On the Northern Hemisphere summer circulation: Disentangling the contributions of different forcings through LESFMIP experiments.

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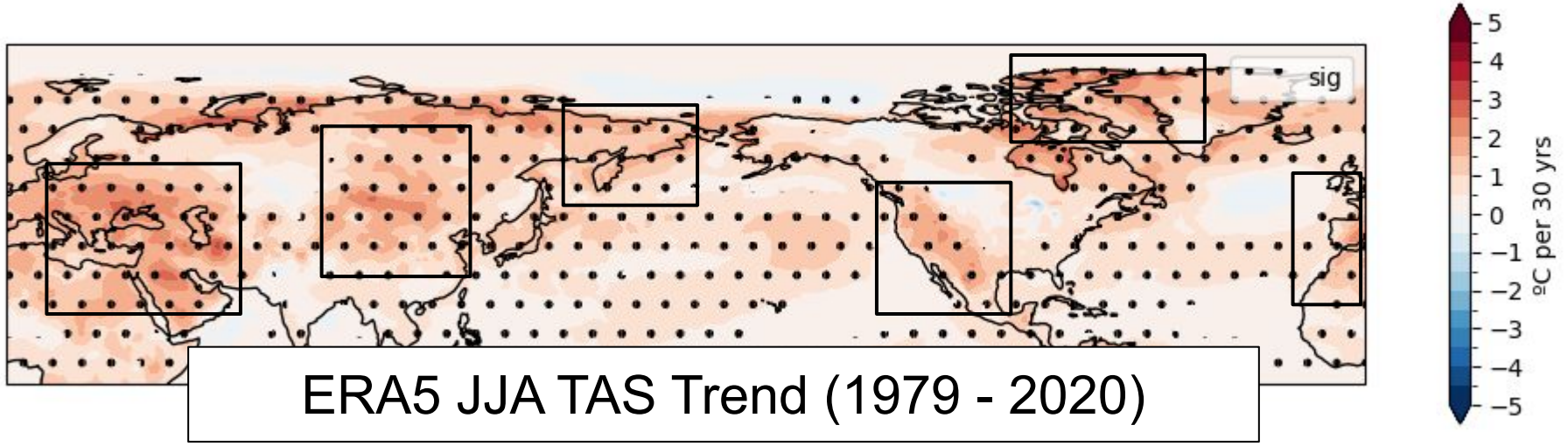
Context

Anomalous summertime warming

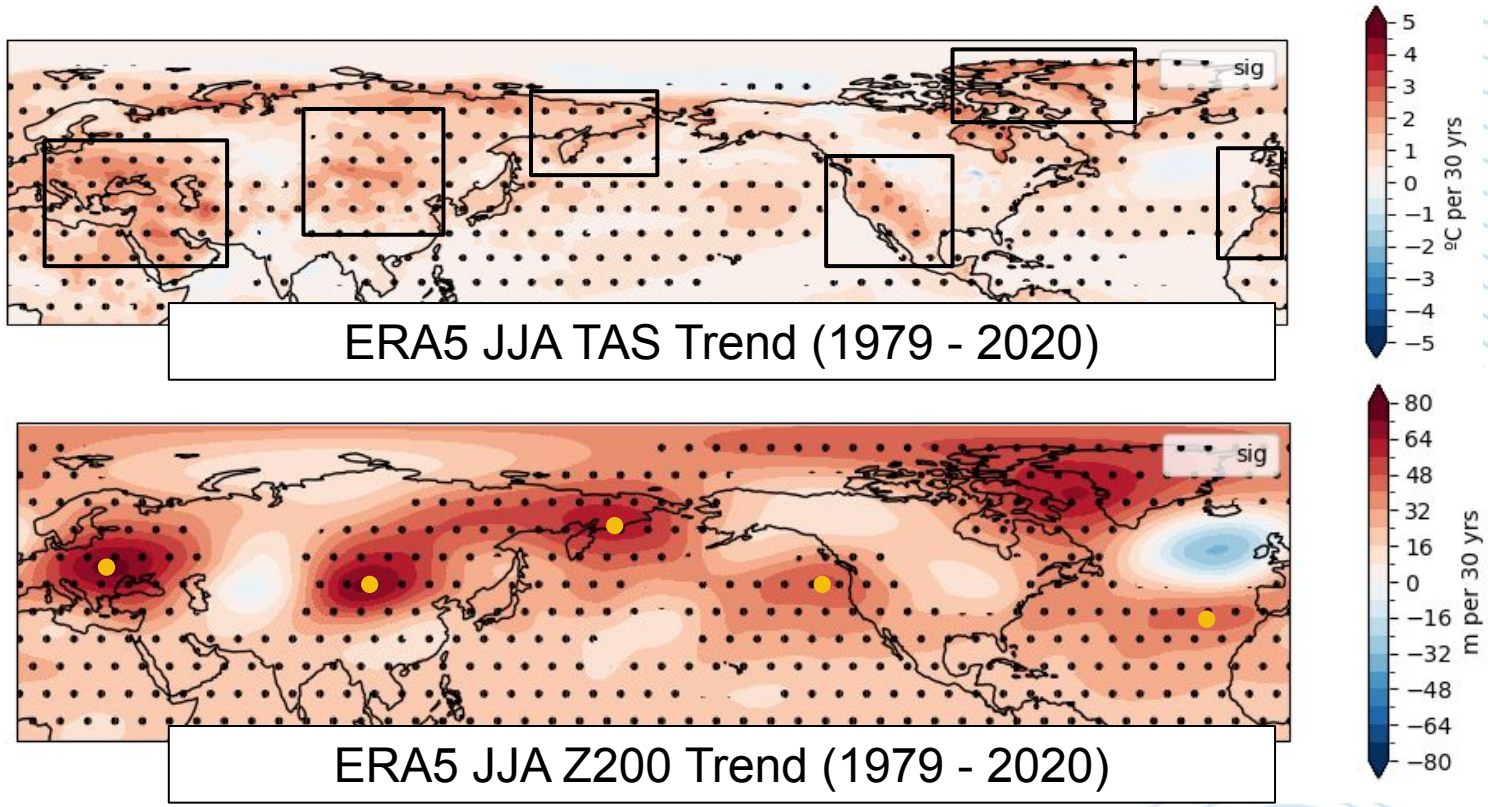
- Temperature trend during summer 1979-2020 not well understood and differs from the projected warming by CMIP5. (Teng, H., Leung, R., Branstator, G., Lu, J., & Ding, Q. (2022)).



ERA5 JJA TAS Trend (1979 - 2020)

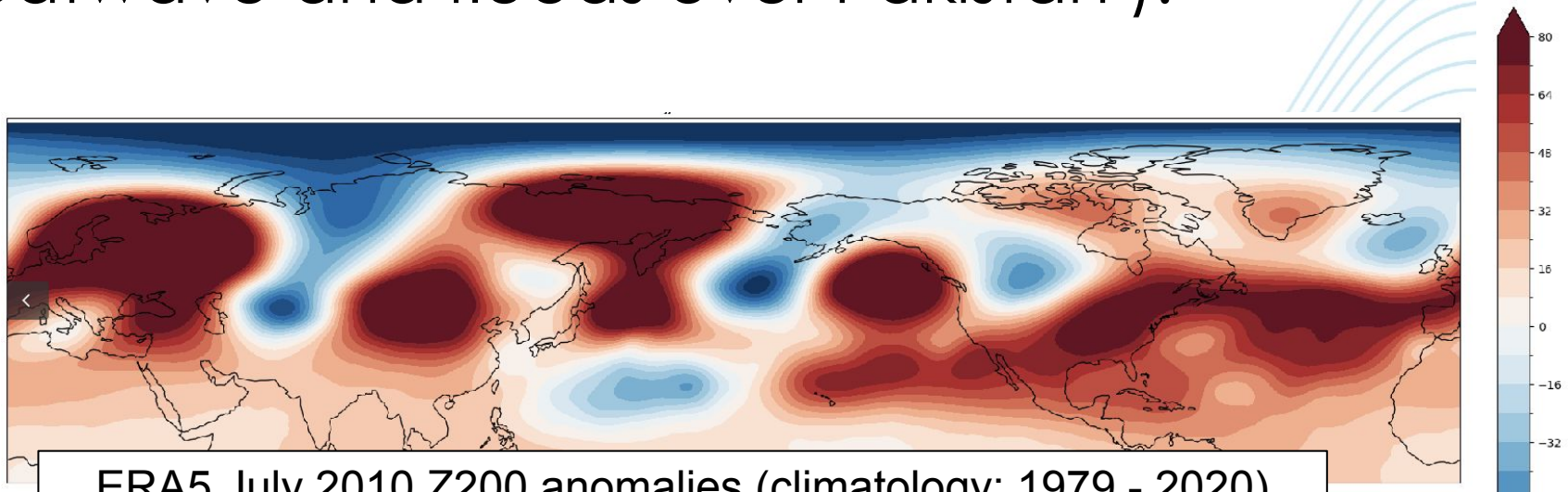
Anomalous summertime warming

- The observed hotspots coincide with centers of Z200 trend.
- Trends in GPH present a circumglobal wave structure



