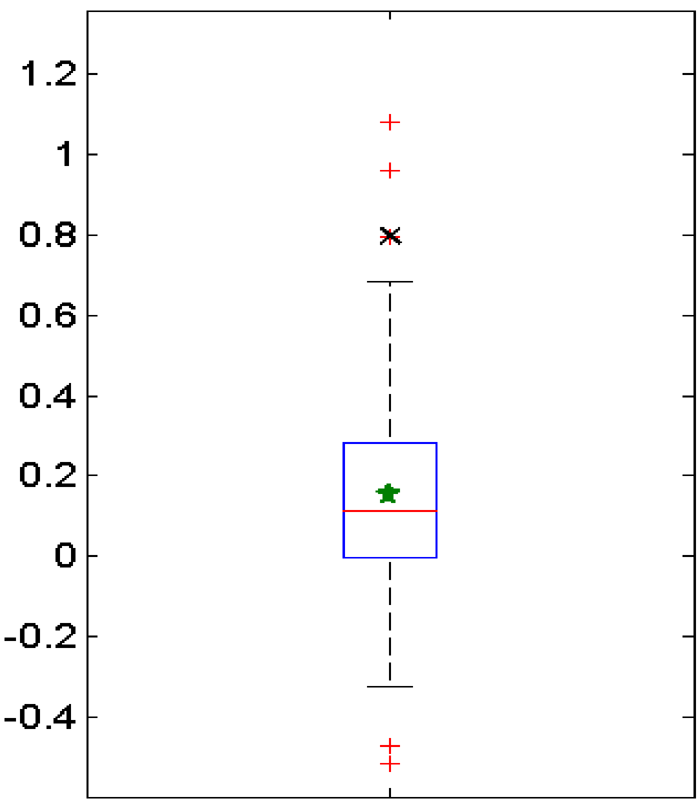


ENSO Amplitude and Asymmetry in CMIP5 Models

Box plot for variance

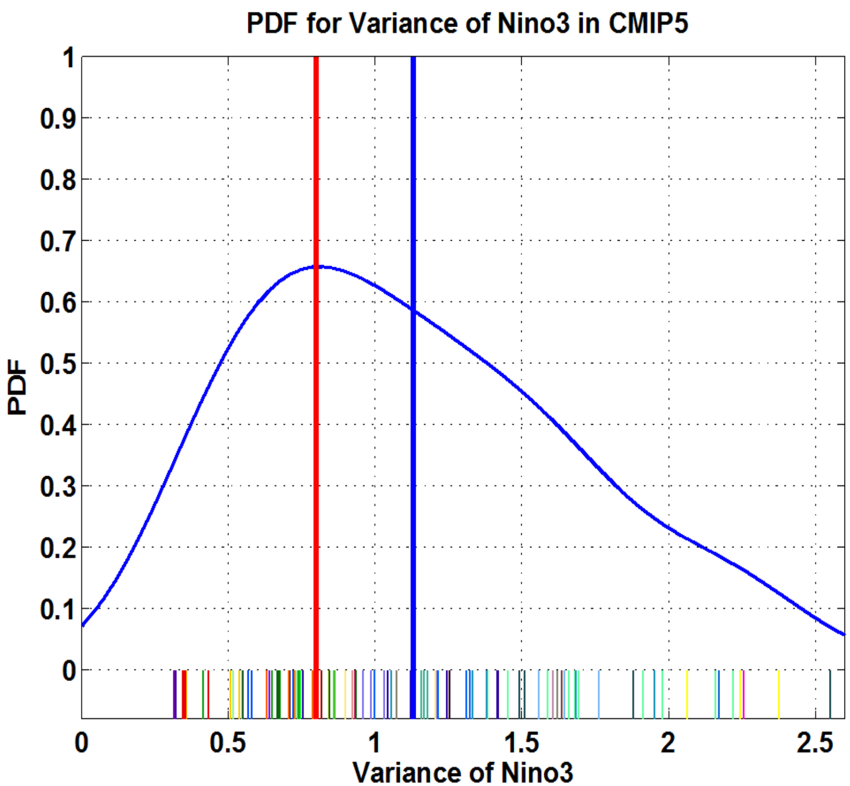


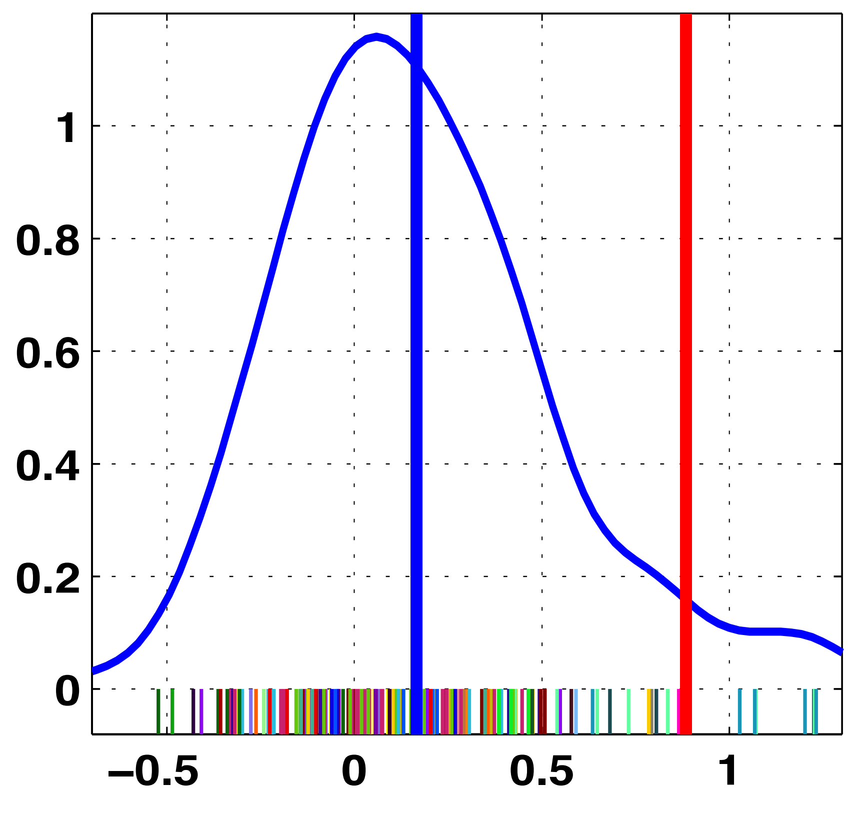
Box plot for Skewness



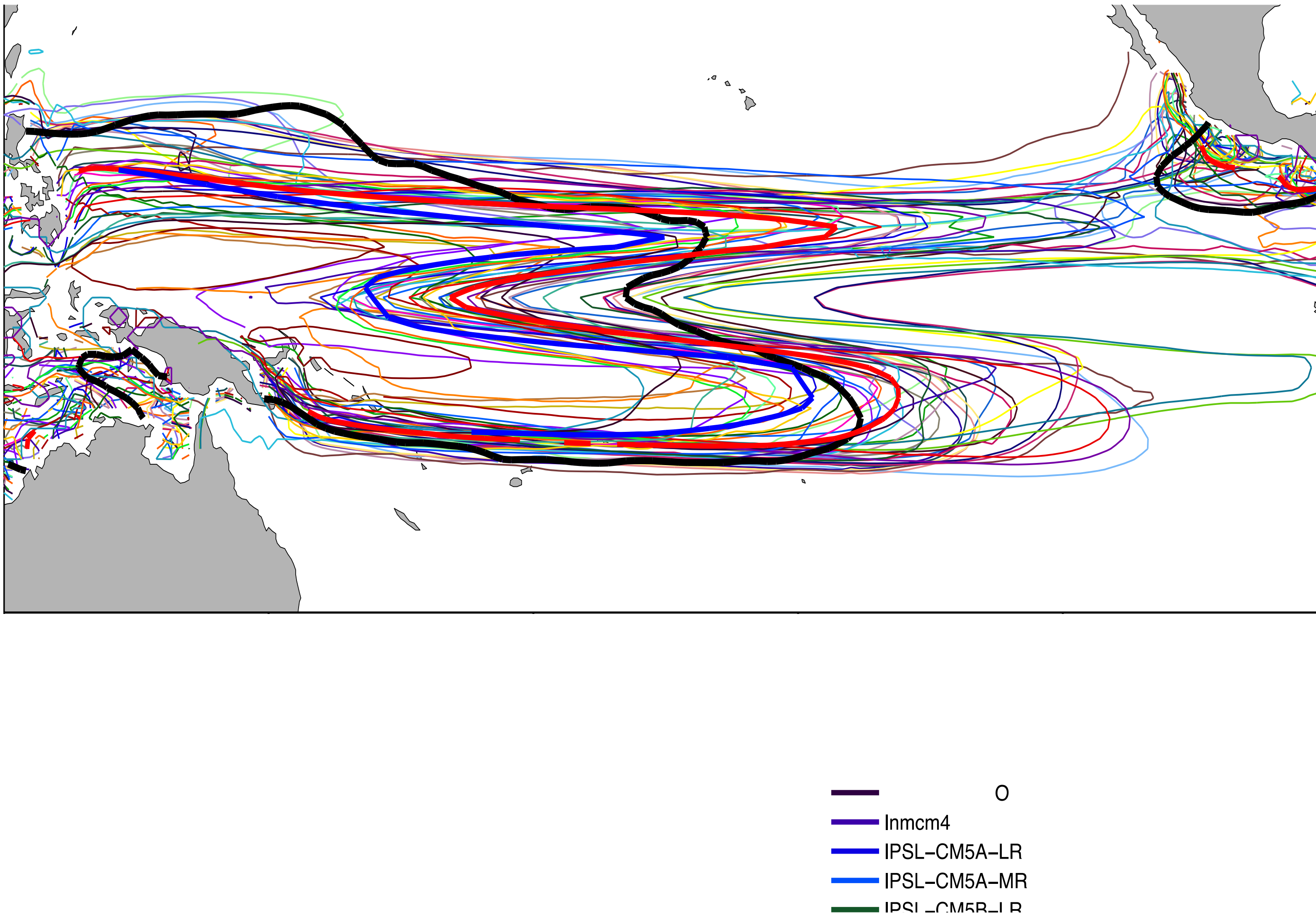
ENSO Amplitude and Asymmetry in CMIP5 Models

Probability Density Distribution of Variance (left) and Skewness (right) of Nino3 SST Across the Multi-Model, Multi-Run Ensemble of CMIP5

