

# Issues in Validating Model Simulated Land Temperature and Precipitation Trends

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## Misrepresentation of Tropical SSTs in Climate Models

1. **Climate models have difficulty in capturing regional climate trends around the globe because of their difficulty in capturing the *spatial variation* of tropical SST trends.**
2. The spatial pattern of the recent observed 50-yr tropical SST trend is not consistent with the radiatively forced multi-model mean trend in the IPCC/AR4 simulations.
3. The discrepancy is not just due to natural variability or climate noise but is also, very substantially, due to tropical modeling errors.

Two relevant papers :

Shin and Sardeshmukh

*Climate Dynamics* 2010

Published Online

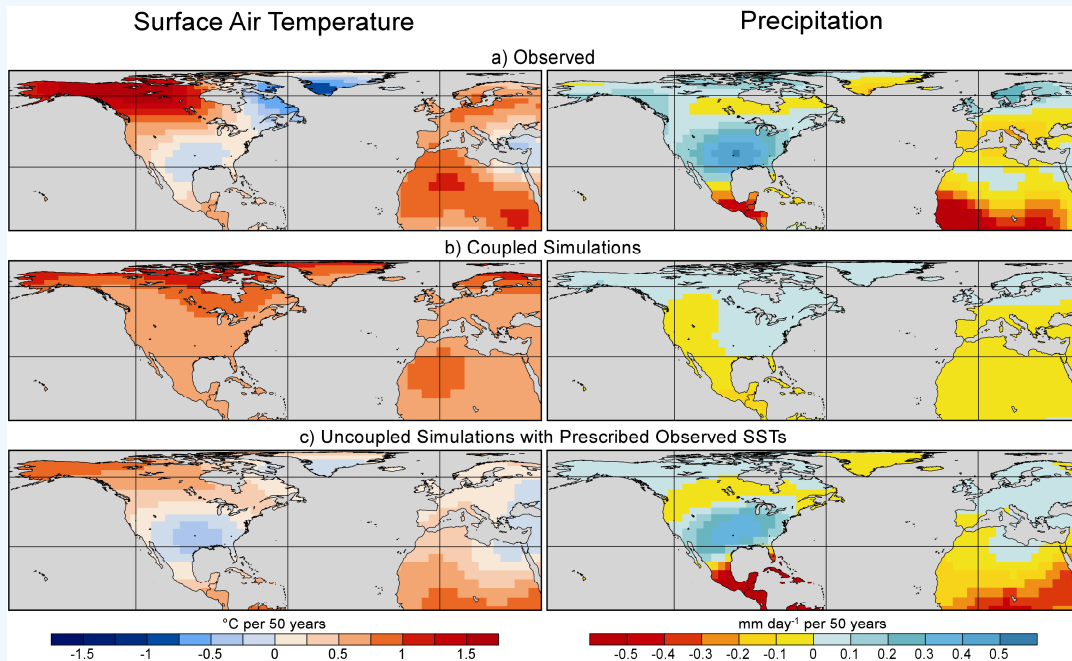
Shin, Sardeshmukh, and Pegion

*JGR-Atmospheres* 2010

Published Online



## Trends of annual-mean Surface Air Temperatures and Precipitation over 1951-1999



Observed Trends

Multi-model ensemble-mean trends in 76 **COUPLED** GCM simulations with prescribed radiative forcings

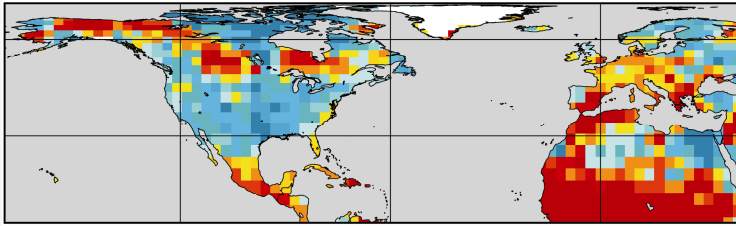
Multi-model ensemble-mean trends in 87 **UNCOUPLED** atmospheric GCM simulations with prescribed observed global or tropical SSTs, but no explicitly specified radiative forcings.



# Trend of annual Palmer Drought Severity Index (PDSI) over 1951-1999

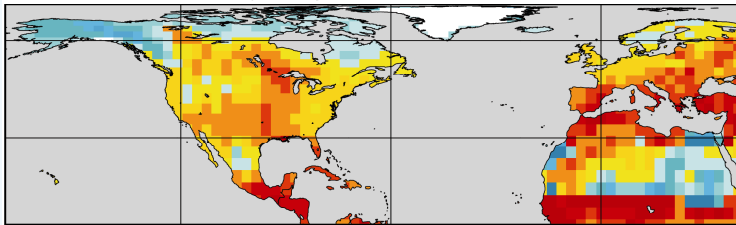
## Drought Index

a) Observed



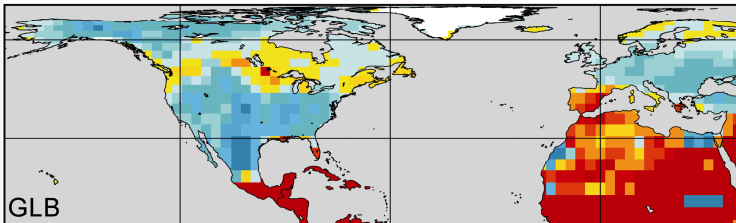
Observed

b) Coupled Simulations

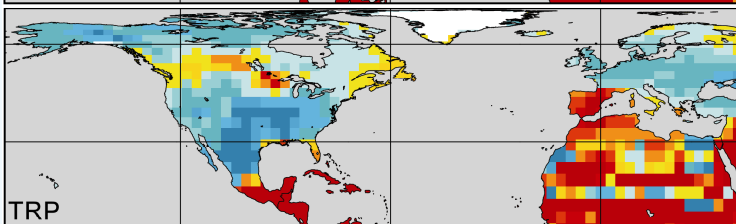


Simulated in **COUPLED** models with prescribed observed radiative forcings

c) Uncoupled Simulations with Prescribed Observed SSTs



Simulated in **UNCOUPLED** atmospheric GCMs with prescribed GLOBAL SSTs, but no explicitly specified radiative forcings (GOGA runs)



