

The relative roles of direct atmospheric radiative forcing vs. indirect sea surface temperature forcing in the atmospheric response to evolving anthropogenic aerosol emissions from 1930 to 2030

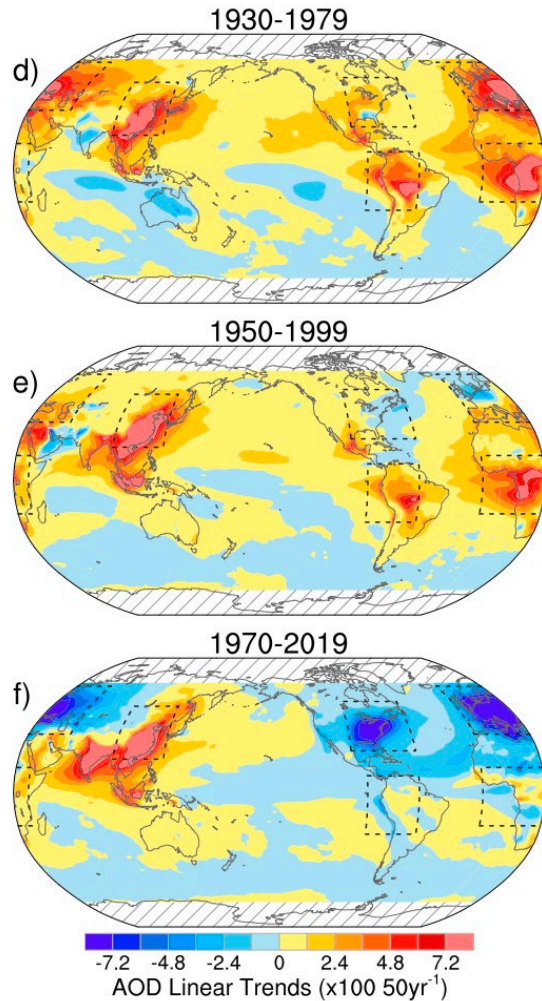
Xueying Zhao, Clara Deser, Geeta Persad, Adam Phillips

2024 CESM CVCWG Meeting

March 6th

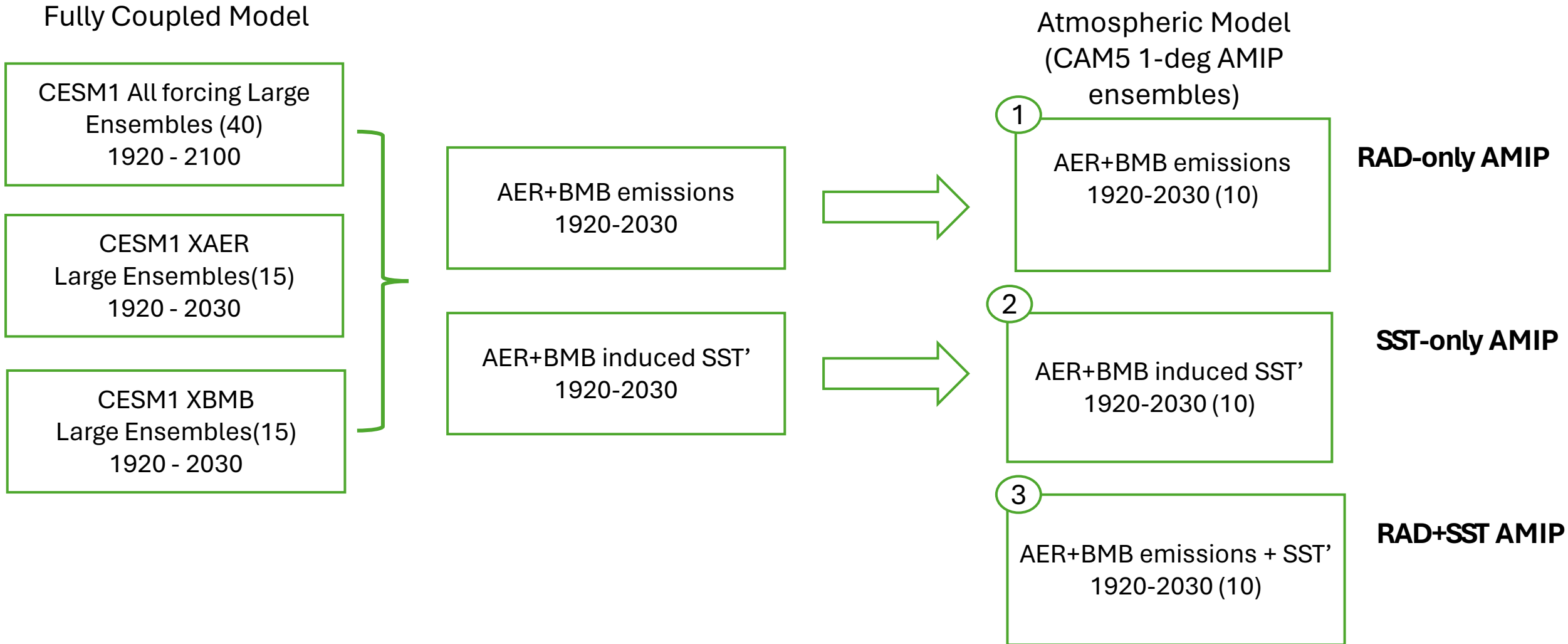


Industrial AER + BMB AOD



- What are the dominant radiative forcing patterns of the time-evolving anthropogenic emissions, including industrial aerosol (AER) and biomass burning (BMB)?
- How does atmosphere respond, and what are the relative roles of direct atmospheric radiative forcing vs. indirect SST forcing?

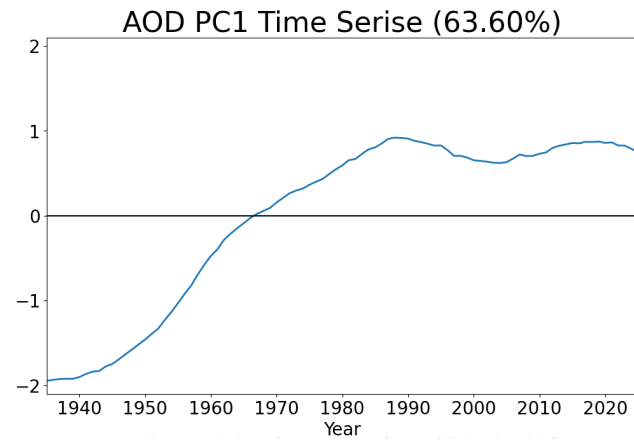
Experiment Designs



(Deser et al. 2020)

Leading Forcing Patterns

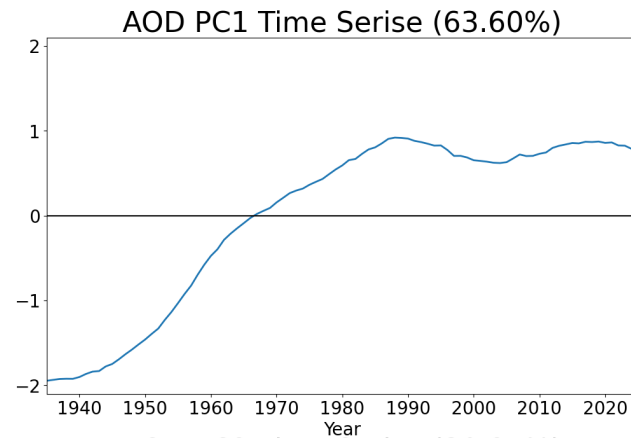
JJA



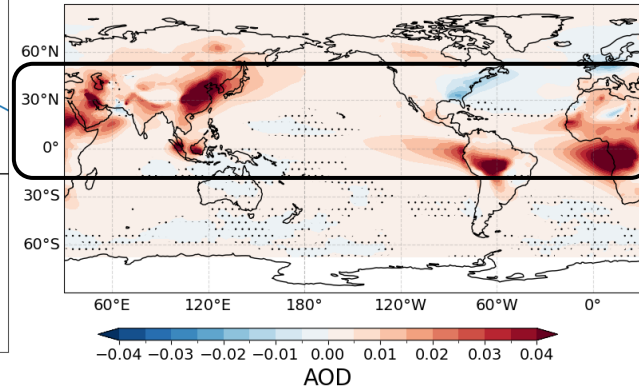
Leading Forcing Patterns

JJA

Low-latitude
AOD mode.



AOD Regression

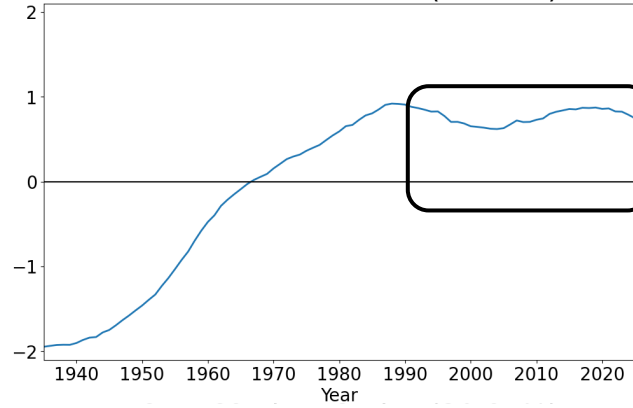


Dotted denotes insignificant.