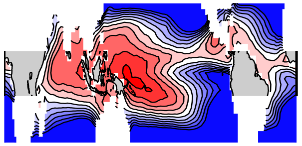




The Excessive Cold-tongue



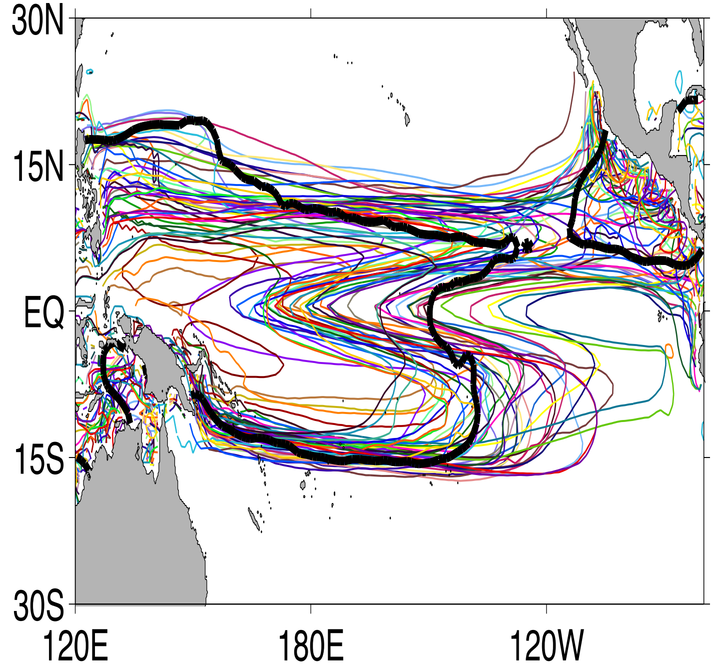
The Excessive Cold-tongue

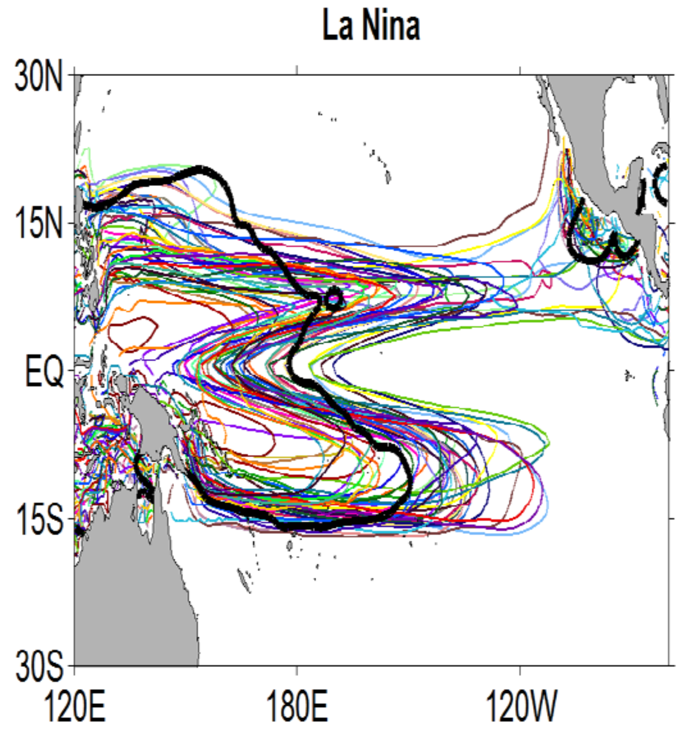


30

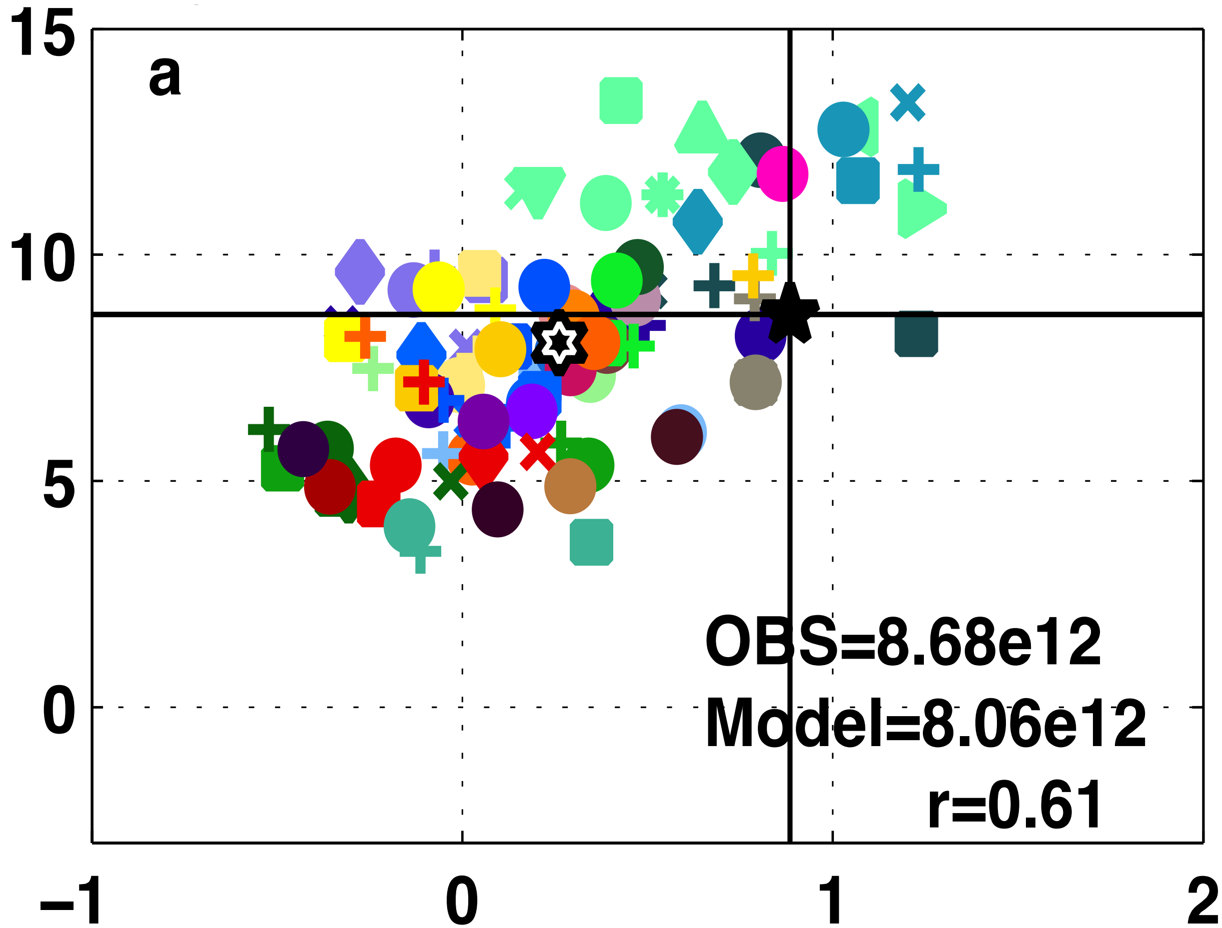
9.5

The Cold-tongue stratified by the two phases of ENSO

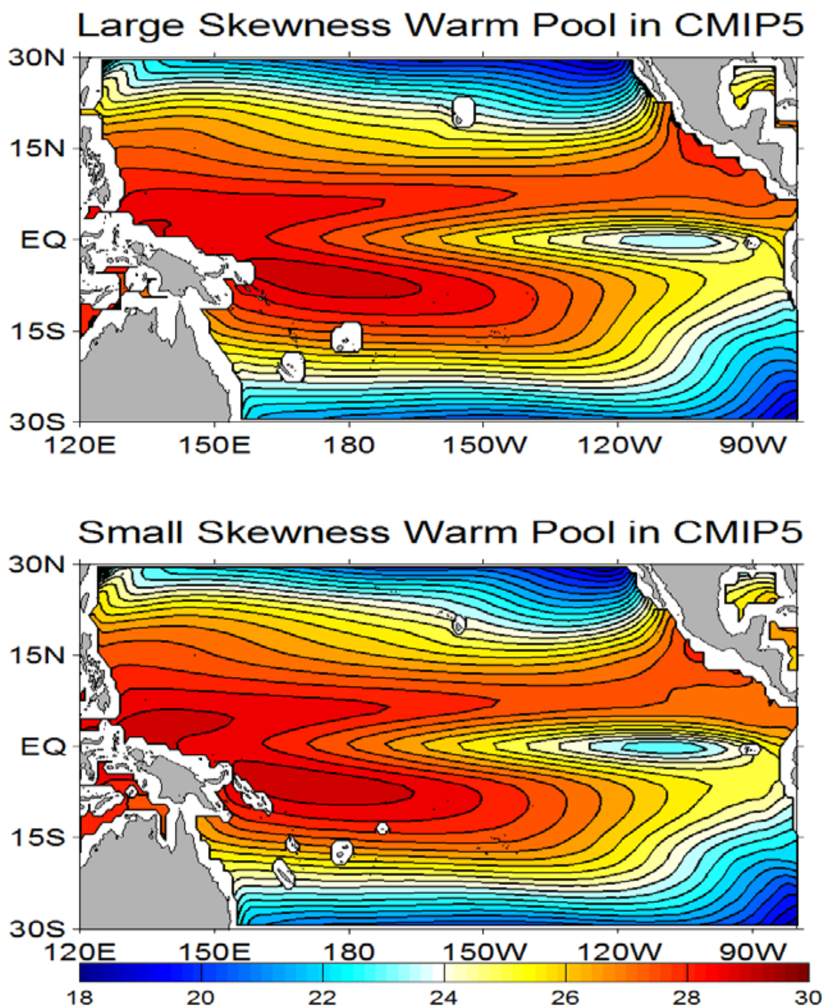


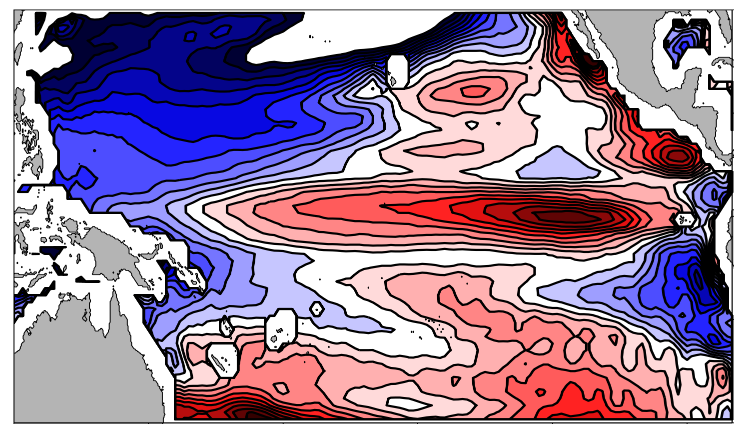


Correlation of ENSO asymmetry with warm-pool size differences



Differences in the Mean SST between models with above-average ENSO asymmetry and those with below average ENSO asymmetry





