Theme 1: Climate, Weather, and Water Science

Earth System Research Laboratory

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Misrepresentation of Tropical SSTs in Climate Models

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.

<u>Two relevant papers</u> :

| Shin and Sardeshmukh | *Climate Dynamics* 2010 | Published Online |
| Shin, Sardeshmukh, and Pegion | *JGR-Atmospheres* 2010 | In Review |
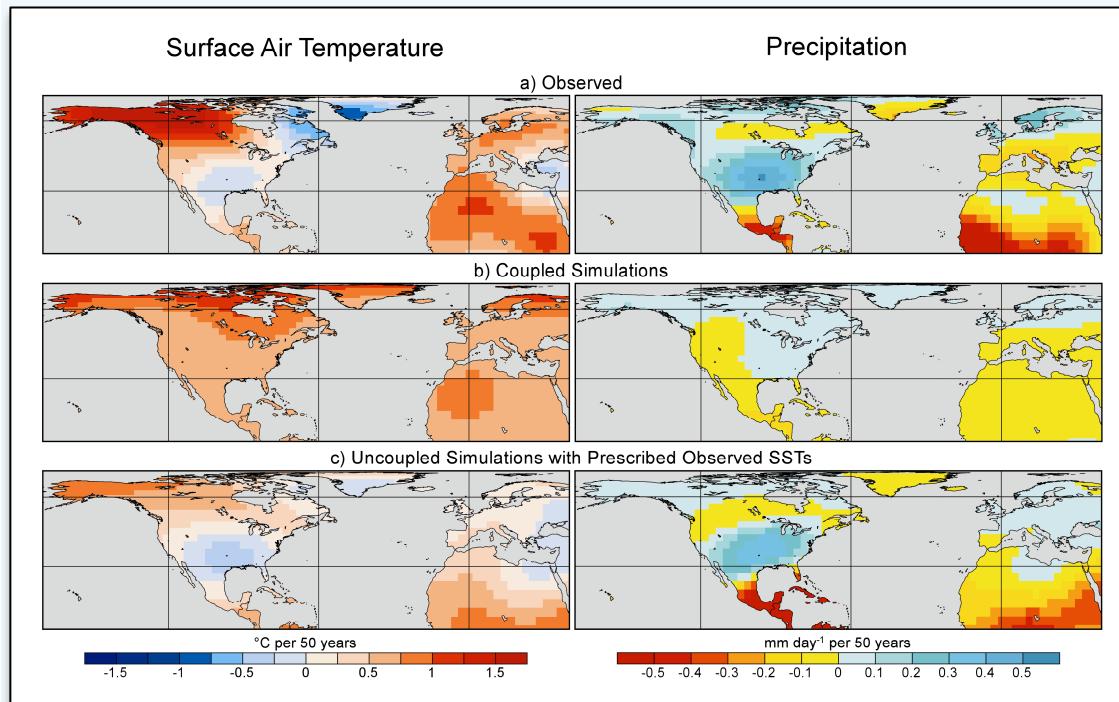
Trends of annual-mean Surface Air Temperatures and Precipitation over 1951-1999