Simulated in **UNCOUPLED** atmospheric GCMs with prescribed TROPICAL SSTs, but no explicitly specified radiative forcings (TOGA runs)

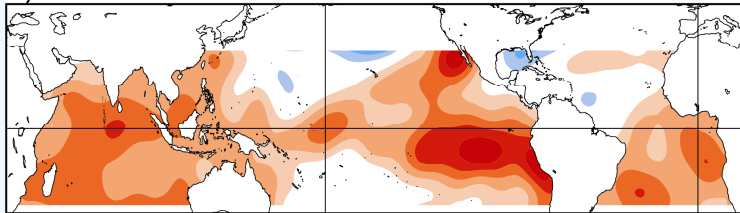




## Trends of annual-mean Tropical SSTs over 1951-1999

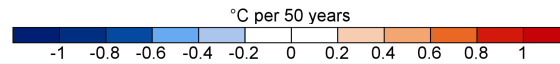
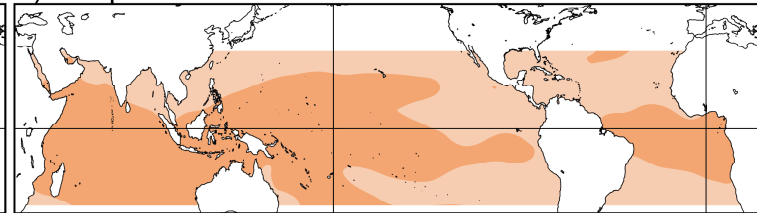
### OBSERVED TREND

(average of 3 datasets)



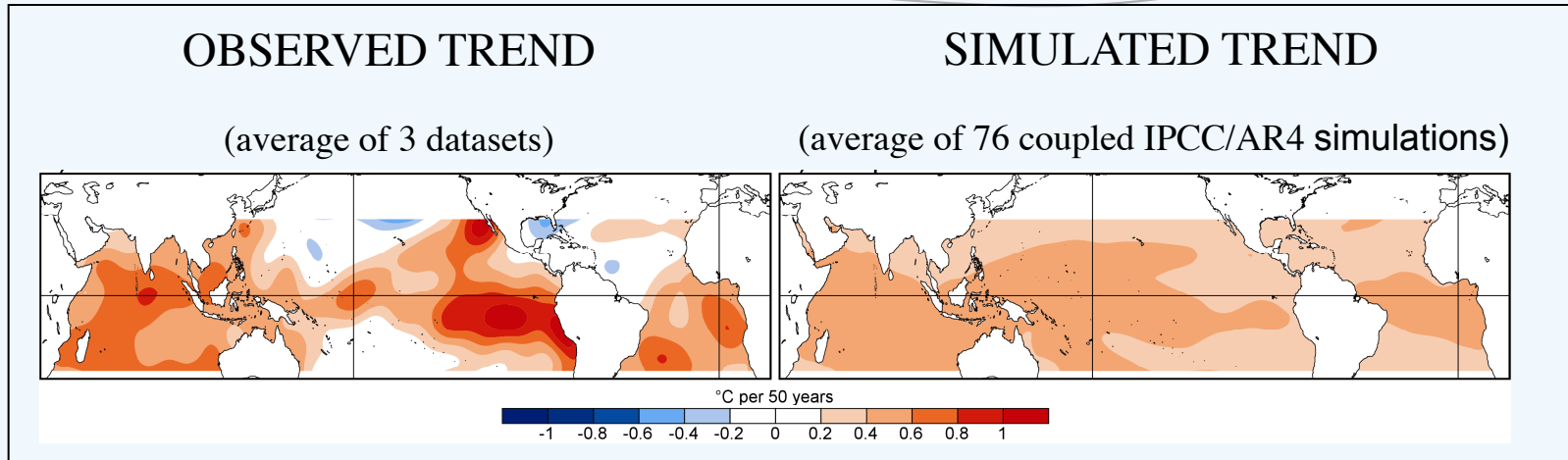
### SIMULATED TREND

(average of 76 coupled IPCC/AR4 simulations)



