The Insensitivity of the Atmospheric Circulation Response to the Pattern of Sea Surface Temperature Change

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1. Introduction

The response of tropical SST pattern to increasing CO2 is important because of its potential impact on global climate through atmospheric teleconnections. The present study investigates the impact of tropical SST pattern change on global circulation change by comparing AGCM simulations forced with uniform SST increase and structured SST increase. Surprisingly, these two simulations produce similar circulation changes, especially at extra-tropics, indicating an insignificant impact of SST pattern change.

2. Data

We analyze three AGCM simulations that were performed as part of CMIP5. These simulations are 1) the control simulation (CTRL), which was run from year 1979 to year 2008 forced with observed monthly mean SST and sea ice concentration, 2) the uniform SST increase simulation (Uniform), which is the same as CTRL except adding a uniform +4K SST anomaly, 3) the structured SST increase simulation (Structured), which is the same as CTRL except adding the SST anomalies as the long-term SST changes simulated by coupled models (Fig. 1). Each simulation is analyzed from an ensemble of seven models.

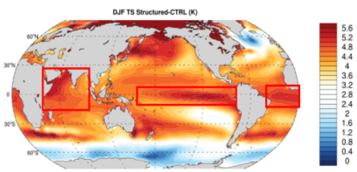

Figure 1. Ensemble mean DJF surface temperature difference between Structured and CTRL simulations.

3. Results

All seven models show that the response of atmospheric circulation to uniform and structured SST increase is very similar in the tropics and almost identical in the extra-tropics (Table 1).

	SLP	H500	Omega500
Tropics	0.65	0.82	0.77
Extra-tropics	0.94	0.92	0.89

Table 1. Ensemble mean pattern correlation between circulation changes due to uniform and structured SST increase.

3.1. Tropics

Changes in DJF Omega500 in response to uniform and structured SST increase are dominated by their common features, which include reduced convection at major climatological convective regions and reduced subsidence at the northern flank of convective regions (Fig. 2.b, 2.c). These common features, to the first order, can be explained by the global energetic constraints (e.g., Held and Soden 2006), which predict a 5% reduction of the climatological Omega500 (Fig. 2.a).
Omega500 change due to SST pattern change is mostly at the Equator (Fig. 2.d).

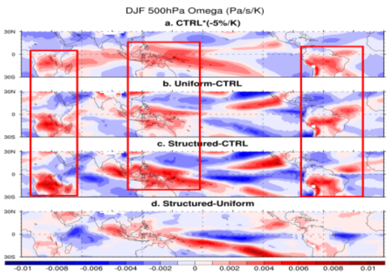

Figure 2. a) -5% times the ensemble mean DJF Omega500 in CTRL; b) ensemble mean DJF Omega500 change due to uniform SST increase; c) ensemble mean DJF Omega500 change due to structured SST increase; d) c – b. For b) and c), the Omega500 change is normalized by each model's global mean surface temperature change before averaged across models.

3.2. Extra-tropics

The mechanism by which tropical sea surface temperature variations influence extra-tropical circulation is through the poleward dispersion of Rossby waves forced by tropical upper-level divergence (e.g., Sardeshmukh and Hoskins 1988;). The dominant term of Rossby Wave Source (RWS) change can be written as $RWS' \approx -\varsigma \cdot D'$, where ς is the absolute vorticity and D is the upper-level divergence.
Although the upper-level divergence field changes throughout the tropics (Fig. 3), most of the RWS changes are in the subtropics (Fig. 4). This is due to the small absolute vorticity near the Equator. Changes in upper-level divergence due to changes in SST pattern are mostly near the Equator and cannot be transformed into RWS (Fig. 3c, 4c), hence the similar circulation change in the extra-tropics.

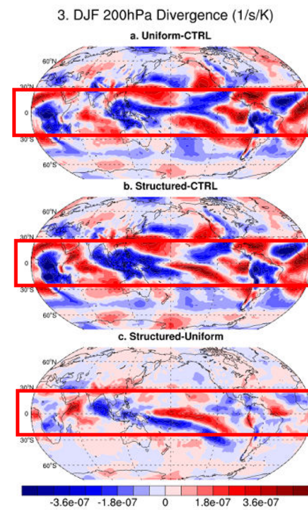

Figure 3. Same as Fig. 2.b, 2.c, 2.d, except for 200 hPa Divergence

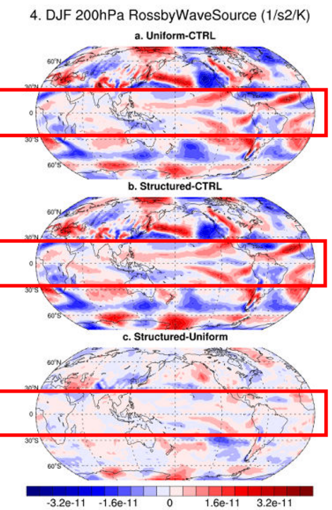

Figure 4. Same as Fig. 3, except for 200hPa RWS.

4. Conclusions

The circulation changes under the two types of SST forcing are similar in both the tropics and extra-tropics, indicating that the pattern of SST change has a relatively small impact on the character of the circulation response.
The tropical similarity partially reflects global energetic constraints on the circulation response, while the extra-tropical similarity results from the insensitivity of Rossby Wave generation to changes tropical upper-level divergence.

References
Held, I. M., and B. J. Soden, 2006: Robust Responses of the Hydrological Cycle to Global Warming. J. Clim., 19, 5686-5699.
Sardeshmukh, P. D., 1988: The Generation of Global Rotational Flow by Steady Idealized Tropical Divergence. J. Atmos. Sci., 45, 1228-1251.

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