Surface Air Temperature — Precipitation

a) Observed

b) Coupled Simulations

c) Uncoupled Simulations with Prescribed Observed SSTs

°C per 50 years

-1.5 -1 -0.5 0 0.5 1 1.5

mm day⁻¹ per 50 years

-0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5
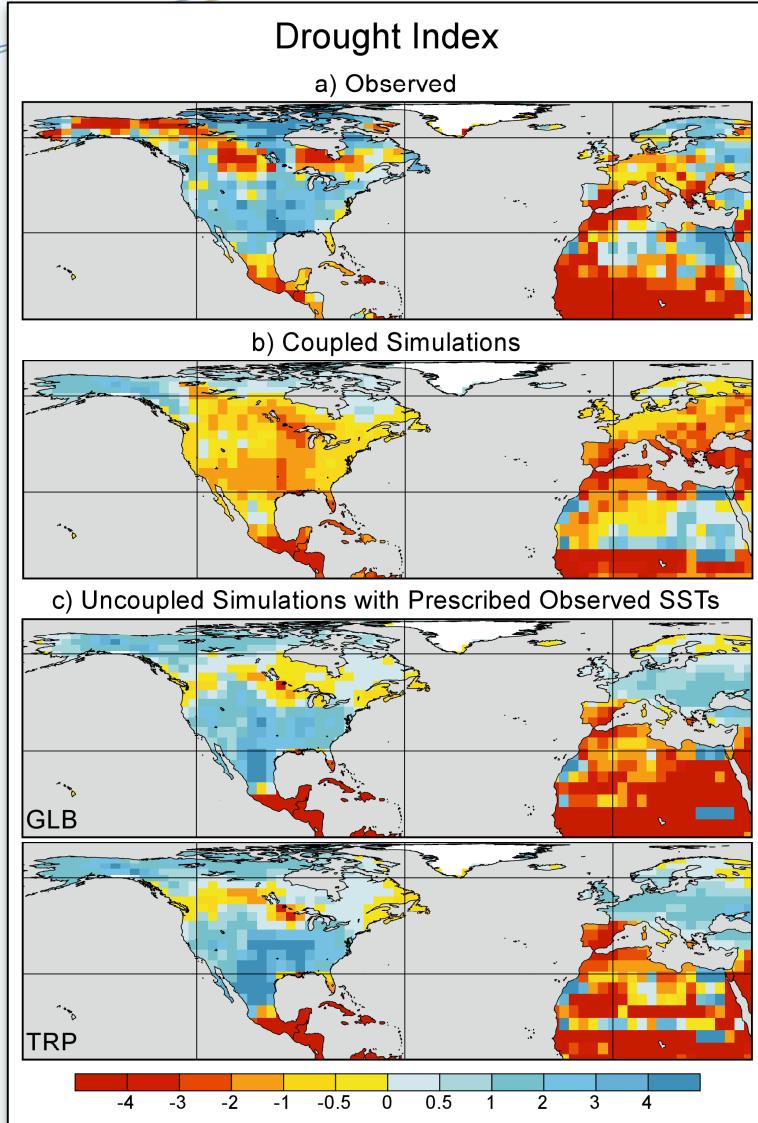
Observed Trends

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.

Drought Index

a) Observed

b) Coupled Simulations

c) Uncoupled Simulations with Prescribed Observed SSTs

GLB

TRP

-4 -3 -2 -1 -0.5 0 0.5 1 2 3 4

Observed

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

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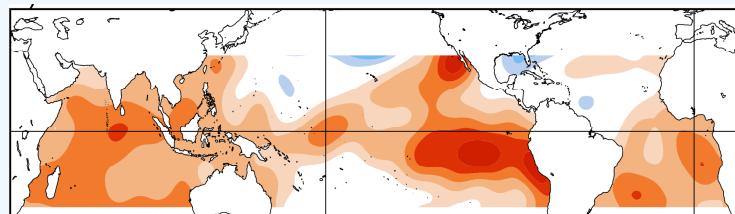
Simulated in **UNCOUPLED** atmospheric GCMs with prescribed
TROPICAL SSTs, but no explicitly specified radiative forcings
(TOGA runs)

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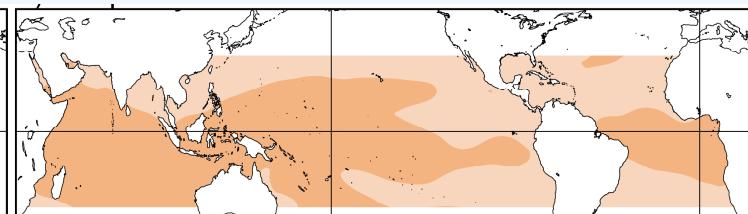
OBSERVED TREND

(average of 3 datasets)