Biases in the warm phase and cold phase anomalies (ensemble mean)

Biases in the Mean SST (ensemble mean)

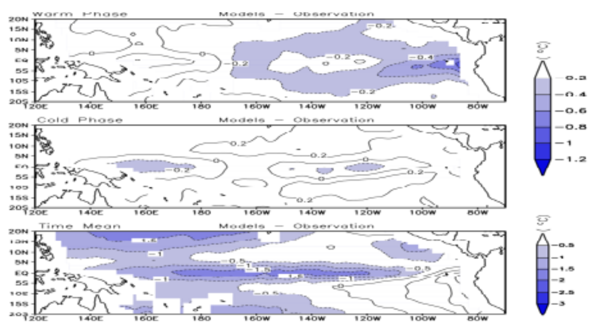
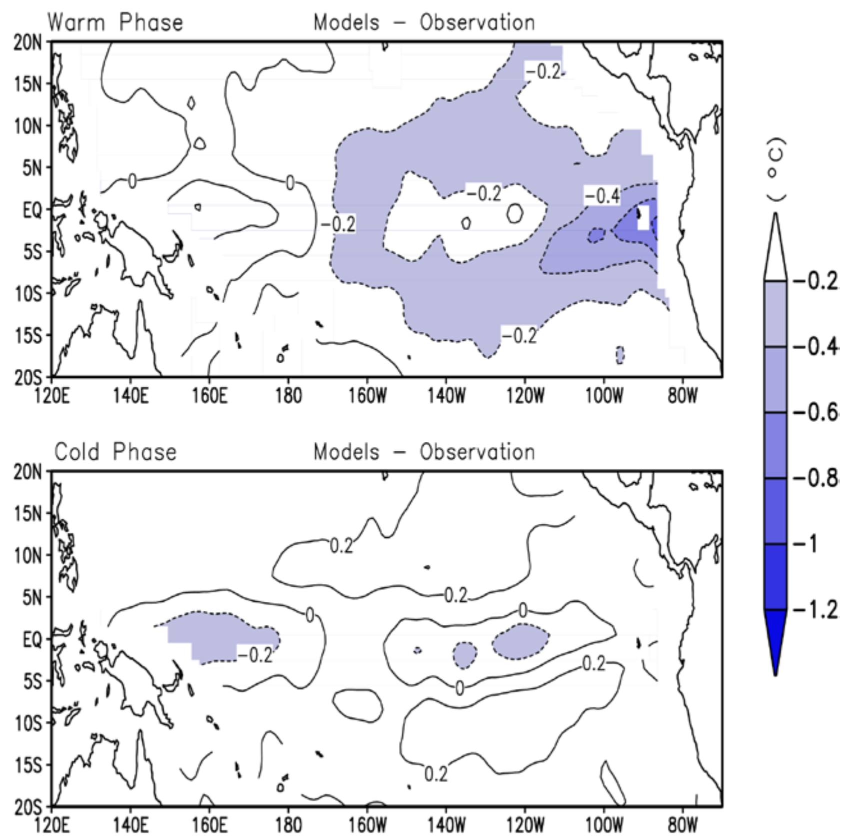


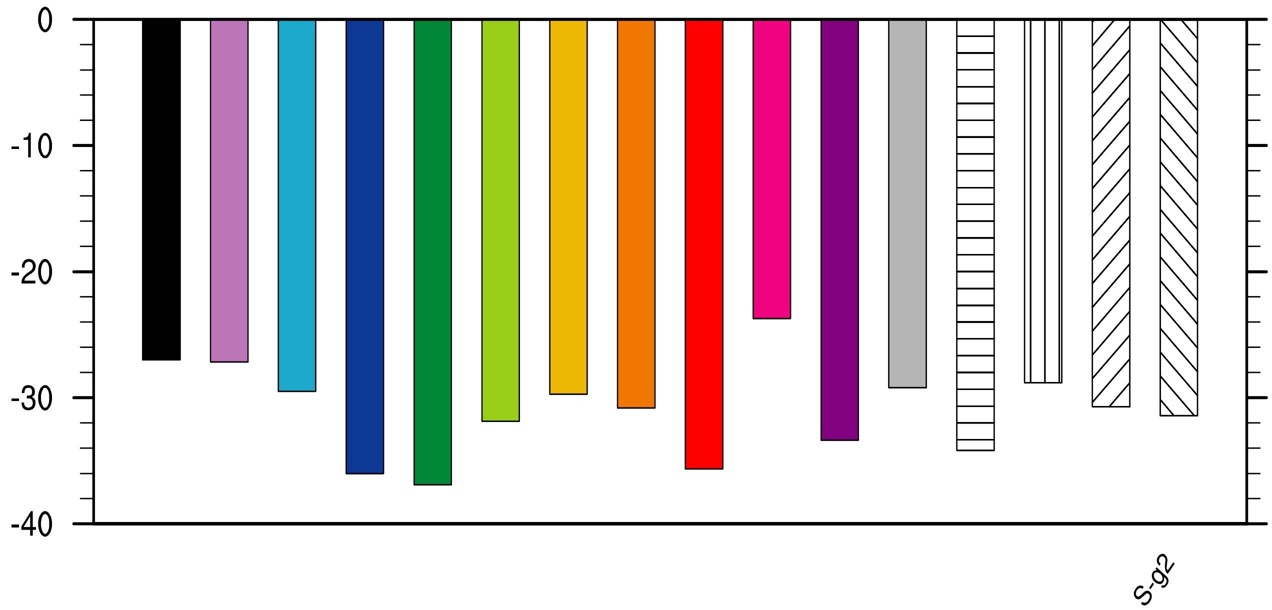
Figure 6: The difference between observations and ensemble mean composite SST anomalies for warm phase of ENSO (top), the difference between observations and ensemble mean composite SST anomalies for cold phase of ENSO (middle), and the difference between observations and ensemble mean SST annual climatology (bottom) from fourteen CMIP5 coupled models.

43

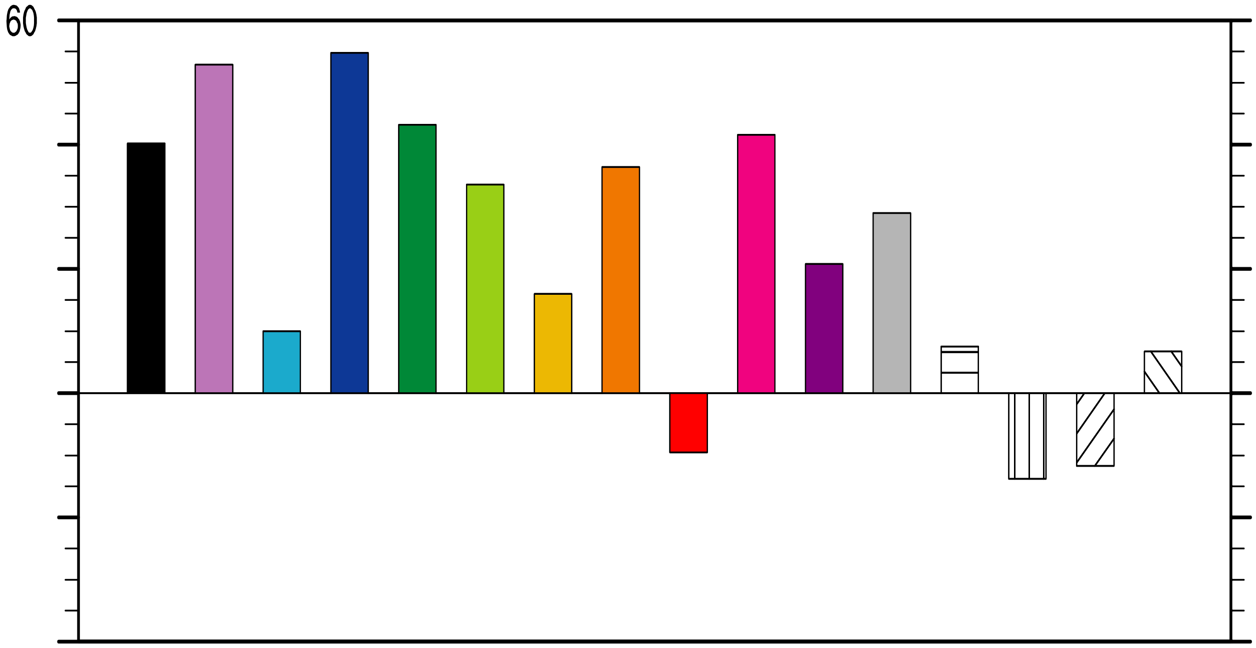


A Possible Cause of An Excessive Cold-tongue:

A too strong zonal wind in AMIP runs already ?



Skewness of equatorial zonal wind stress



Sensitivity of ENSO asymmetry to changes in mean zonal winds and skewness of the zonal wind anomalies

!

!!!!!!!! !!!Experiment!ID!!! (label!in!figures)!	!!!!!!Surface!wind!stress! !		!!!Statistics!of!Nino3!SSTA!!	
	Climatology!	!Anomaly!	Skewness!	!Standard! deviation(!ºC)!!
!!!Experiment!I!	Observation! ! !	Observation! !	!!!!1.16!	!!!!!!!0.75!
! !!!Experiment!II! (control)	CMIP5!!amip!! ensemble! !	Observation! !	!!!!0.92!	!!!!!!!0.73!
! !!!Experiment!III!	CMIP5!!amip! ensemble! !	CMIP5!!amip! ensemble! !	!!!!!0.70!	!!!!!!!!0.63!
! !!!Experiment!IV!	Observation! !	CMIP5!!amip! ensemble! !	!!!!!1.18!	!!!!!!!!0.64!

!

Wind-forced ocean GCM experiments suggest that the stronger time-mean zonal winds and weaker asymmetry in the inter-annual anomalies of the zonal winds in AMIP models can both be a contributing factor to a weaker ENSO asymmetry in the corresponding coupled models, but the former appears to be a more fundamental factor, possibly through its impact on mean SST and thereby stability the coupled system: deep convection is less responsive when the mean SST is cold.