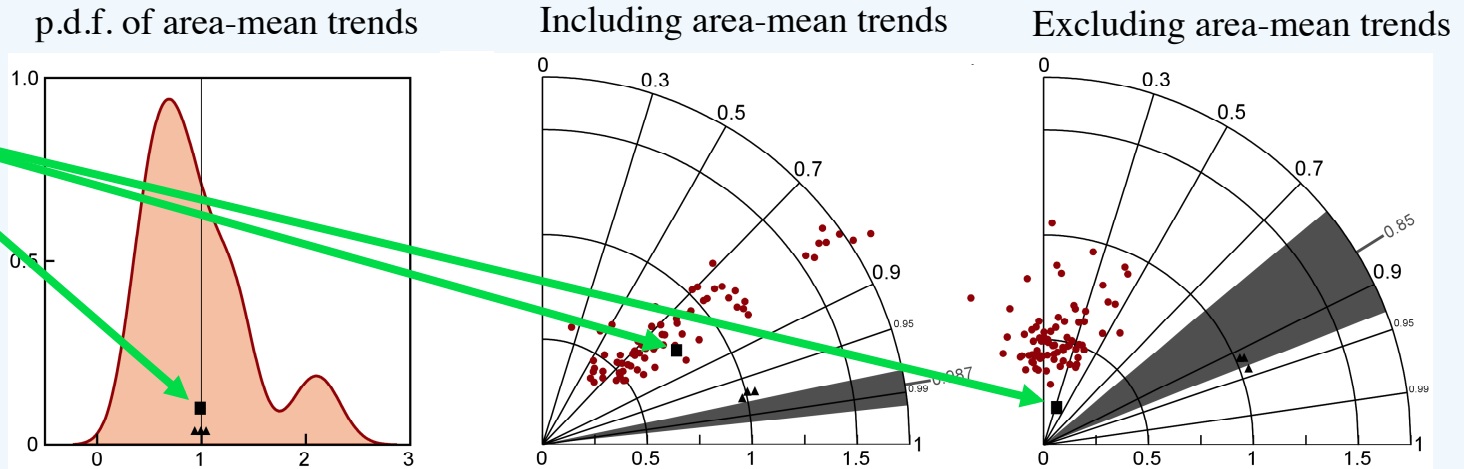


# Trends of annual-mean Tropical SSTs over 1951-1999



## Fidelity of all 76 simulated SST trend fields

Multi-model Ensemble Mean





## How well do coupled models represent the SST interactions between different tropical regions ?

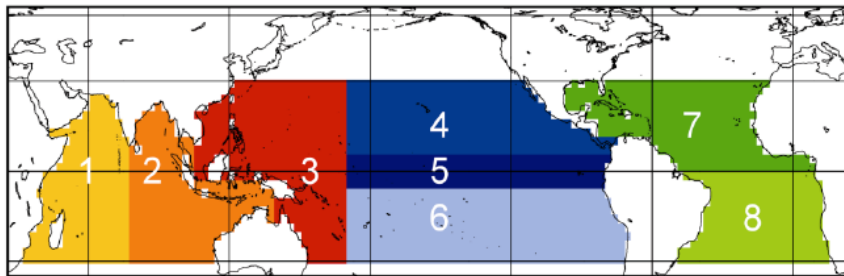
We have estimated the **LOCAL AND REMOTE FEEDBACKS** on SSTs in 8 tropical regions, using detrended monthly SSTs in **3 observational** and **76 AR4 simulation** datasets of the 20th century

These feedbacks were identified with the elements of the 8x8 matrix **L** in the following approximate short-term evolution equation for the monthly SST anomaly vector **x(t)** (whose 8 components are the SSTs in the 8 regions) :

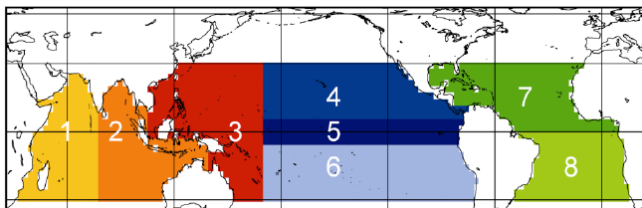
$$dx / dt = L x + \text{stochastic noise}$$

**L** was estimated via Linear Inverse Modeling (Penland and Sardeshmukh 1995) as where  $C_{ij}(\tau) = \langle x_i(t+\tau) x_j(t) \rangle$  is the SST lag-covariance matrix for lag  $\tau$

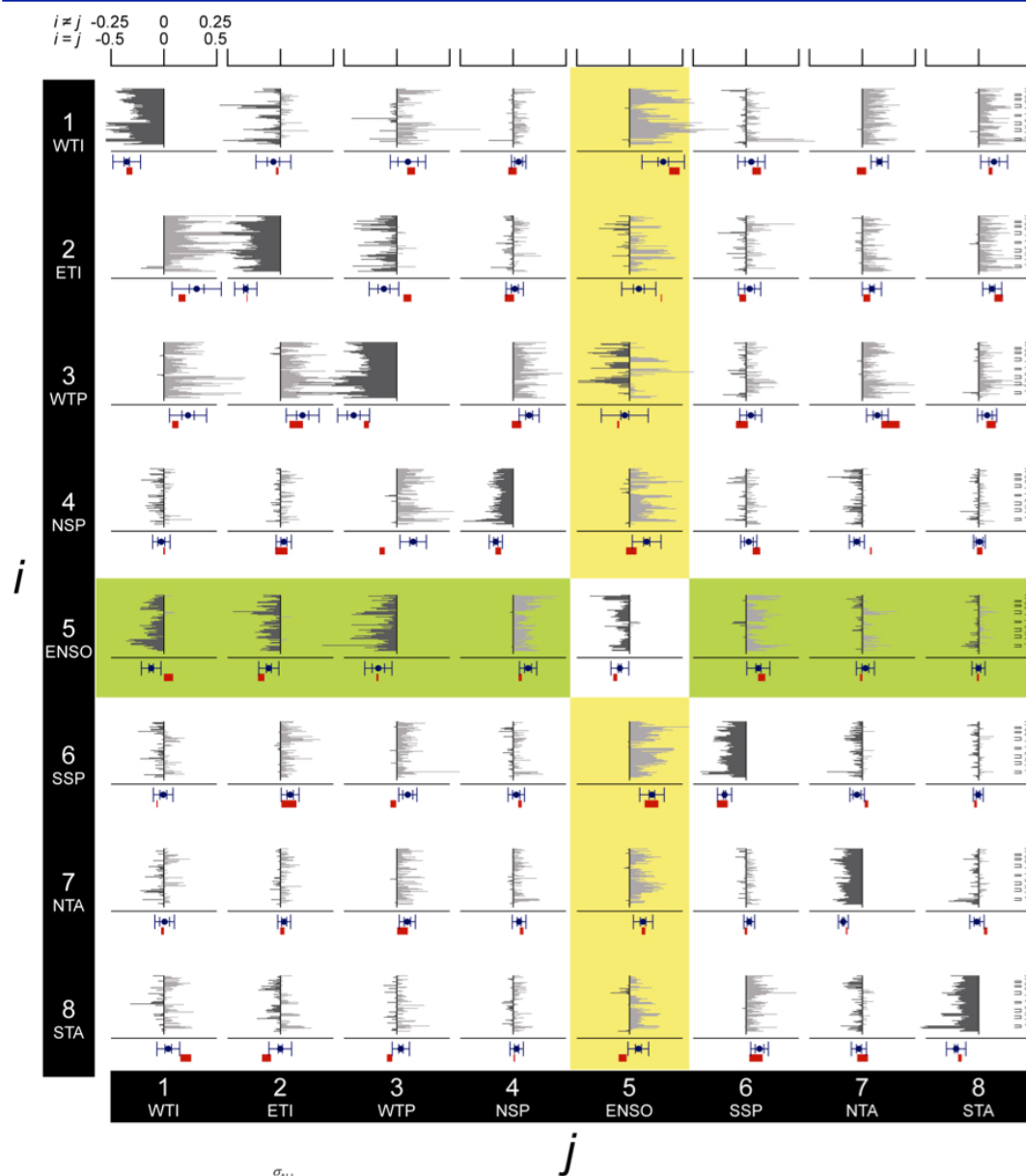
$$L = \frac{1}{\tau} \ln [ C(\tau) C(0)^{-1} ]$$