SIMULATED TREND

(average of 76 coupled IPCC/AR4 simulations)

°C per 50 years

-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1

Trends of annual-mean Tropical SSTs over 1951-1999

OBSERVED TREND

(average of 3 datasets)

SIMULATED TREND

(average of 76 coupled IPCC/AR4 simulations)

°C per 50 years

-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1
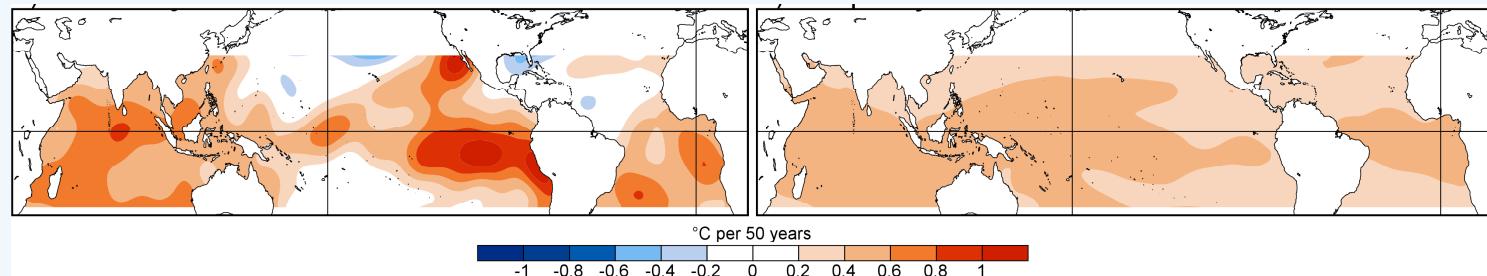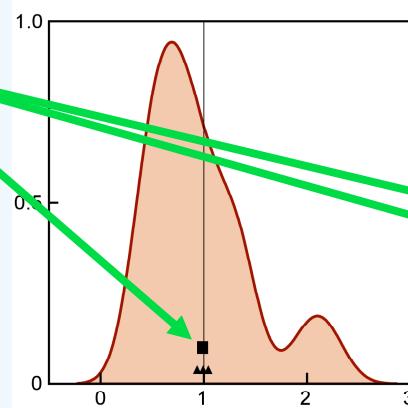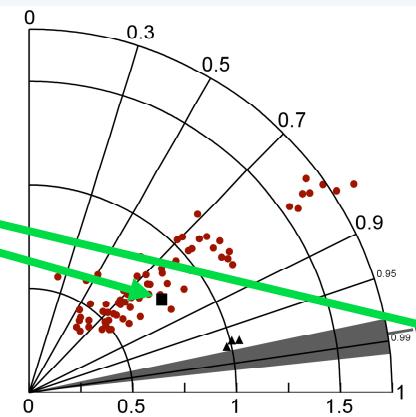
Fidelity of all 76 simulated SST trend fields

Multi-
model
Ensemble
Mean
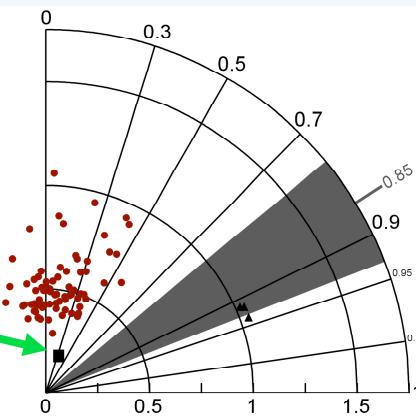
p.d.f. of area-mean trends

