Does “ENSO Diversity” remotely matter ?

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<u>Main Points</u>

1) ENSO-related SST *variability* is largest in the **central and <u>eastern</u> tropical Pacific oceans.**

2) However, the global climate has the largest *sensitivity* to SST changes in the **central and <u>western</u> tropical Pacific and Indian oceans.**

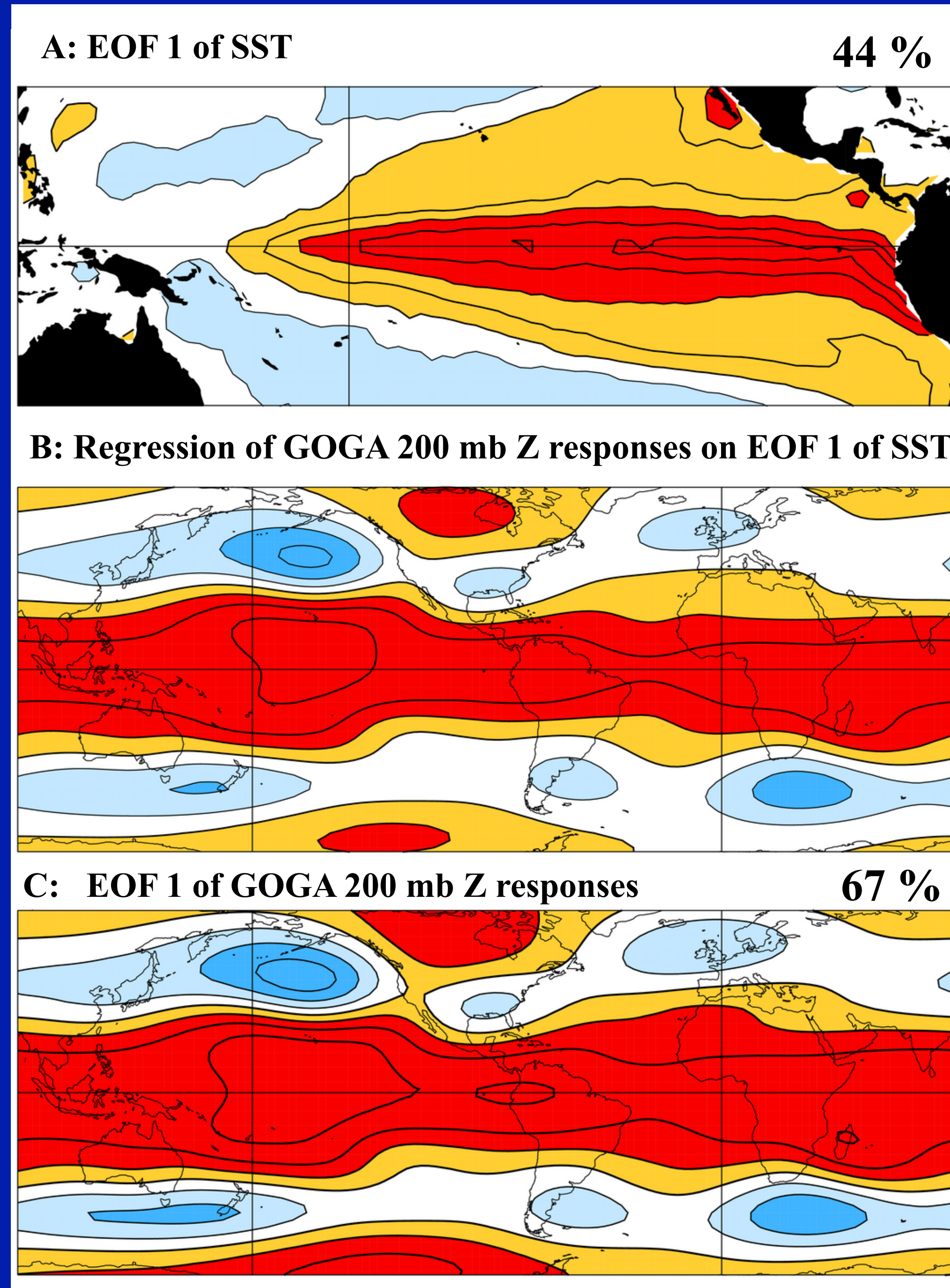
3) Therefore, “ENSO Diversity” and future changes in ENSO-related SST variability will have relatively minor global impacts **unless** those SST changes are large in the **central and <u>western</u> tropical Pacific and Indian oceans.**

The response to the dominant ENSO SST pattern in winter dominates the detrended responses to *all* SST patterns in GOGA runs (Here a 12-member NCEP/MRF9 AGCM ensemble with observed SSTs for 1950-95).

Note, however, that although B has a nearly identical pattern to C, it is associated with a smaller portion of the SST variability (44%) than is C (67%).