From  
Shin, Sardeshmukh, and Pegion  
2010

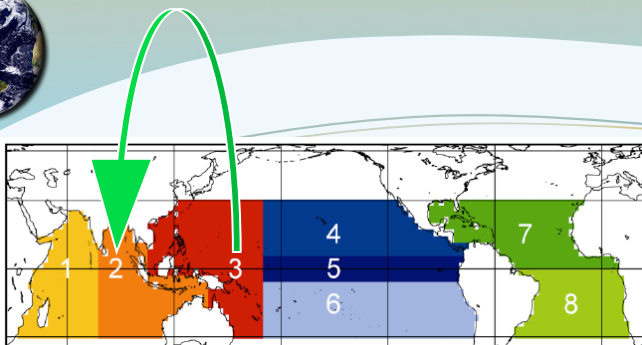


# The 8 x 8 Tropical SST Feedback Matrix $L$

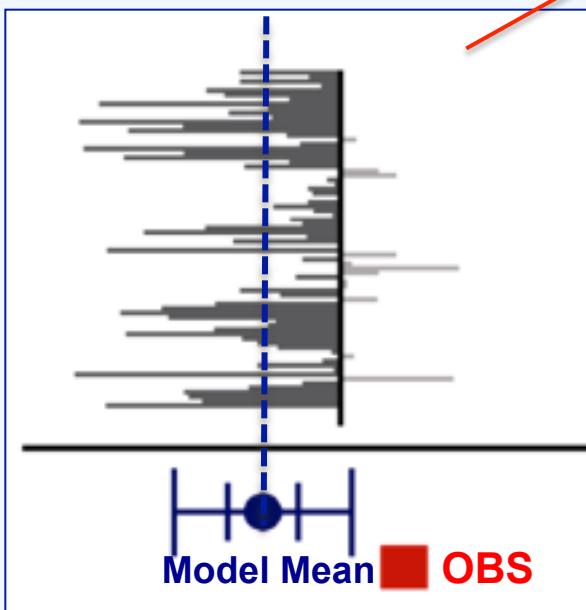


From Shin, Sardeshmukh, and Pegion 2010

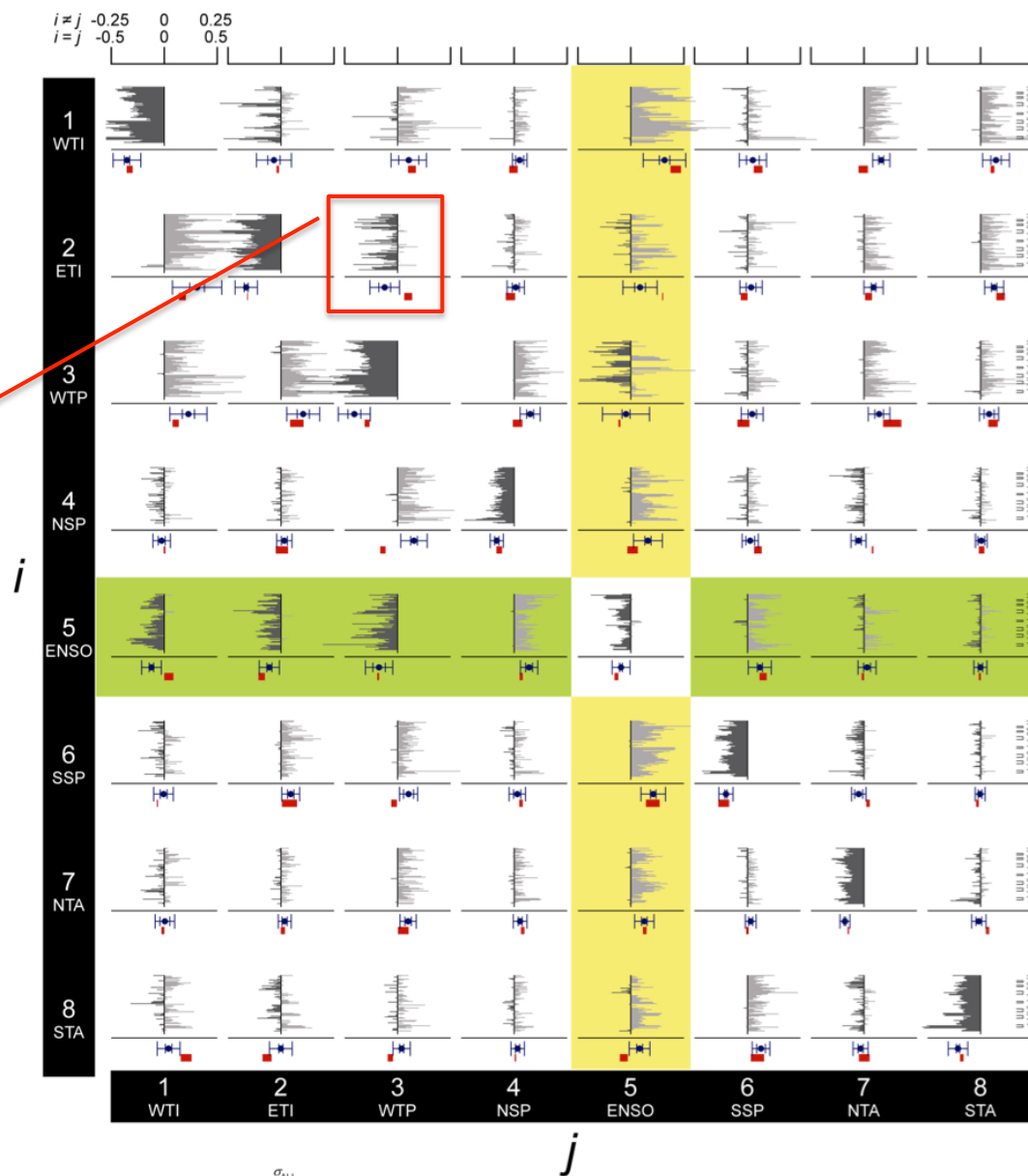




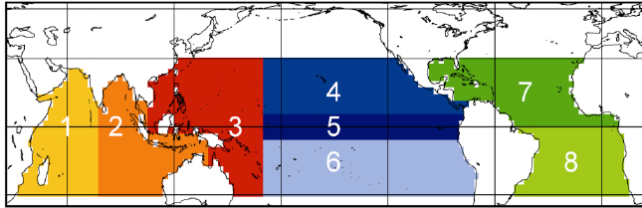
$L_{23}$  = Effect of Region 3  
on Region 2