Including area-mean trends

Excluding area-mean trends

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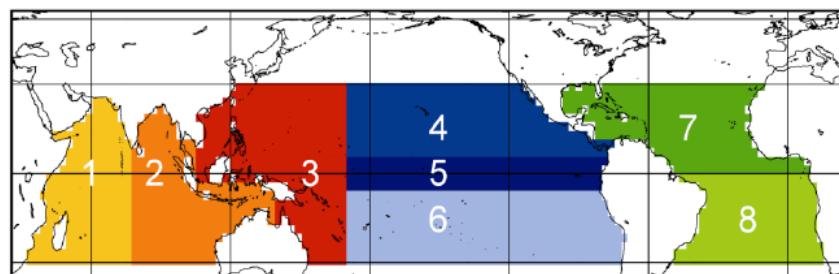
*These feedbacks were identified with the elements of the 8x8 matrix **L** in the following approximate short-term evolution equation for the monthly SST anomaly vector **x(t)** (whose 8 components are the SSTs in the 8 regions) :*

$$ dx / dt \quad = \quad L x \quad + \quad stochastic\ noise $$

L was estimated via Linear Inverse Modeling (Penland and Sardeshmukh 1995) as

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

where $C_{ij}(\tau) = \langle x_i(t+\tau)\, x_j(t) \rangle$ is the SST lag-covariance matrix for lag τ

From

Shin, Sardeshmukh, and Pegion
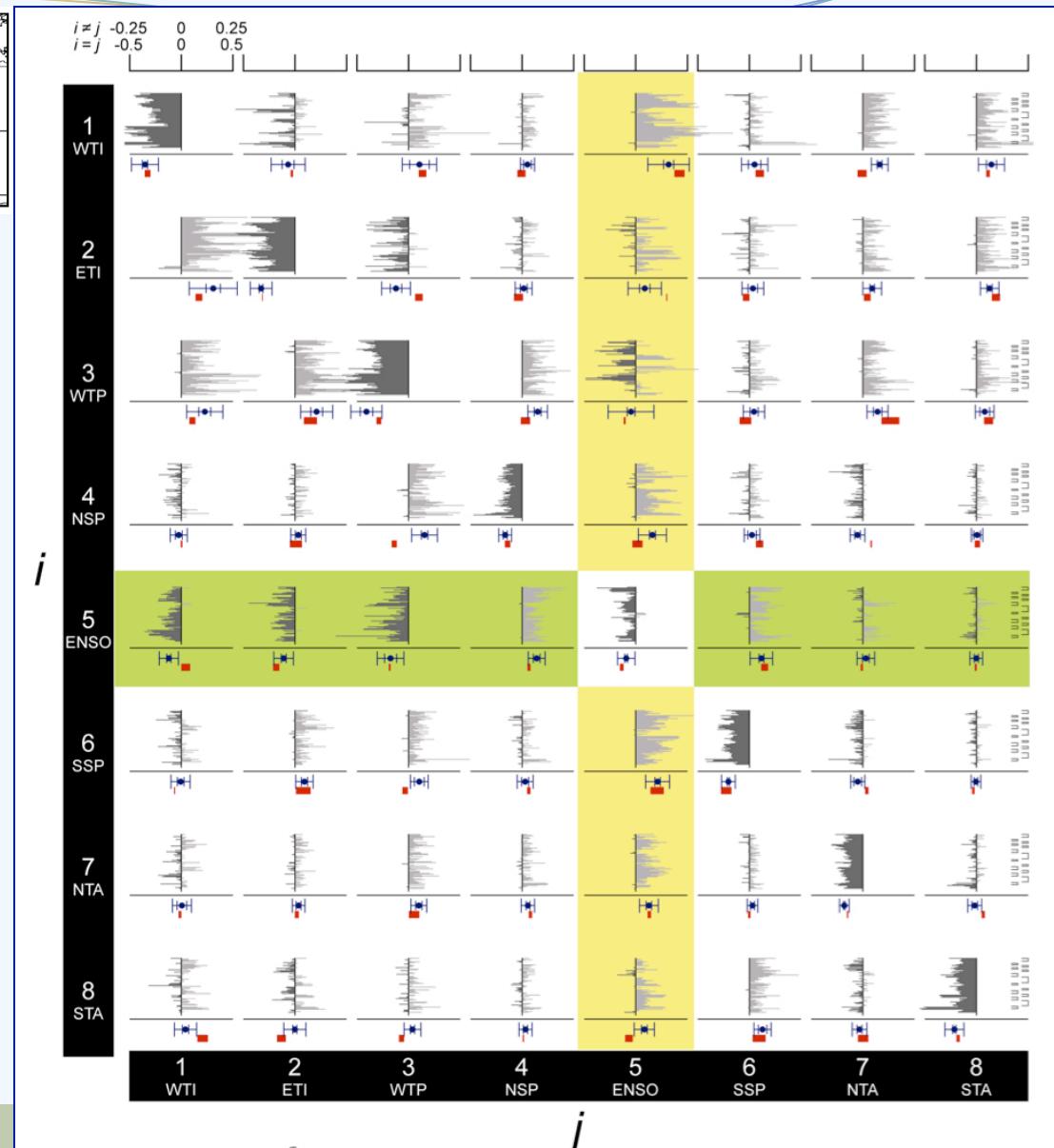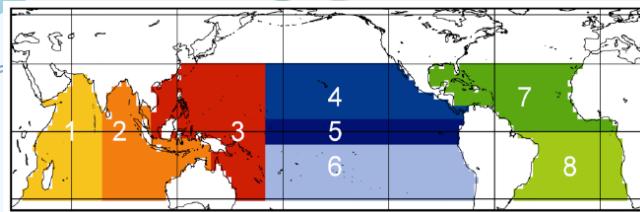
2010