This suggests that:

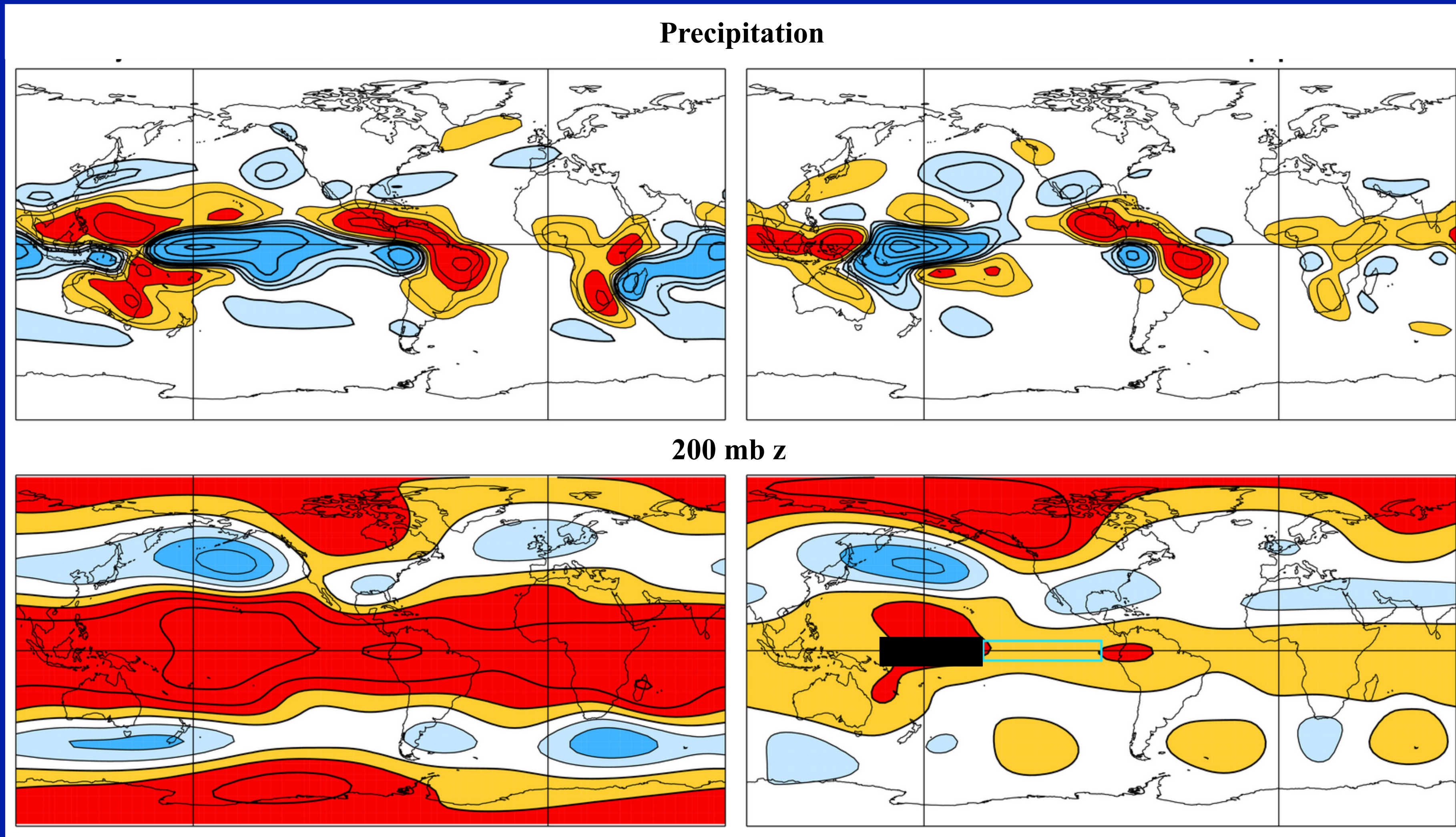
1. C is a preferred response pattern that is strongly excited by SST EOF1, but to some extent also by other very different SST EOF patterns.
2. Both B and C must therefore primarily reflect responses to SSTs in a relatively small area of A where both EOF1 and other EOFs have appreciable amplitude.