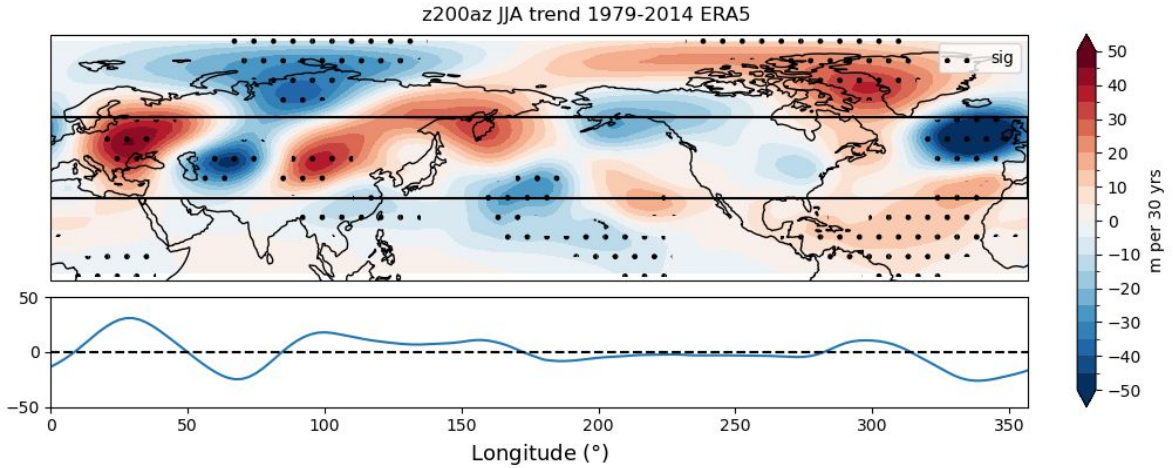
Anomalous summertime warming

- Z200 anomalies during simultaneous extreme events present a similar structure to the trend (e.g. July 2010 Russian heatwave and floods over Pakistan).

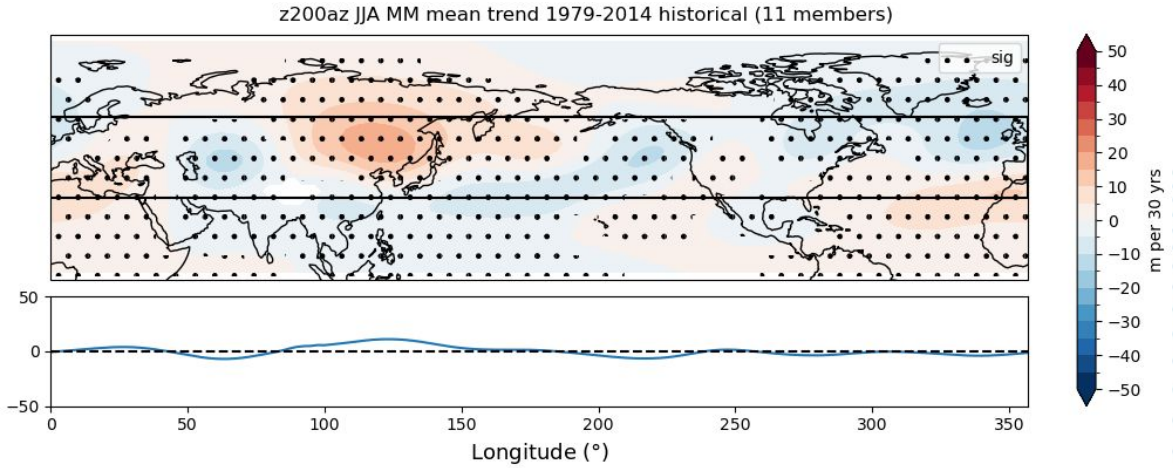


ERA5 July 2010 Z200 anomalies (climatology: 1979 - 2020)

Circulation response in CMIP6



ERA5



CMIP6 MM-Mean

Effect of external forcings

LESFMIP Experiments

- Coordinated experiments using isolated prescribed forcings to understand the role of each forcing has in the climate
  - Specifically there are experiments studying:
    - Aerosols
    - Well-mixed Greenhouse Gasses
    - Solar radiation
    - Ozone concentration
    - Volcanic

LESFMIP Experiments

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Results must take into account possible model errors, non-additivity of drivers, and missing processes such as glacial melt!

AMIP Experiments

- Atmospheric models with prescribed forcings and SST temperatures and sea ice concentration based on observations as boundary conditions.

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- Can be used to infer the role of SST forcing to the atmosphere.

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- Can be used to infer the role of SST forcing.

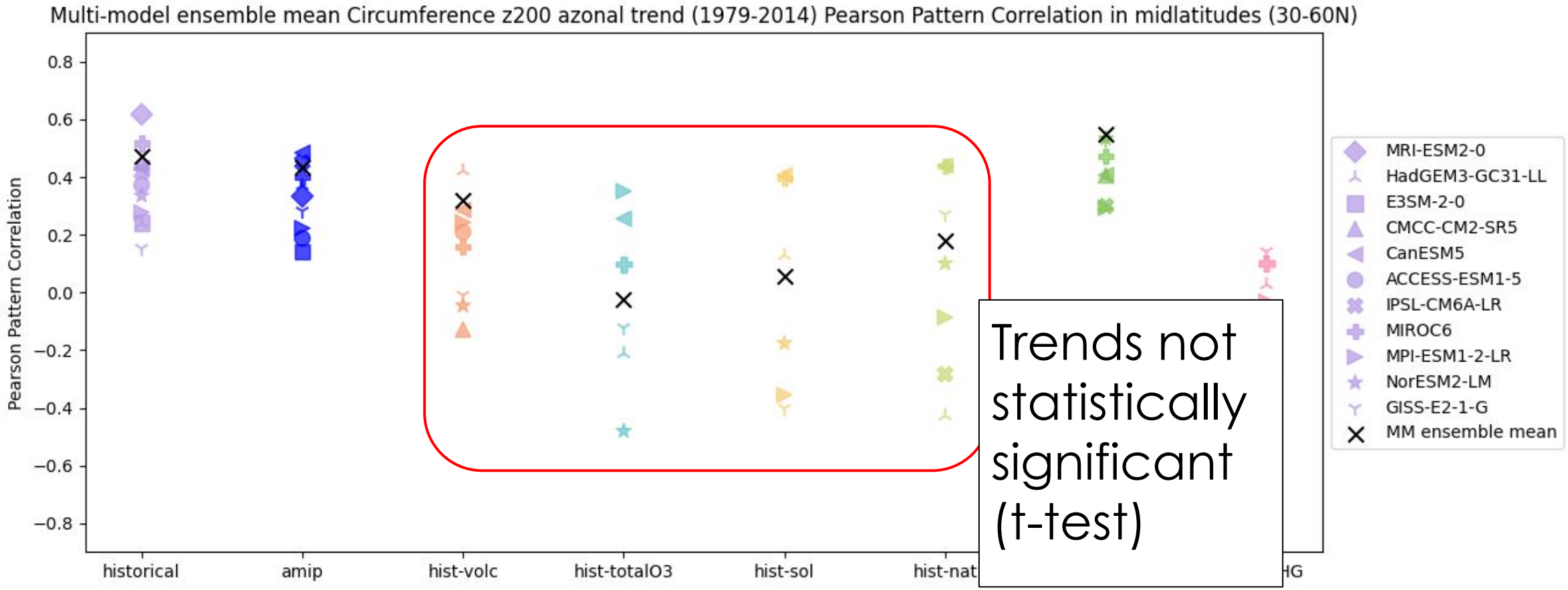
- No atmosphere-ocean interaction.
- SST changes are smoothed due to the methods used in prescribing ocean surface temperatures.

Methods

- Computed trend of Z200 azonal component for period 1979-2014 during JJA for each run, model ensemble mean and MM ensemble mean.
- Selected models with at least 10 members in LESFMIP or 3 members in AMIP.
- Computed pearson pattern correlation for NH mid-latitudes (30°-60°N) with respect to ERA5 reanalysis trend.