From Shin, Sardeshmukh, and Pegion 2010
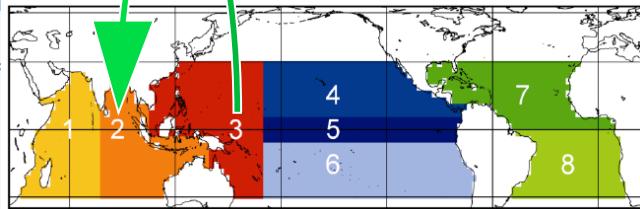
The 8 x 8 Tropical SST Feedback Matrix L
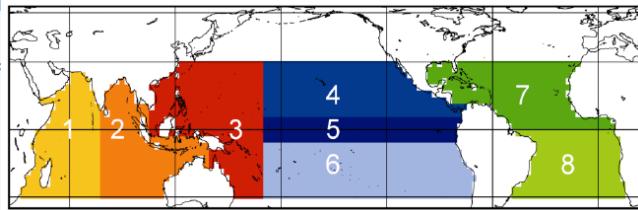
L_{23} = Effect of Region 3 on Region 2

Model Mean ■ OBS

*From Shin, Sardeshmukh, and Pegion 2010*
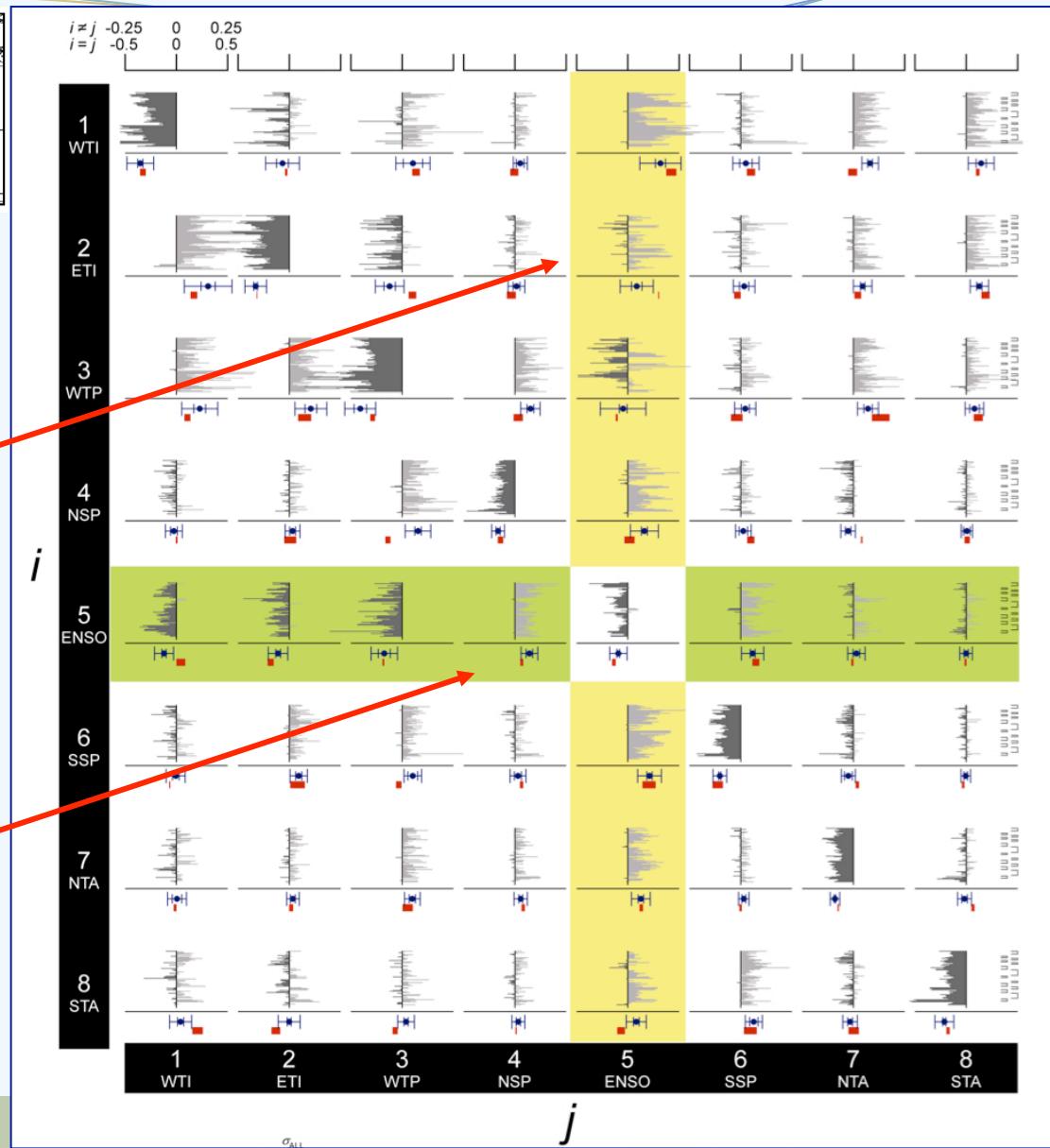
Effect OF ENSO-region SSTs

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

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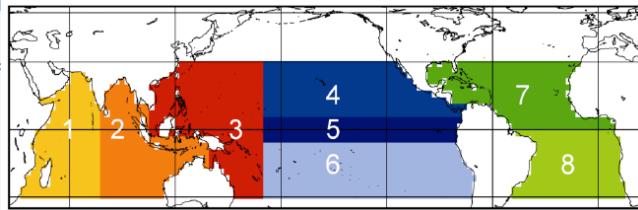
Monthly SST tendency in Region 5 (ENSO region) due to a 1-sigma warming in other regions.

From Shin, Sardeshmukh, and Pegion 2010
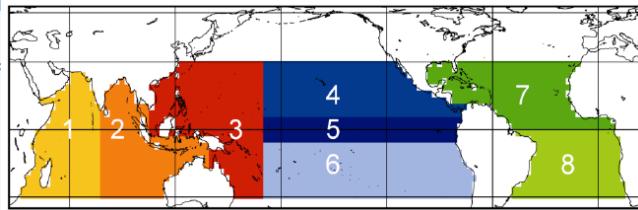
BLUE CIRCLES highlight those model feedbacks that are *CLEARLY* inconsistent with the observed feedbacks

From Shin, Sardeshmukh, and Pegion 2010

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.