And indeed, the Central Pacific SSTs account for most of the GOGA responses

EOF 1 of GCM responses to observed 1950-95 global SSTs

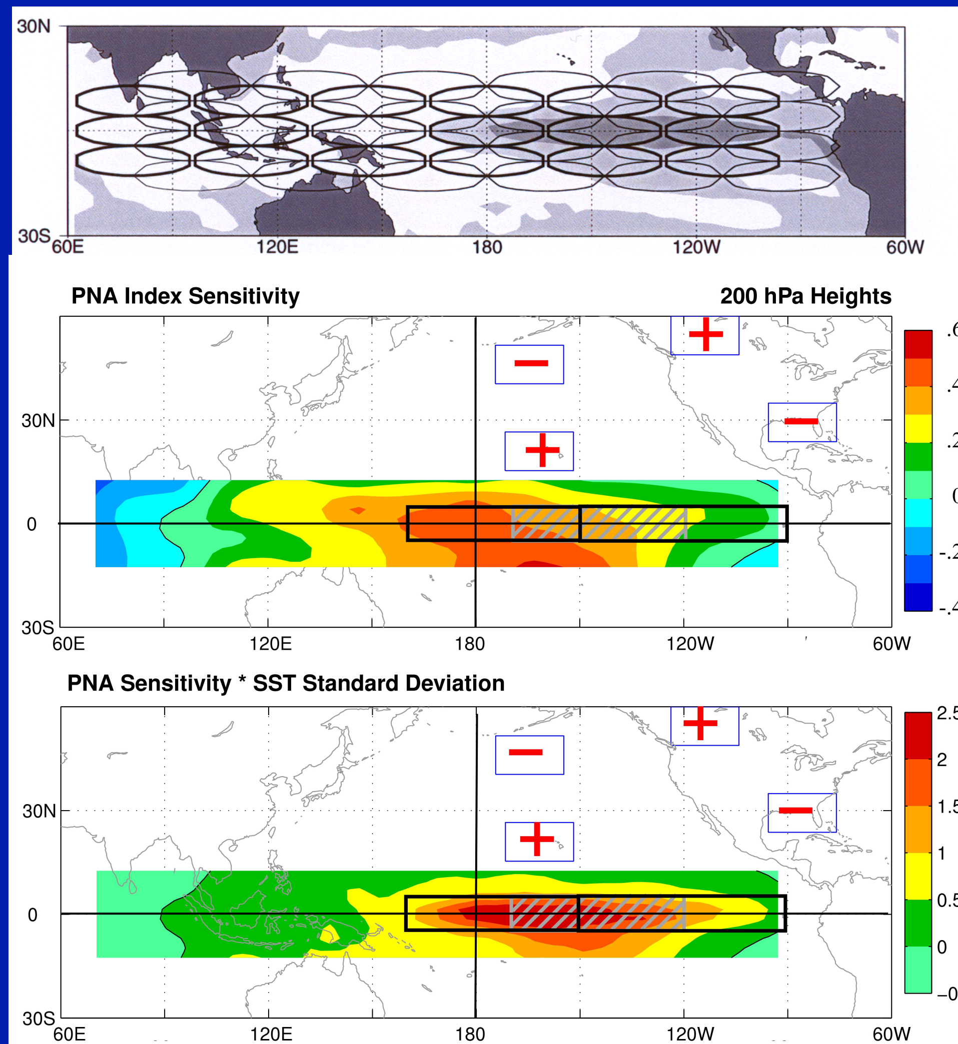
Linear part of GCM response to 1 K SST anomaly in Nino-4



The PNA circulation index is found to be most sensitive to Central Pacific SSTs when the NCEP GCM is forced by localized SST anomaly "patches" of the same 0.5°C magnitude throughout the Indo-Pacific basin.

This relatively greater **sensitivity**, together with the appreciable **magnitude** of internnual SST variability in the Central Pacific, explains why SSTs in that region account for most of the dominant response to global SSTs in the GOGA runs.

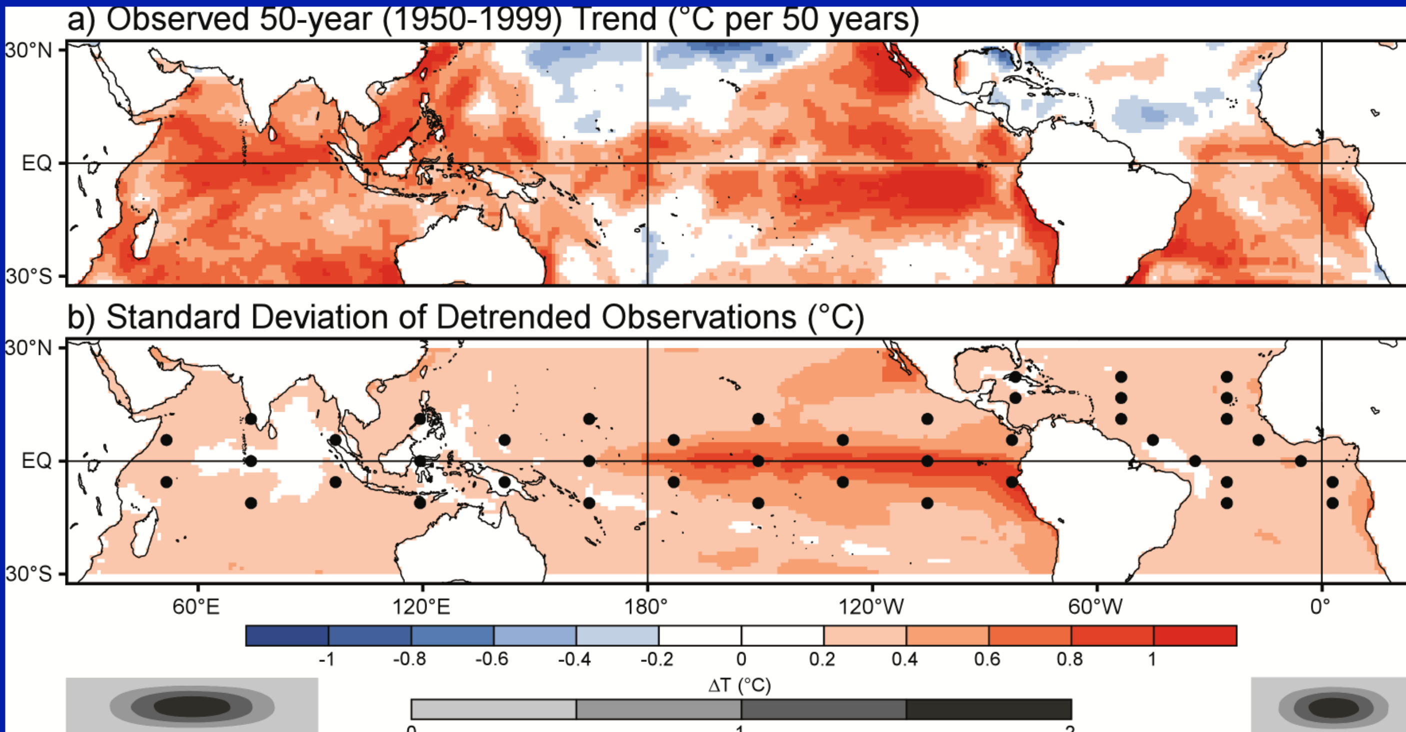
(From Barsugli and Sardeshmukh, J. Climate 2002