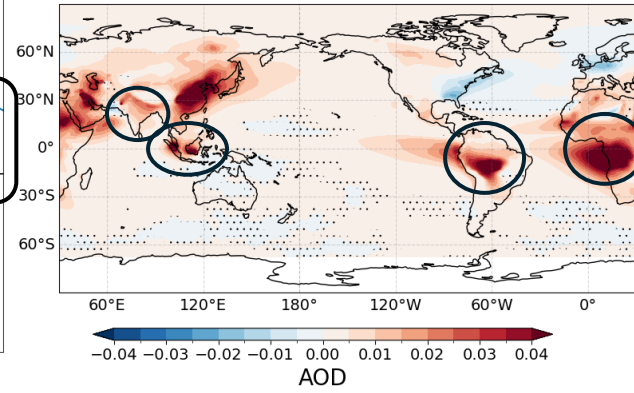
Leading Forcing Patterns

JJA

AOD PC1 Time Serise (63.60%)



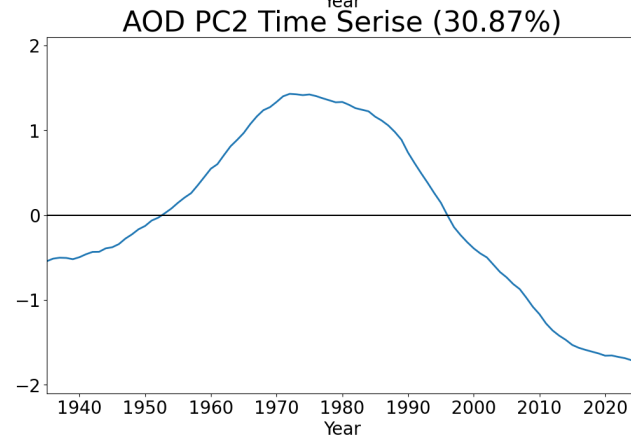
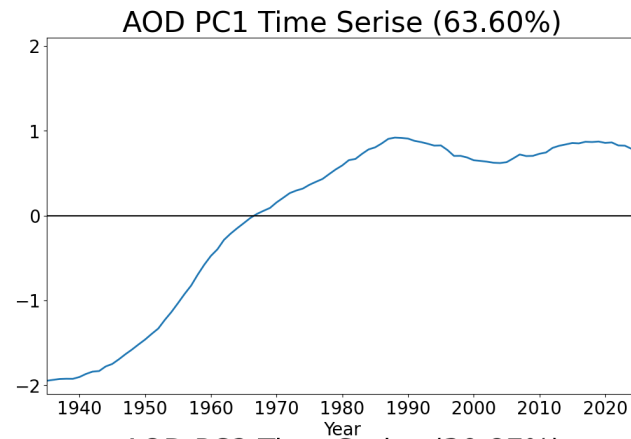
AOD Regression



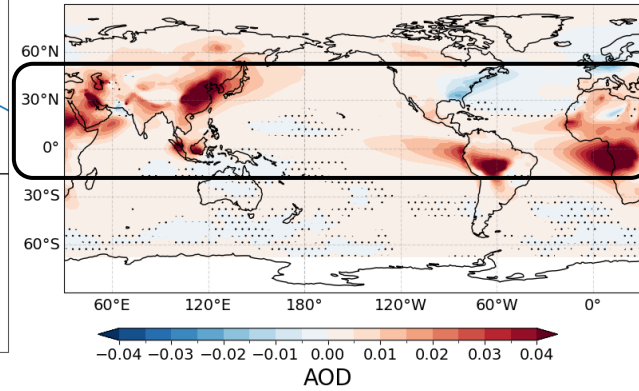
Leading Forcing Patterns

JJA

Low-latitude
AOD mode.



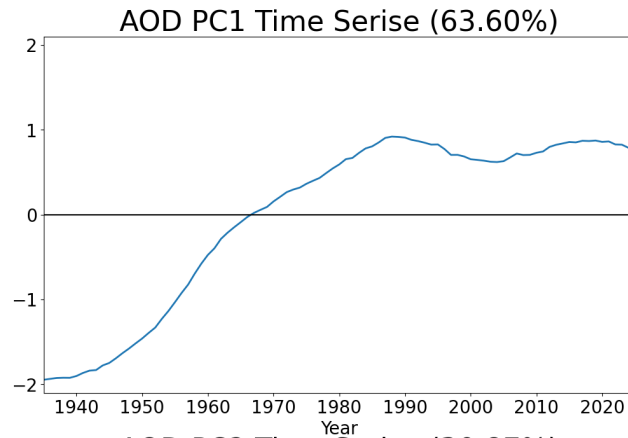
AOD Regression



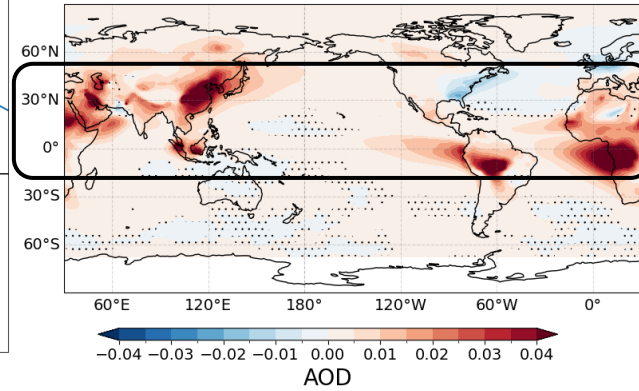
Leading Forcing Patterns

JJA

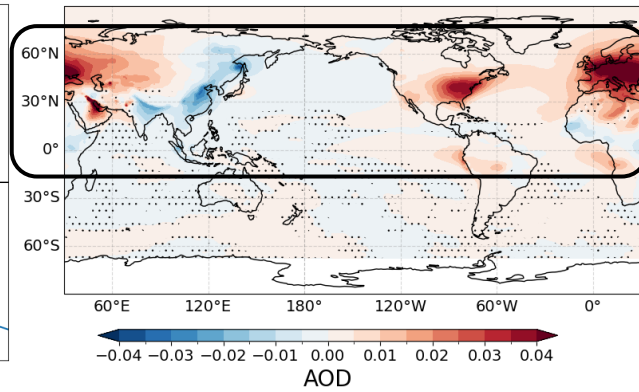
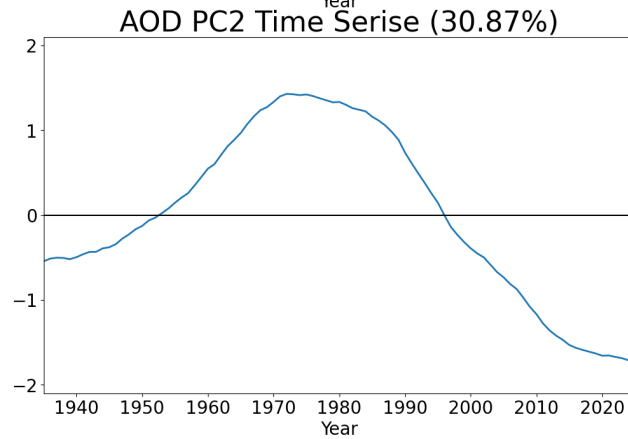
Low-latitude
AOD mode.



AOD Regression



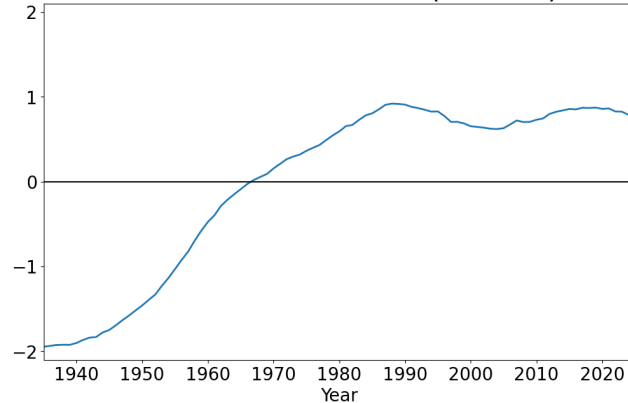
NH mid-latitude
AOD mode.



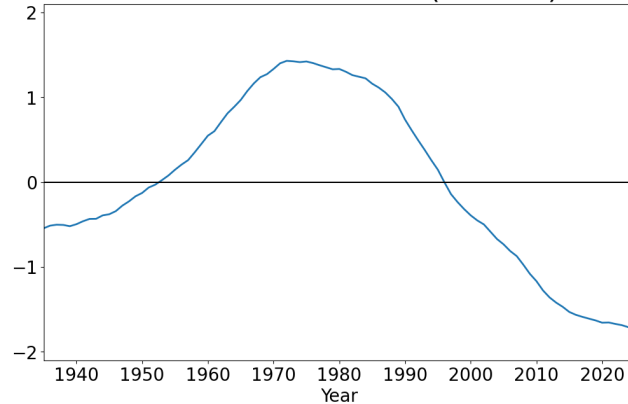
Leading Forcing Patterns

JJA

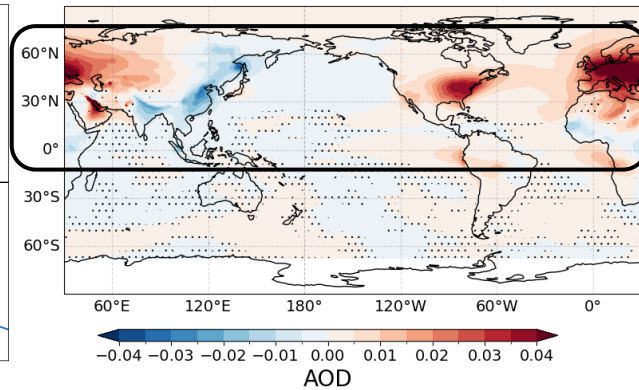
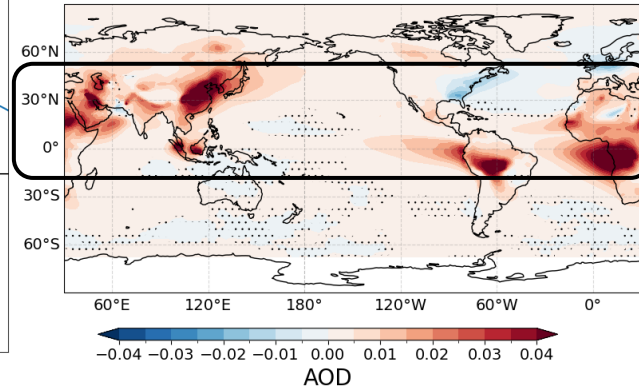
AOD PC1 Time Serie (63.60%)



AOD PC2 Time Serie (30.87%)



AOD Regression



Low-latitude
AOD mode.

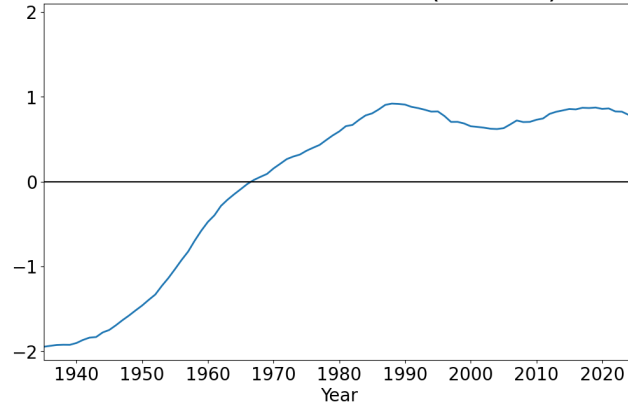
NH mid-latitude
AOD mode.

