Exploring Model Spread of Surface Warming Pattern in LongRunMIP

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Motivation

In response to CO_2 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 (ΔTAS) over three regions: the eastern tropical Pacific, western tropical Pacific, and the Southern Ocean. We use control and abrupt4xCO_2 simulations from 11 LongRunMIP models: CCSM3, CESM104, CNRMCM61, ECHAM5MPIOM, FAMOUS, GISSE2R, HadCM3L, HadGEM2, IPSLCM5A, MPIESM11, and MPIESM12.

Time series with global mean

Model spread of ΔTAS

At year 150,

- 2.5-8.9K in South (6.4K);
- 3.2-8.5K in EPacific (5.3K);
- 2.8-8.0K in WPacific (5.2K).

At year 1000,

- 4.6-12.0K in South (7.4K);
- 3.7-10.4K in EPacific (6.7K);
- 3.2-9.9K in WPacific (6.7K).

Model spread of equilibrateness

At 80%,

- 174-432 years in South (258years);
- 39-124 years in EPacific (85years);
- 40-135 years in WPacific (95years).

At 90%,

- 333-651 years in South (318years);
- 85-299 years in EPacific (214years);
- 140-406 years in WPacific (266years).

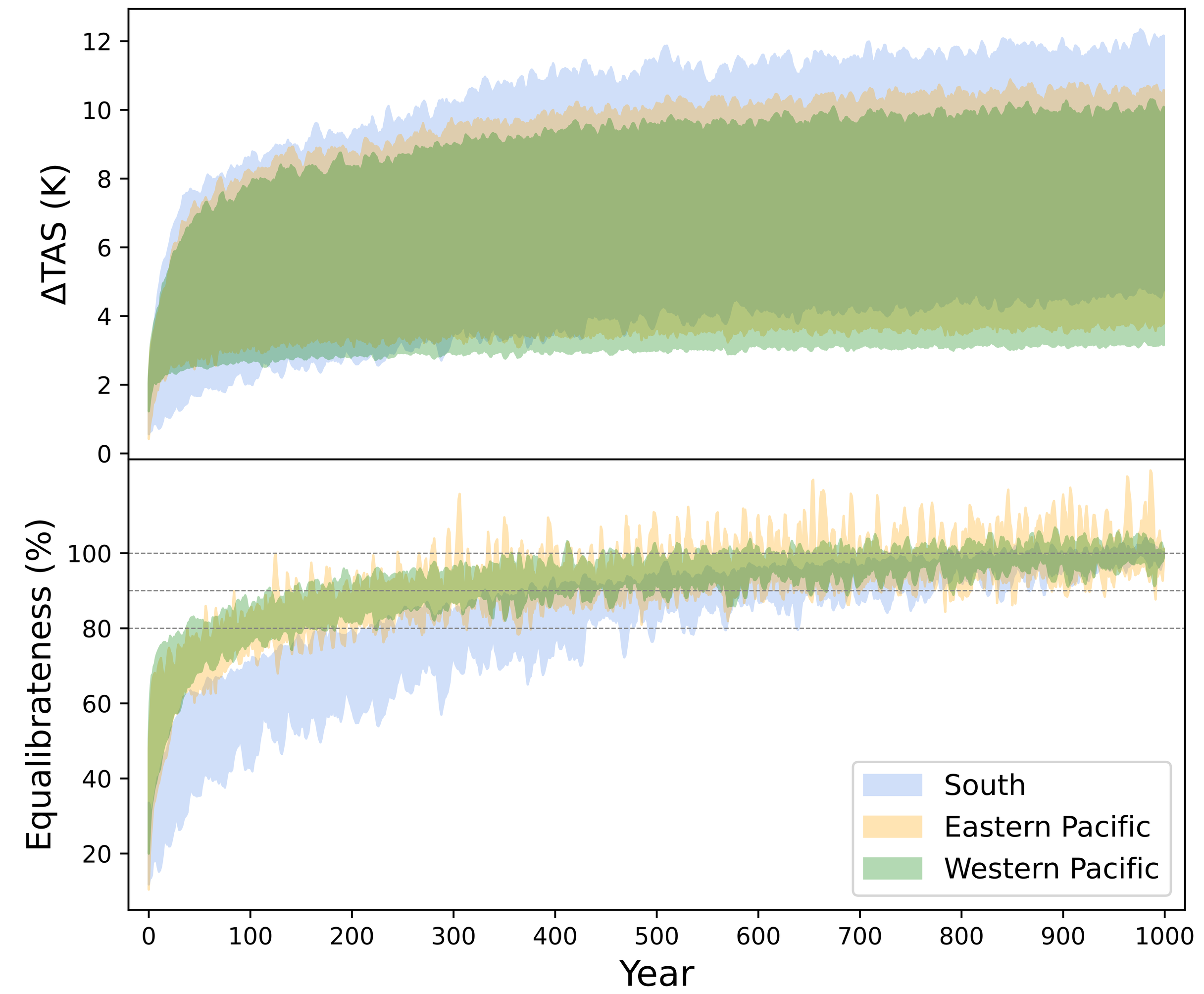

Figure 1. Ranges of 11 LongRunMIP models in 5-year running-mean ΔTAS (upper panel), and the equilibrateness of ΔTAS in relative to the year 1000 (bottom panel) in the Southern Ocean, eastern tropical Pacific, and western tropical Pacific.