A study of atmospheric sensitivity to tropical SSTs using the NCAR/CCM3 AGCM

A “GASPATCHO” warming and cooling experiment

(**G**lobal **A**tmospheric **S**ensitivity to **PATCH**y **O**cean warming and cooling)



Observed 50-yr (1950-99) SST trends.

Observed standard deviation of detrended seasonal SST anomalies.

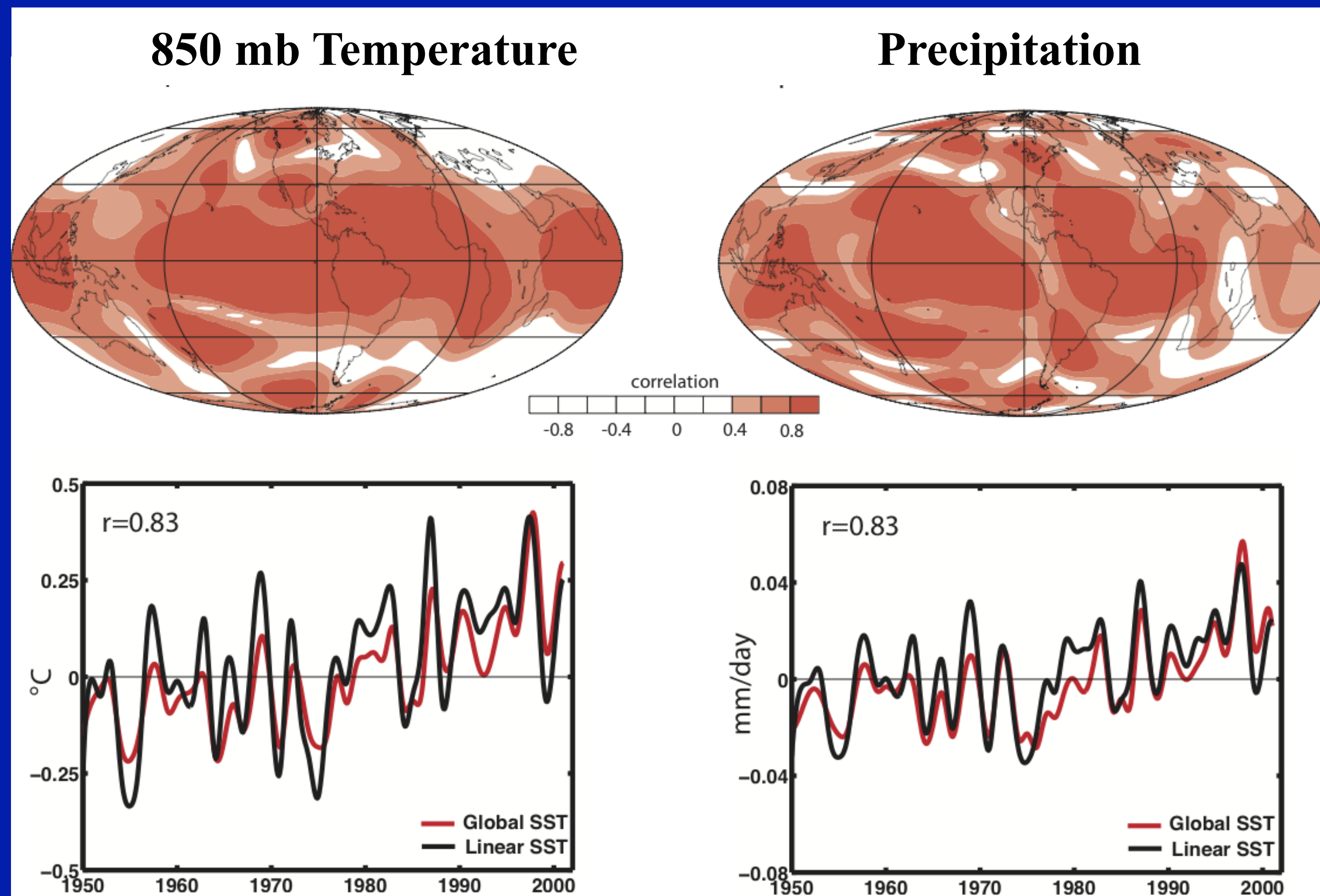
We determine the AGCM’s seasonally varying ensemble-mean responses to each of 43 localized ± 2/3°C SST anomaly “patches” at the locations shown.