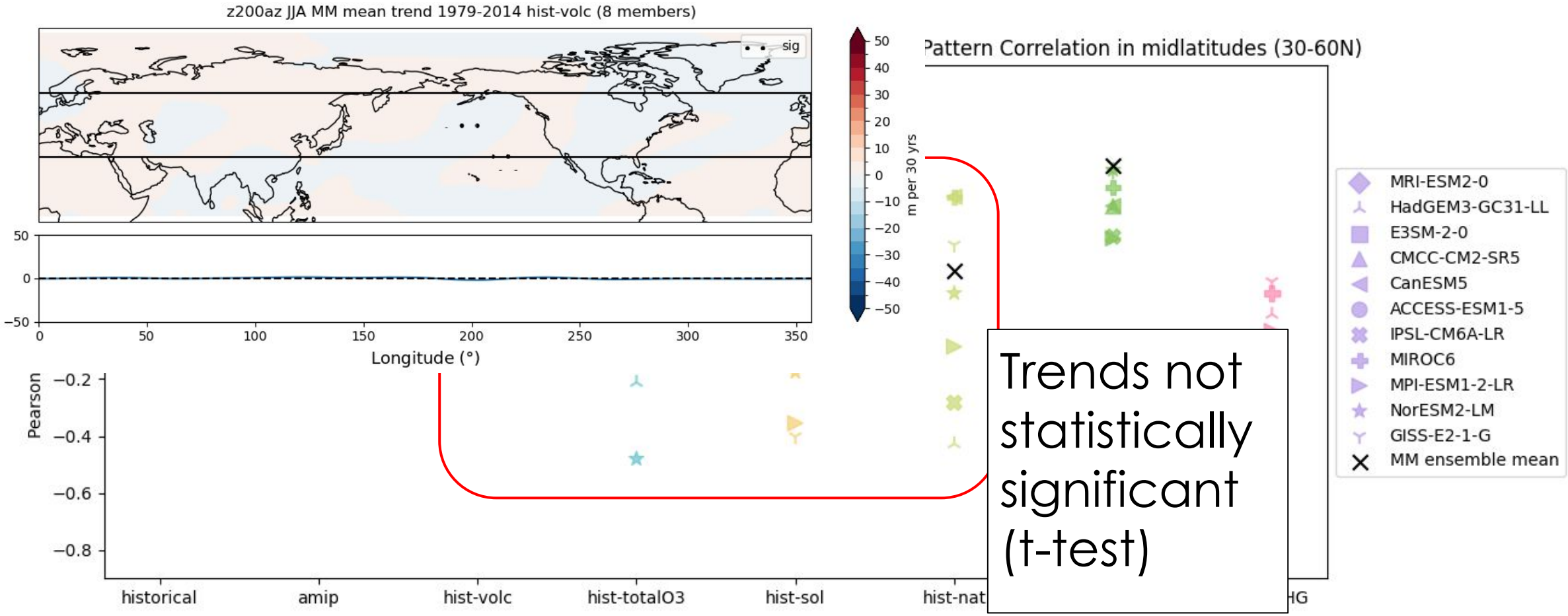
Forced response comparison

Forced response comparison



Trends not statistically significant (t-test)

Forced response comparison



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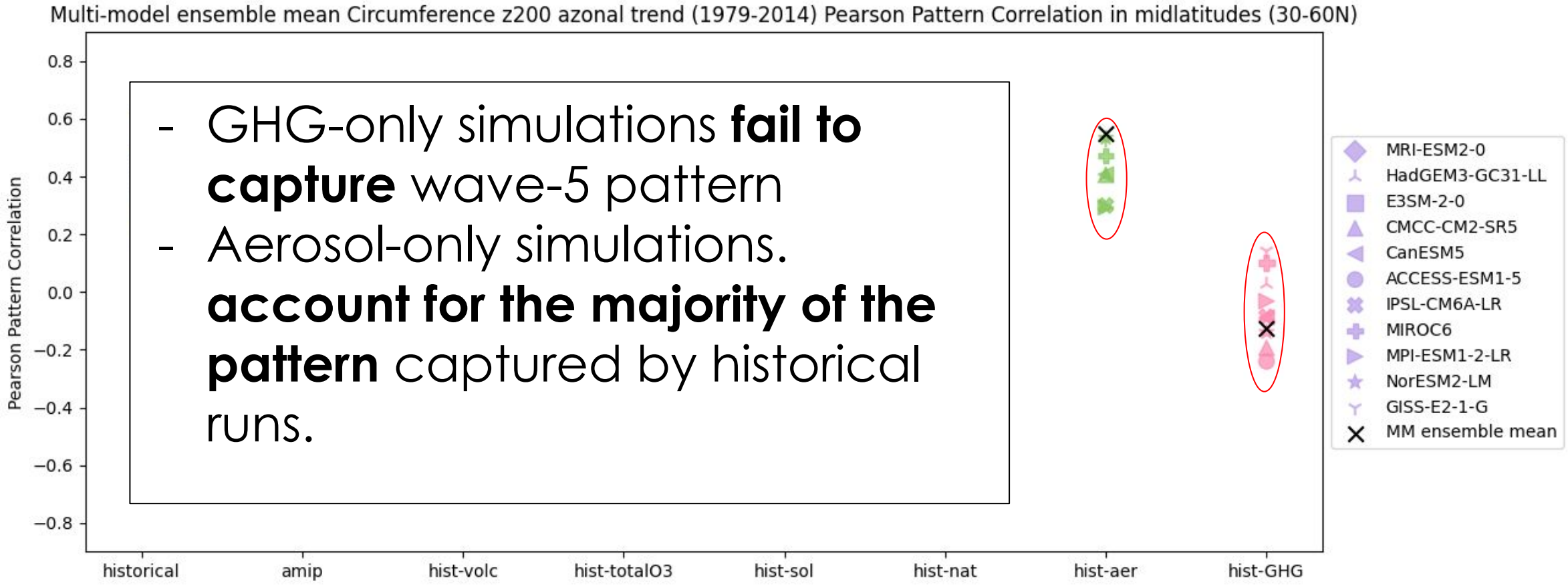
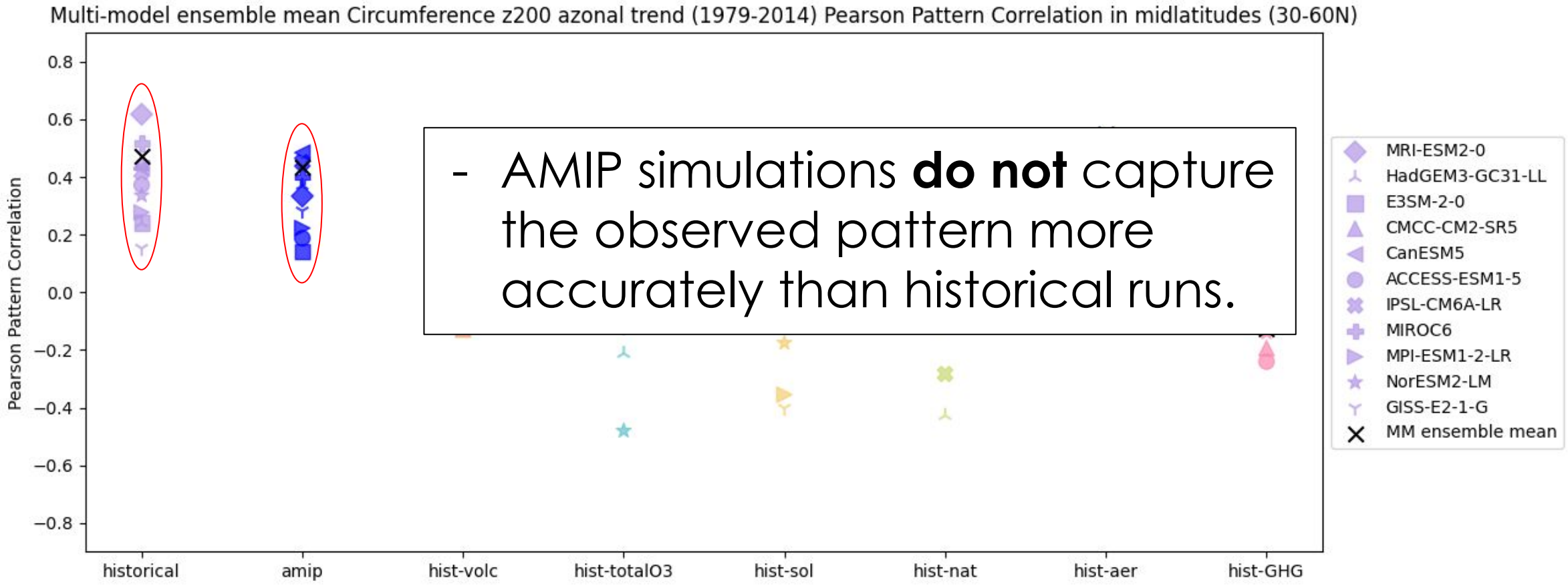


- GHG-only simulations **fail to capture** wave-5 pattern
- Aerosol-only simulations. **account for the majority of the pattern** captured by historical runs.