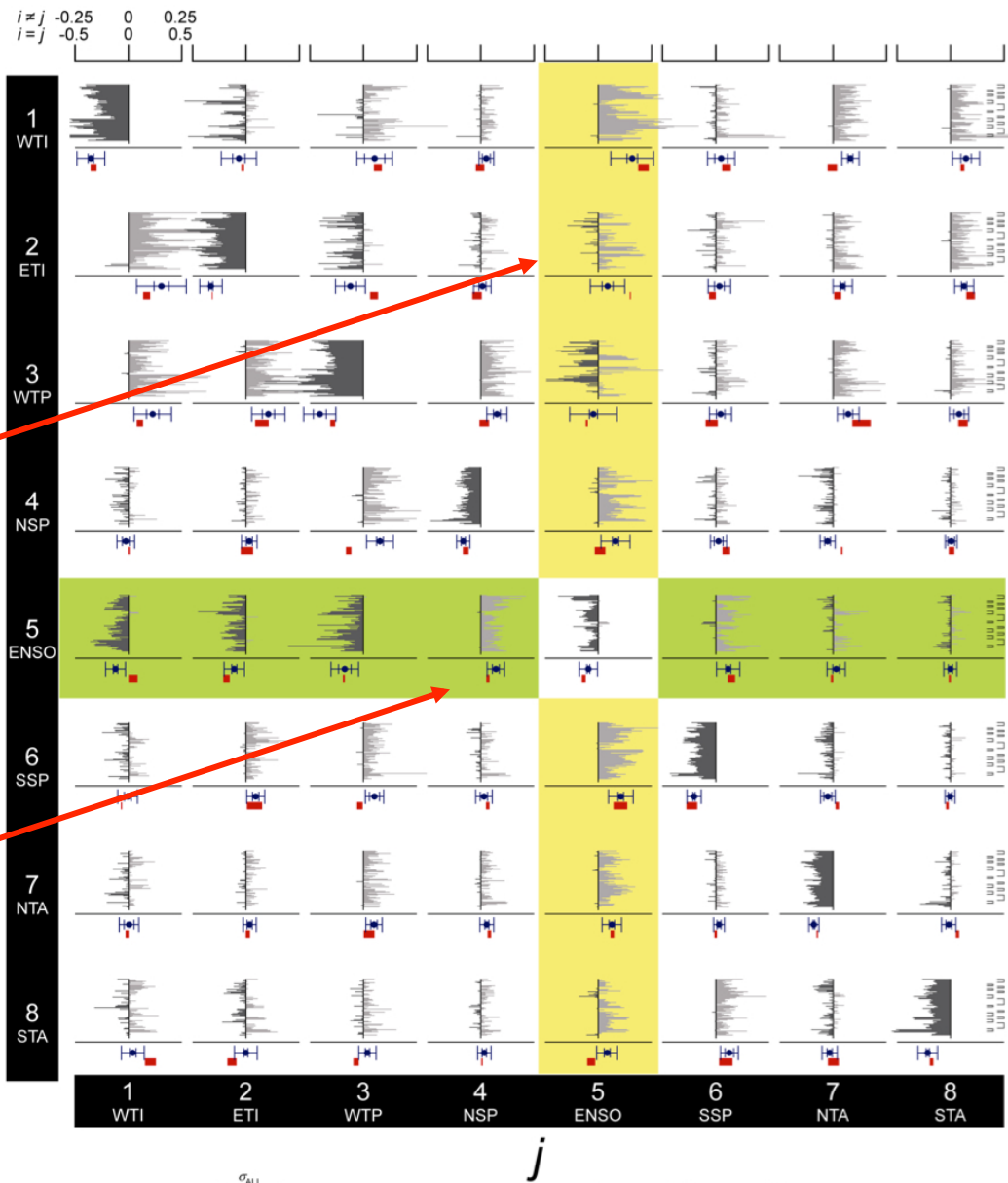
## The 8 x 8 Tropical SST Feedback Matrix $L$



From Shin, Sardeshmukh, and Pegion 2010



## The 8 x 8 Tropical SST Feedback Matrix $L$

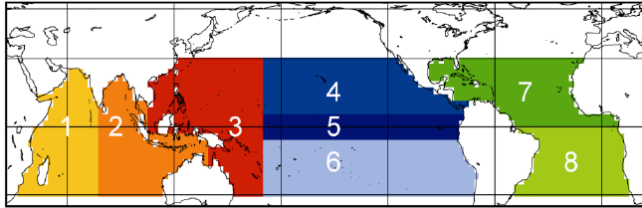


### Effect OF ENSO-region SSTs

Monthly SST tendency in other regions due to a 1-sigma warming in Region 5 (ENSO region)