- What are the dominant radiative forcing patterns of the time-evolving anthropogenic emissions?
- 1. Low-latitude mode;**
 - 2. NH mid-latitude mode.**
- (same for industrial-sector and biomass burning aerosols individually).

Leading Forcing Patterns

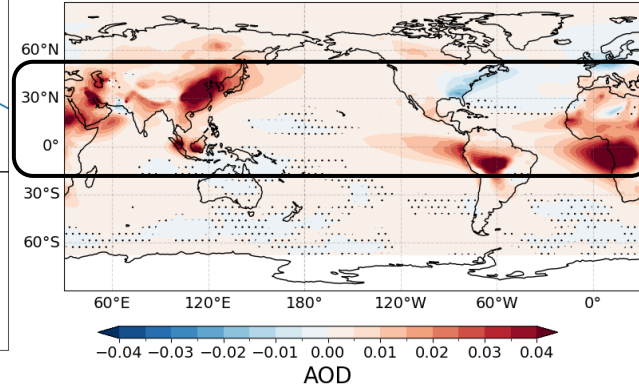
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AOD PC1 Time Serise (63.60%)

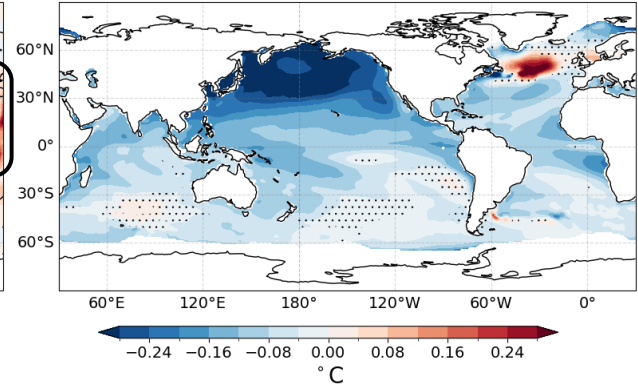


Low-latitude
AOD mode.

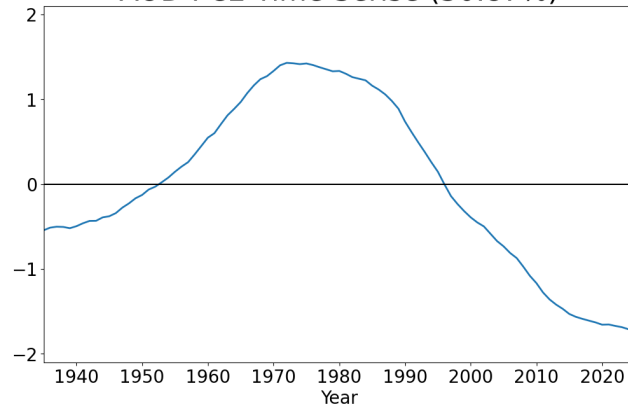
AOD Regression



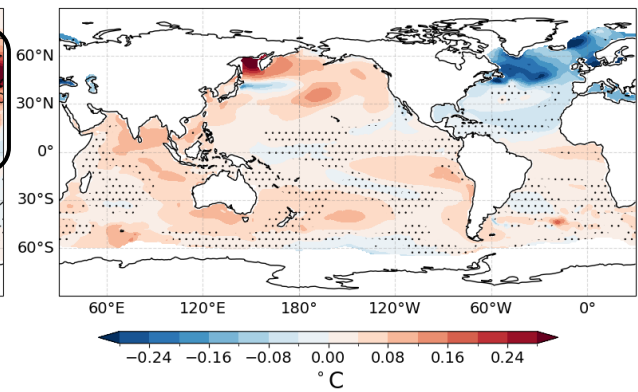
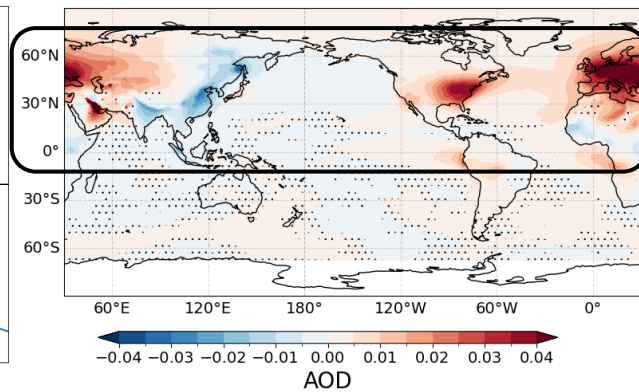
SST Regression



AOD PC2 Time Serise (30.87%)



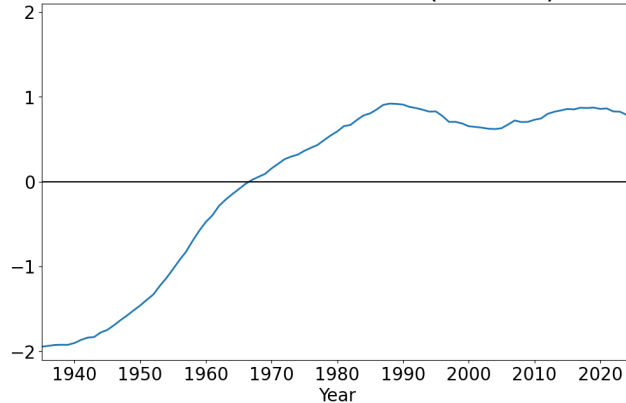
NH mid-latitude
AOD mode.



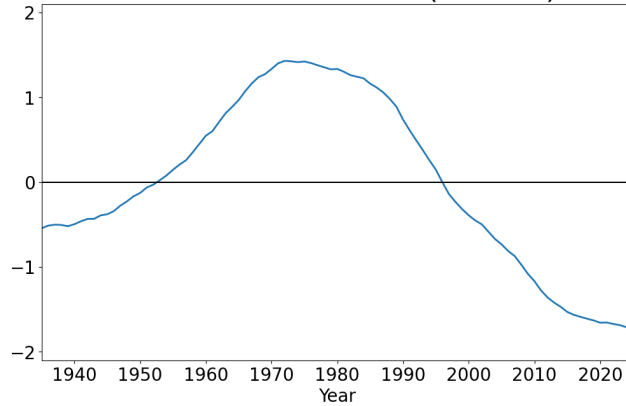
Leading Forcing Patterns

JJA

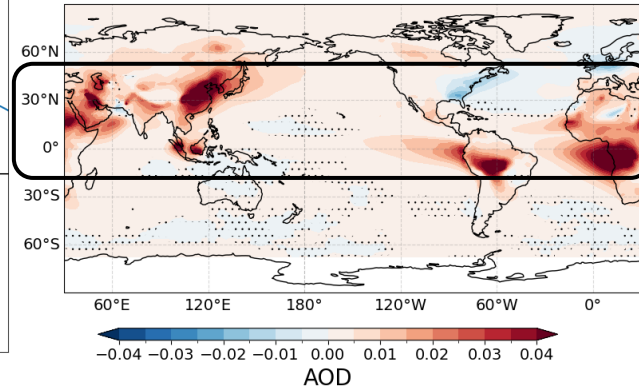
AOD PC1 Time Serie (63.60%)



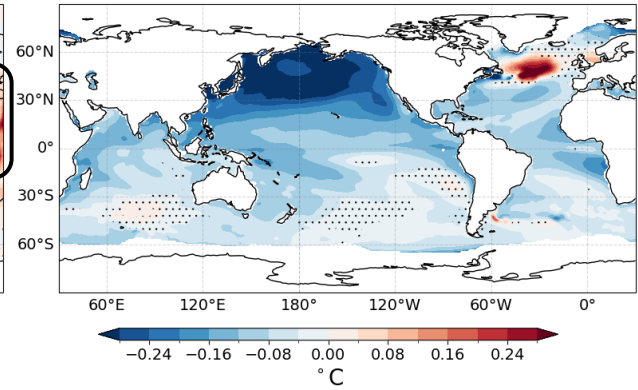
AOD PC2 Time Serie (30.87%)



AOD Regression



SST Regression



Low-latitude
AOD mode.

NH mid-latitude
AOD mode.

**Atmospheric radiative forcing
patterns**

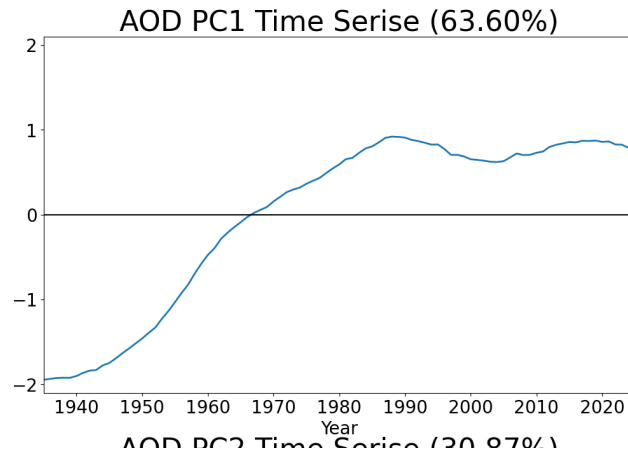
Indirect SST forcing patterns

- How does atmosphere respond to these dominant radiative forcing patterns? And what are the relative roles of direct atmosphere radiative forcing vs. indirect SST forcing?