Forced response comparison

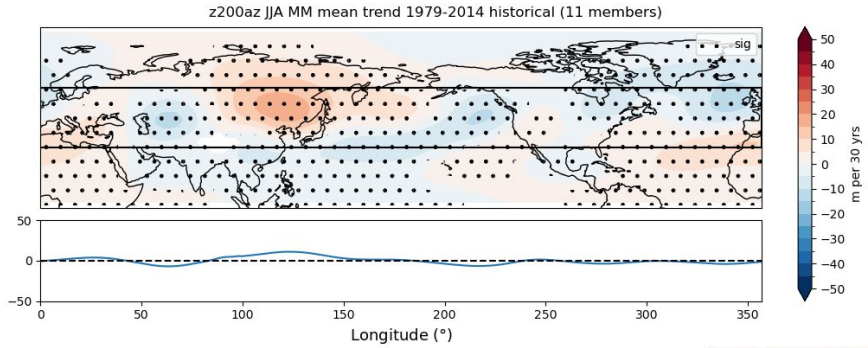
Forced response comparison



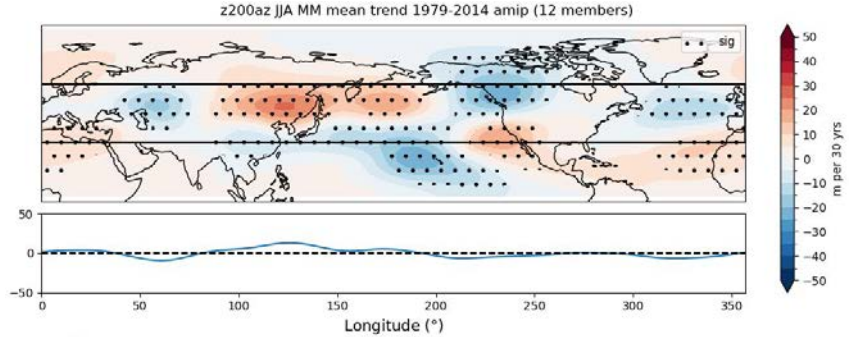
- AMIP simulations **do not** capture the observed pattern more accurately than historical runs.

Magnitude of the trend (MM-Mean)

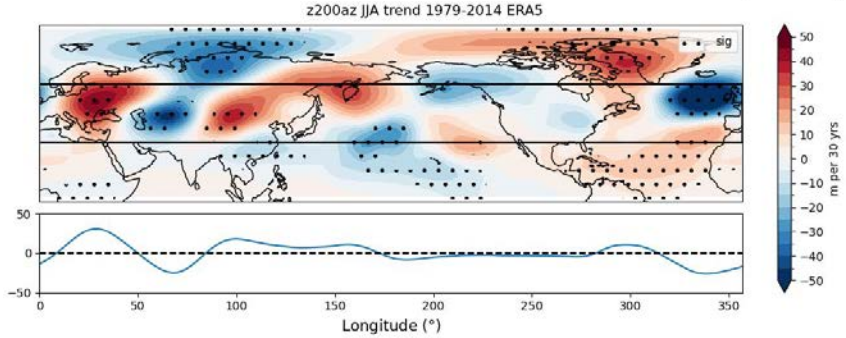
Historical



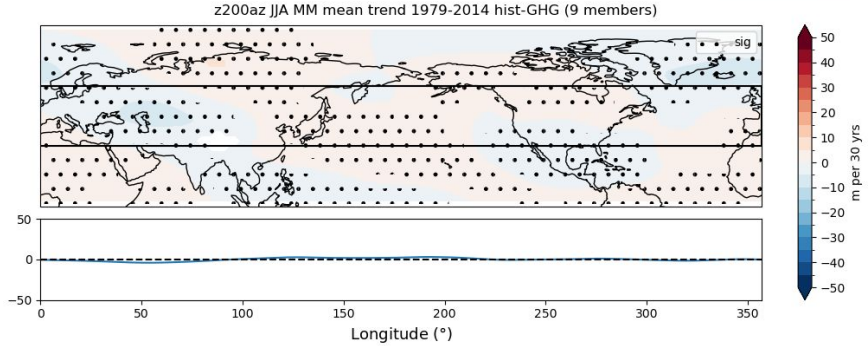
AMIP



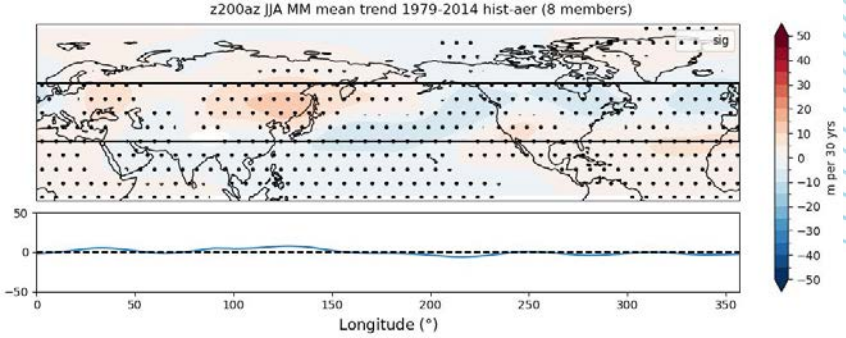
ERA5



GHG

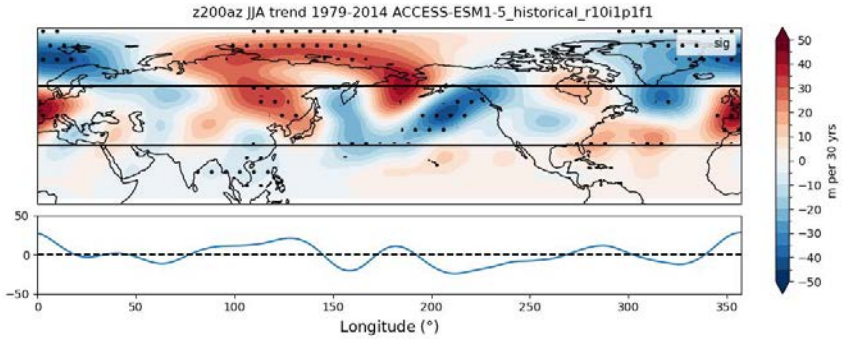


Aerosols

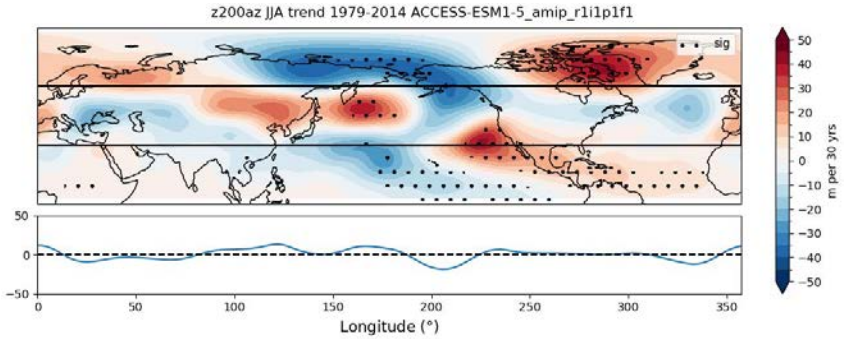


Magnitude of the trend (single runs)