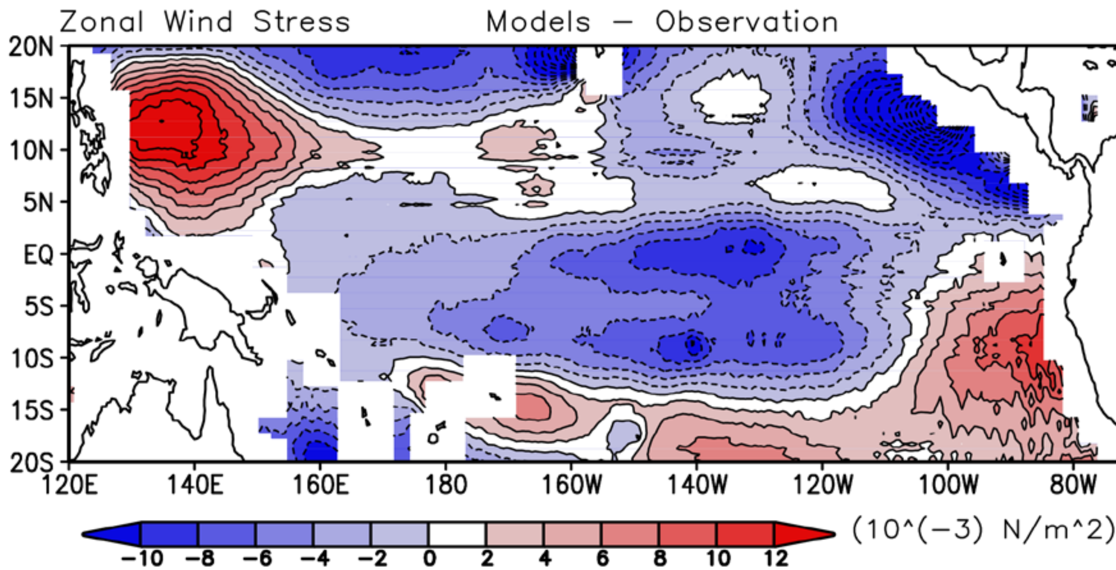
Summary

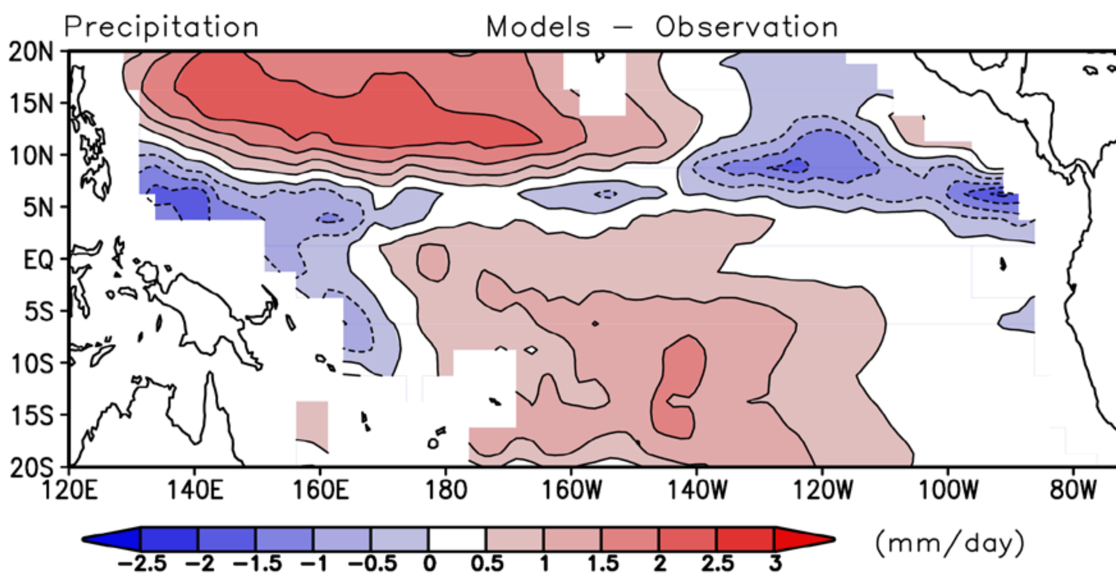
- Underestimate of ENSO asymmetry is a common bias in CMIP5 models, but some models are less biased than others. The NCAR CCSM4 stands out as the best model in simulating ENSO asymmetry!

- The common underestimate of ENSO asymmetry in the models appear to be linked to the prevalence of an excessive cold-tongue in the models.

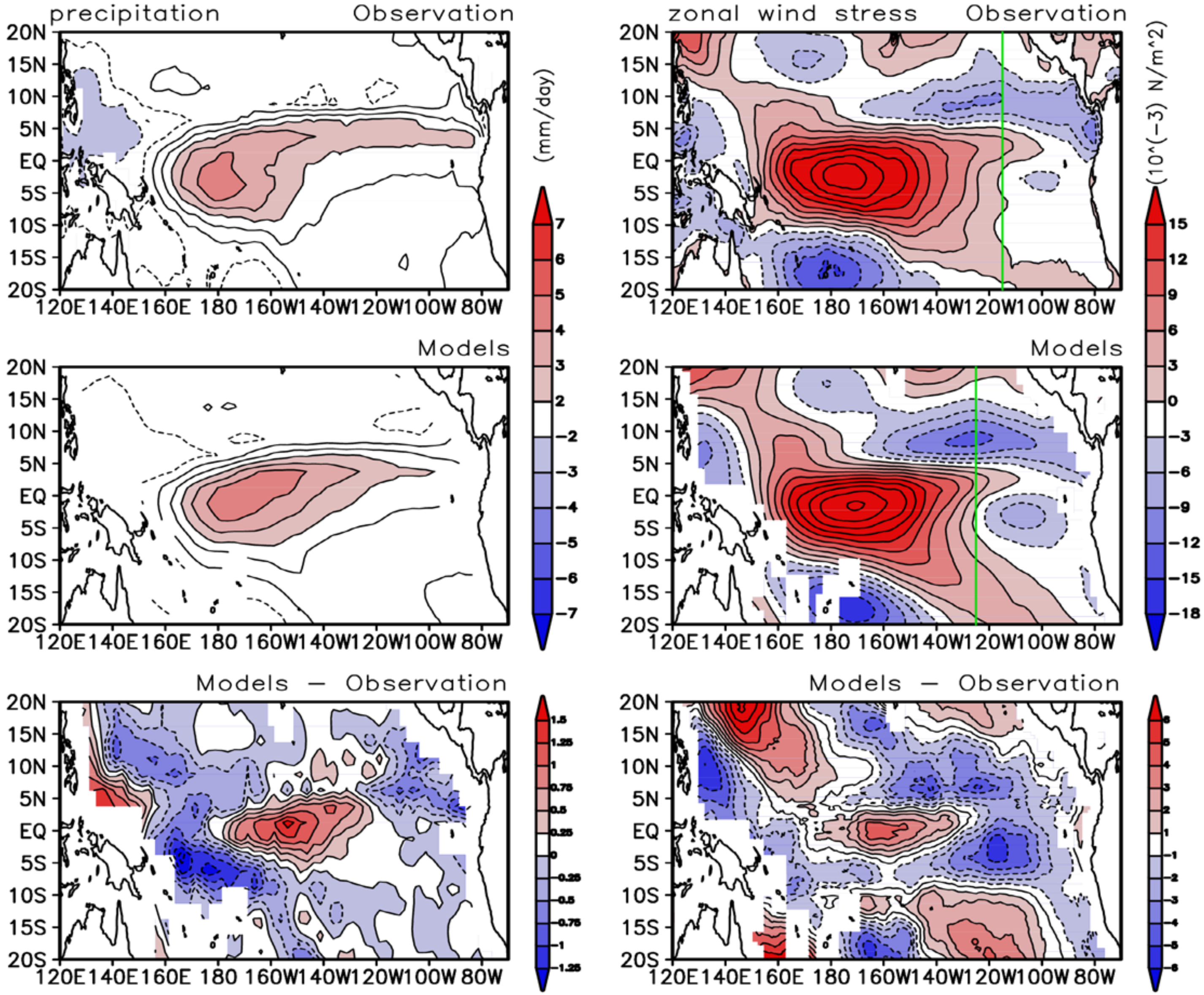
- The generally stronger zonal winds in the AMIP runs of the models than observations is suggested as a possible root cause of the development of an excessive cold-tongue in the coupled models.