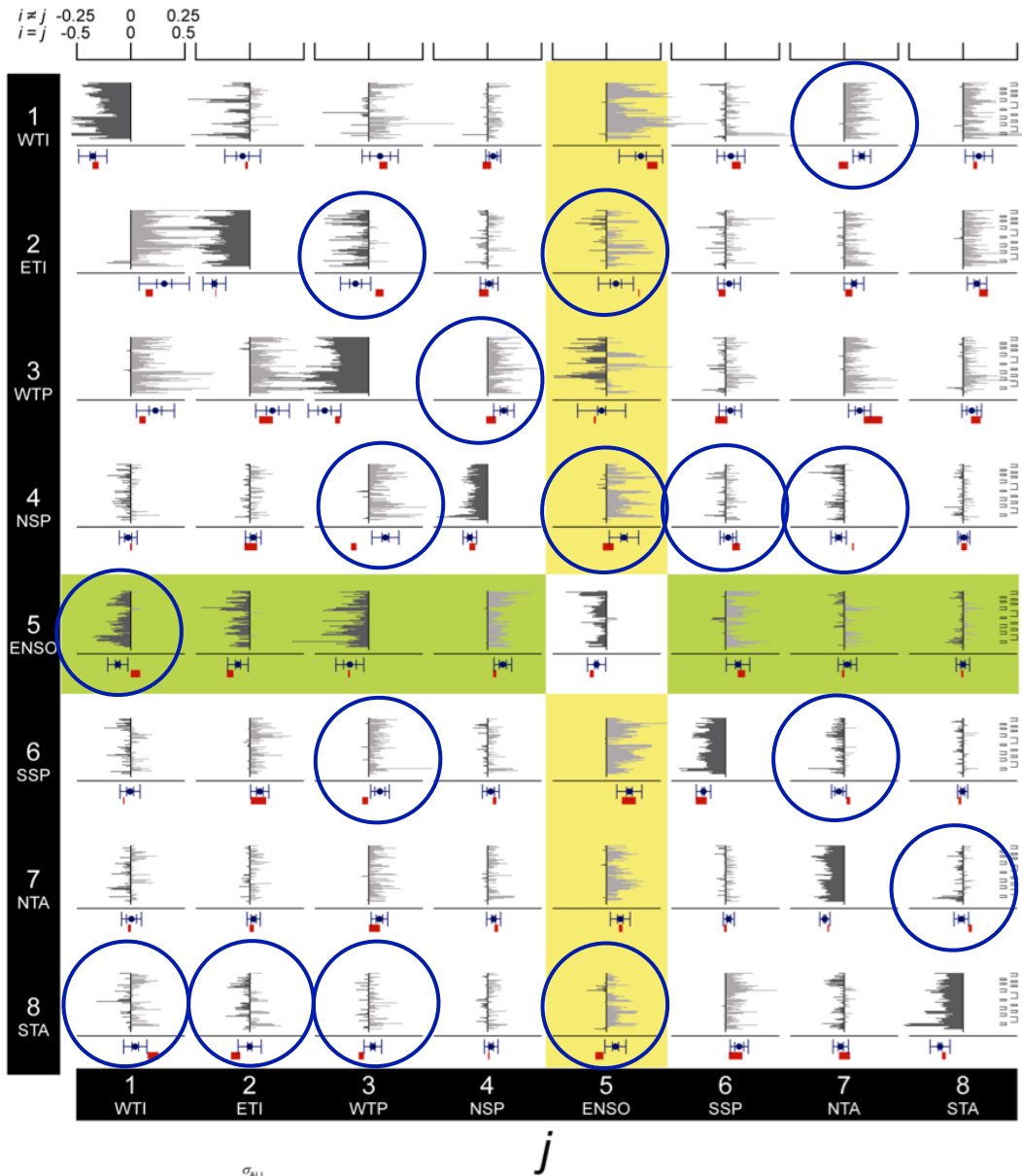
### Effect ON ENSO-region SSTs

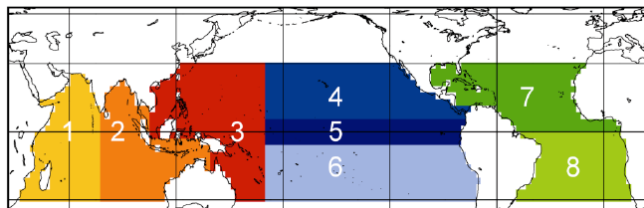
Monthly SST tendency in Region 5 (ENSO region) due to a 1-sigma warming in other regions.