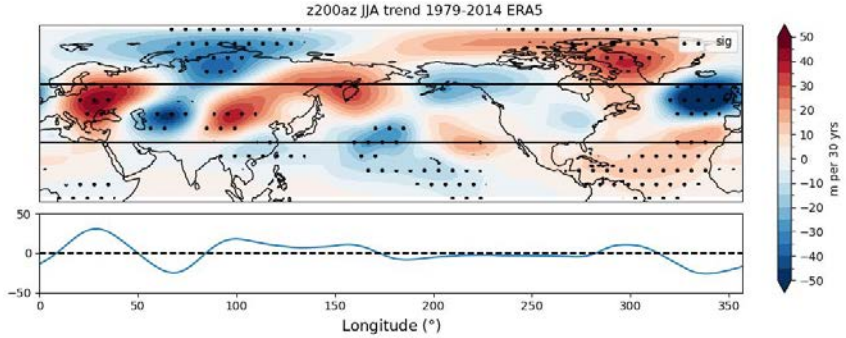
Historical



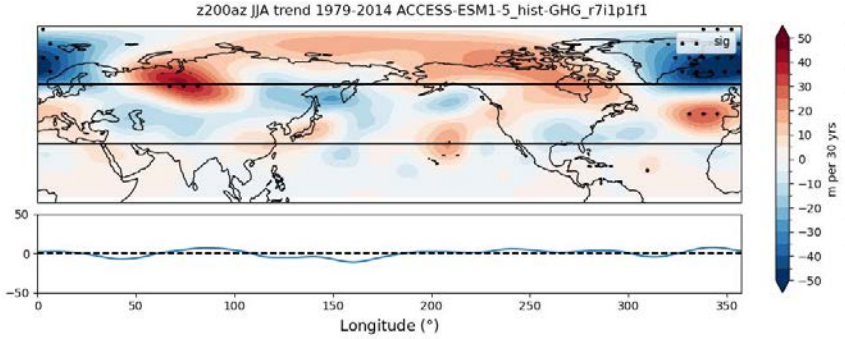
AMIP



ERA5



GHG



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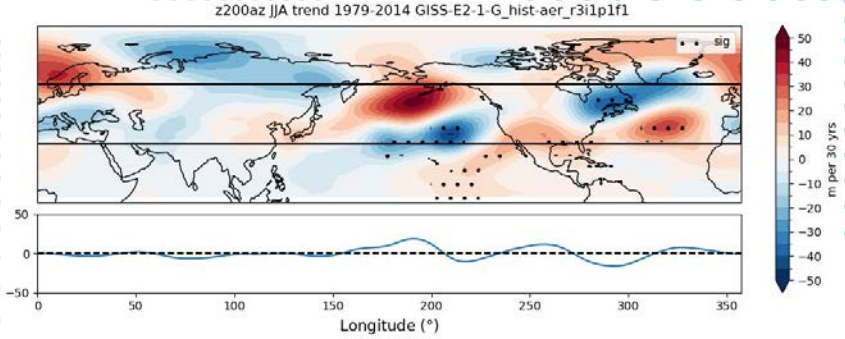
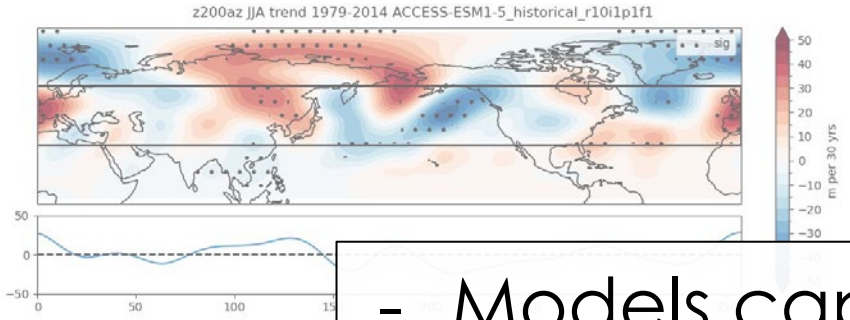
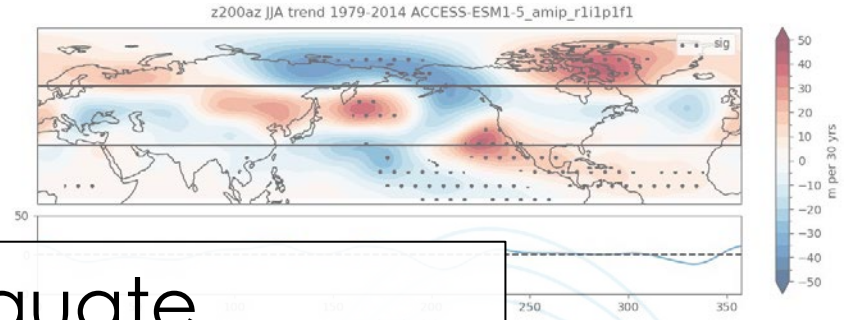


Magnitude of the trend (single runs)

Historical

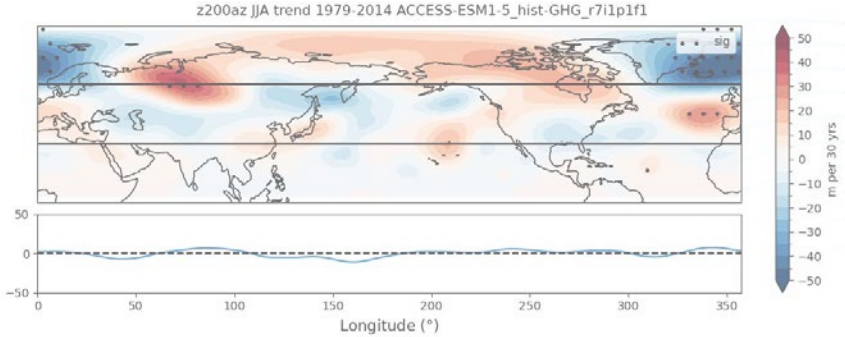


AMIP

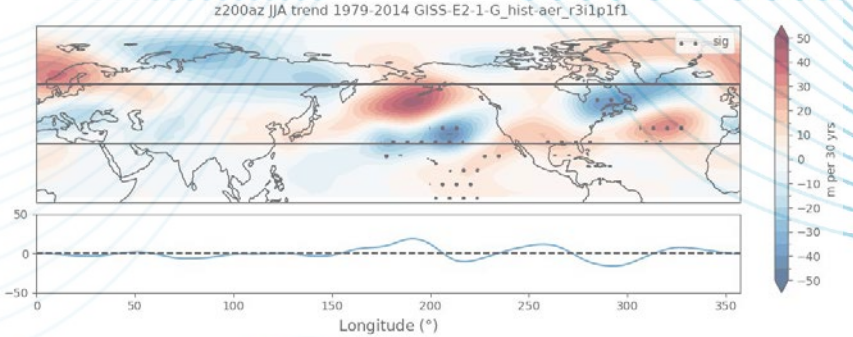


- Models capture the adequate magnitude but it is reduced when taking the ensemble mean.