Model-Obs. Differences in Mean Zonal Wind Stress and Precipitation

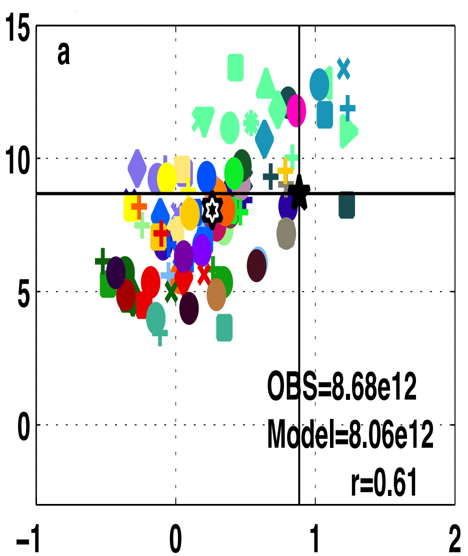




Warm Phase Precipitation and Zonal Wind stress in the AMIP runs



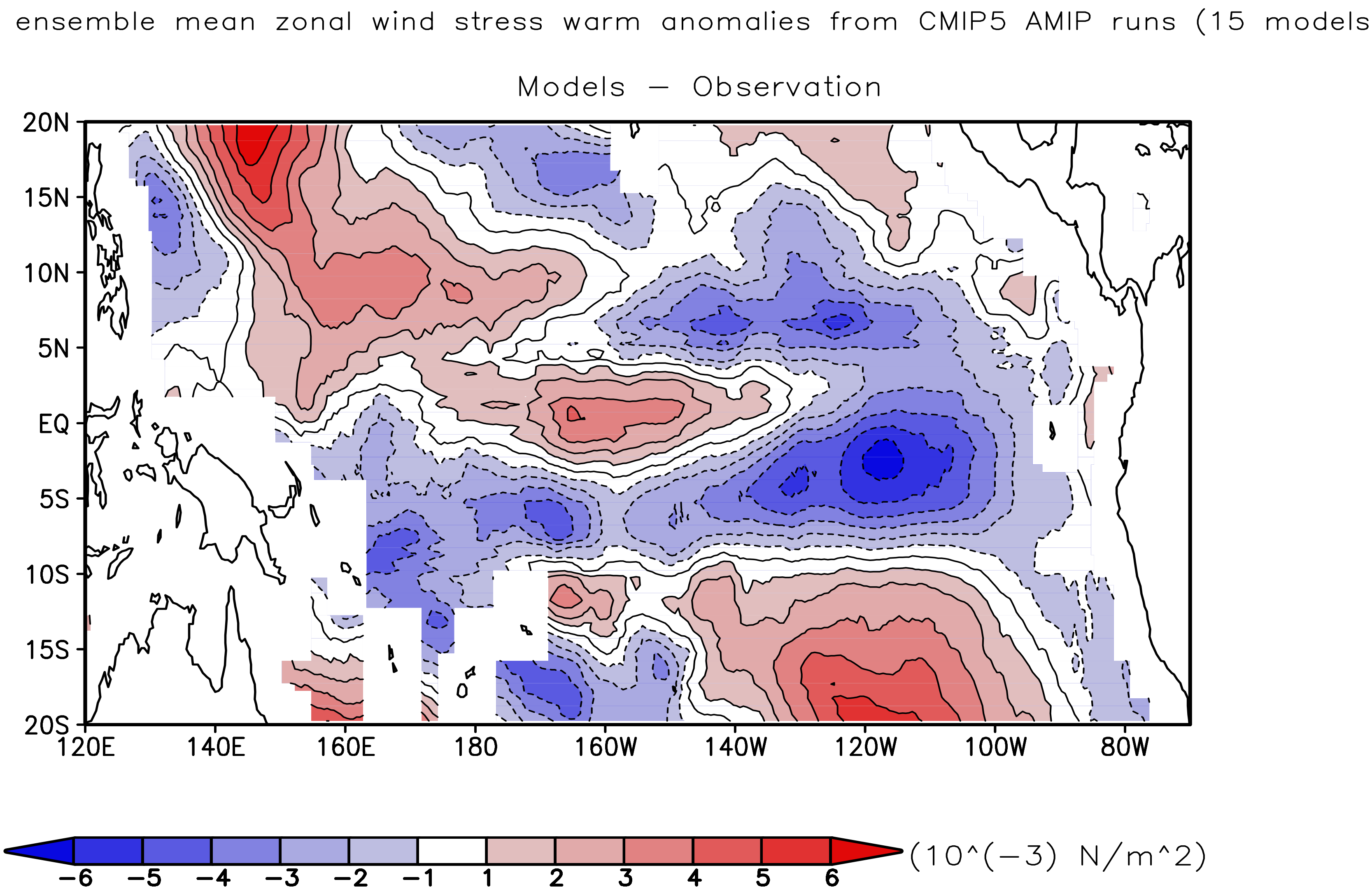
Correlation across models between ENSO Asymmetry and Warm-pool size



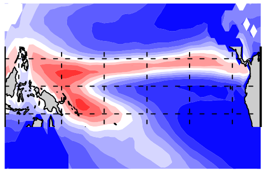
c

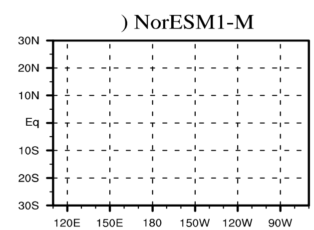
OBS=0.24
Model=0.24
r=0.46

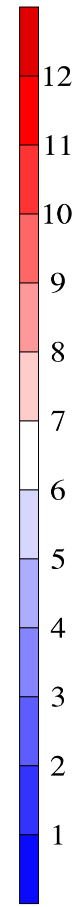
Ensemble mean warm anomalies from AMIP (15 models)
Models -OBS