The CCM3's GOGA responses are skillfully captured by linear combinations of the responses to the individual patches

So, not only does TOGA approximate GOGA, but *linear* TOGA approximates GOGA

Local correlations of annual-mean GOGA and linearly reconstructed responses

Time series of annual mean and global mean GOGA and linearly reconstructed responses.



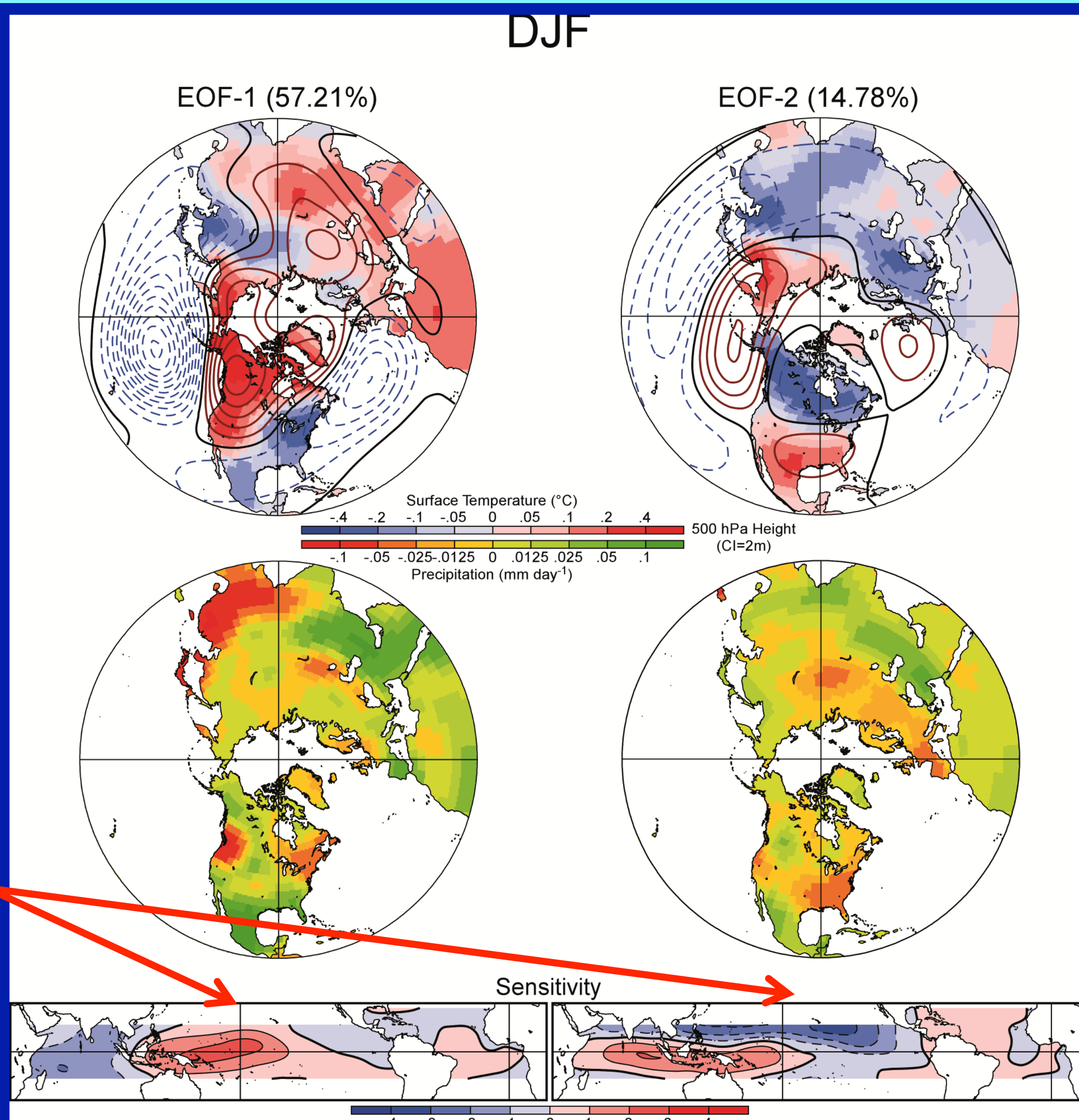
Dominant EOFs of the 43 responses to the 43 patches in DJF

Combined EOFs of 500 mb heights, land temperature, and land precipitation responses