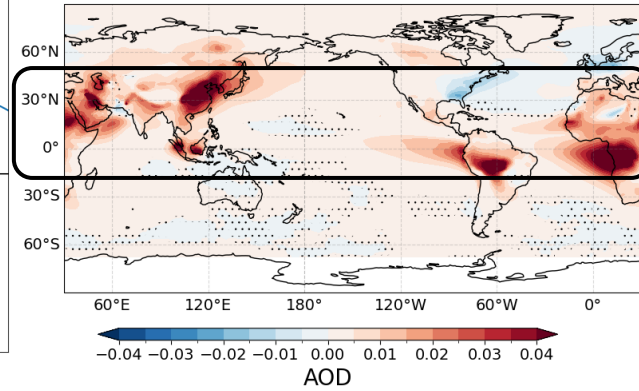
Leading Forcing Patterns

JJA

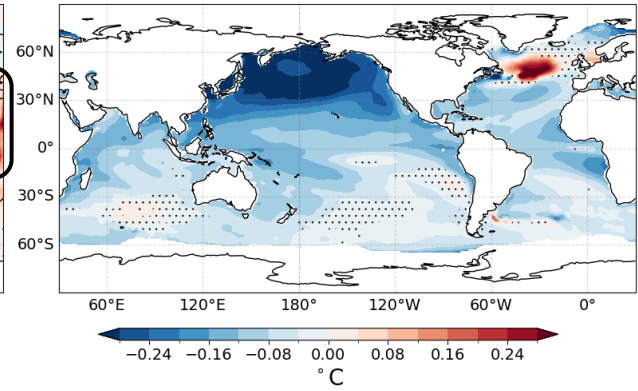
Low-latitude
AOD mode.



AOD Regression



SST Regression



**Atmospheric radiative forcing
patterns**

Indirect SST forcing patterns

Responses to low-latitude AOD mode

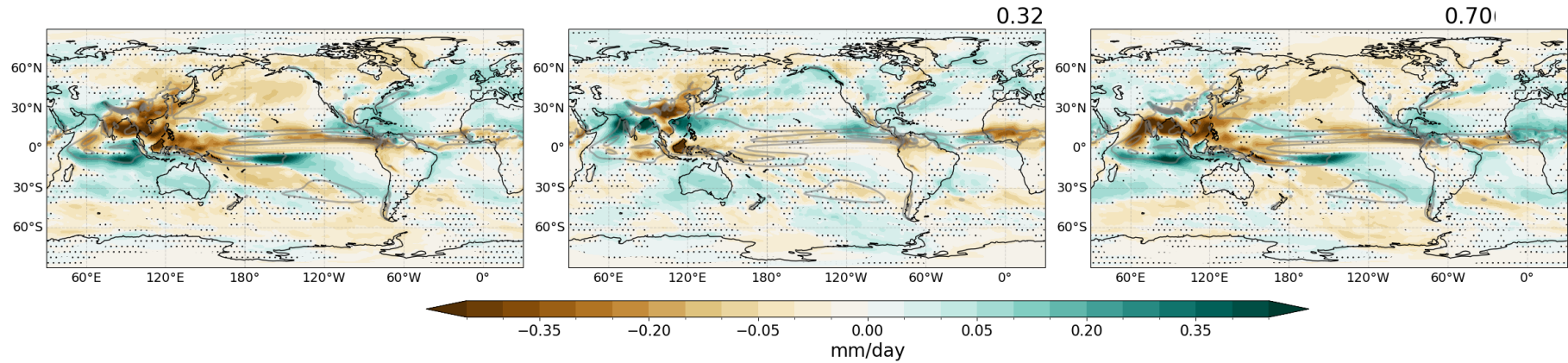
JJA

Precipitation regressions

RAD+SST AMIP

RAD-only AMIP

SST-only AMIP



Responses to low-latitude AOD mode

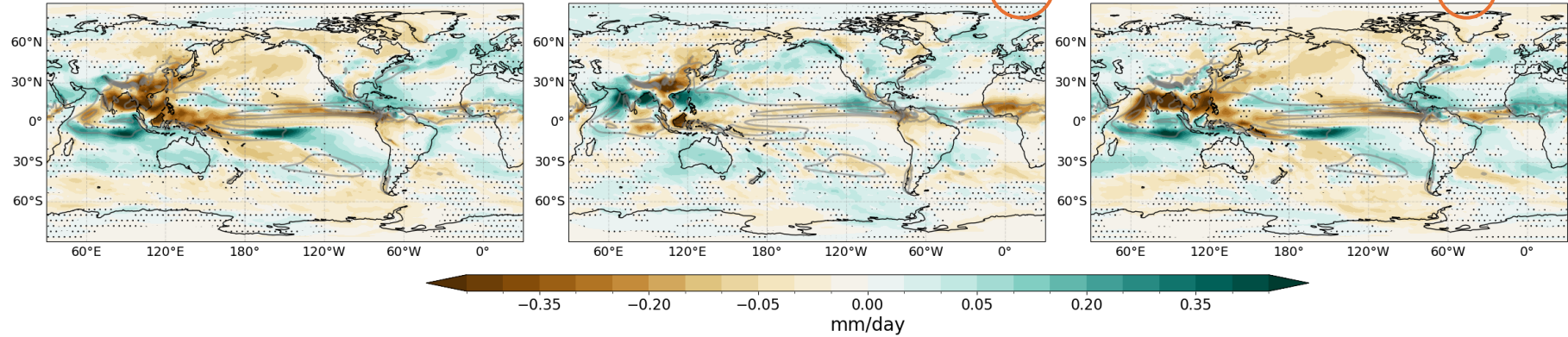
JJA

Precipitation regressions

RAD+SST AMIP

RAD-only AMIP

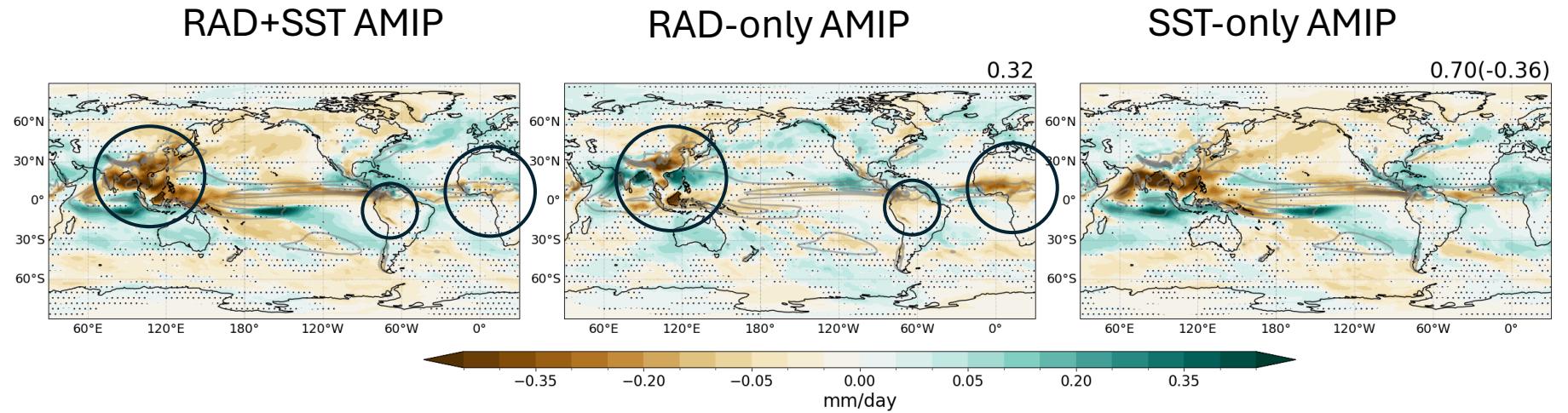
SST-only AMIP



Responses to low-latitude AOD mode

JJA

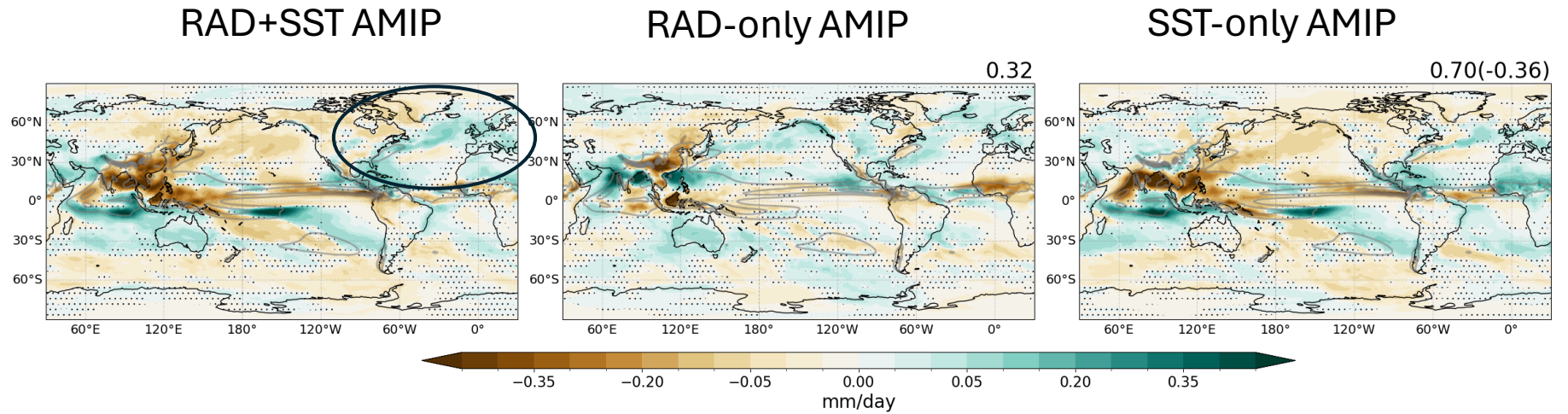
Precipitation regressions



Responses to low-latitude AOD mode

JJA

Precipitation regressions



Responses to low-latitude AOD mode

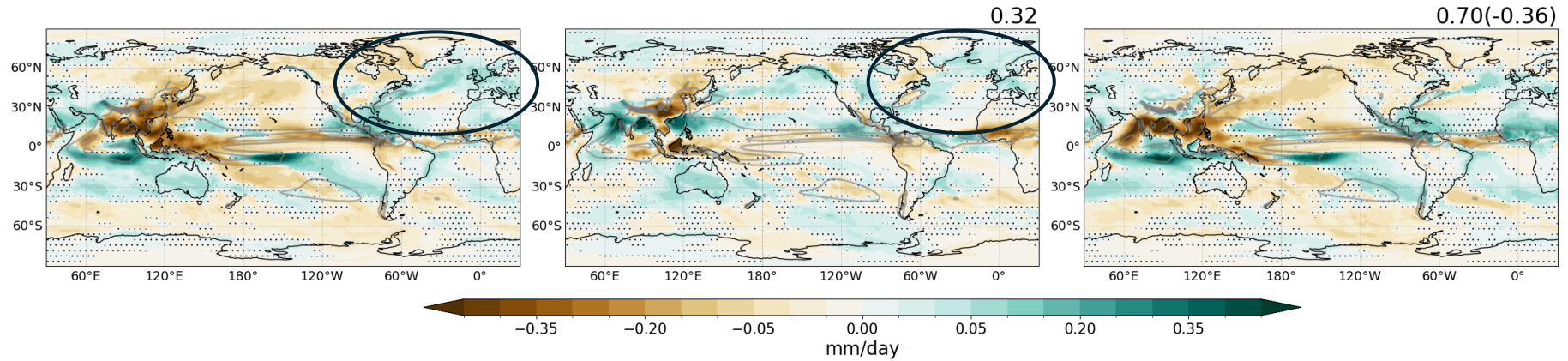
JJA

Precipitation regressions

RAD+SST AMIP

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Responses to low-latitude AOD mode