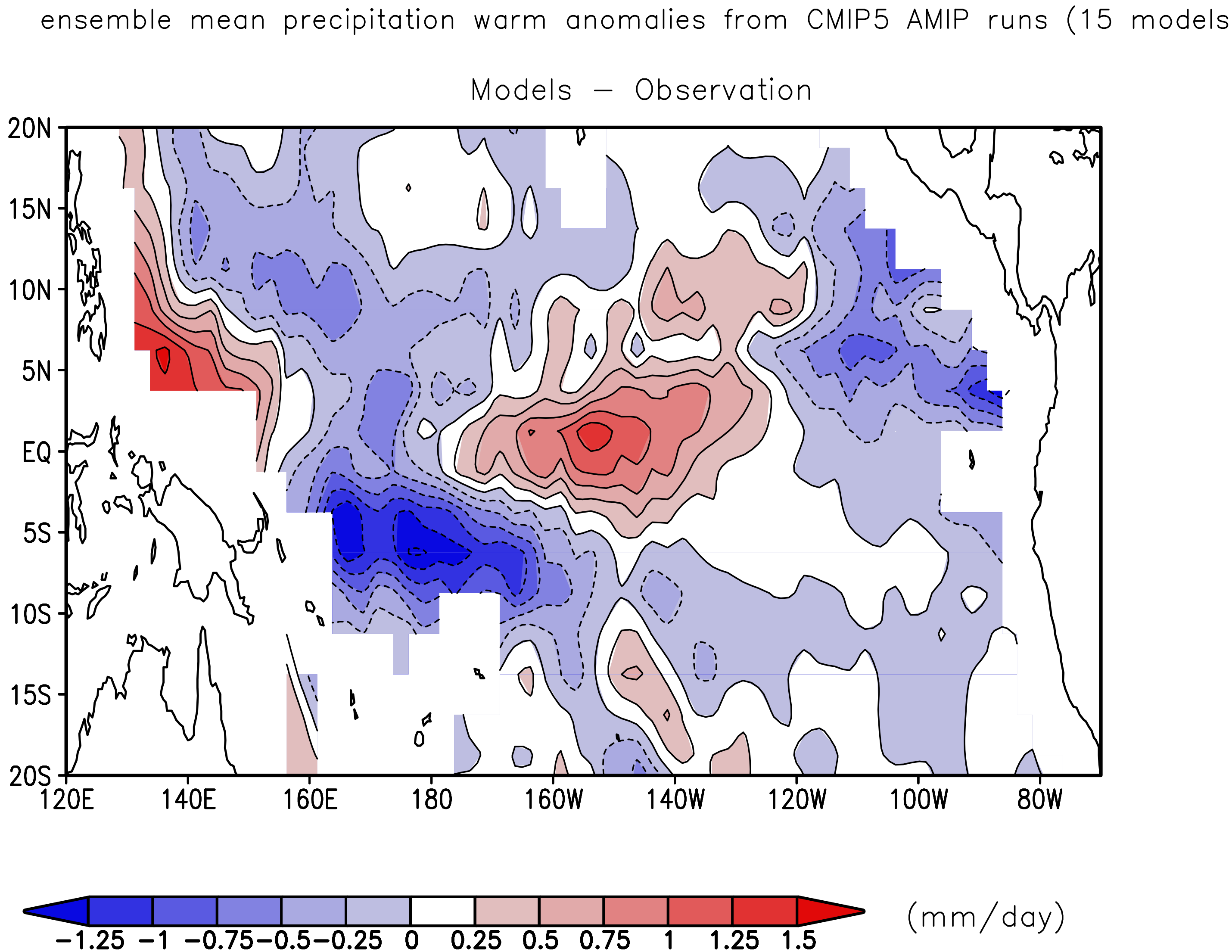
The Associated Double ITCZ Syndrome



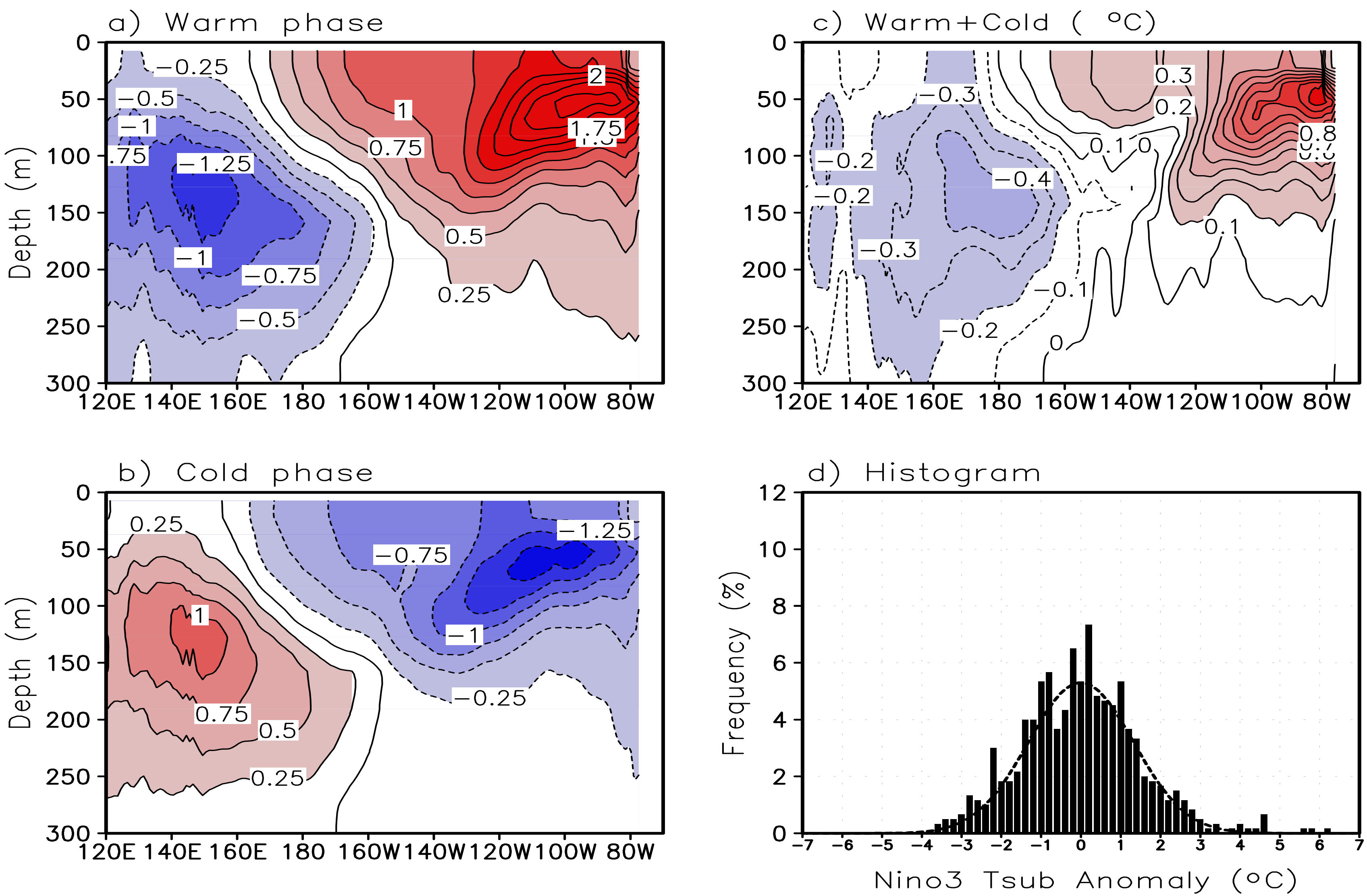




Ensemble mean warm anomalies from AMIP (15 models)
Models -OBS

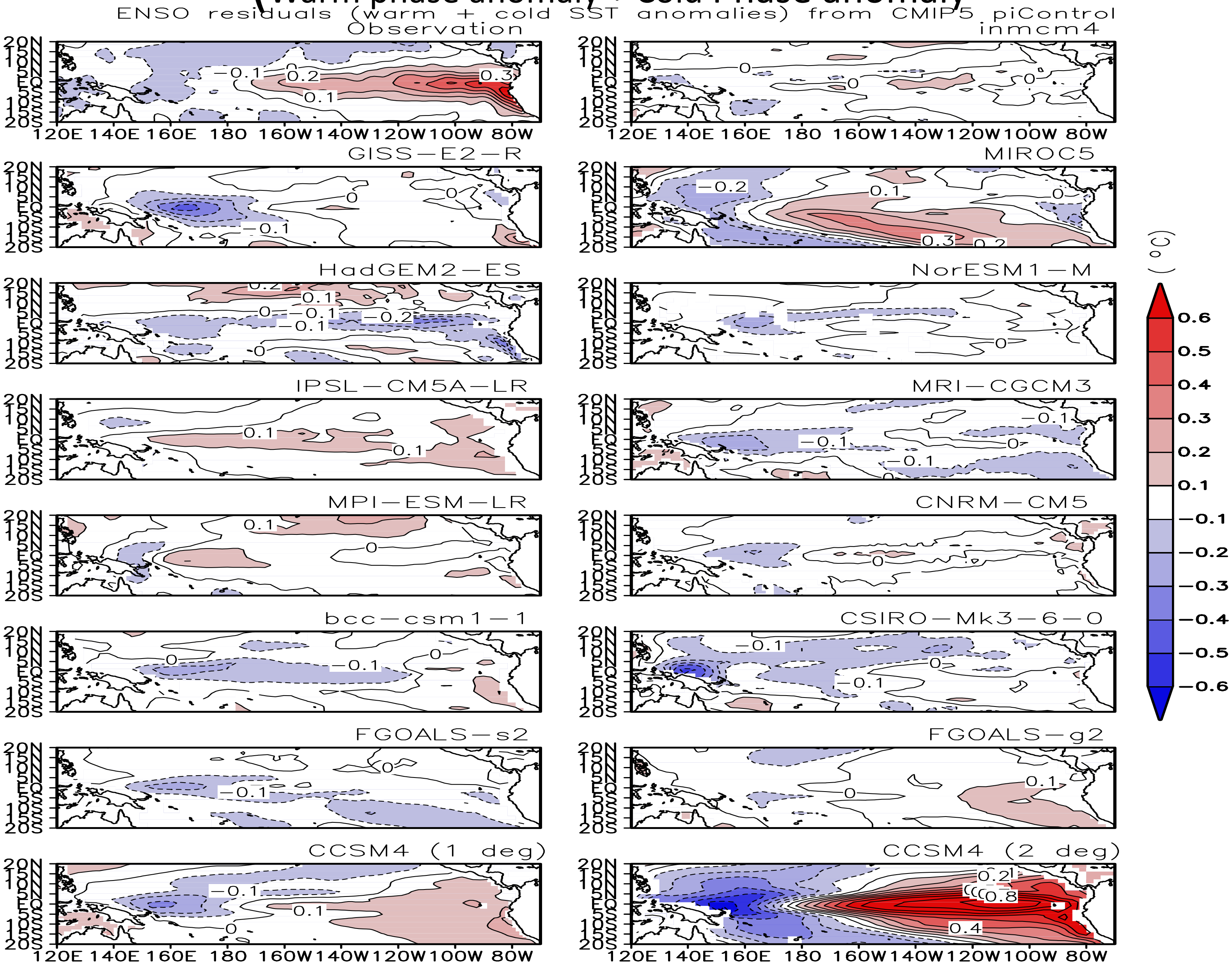


Asymmetry in the subsurface

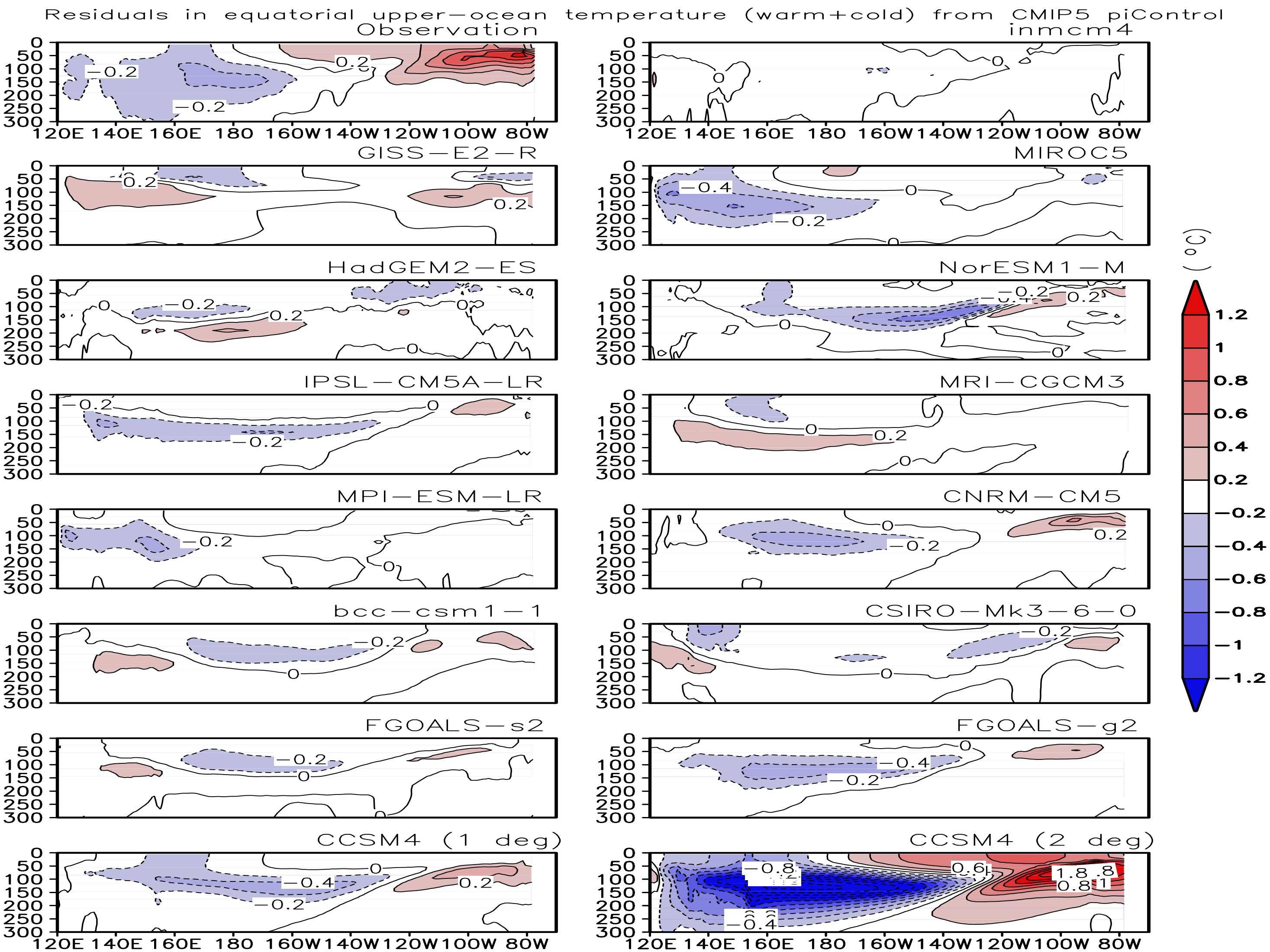


As Measured by SST Residual

(Warm phase anomaly + Cold Phase anomaly

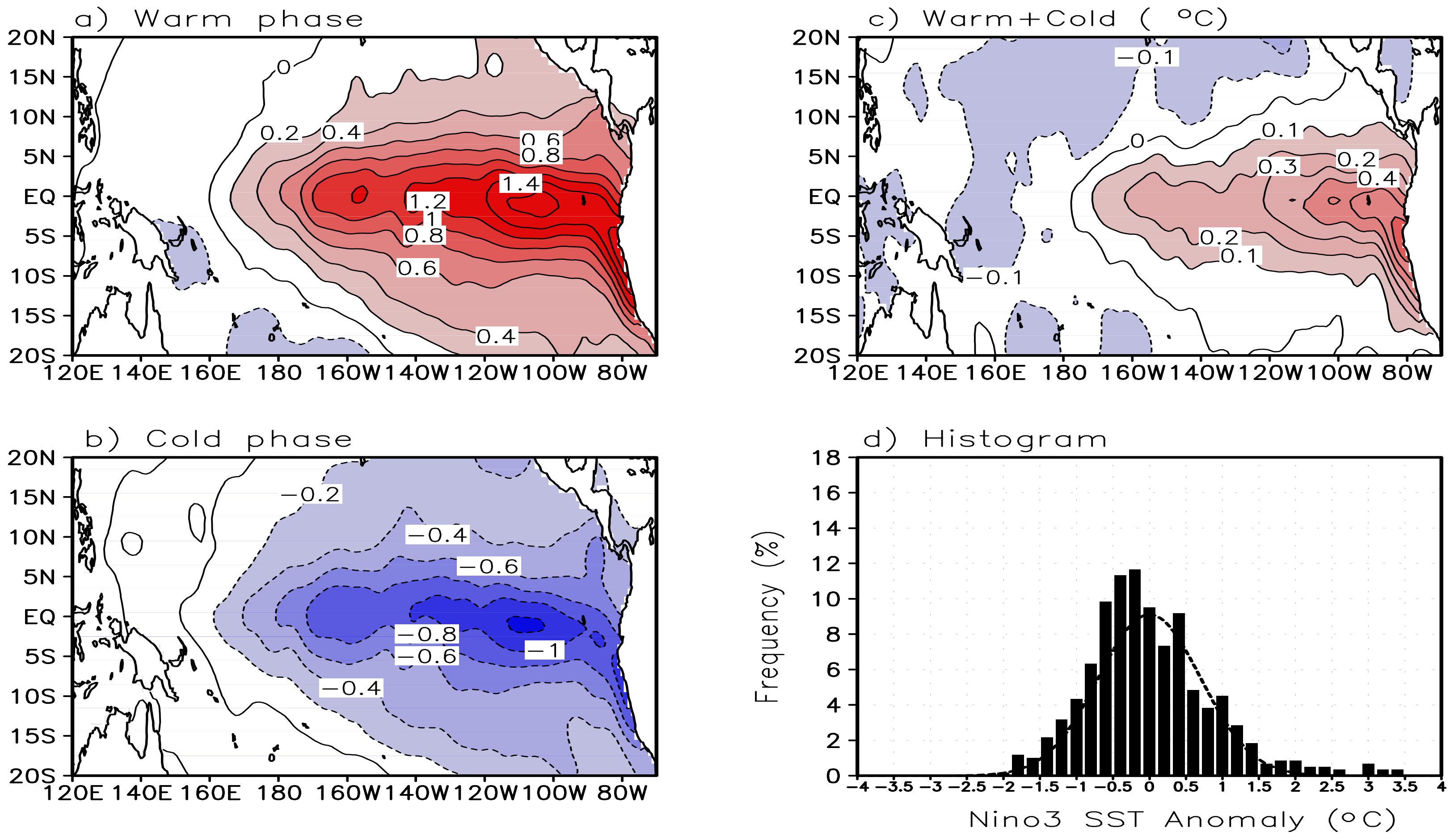


subsurface temp. residuals (warm+cold)