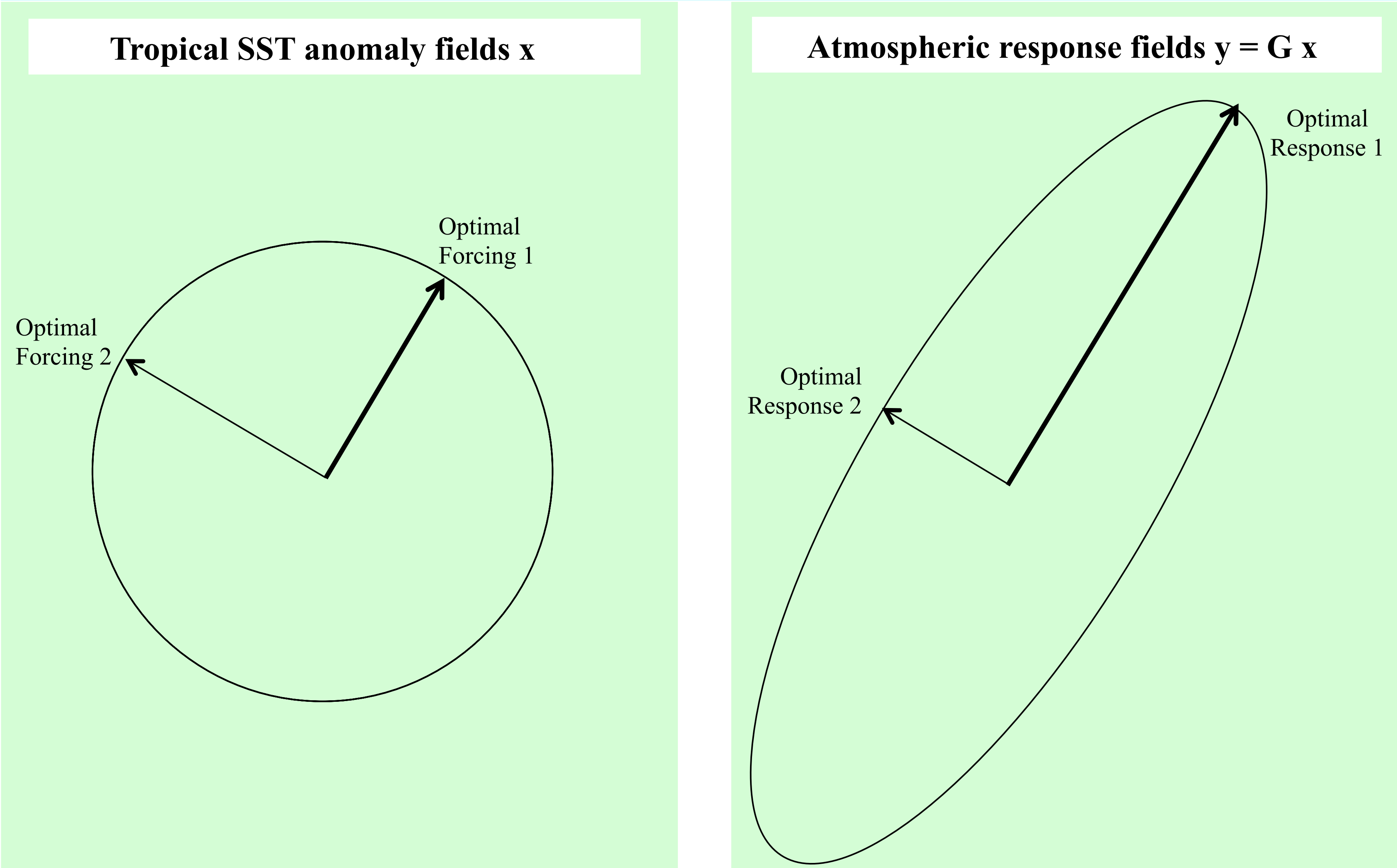
(optimal response patterns)

Amplitude with which the above EOFs are excited by the SST patches at different locations

(sensitivity maps, or optimal forcing patterns)