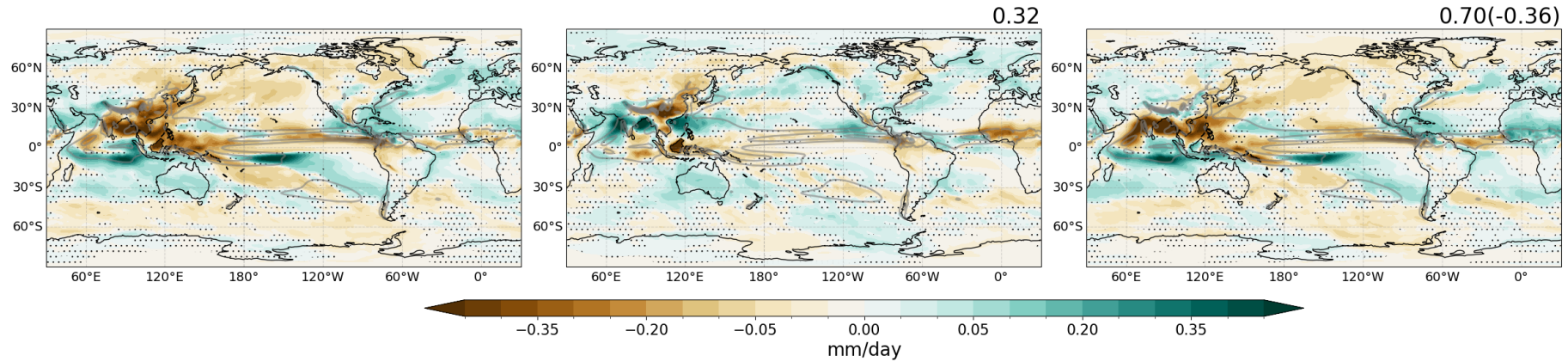
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Precipitation regressions

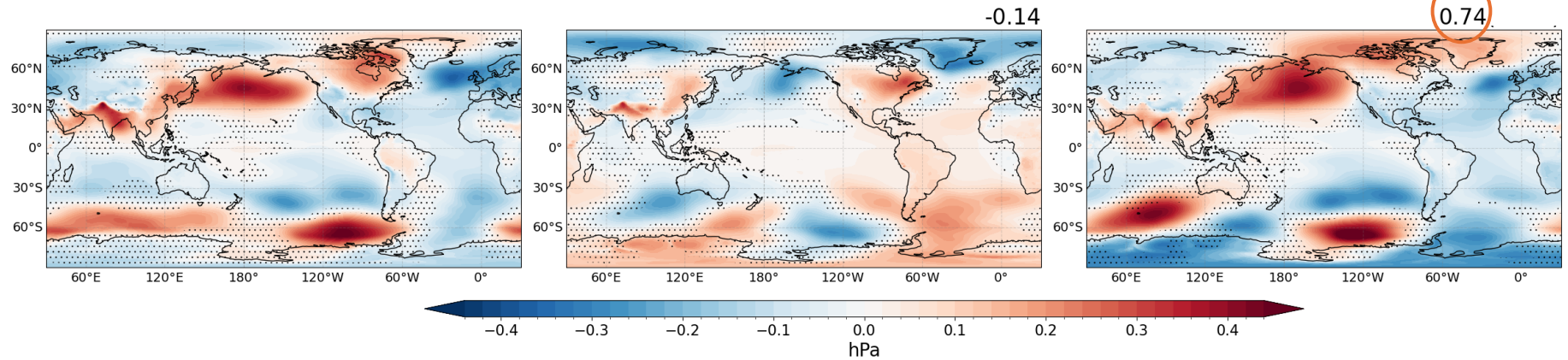
RAD+SST AMIP

RAD-only AMIP

SST-only AMIP



SLP regressions

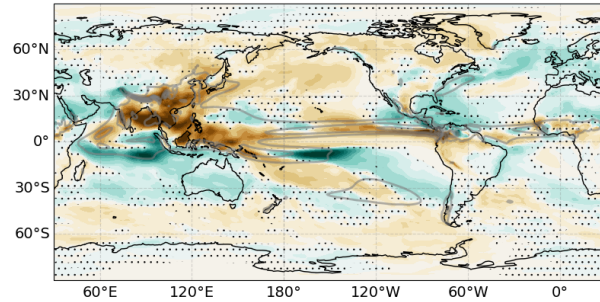


Responses to low-latitude AOD mode

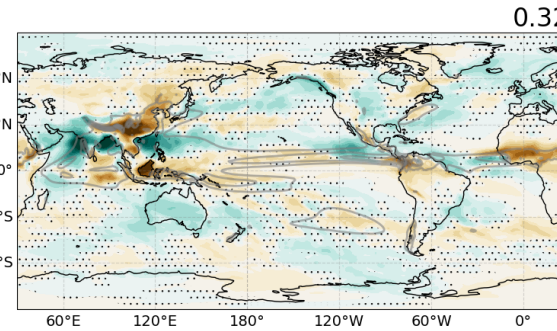
JJA

Precipitation regressions

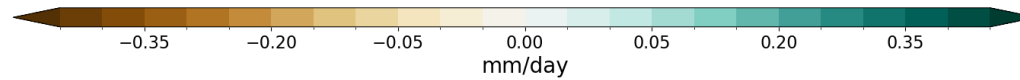
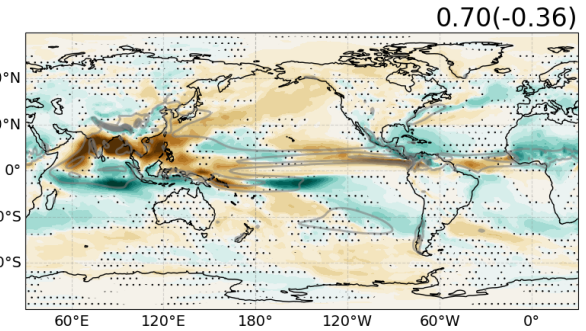
RAD+SST AMIP



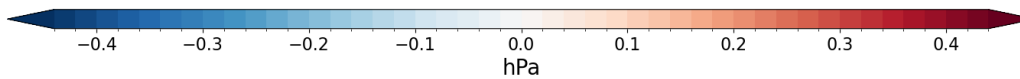
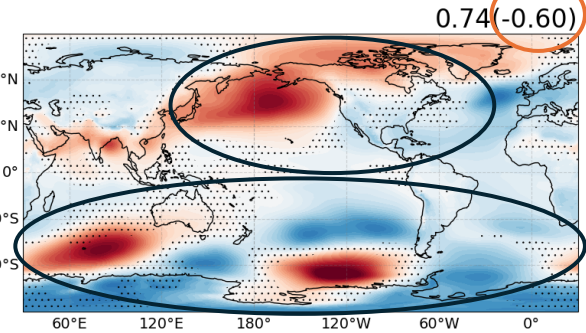
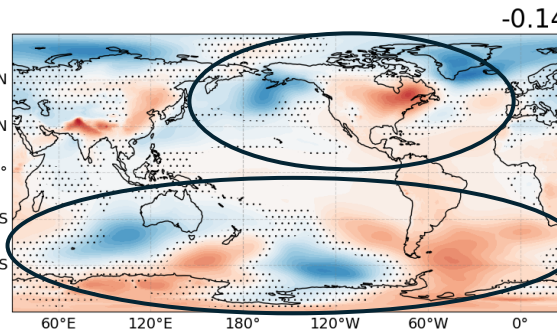
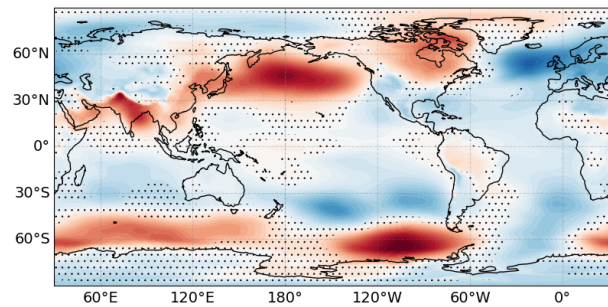
RAD-only AMIP