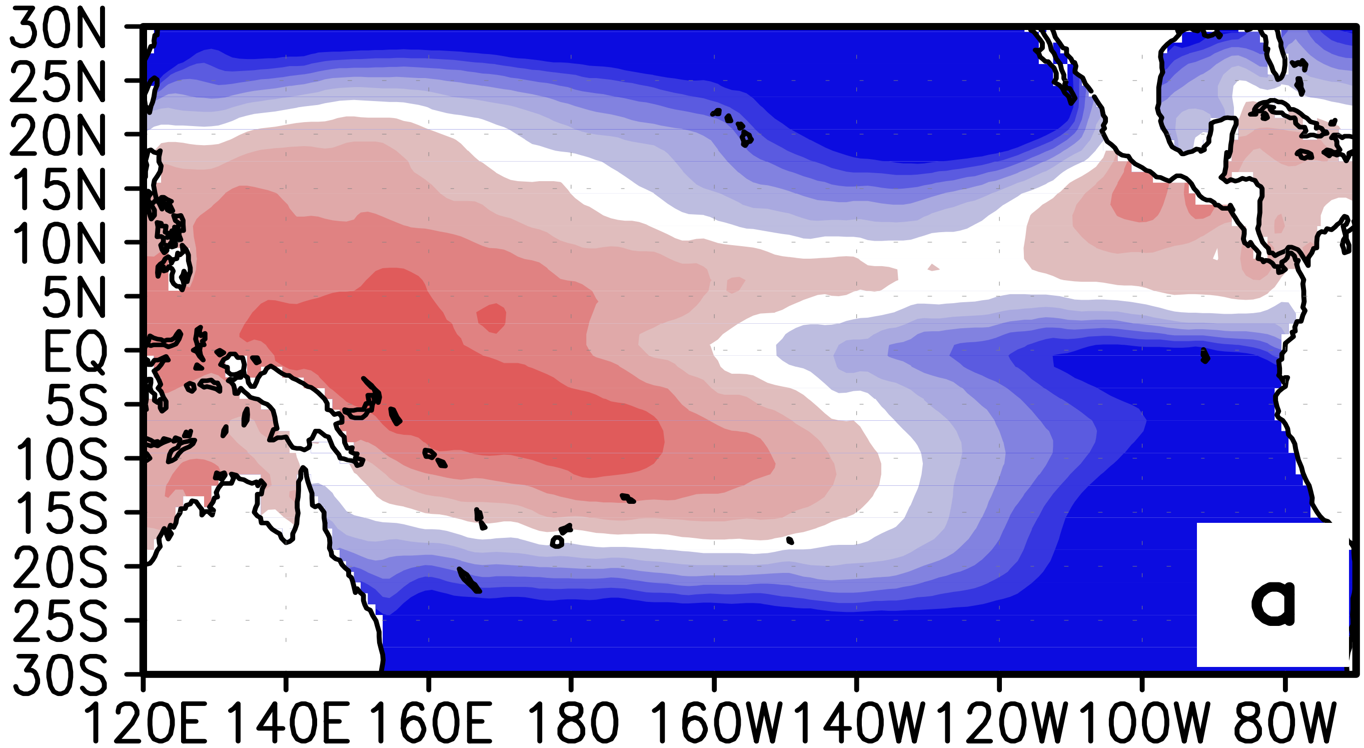


Consistent with SST residual, 2 deg CCSM4 has the strongest residual in subsurface temp.

What is ENSO asymmetry?



The Warm-pool & Cold-tongue Configuration in the Tropical Pacific



Nonlinear Heating From ENSO Fluctuations

(a)

(b)

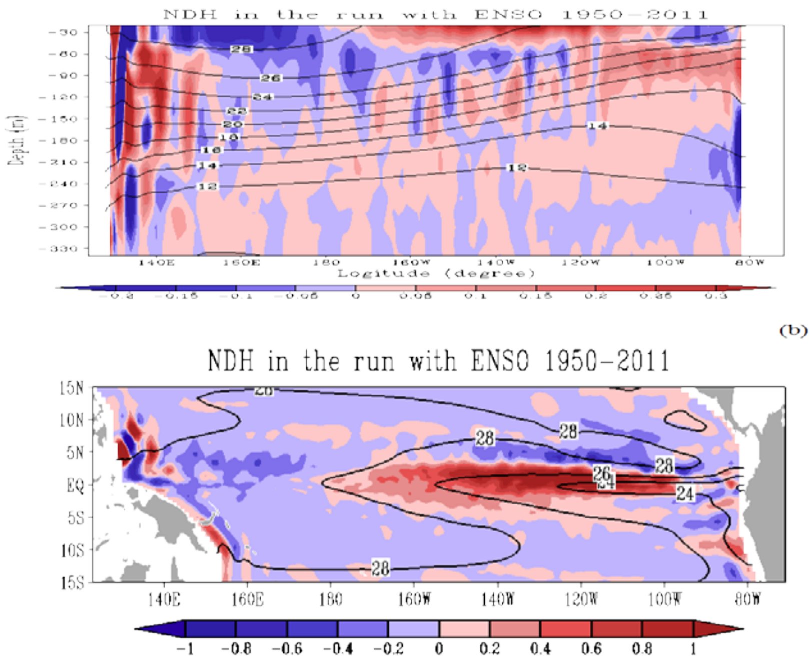
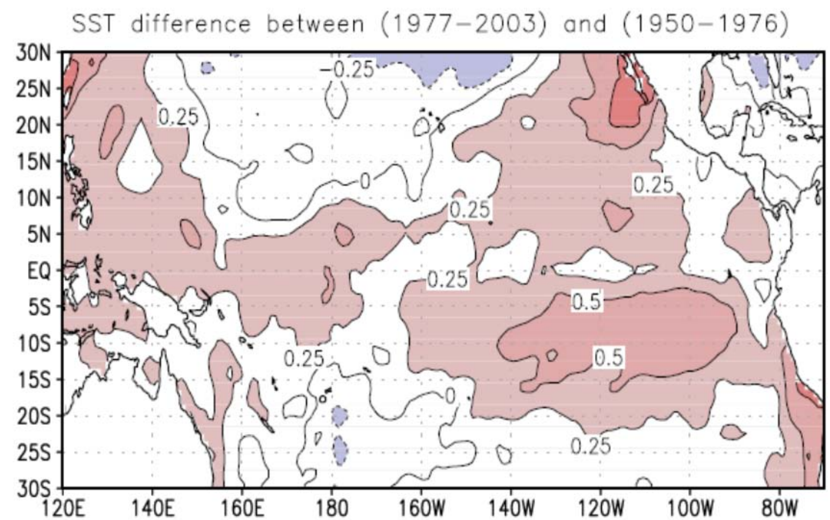
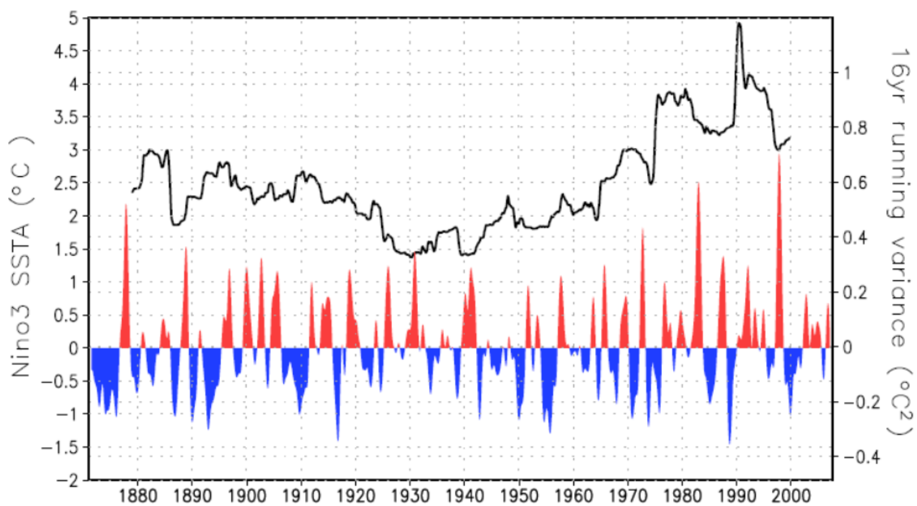


FIG.8 : Distribution of Nonlinear Dynamics Heating (NDH) in the run with ENSO for the equatorial upper ocean (5°S-5°N) as a function of longitude and depth (a) and for the surface layer of the tropical Pacific as a function of latitude and longitude (b). The contours are the corresponding time mean upper ocean temperature (a) and SST (b). The units for the heating rate are in °C/month.

Are these two biases Linked?





Theory: They Are Linked!