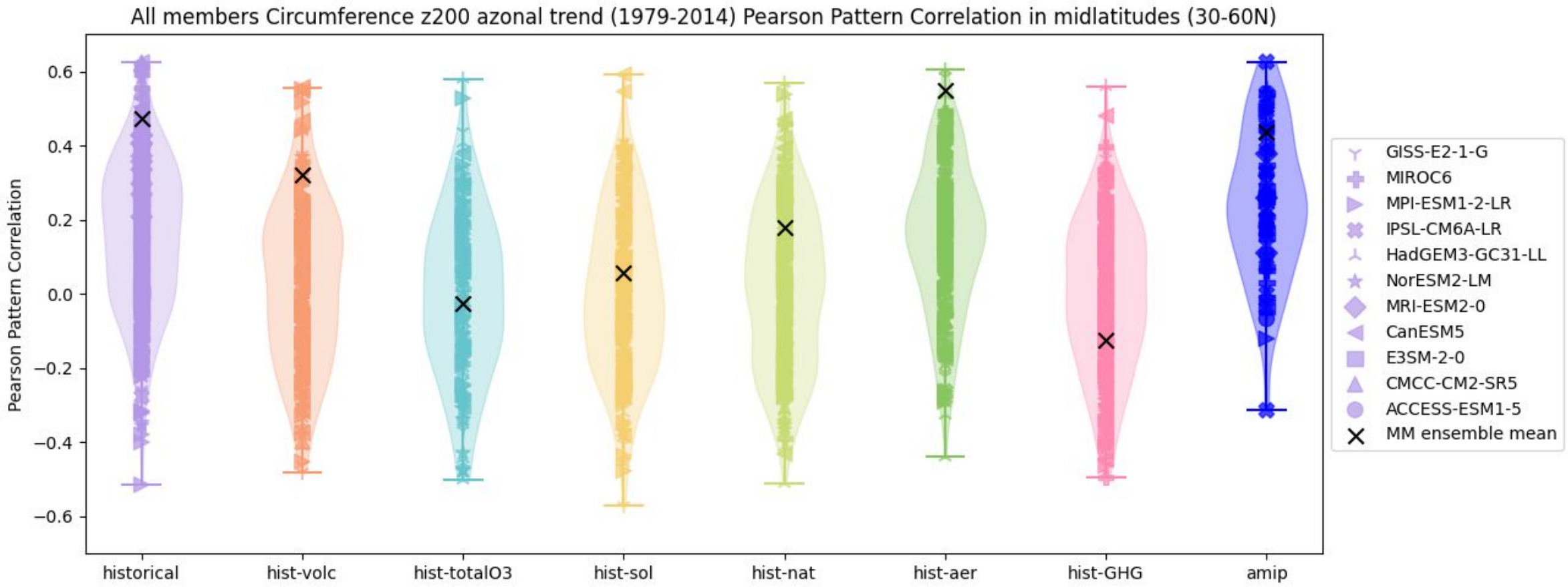
GHG



Aerosols



Response variability



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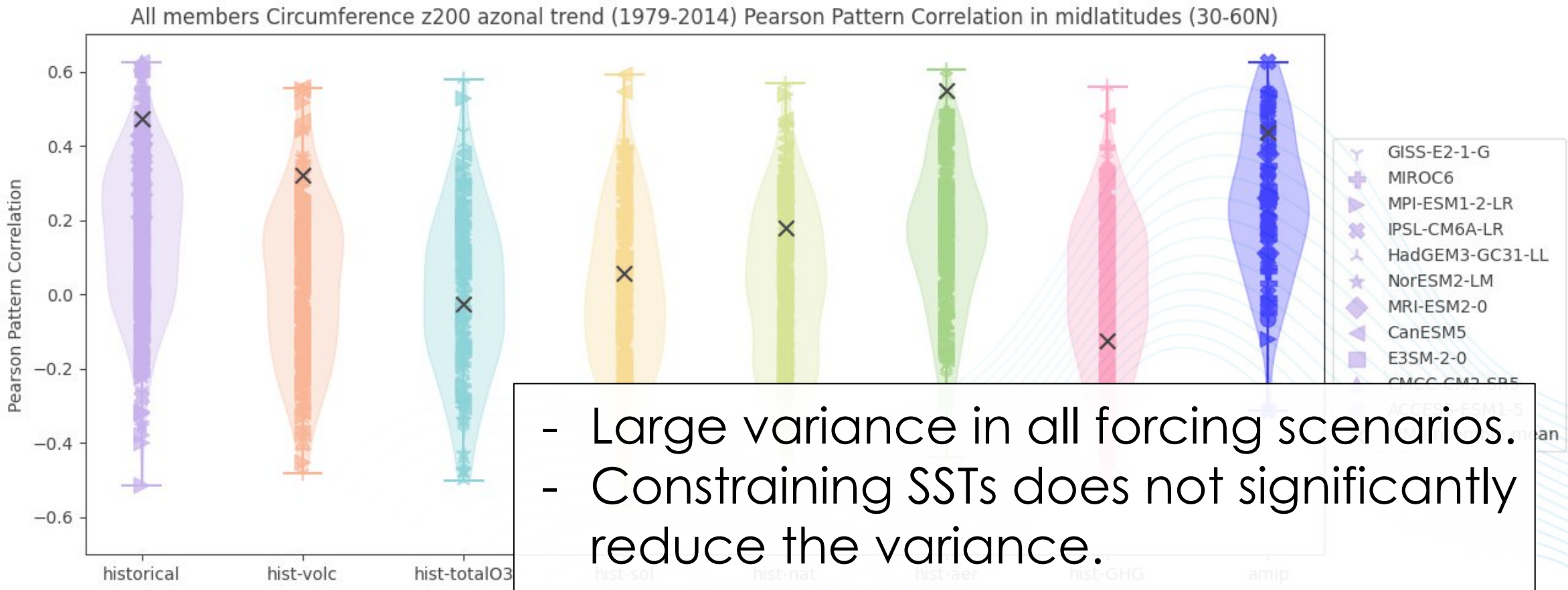

- Large variance in all forcing scenarios.
- Constraining SSTs does not significantly reduce the variance.

Thoughts & conclusions

Response to forcings

- Ensemble mean can capture some of the structure at low amplitude and there is distinct behavior from different forcings, which implies a response to forcings.
- GHG appear to not contribute to the formation of the observed structure, while aerosols seem to account for most of the forced response.

Internal variability

- There is lots of variance between individual runs for each forcing scenario. This points at internal variability playing a role modulating the circulation trend.
- AMIP runs were unable to provide significant additional value compared to historical forcings. Which hints at internal variability modulating the response via processes not well represented/constrained in AMIP runs.

Next steps

- Find a physical mechanism tying aerosols with the observed changes.
- Investigate the origin of the observed variance in models.
- Explore how these changes affect weather extremes.

Thank you!

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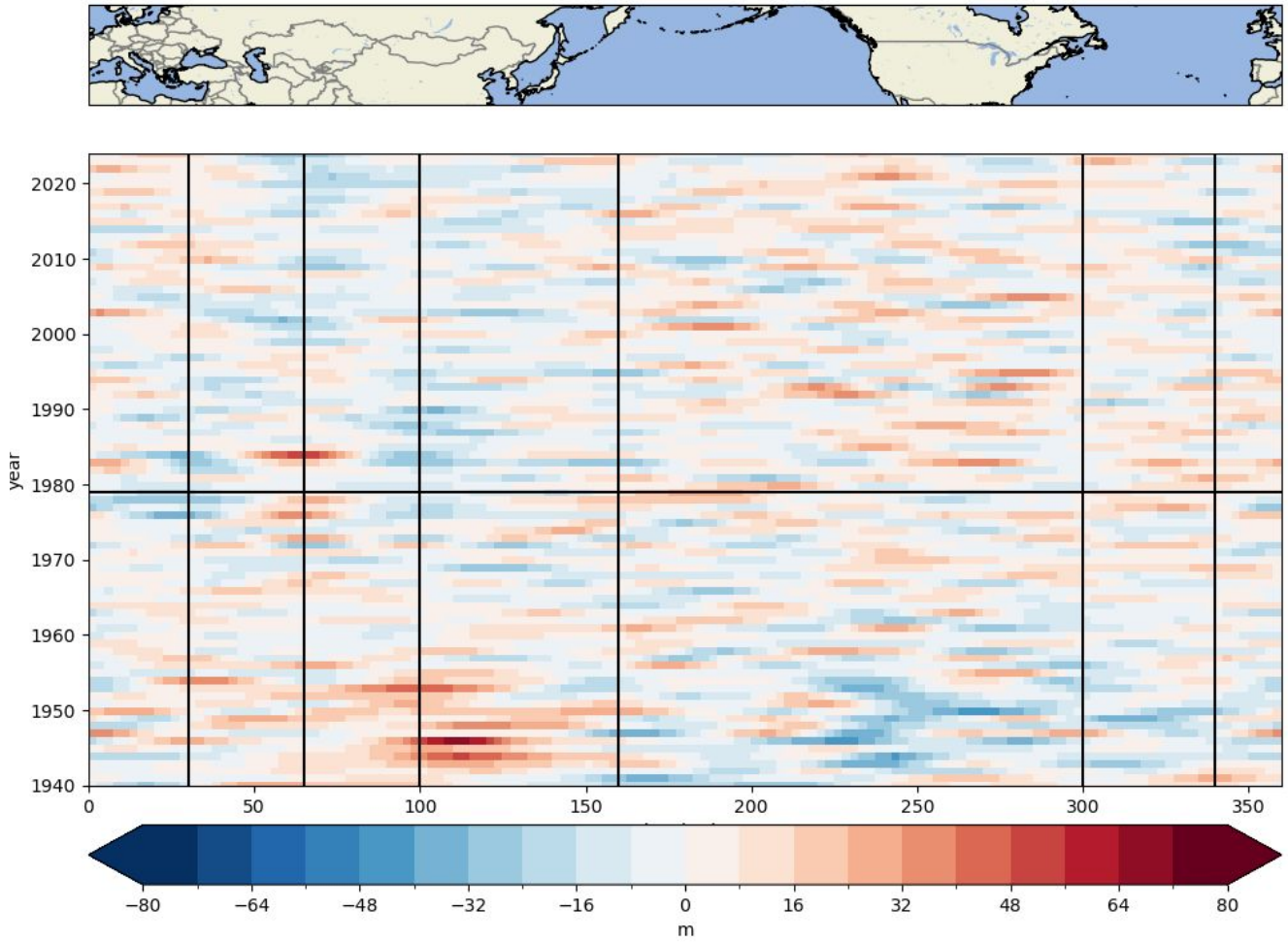
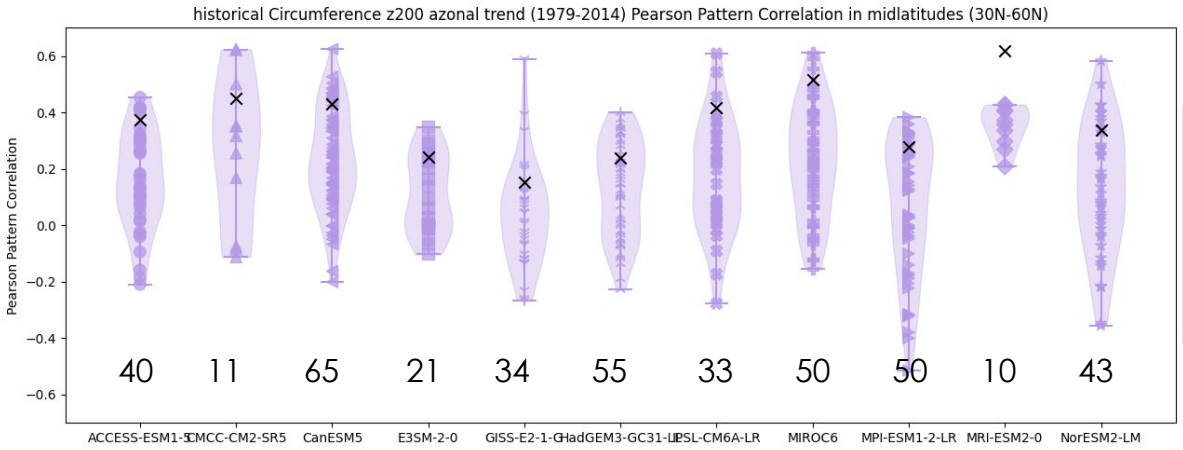
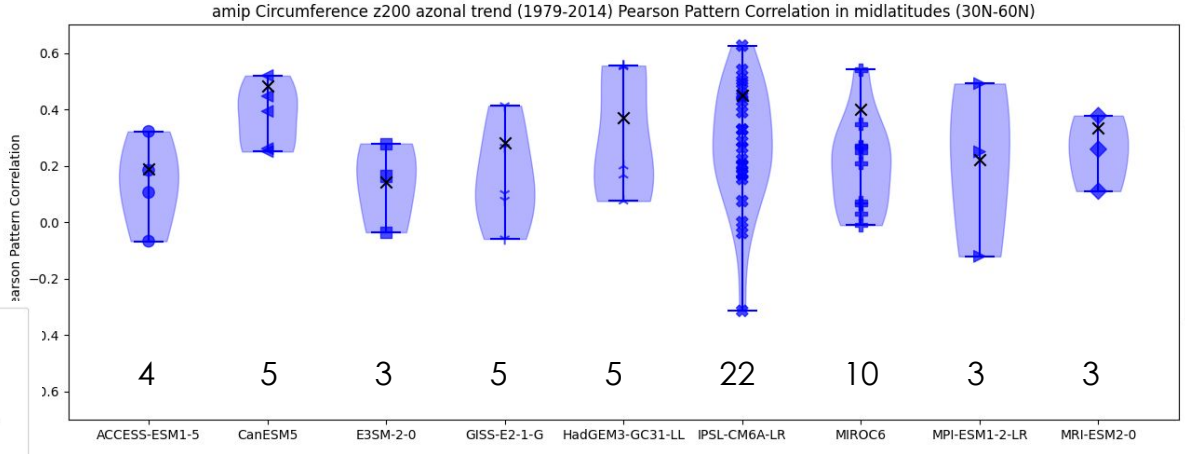
Additional Figures