SST-only AMIP

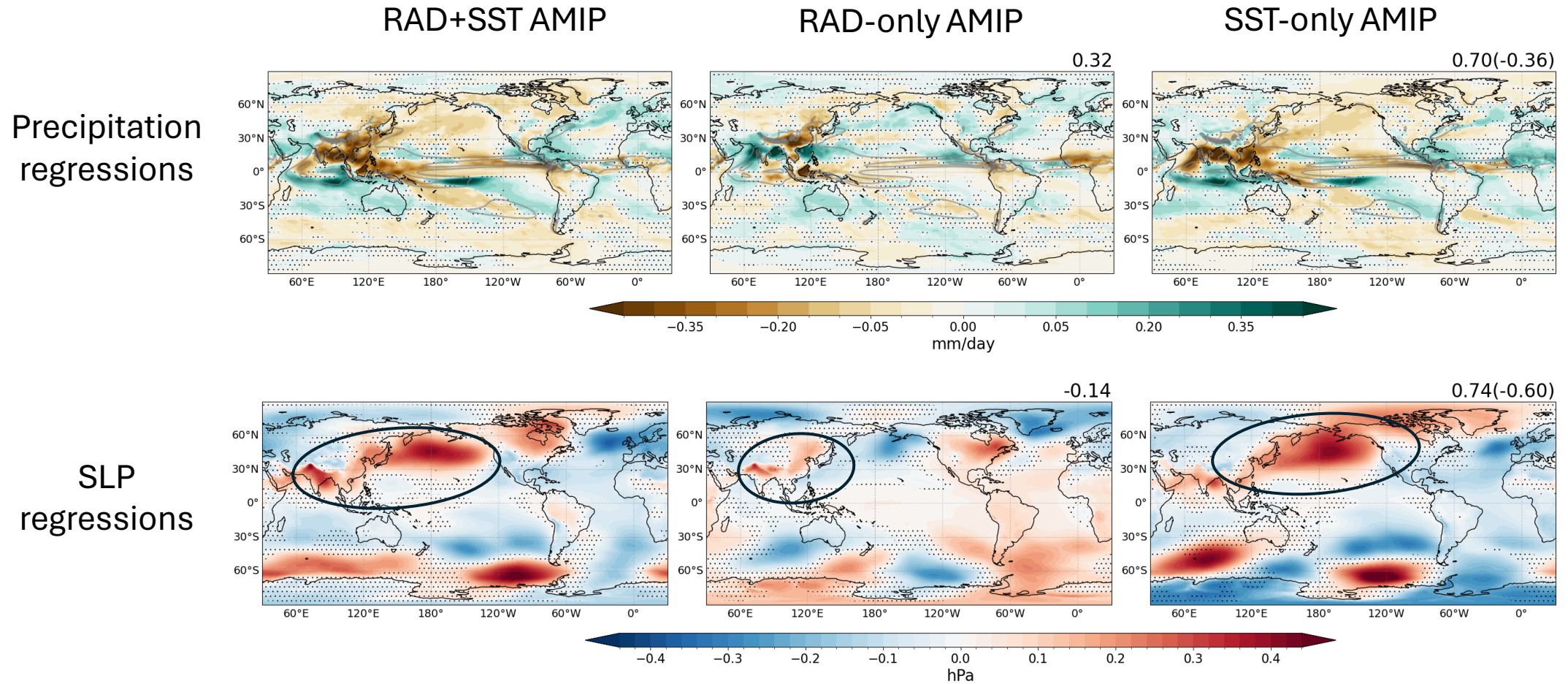


SLP regressions



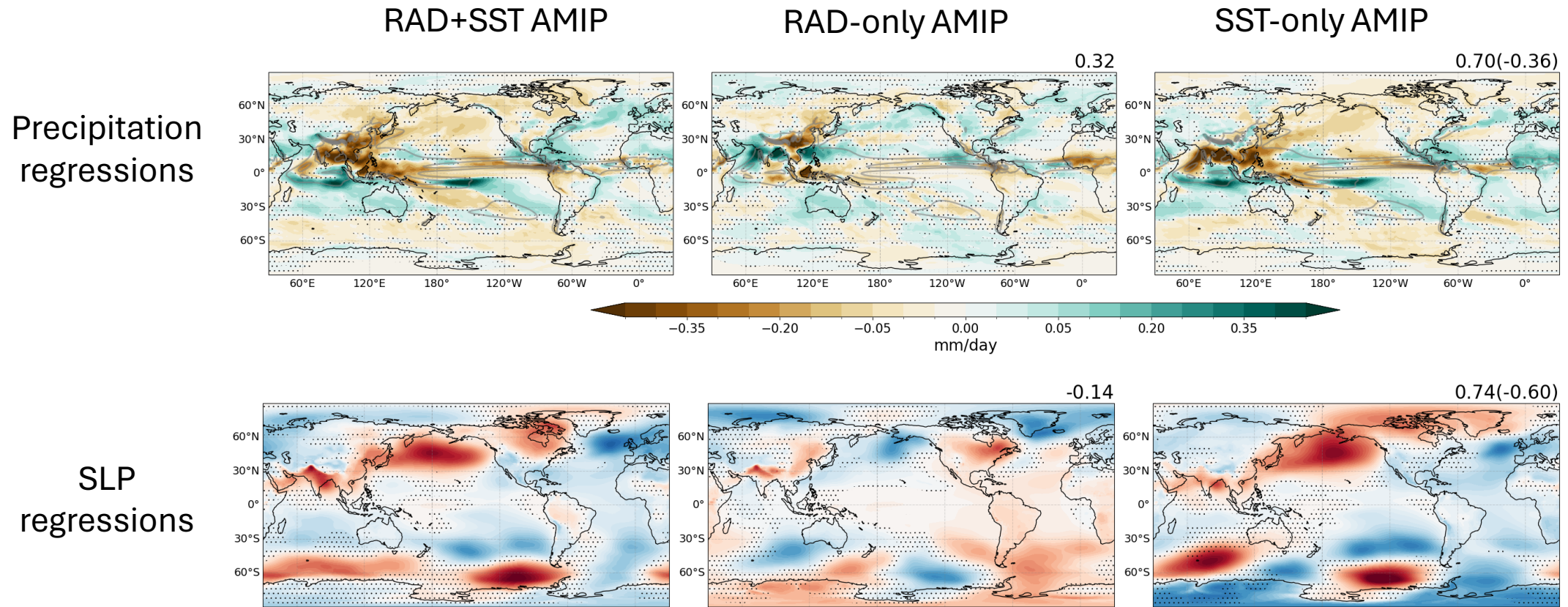
Responses to low-latitude AOD mode

JJA



Responses to low-latitude AOD mode

JJA

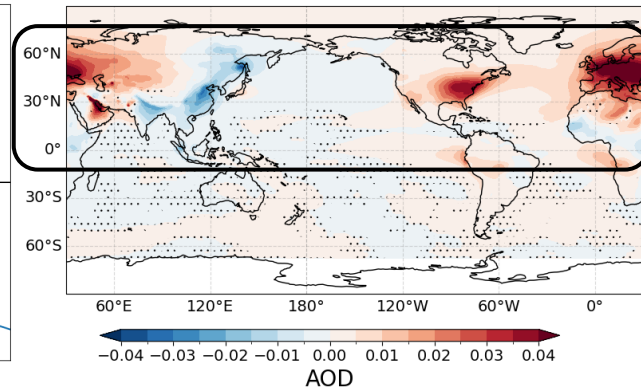
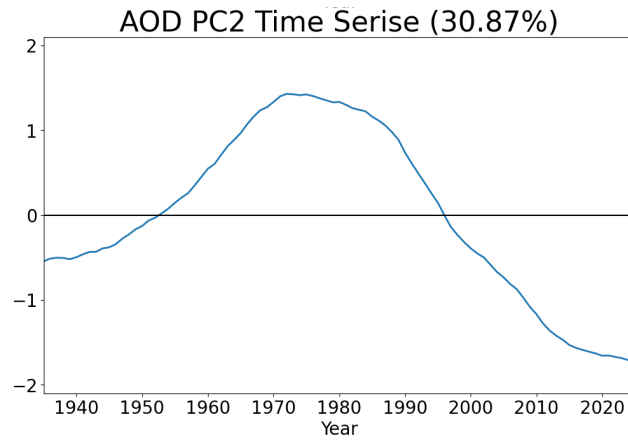


- How does atmosphere respond to these dominant radiative forcing patterns? And what are the relative roles of direct atmosphere radiative forcing vs. indirect SST forcing?
- Indirect SST forcing dominates the pattern of the full response.
 - Low-latitude radiative forcing induces strong local precipitation response.

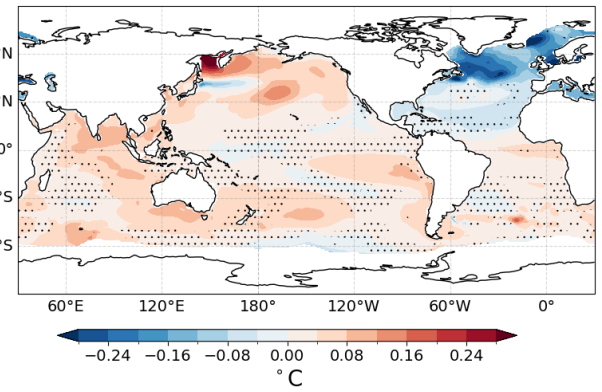
Leading Forcing Patterns

JJA

NH mid-latitude
AOD mode.