## The 8 x 8 Tropical SST Feedback Matrix L

**BLUE CIRCLES** highlight those model feedbacks that are **CLEARLY** inconsistent with the observed feedbacks





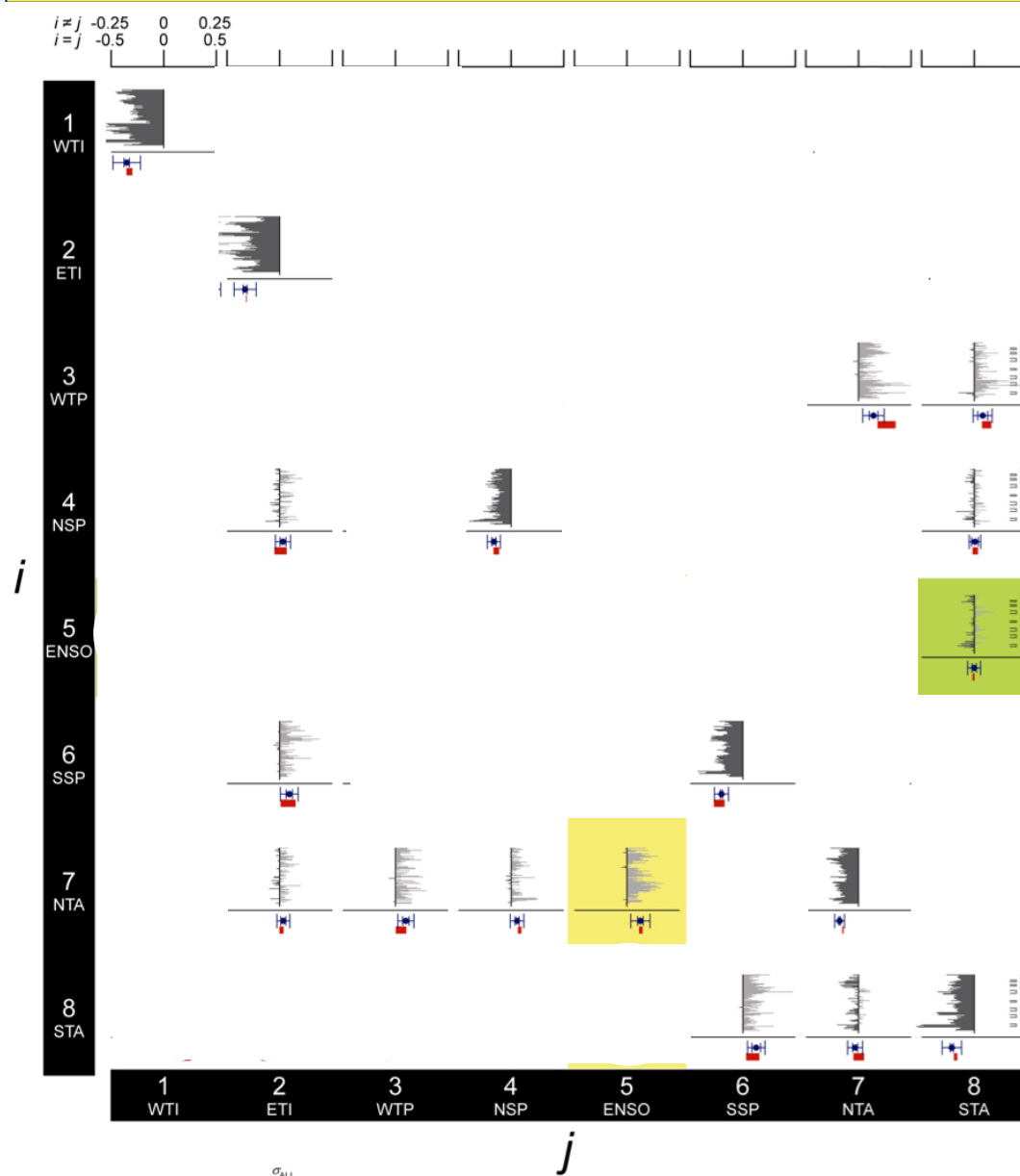
## The 8 x 8 Tropical SST Feedback Matrix $L$

$$i \neq j \begin{cases} -0.25 & 0 & 0.25 \\ -0.5 & 0 & 0.5 \end{cases}$$

**IN GENERAL :**

*the local damping feedbacks are reasonably consistent among the observations and models*

*but the non-local feedbacks are generally not consistent*



From Shin, Sardeshmukh, and Pegion 2010



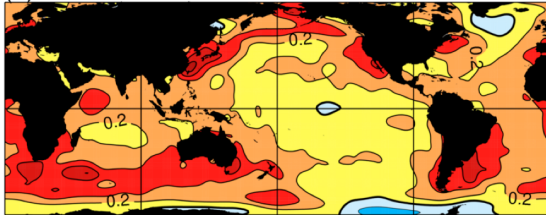
## Summary

1. **Climate models will continue to have difficulty in capturing regional climate trends around the globe unless they are able to capture the spatial variation of tropical SST trends.**
2. **The large discrepancy of the observed and simulated recent 50-yr trends is not just due to natural variability or climate noise, but is also very substantially due to modeling errors.**
4. To help isolate these modeling errors, we estimated **the local and nonlocal feedbacks** on monthly SSTs in 8 tropical regions in observations and the IPCC models .
5. We found that the models reasonably capture the *local* feedbacks (except in the ENSO and western Pacific Warm Pool regions), but not the *non-local* feedbacks.
6. Because these non-local feedbacks occur on time scales as short as 1 month, their misrepresentation is likely associated with the misrepresentation of remote atmospheric teleconnections in the models.

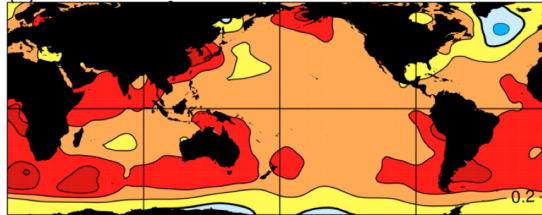
## Why did we not perform this study for trends over the entire 20<sup>th</sup> century ?