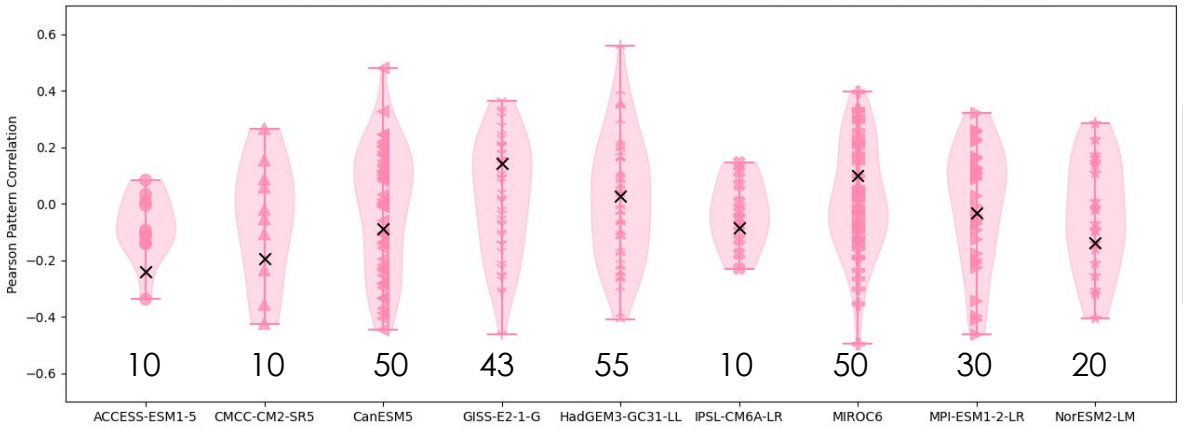
Hovmoller diagram (ERA5)

