Radiation is sensitive to the geographic patterns of surface temperature changes, which is referred to as the “pattern effect” (Stevens et al. 2016).

Difference in surface warming -> changes in atmospheric circulation-> changes in convection/clouds -> changes in temperature changes, which is referred to as the “pattern effect” (Stevens et al. 2016).

The Green’s function approach

To better understand the pattern effect, previous studies applied the Green’s function (GF) approach to atmosphere-only simulations forced by patches of anomalous SSTs (e.g., Zhou et al. 2017, Dong et al. 2019).

The change of a variable \( X \) (e.g., net TOA radiation, surface air temperature, and so on) at a grid point \( i \) in response to perturbations in SST is computed as

\[
\Delta X_i = \sum_{j=1}^{n} \frac{\partial X_i}{\partial SST_j} \Delta SST_j + \epsilon_X
\]

For the change at grid point \( i = 1 \)

\[
\Delta X_1 = \left[ \frac{\partial X_1}{\partial SST_1} \cdots \frac{\partial X_1}{\partial SST_n} \right] \Delta SST_1
\]

The global-annual-mean response for net TOA radiation (a, d), surface air temperature (b, e), and radiative feedback (c, f) retrieved from the AM4 Amip-piForcing run (a-c) and the AM4 4xCO2 run. The black lines are model outputs while the red lines are values reconstructed by the GF.

- The GF overestimates the magnitude of radiative cooling and radiative feedback for the AM4 4xCO2 simulations.

Global-mean results

Maps of global-annual-mean changes in response to 1-degree local SST warming at each ocean grid point (values are normalized by actual physical area of each grid box). Note that the unit for (a), (d), (e) and (f) is \( 10^{-8} \) W m\(^{-2}\) per unit local SST warming per square km, for (b) is \( 10^{-8} \) K per unit local SST warming per square km, for (c) is W m\(^{-2}\) per 1 degree Kelvin global-mean surface air temperature warming (actual physical area has been canceled out), for (g)-(l) is \( 10^{-8} \) percent per unit local SST warming per square km.

Sensitivity to the amplitude and sign of the SST perturbation

Maps of geographic locations of SST patches used in this study. Contours show half-amplitude of the patches (e.g., contours are +2.0K when the parameter \( A \) is set as +4.0K).

Regional responses

Considering SST patterns associated with the ENSO:

- Overall, the GF can reproduce the model-simulated regional responses.
- Surface air temperature is better reproduced by the GF, compared to net TOA radiation.
- Noticeable biases are found over land.

Conclusion

- For the Amip-piForcing run, the GF can reproduce model-simulated responses at both global and regional scales.
- The derived GF is sensitive to the amplitude and sign of the SST perturbation.
- More research is required to understand the discrepancy between model-simulated responses and the GF reconstructed ones, especially for atmosphere-only simulations forced by relatively uniform warming patterns.

Reference