**Atmospheric radiative forcing
patterns**



Indirect SST forcing patterns

Responses to NH mid-latitude AOD mode

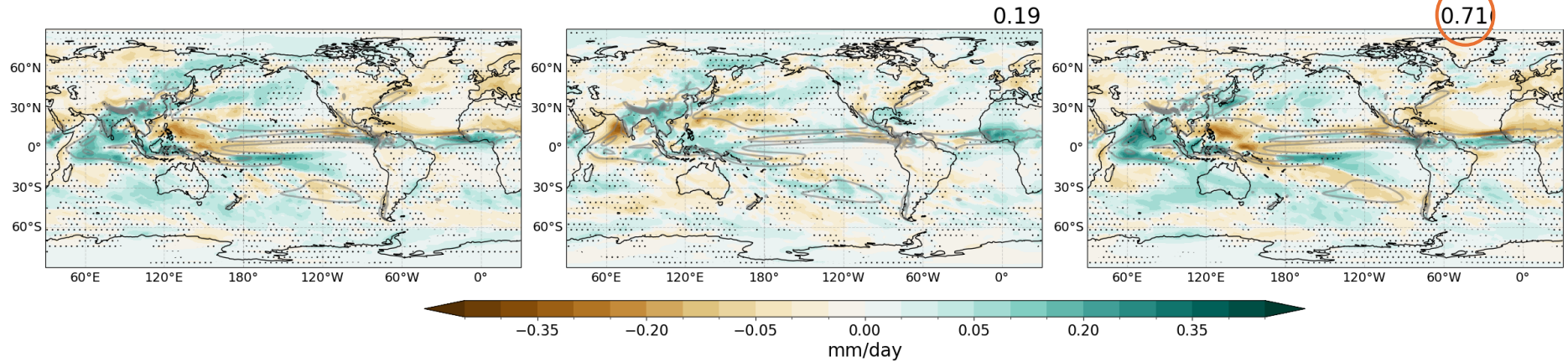
JJA

RAD+SST AMIP

RAD-only AMIP

SST-only AMIP

Precipitation regressions



Responses to NH mid-latitude AOD mode

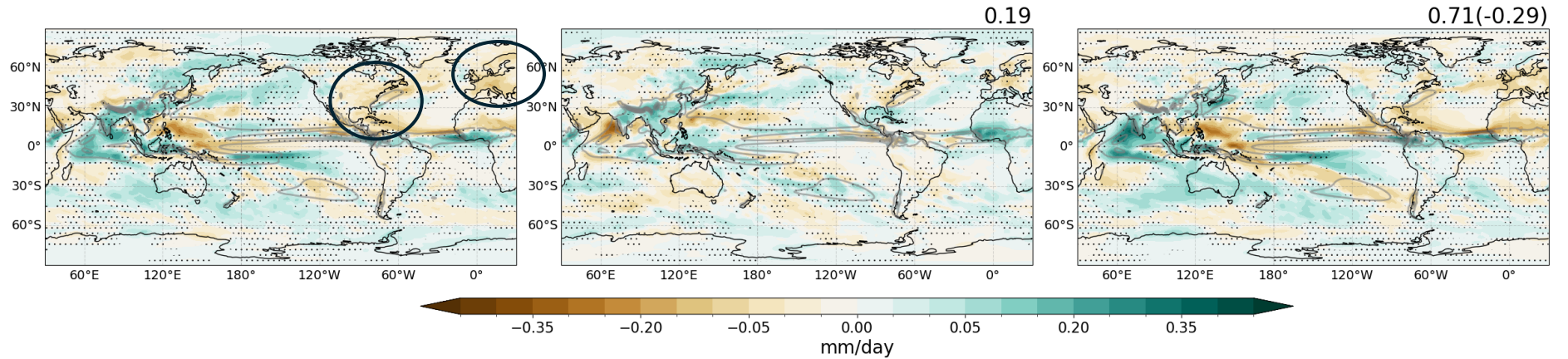
JJA

RAD+SST AMIP

RAD-only AMIP

SST-only AMIP

Precipitation regressions



Responses to NH mid-latitude AOD mode

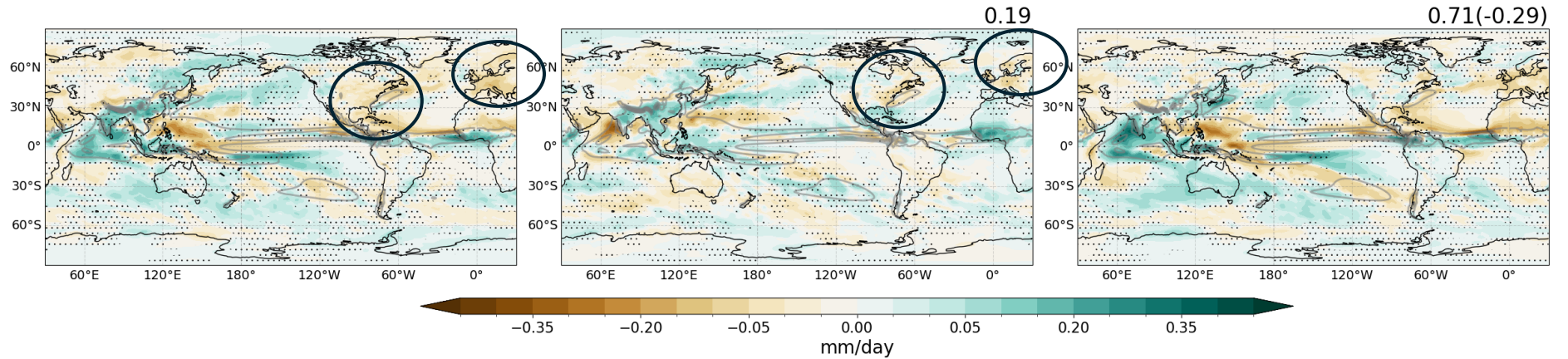
JJA

RAD+SST AMIP

RAD-only AMIP

SST-only AMIP

Precipitation regressions



Responses to NH mid-latitude AOD mode

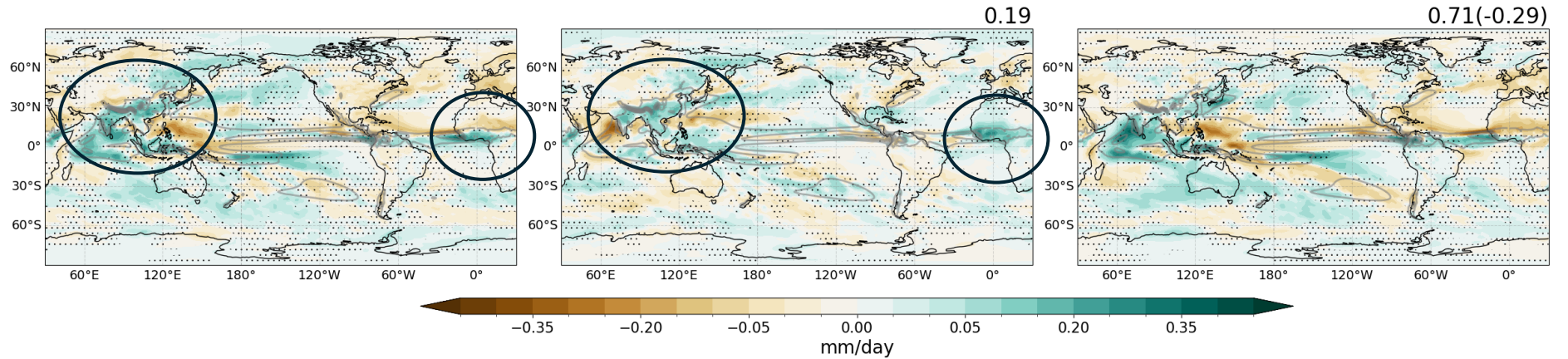
JJA

RAD+SST AMIP

RAD-only AMIP

SST-only AMIP

Precipitation regressions



Responses to NH mid-latitude AOD mode

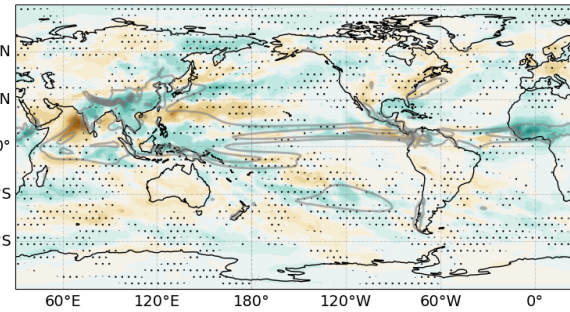
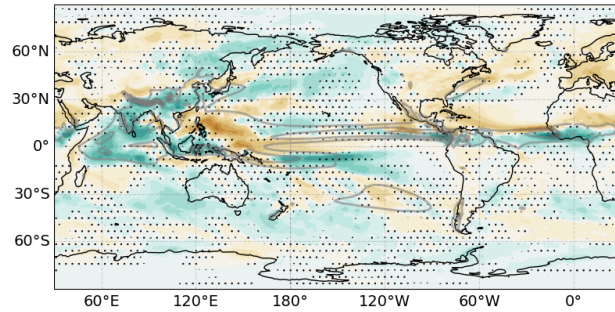
JJA

RAD+SST AMIP

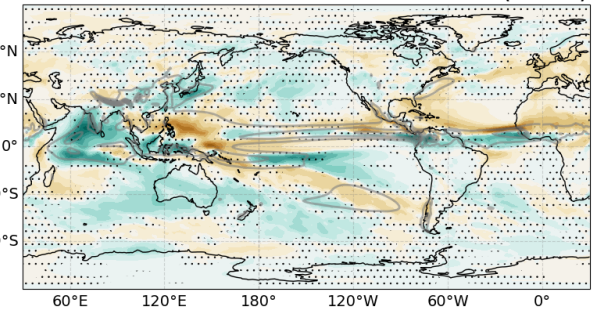
RAD-only AMIP

SST-only AMIP

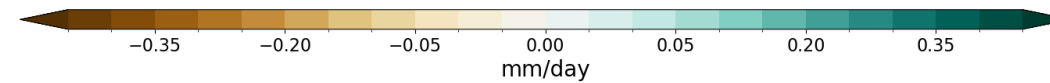
Precipitation regressions



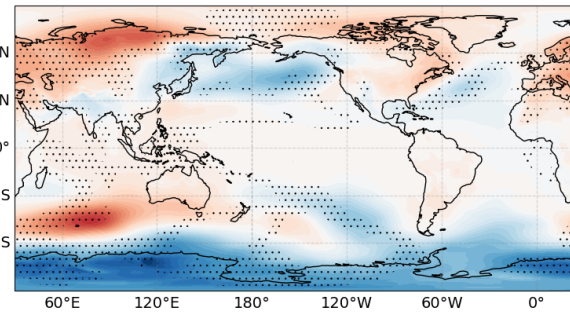
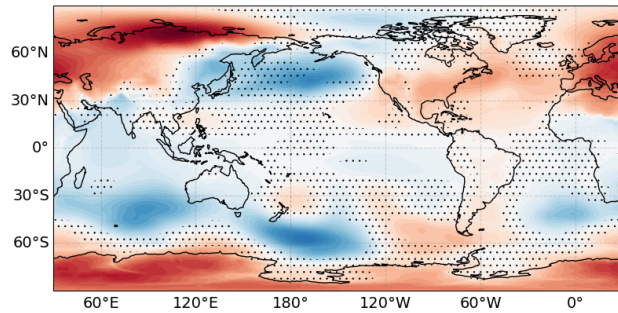
0.19



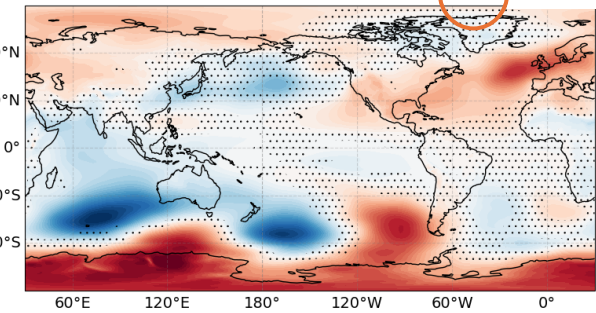
0.71(-0.29)