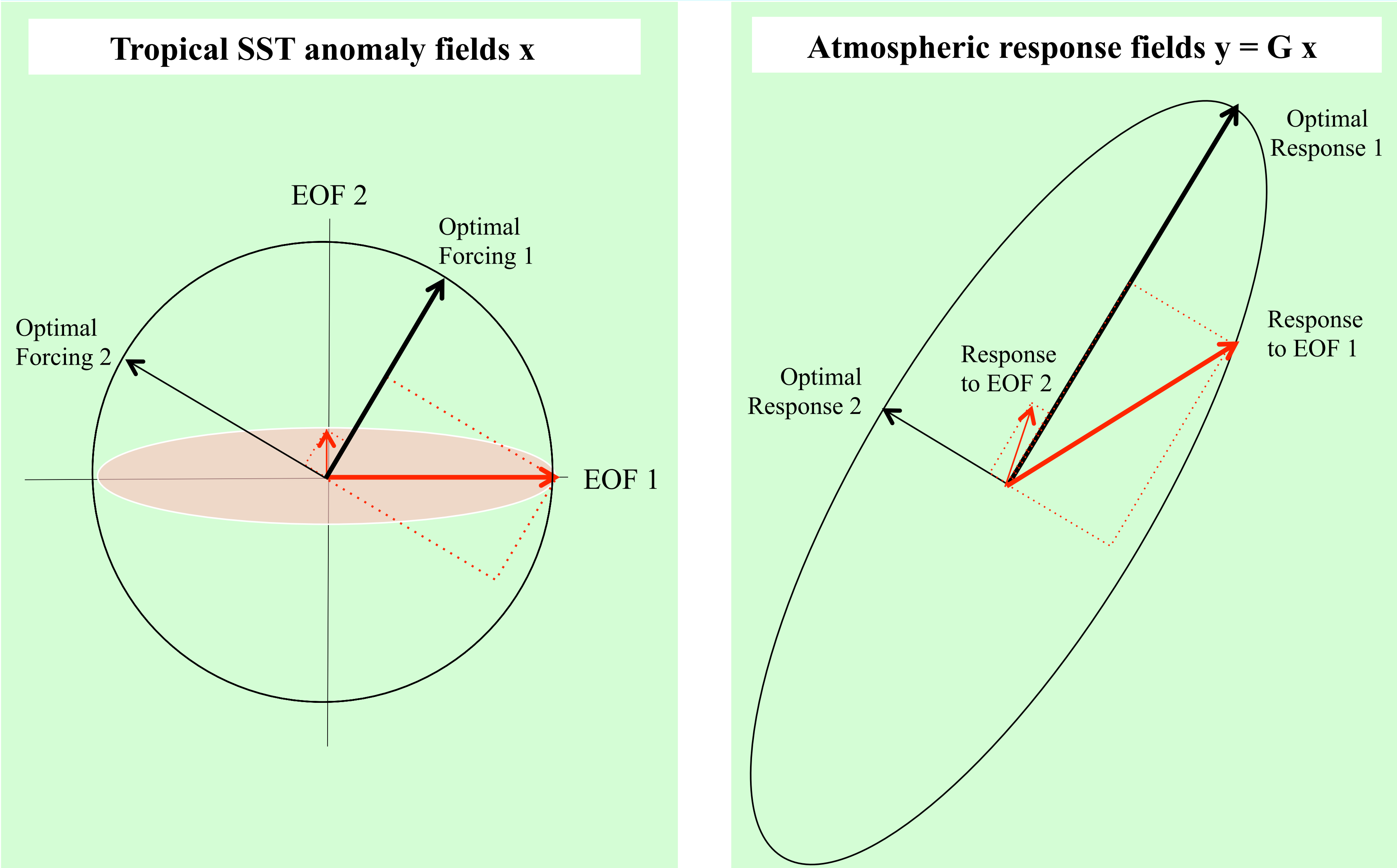


A simple conceptualization of tropical SST impacts on the global atmosphere



The response operator G may be characterized by its two dominant right/left singular vector pairs, which may also be interpreted as two optimal forcing/response pattern pairs. The response to an arbitrary SST forcing is then determined simply from its projection on the optimal forcing patterns.

A simple conceptualization of tropical SST impacts on the global atmosphere



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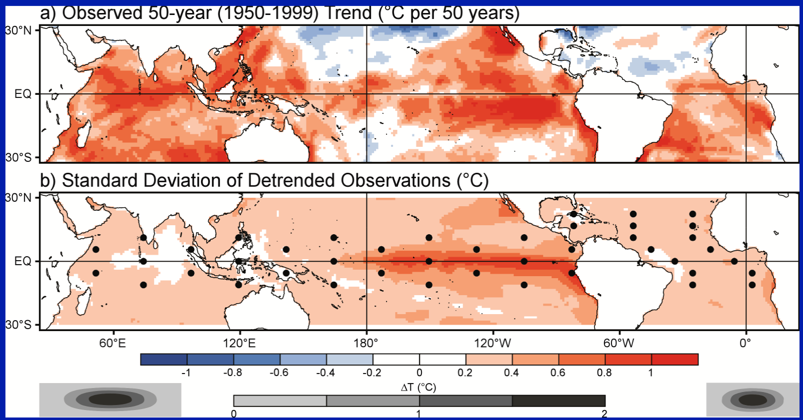
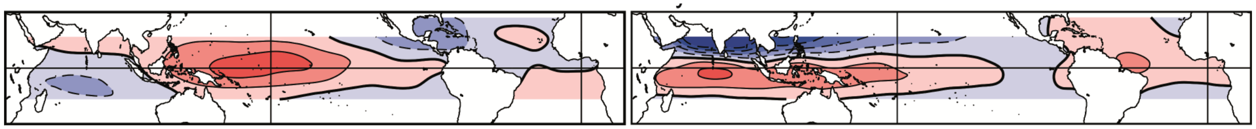
In summary, the global impacts of tropical SST variability and trend patterns *depend strongly on how they project on the dominant <u>sensitivity</u> patterns shown below.*



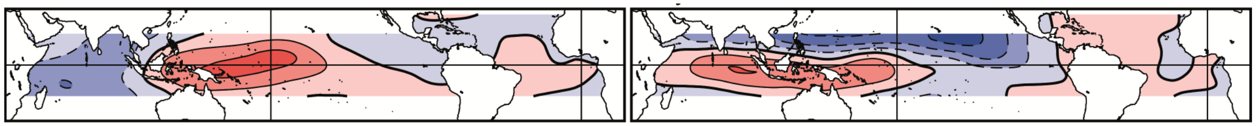
Optimal SST forcing patterns for maximizing atmospheric responses

(Dominant Sensitivity Patterns)

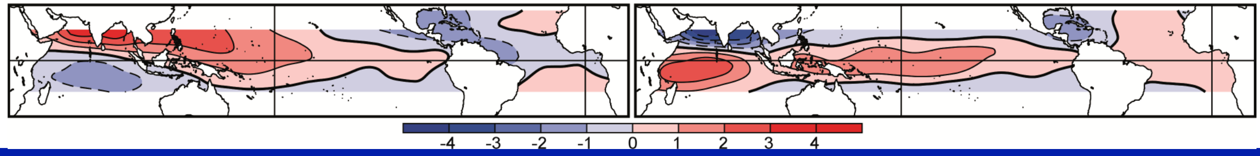
<u>Pattern 1</u>		<u>Pattern 2</u>
36 %	Annual	18 %



57 %	DJF	15 %



40 %	JJA	23 %



To have confidence in climate model projections of climate trends, it is necessary for their tropical SST trend patterns to project correctly on the SST sensitivity maps.