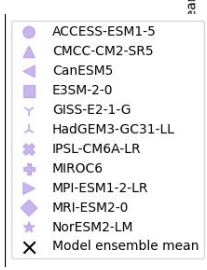


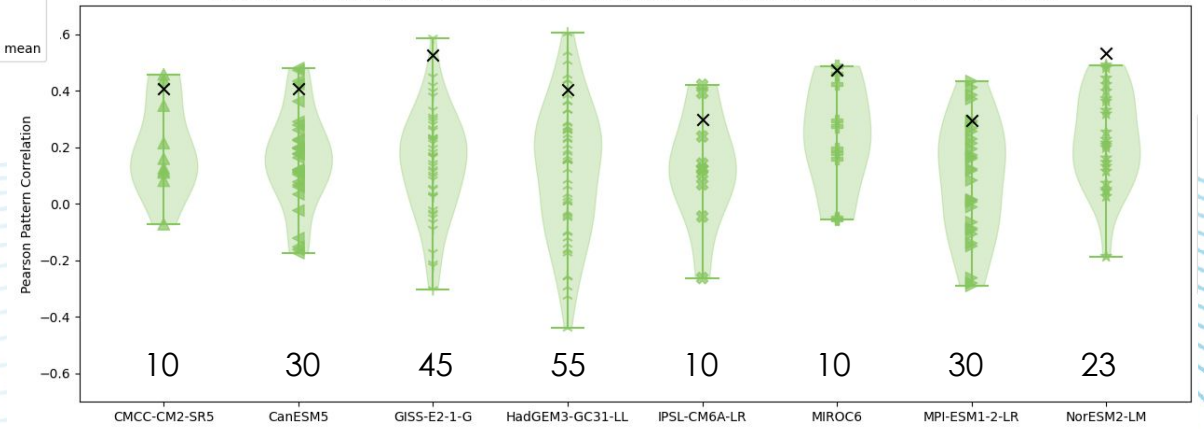
Variability in models' Z200 trends



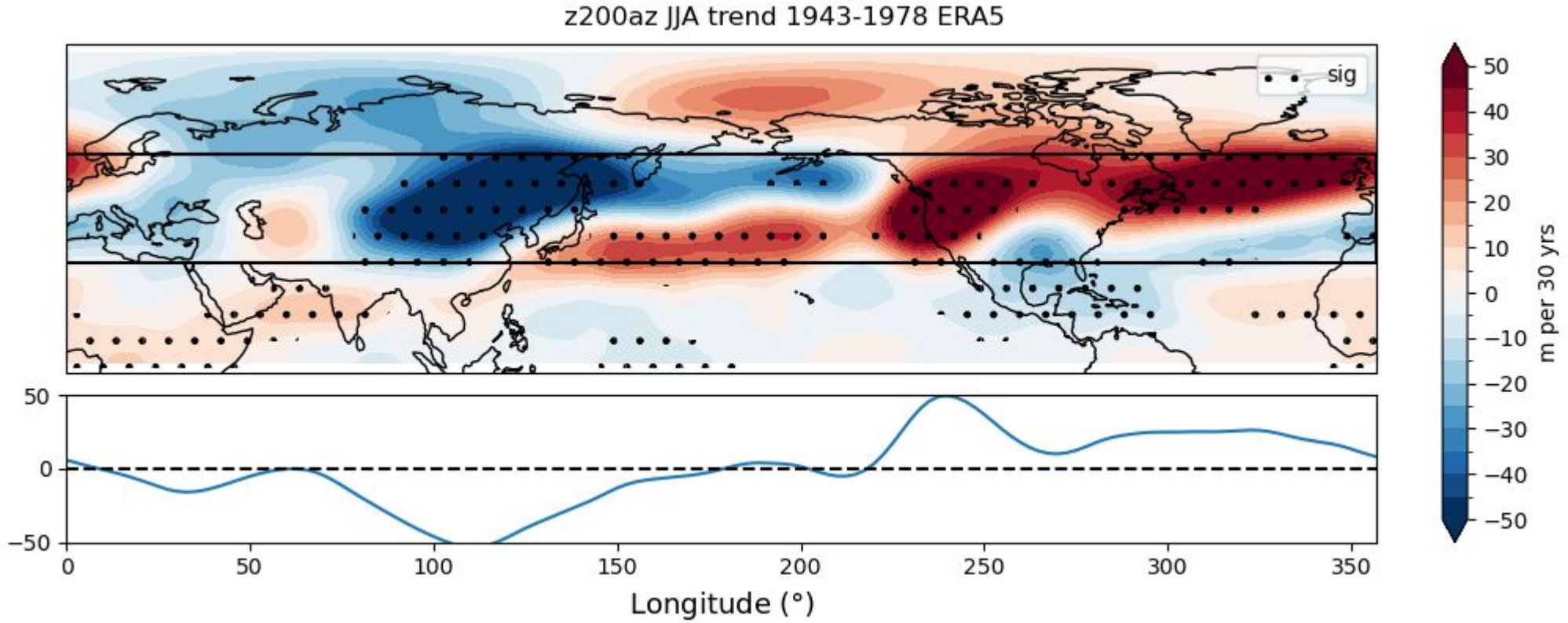




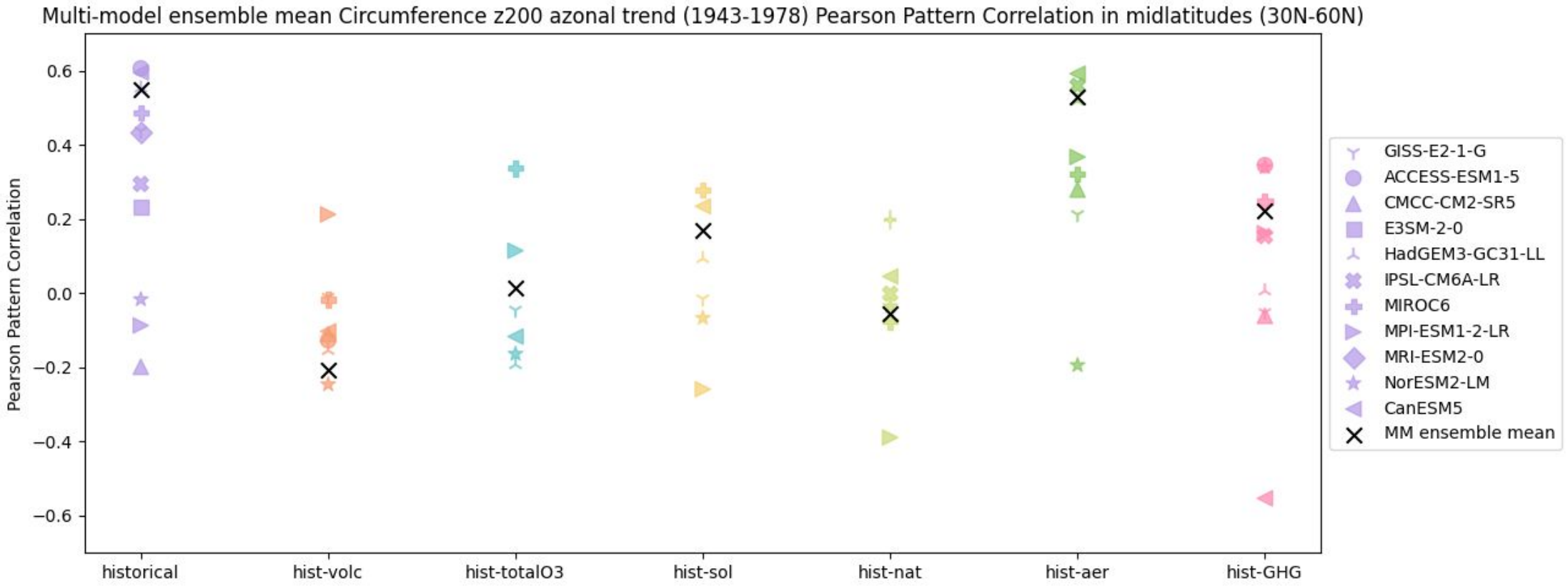




Reanalysis 1943-1978 trend

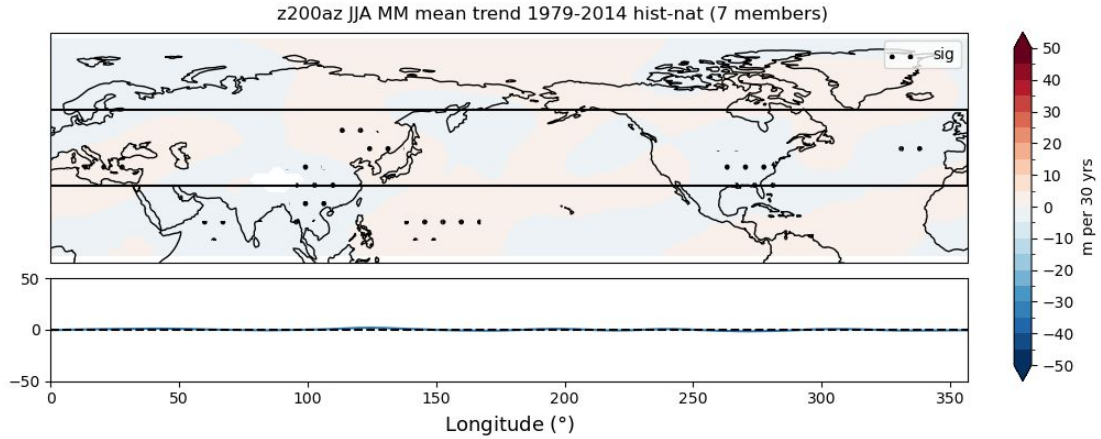


1943-1978 pattern correlation

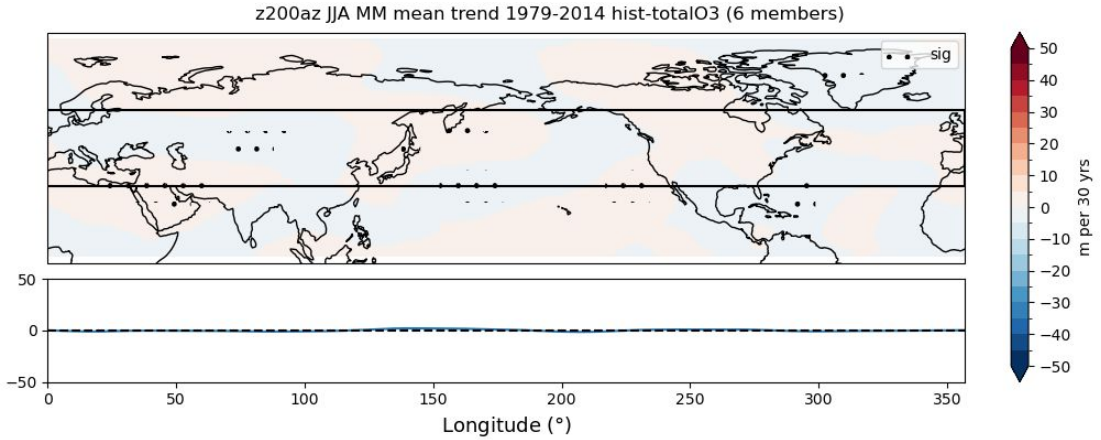


Magnitude of the trend (MM-Mean)

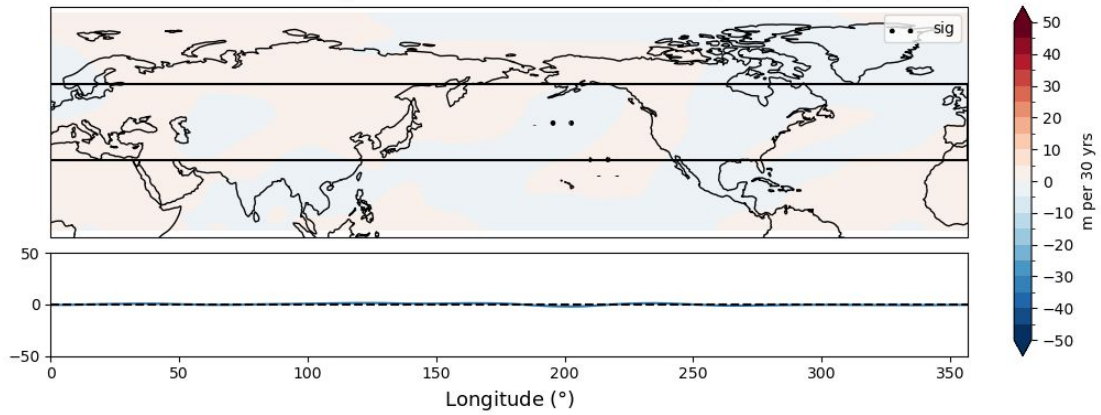
Natural



Total O3



Volcanic



Solar