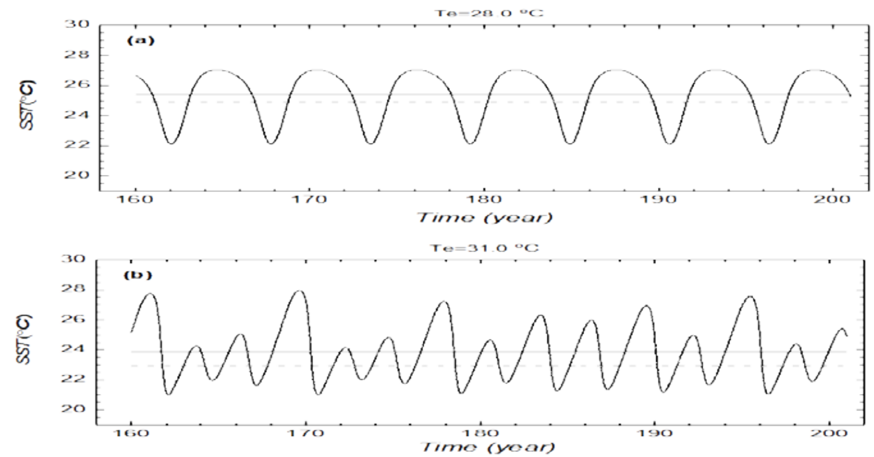
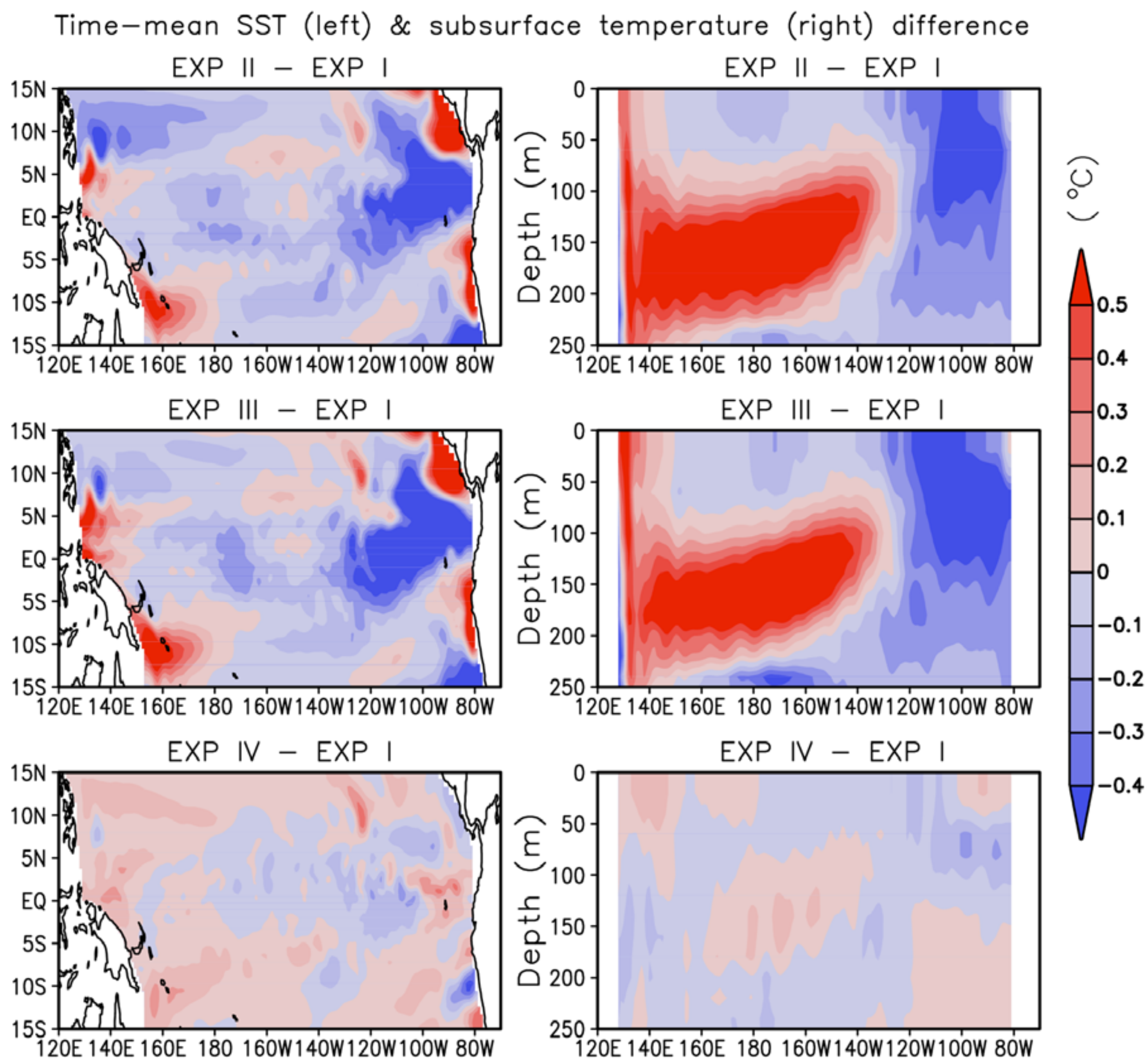
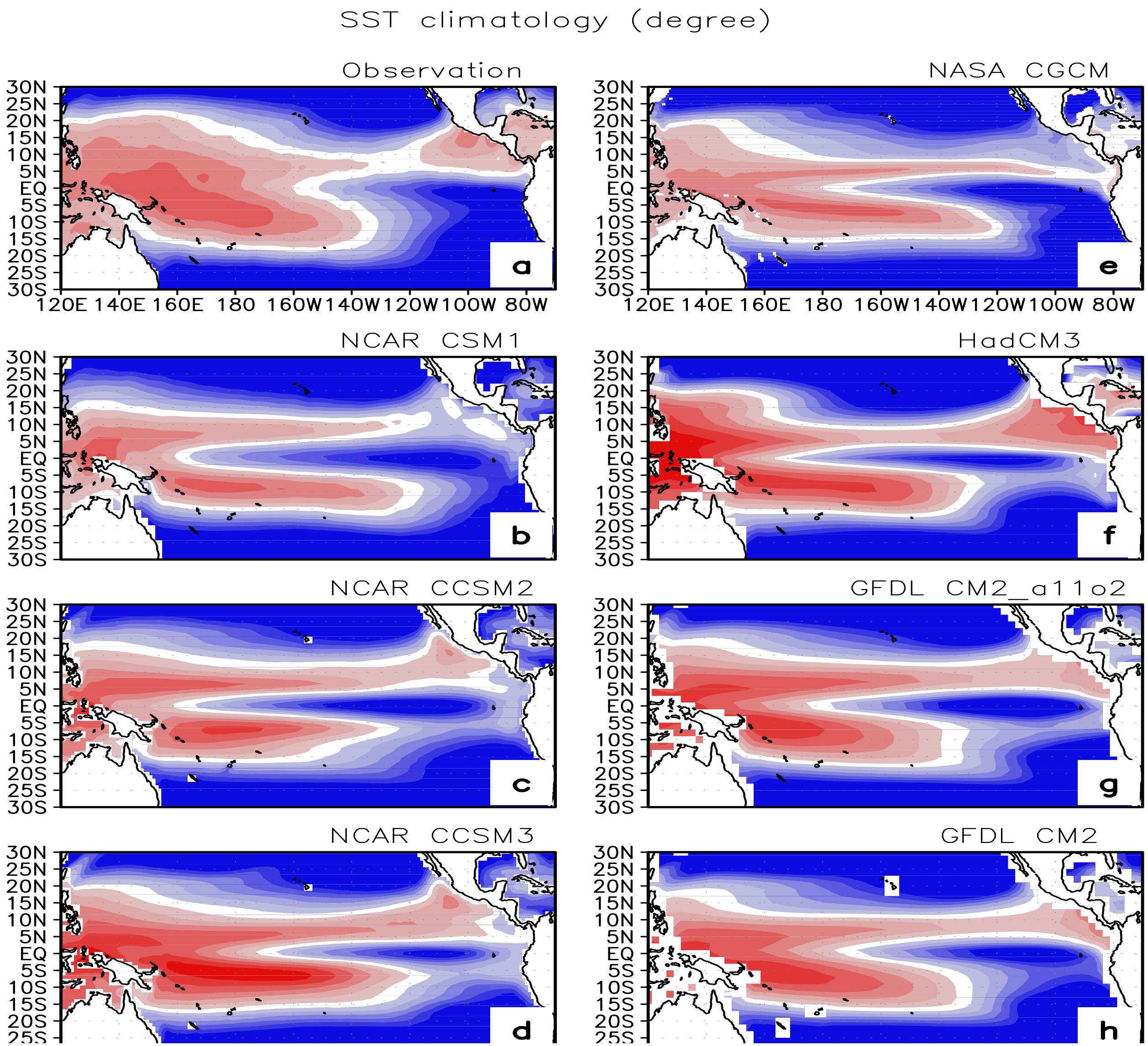


FIG. 5. Time series of T_2 when T_e=28.5°C and T_e=31°C. The time series are taken from the case with s=0.096 (Fig. 4cd). The two horizontal lines in the figure indicate respectively the time-mean value of T_2 *(solid line)* and its equilibrium value *(dashed line)*.

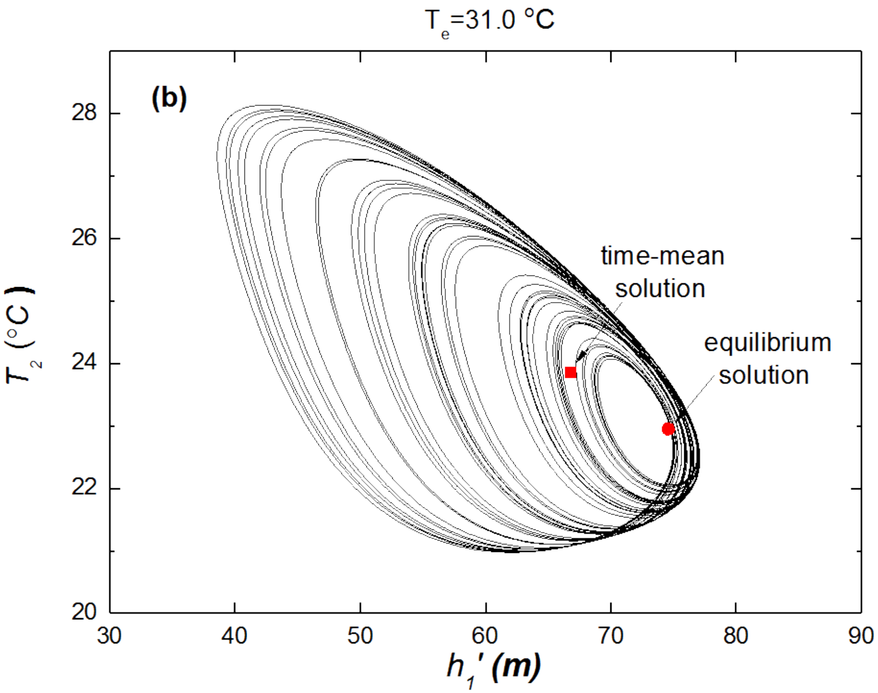
Are They Linked?



The Excessive Cold-tongue



Are They Linked?



Are these two biases linked?