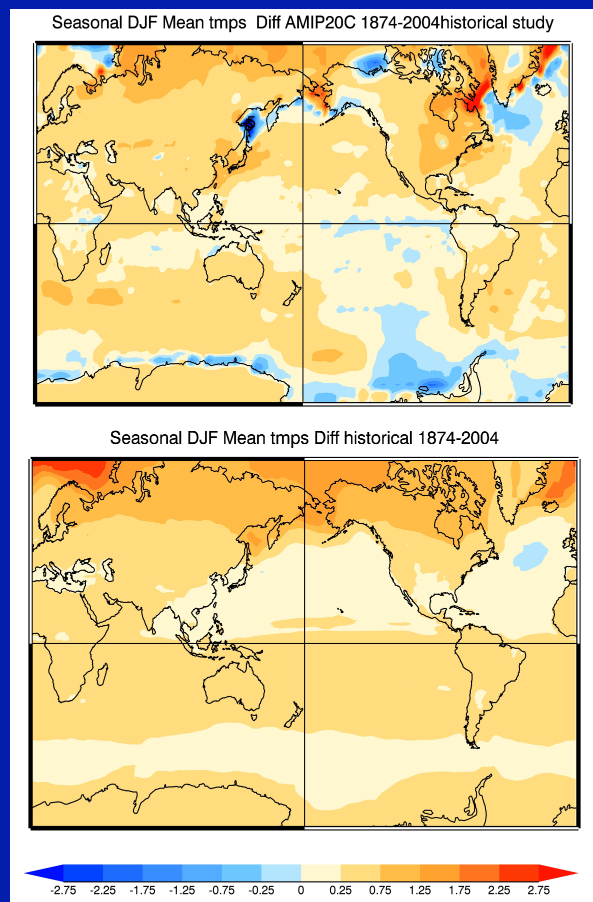
Not doing so could result in model changes of the wrong sign, as illustrated below for atmospheric circulation changes associated with 20th century global warming (1940-2004 DJF average minus 1874-1939 DJF average)

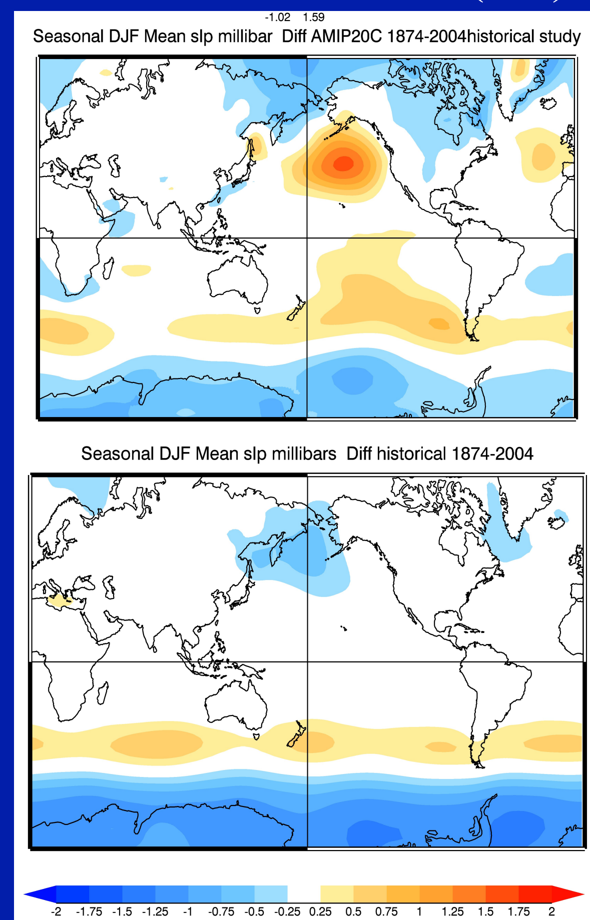
Surface Temperature (C)

Sea Level Pressure (mb)

AMIP20C Ensemble-mean change

CMIP5 Multi-model ensemble mean change





Summary

1) There is a highly preferred global atmospheric response pattern (an "optimal response pattern") to even spatially random tropical SST forcing. To that extent, the details of ENSO-related SST forcing don't really matter for the remote atmospheric response.

2) The optimal response pattern is mostly strongly excited by an optimal SST forcing pattern, that may also be interpreted as a dominant sensitivity pattern. The sensitivities are generally largest in the **central and <u>western</u> tropical Pacific and Indian oceans.**

3) Because ENSO-related SST variability is largest in the central and eastern tropical Pacific, it impacts the global circulation primarily through its central Pacific portion.

4) "ENSO Diversity" and future changes in ENSO-related SST variability will matter mainly to the extent that those changes are large in the **central and <u>western</u> tropical Pacific and Indian oceans.**