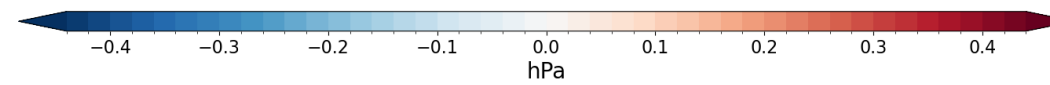
SLP regressions



0.02



0.74



Responses to NH mid-latitude AOD mode

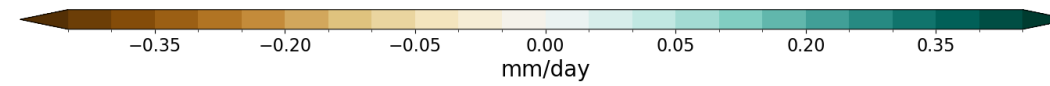
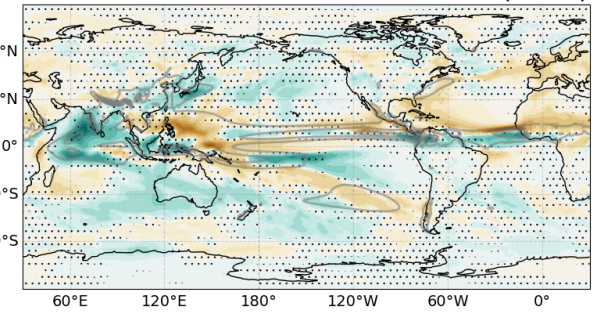
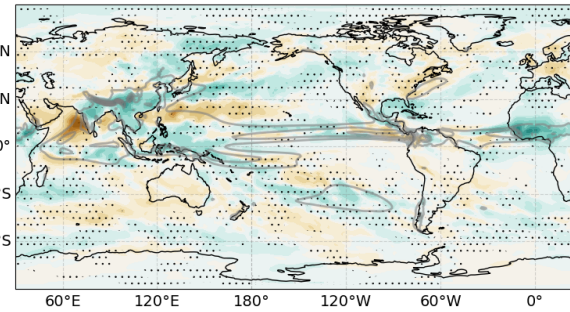
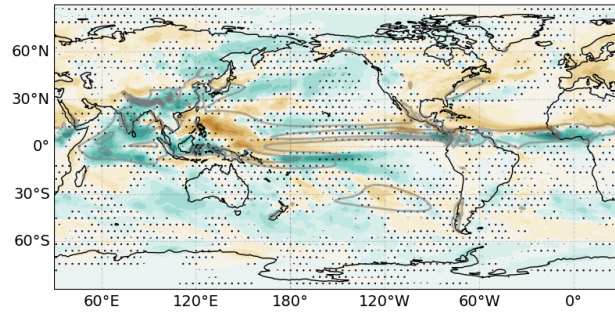
JJA

RAD+SST AMIP

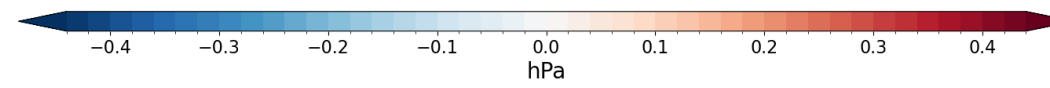
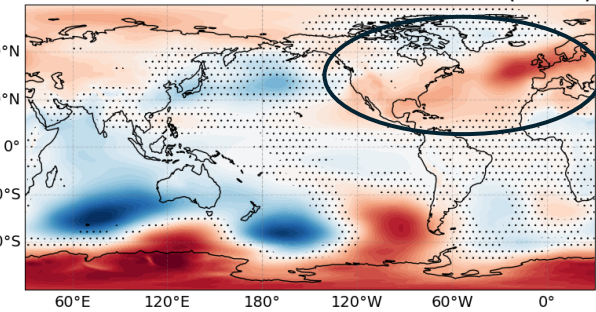
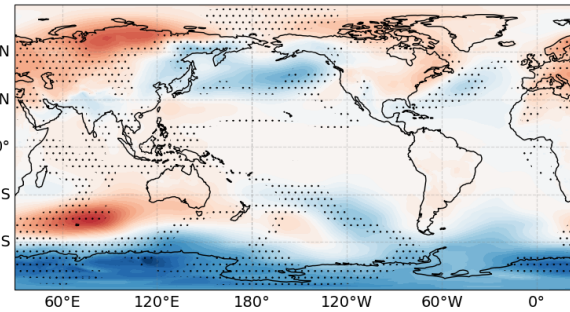
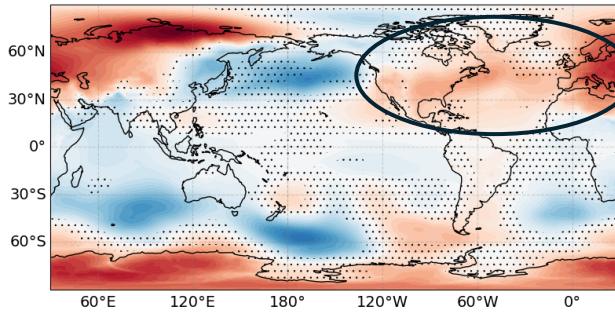
RAD-only AMIP

SST-only AMIP

Precipitation regressions



SLP regressions



Responses to NH mid-latitude AOD mode

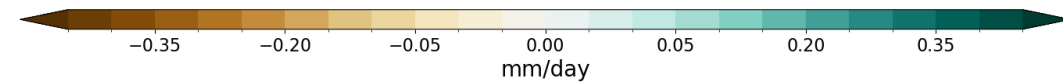
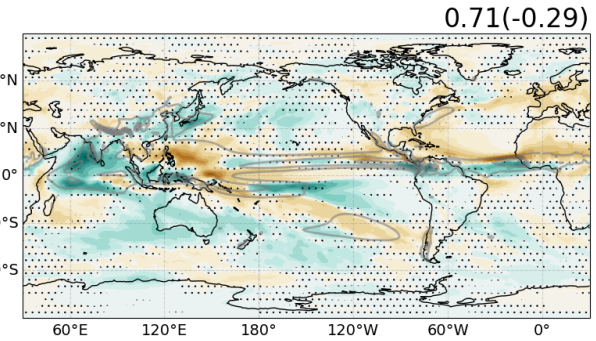
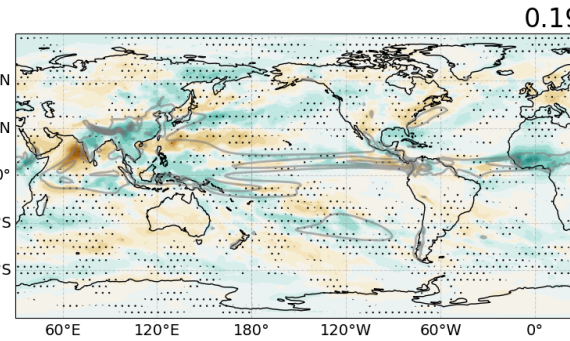
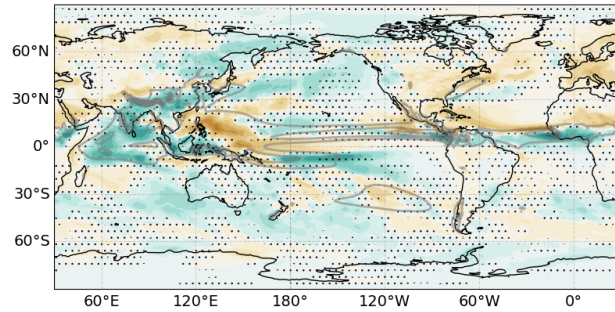
JJA

RAD+SST AMIP

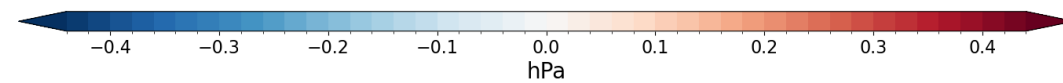
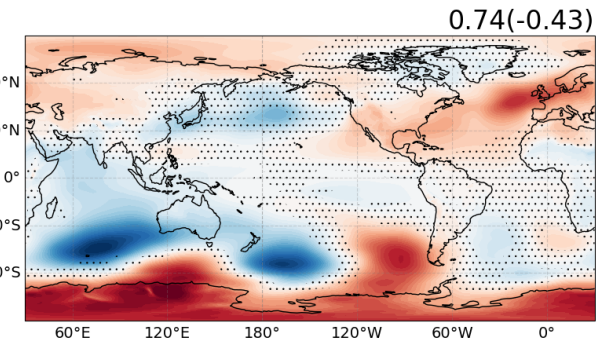
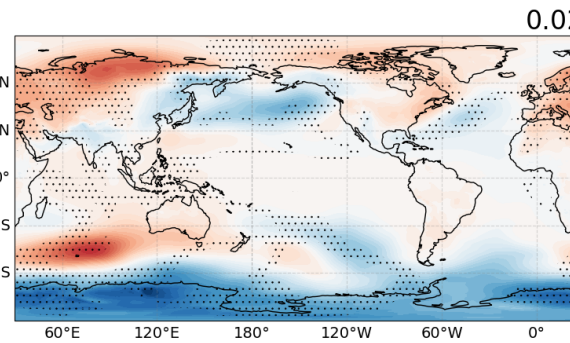
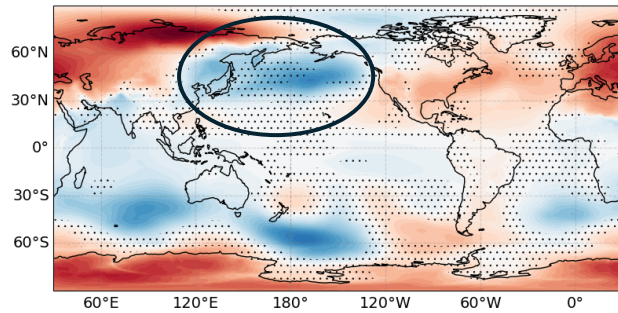
RAD-only AMIP

SST-only AMIP

Precipitation regressions



SLP regressions



Summary

- What are the dominant radiative forcing patterns of the time-evolving anthropogenic emissions?
 - Low-latitude mode ← industrial AER and BMB.
 - NH mid-latitude mode ← industrial AER.
- How does atmosphere respond, and what are the relative roles of direct atmospheric radiative forcing vs. indirect SST forcing?
 - Indirect SST forcing dominates the pattern of the full response.
 - Direct atmospheric radiative forcing also contributes, particularly over low-latitude land regions, and even counteracts in some (remote) regions.
 - Further investigation of the mechanism is needed.