Time series without global mean

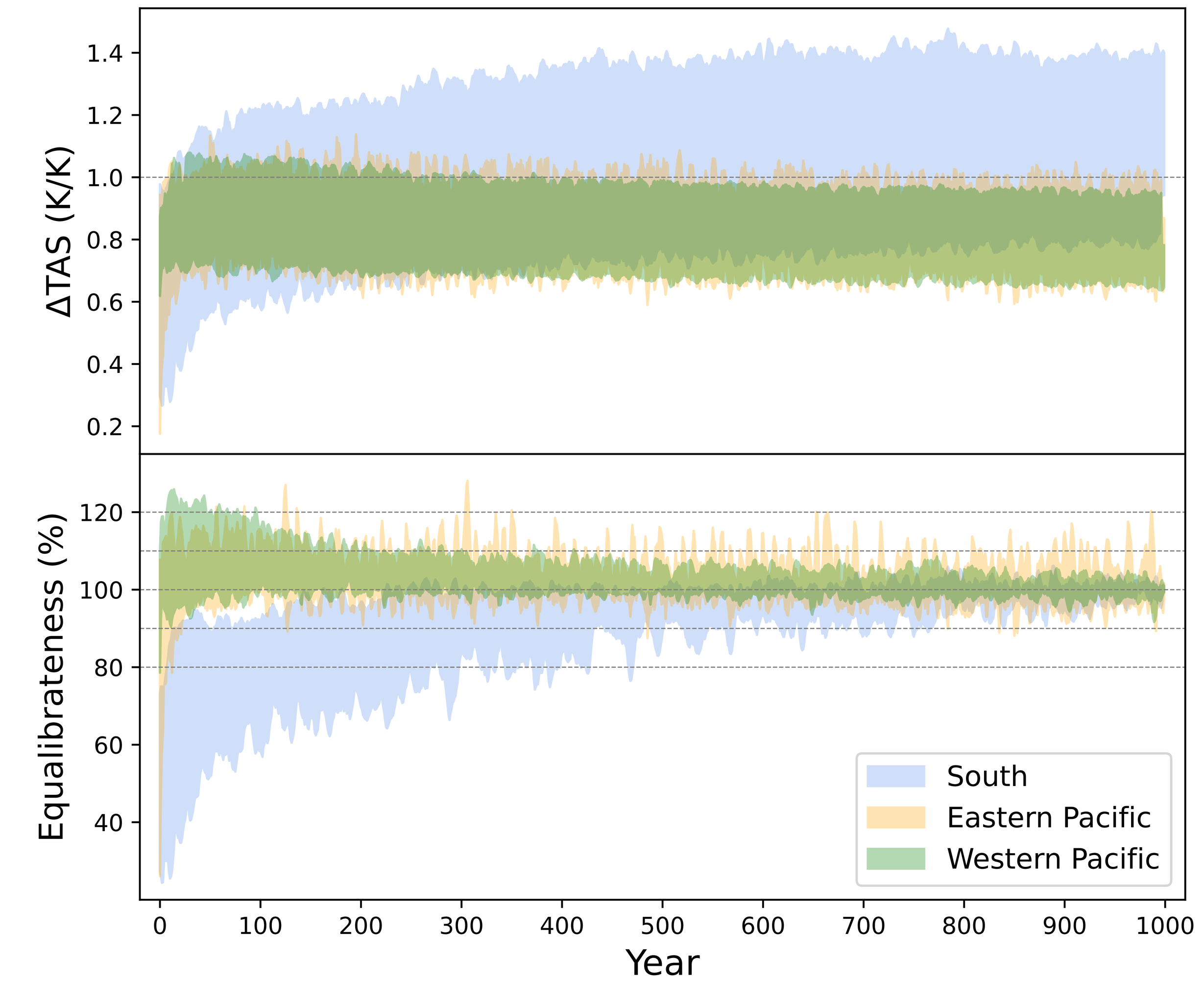

Figure 2. As Fig. 1, but divided by global mean for every time step.

Model spread of ΔTAS

At year 150,

- 0.6-1.2 in South (0.6);
- 0.7-1.0 in EPacific (0.3);
- 0.7-1.0 in WPacific (0.3).

At year 1000,

- 0.9-1.4 in South (0.5);
- 0.6-0.9 in EPacific (0.3);
- 0.6-1.0 in WPacific (0.4).

Model spread of equilibrateness

At 80%,

- 10-270 years in South (260years);
- 1-130 years in EPacific (130years);
- 1-48 years in WPacific (48years).

At 90%,

- 21-438 years in South (417years);
- 1-153 years in EPacific (153years);
- 1-153 years in WPacific (153years).

Key takeaways

- **model spread of ΔTAS** 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-dominant** correlation to an **internal variability-dominant** 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)

Global mean dominates the tropics-Southern Ocean correlation

The global mean dominates the correlation between the Southern Ocean, eastern tropical Pacific and western tropical Pacific.

- The 1-200year correlations are generally higher than the 801-1000year correlations.
- Model spread of the 801-1000year correlations is larger than the first 200-year, especially the correlation between the eastern tropical Pacific and the western tropical Pacific ΔTAS.

Pattern correlations are weak and model-dependent.

- The 1-200year correlations are generally higher than the 801-1000year correlations.
- Model spread of the 1-200year correlations is larger than the 801-1000year, which is the opposite of global-mean correlation.

