Misrepresentation of Tropical SSTs in Climate Models

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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 In Review
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.
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)
Trends of annual-mean Tropical SSTs over 1951-1999

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SIMULATED TREND
(average of 76 coupled IPCC/AR4 simulations)

Fidelity of all 76 simulated SST trend fields

Multi-model Ensemble Mean
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):

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

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

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

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

From

Shin, Sardeshmukh, and Pegion
2010
$L_{23} = \text{Effect of Region 3 on Region 2}$
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.
BLUE CIRCLES highlight those model feedbacks that are CLEARLY inconsistent with the observed feedbacks.
IN GENERAL:

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

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