

The dominant patterns of historical anthropogenic aerosol emissions and their climate impacts via **atmospheric** and **oceanic** pathways

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CVCWG

CESM Workshop 2024

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TEXAS
The University of Texas at Austin

Objectives

- What are the dominant patterns of historical **time-varying** anthropogenic aerosol emissions (**industrial & biomass burning**)?

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- What are the dominant patterns of historical **time-varying** anthropogenic aerosol emissions (**industrial & biomass burning**)?
- How does the atmosphere respond to these emissions patterns, and what are the relative roles of **radiative forcing** vs. **SST forcing**?

Experimental Design

CESM1 Fully Coupled
Large Ensembles

All forcing
1920 – 2100
(40 members)

XAER
1920 – 2030
(15 members)

XBMB
1920 – 2030
(15 members)

Radiative forcing

AER+BMB emissions
1920-2030

CAM5 AMIP ensembles
(1920-2030, 10 members)

(Deser et al. 2020)

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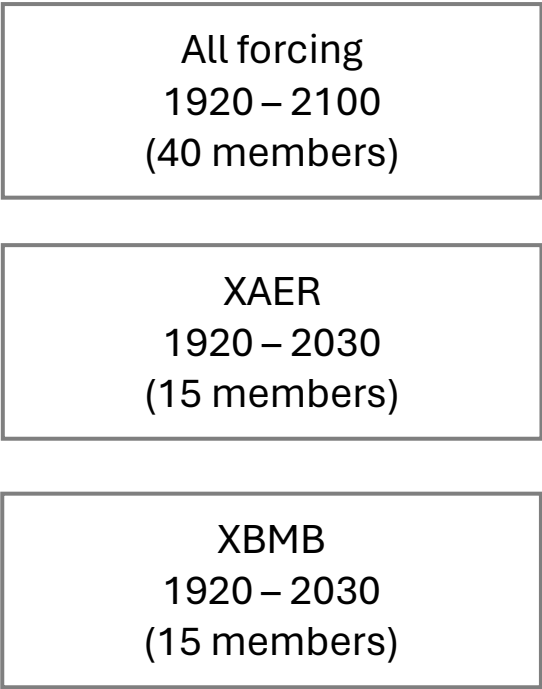
CAM5 AMIP ensembles
(1920-2030, 10 members)

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Time-evolving AER+BMB emissions
(climatological SSTs)
RAD-AMIP

(Deser et al. 2020)

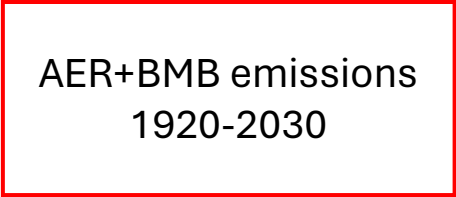
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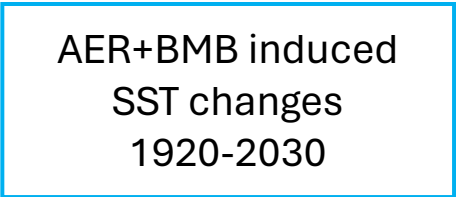


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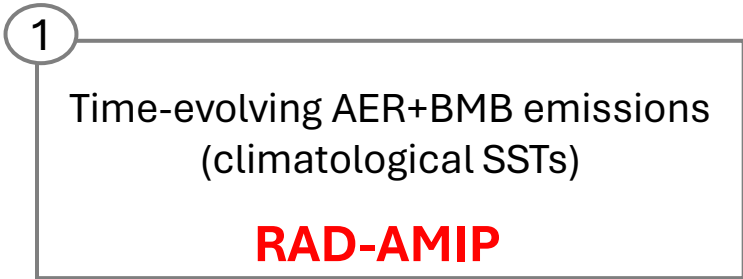
Radiative forcing