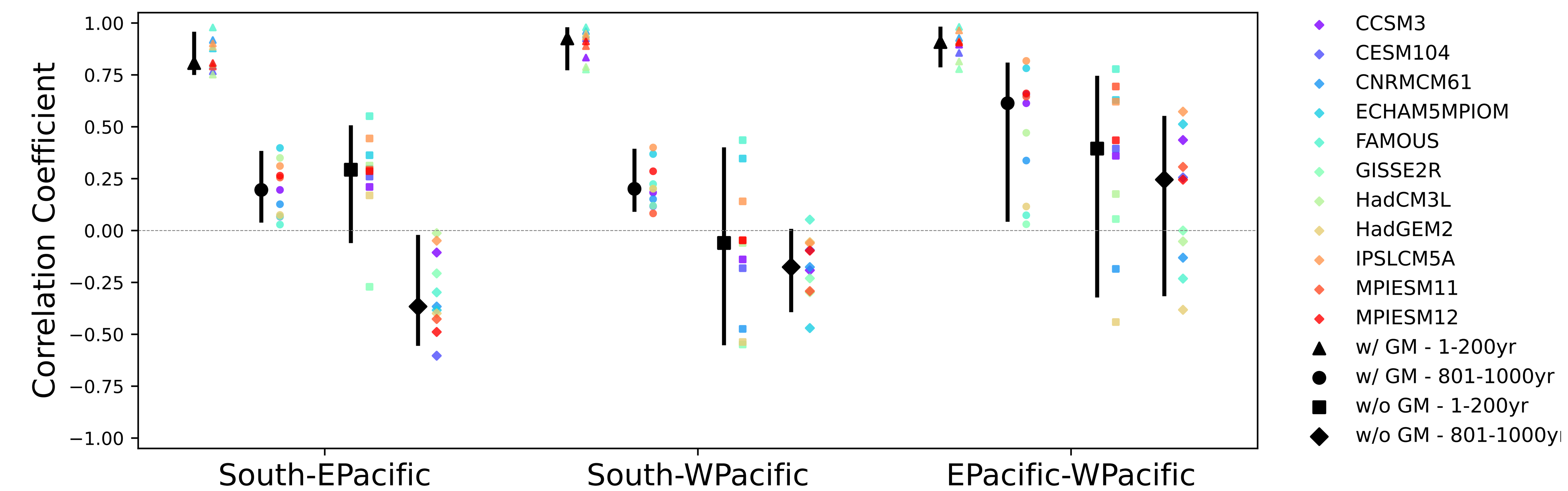

Figure 3. Correlation coefficients between analyzed regions (x-axis) in every model (symbols). In a set of four correlations between two regions, from left to right, the first correlation is applied between the 1-200year of ΔTAS with the global mean, the second correlation is between the 801-1000year of ΔTAS 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 5th to 95th percentile.

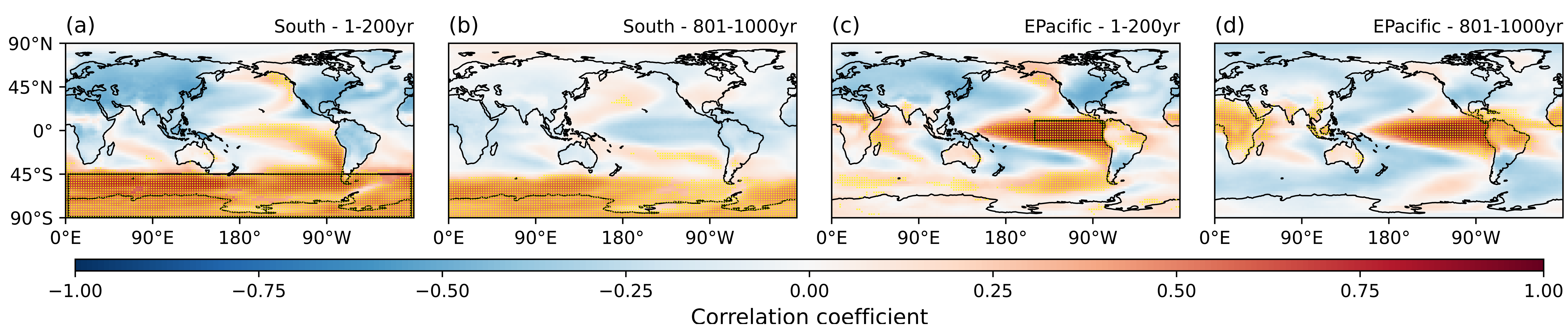

Figure 4. Model mean correlation coefficient maps. The correlations are applied on ΔTAS within different periods and between different regional averages and every grid points. Grids with yellow stippling are where more than 10 models agree on the correlation sign.

Reference

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