Exploring Model Spread of Surface Warming Pattern in LongRunMIP

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Motivation

In response to CO2 forcing, surface temperatures in different regions warm at different rates and magnitudes relative to the global mean warming signal. This spatial pattern of surface temperature anomalies influences the radiative feedbacks. The difference of warming patterns between the eastern and western tropical Pacific dominantly affects this pattern effect. However, models show a large spread of magnitude and equilibration timescale across the tropics. It has been argued that the Southern Ocean and extra-tropical regions drive changes in the tropical Pacific, which should reflect in similar response timescales.

We analyze the annual surface air temperature anomalies (\(\Delta TAS\)) over three regions: the eastern tropical Pacific, western tropical Pacific, and the Southern Ocean. We use control and abrupt4xCO2 simulations from 11 LongRunMIP models: CCSM4, CESM1-B, CESM1-D, CESM1-M, CESM1E-R, ECHAM5-MPIOM, FAMOUS, GISS2R, HadCM3, HadGEM2, IPSL-CM5A, MPI-ESM1-1, and MPI-ESM1-2.

Key takeaways

- **model spread of \(\Delta TAS\) is large and does not reduce with time** (Fig.1)
- **the spread decreases after removing the global mean signal**, especially in the tropics (Fig.2).
- **The pattern correlations between the tropics and the Southern Ocean reduce with time**, which shows a shift from a trend-dependent correlation to an internal variability-dependent correlation (or lack thereof) (Fig.3).
- **With a strong forced trend, the large-scale change in the warming pattern over the Southern Ocean and tropics is coherent** (Fig.4).

Reference


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Figure 1. Ranges of 11 LongRunMIP models in 5-year running-mean \(\Delta TAS\) (upper panel), and the equilibrateness of \(\Delta TAS\) in relative to the year 1000 (bottom panel) in the Southern Ocean, eastern tropical Pacific, and western tropical Pacific.

Figure 2. As Fig. 1, but divided by global mean for every time step.

Figure 3. Correlation coefficients between analyzed regions (a, b, c, d) in every model (symbold). In a set of four correlations between two regions, from left to right, the first correlation is applied between the 1-200 year of \(\Delta TAS\) with the global mean, the second correlation is between the 801-1000 year of \(\Delta TAS\) with the global mean, the third and forth correlation are from the same time scale, but without global mean. The black symbols are medians of model spread, while the black lines represent the 10th to 90th percentiles.

Figure 4. Model mean correlation coefficient maps. The correlations are applied on \(\Delta TAS\) within different periods and between different regional averages and every grid points. Grids with yellow stippling are where more than 10 models agree on the correlation sign.