Observed Trend of Global SSTs in Four Data Sets (1901-2005) °C/50 yr

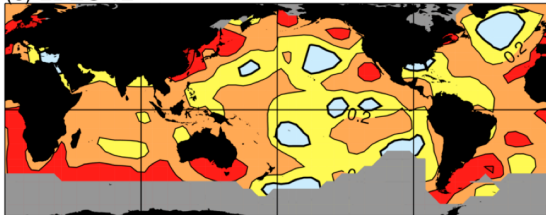
(a) HadISST1.1



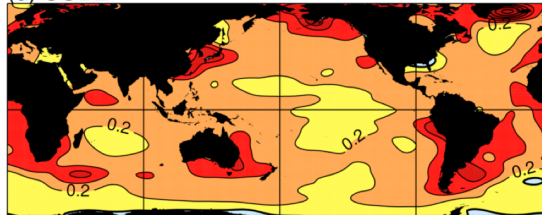
(b) NOAA ERSST v3



(c) LDEO v2

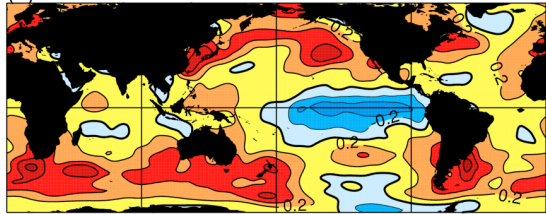


(d) COBE

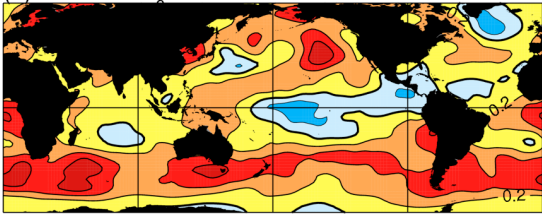


ENSO-unrelated Trend of Global SSTs in Four Data Sets (1901-2005) °C/50 yr

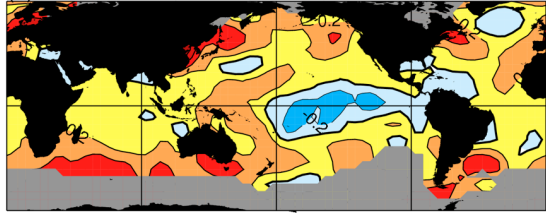
(a) HadISST1.1



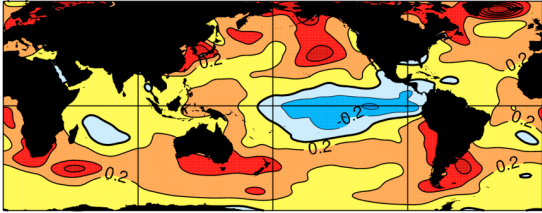
(b) NOAA ERSST v3



(c) LDEO v2



(d) COBE



Mainly because there is considerable disagreement concerning the century-long SST trends in the tropics

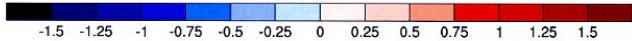
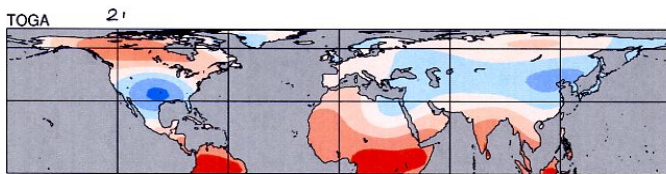
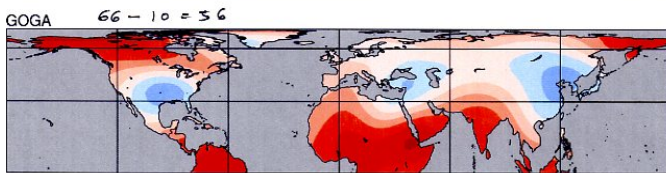
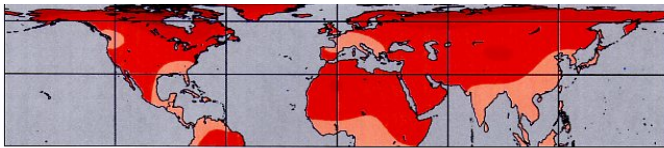
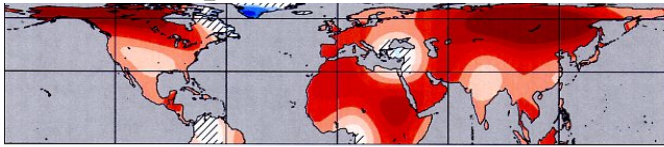
Although .....

It is interesting (and ironic) That there is much better agreement when the ENSO-related part of the trend is removed from the full trend in these datasets

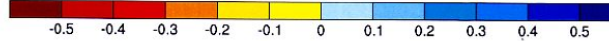
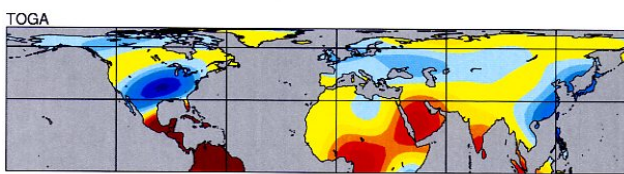
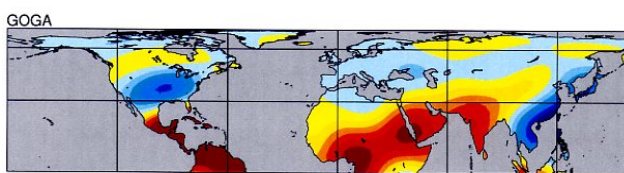
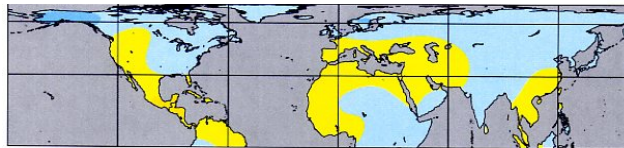
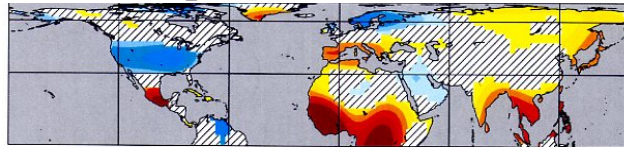
# Why did we not extend our study of the half-century trends to the full globe ?

## Trends of annual-mean Surface Air Temperatures and Precipitation over 1959-1999

### Temperature Trends



### Precipitation Trends



Observed Trends

MME-mean trends in 76 **COUPLED** GCM runs with prescribed radiative forcing

MME-mean trends in 56 **UNCOUPLLED** GOGA runs with no explicitly specified radiative forcing

MME-mean trends in 21 **UNCOUPLLED** TOGA runs with no explicitly specified radiative forcing