SST forcing

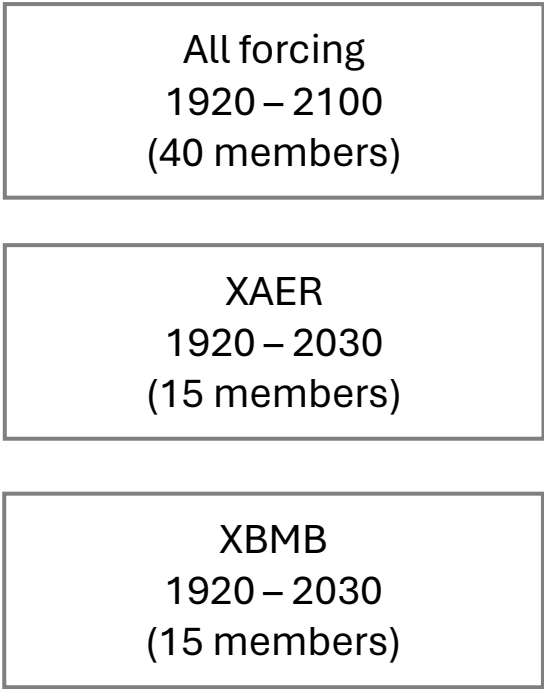


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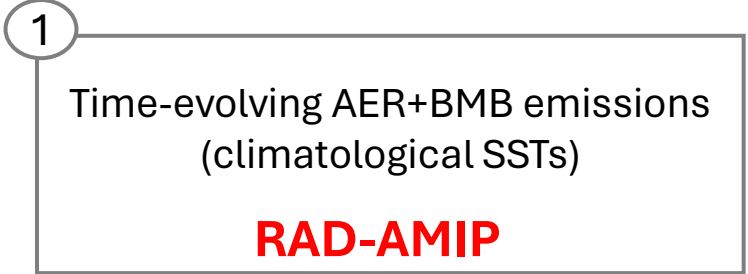
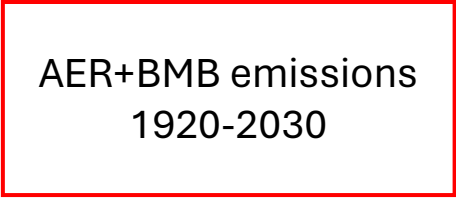


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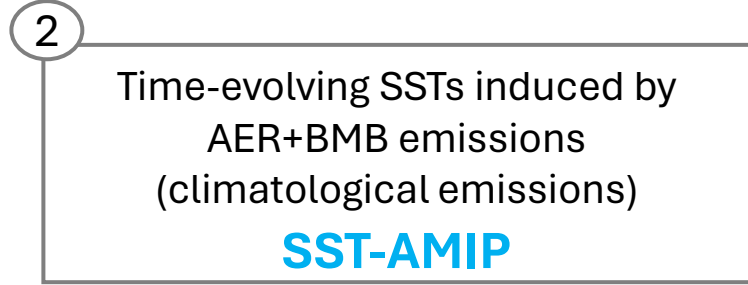
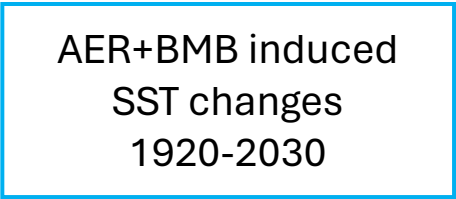
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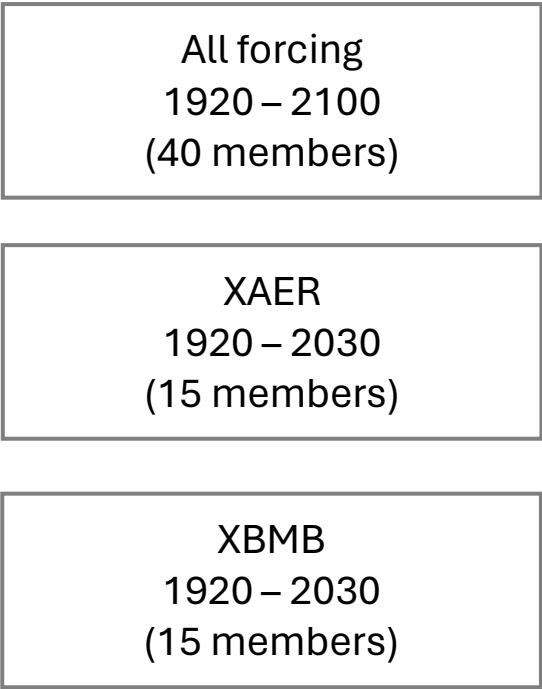
SST forcing



(Deser et al. 2020)

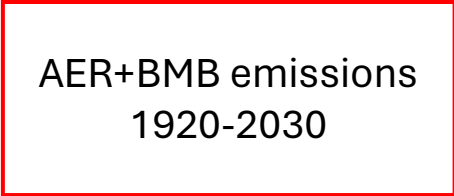
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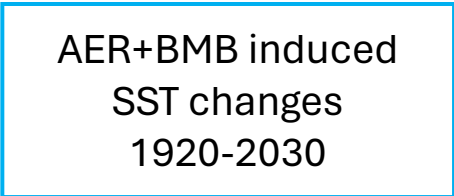


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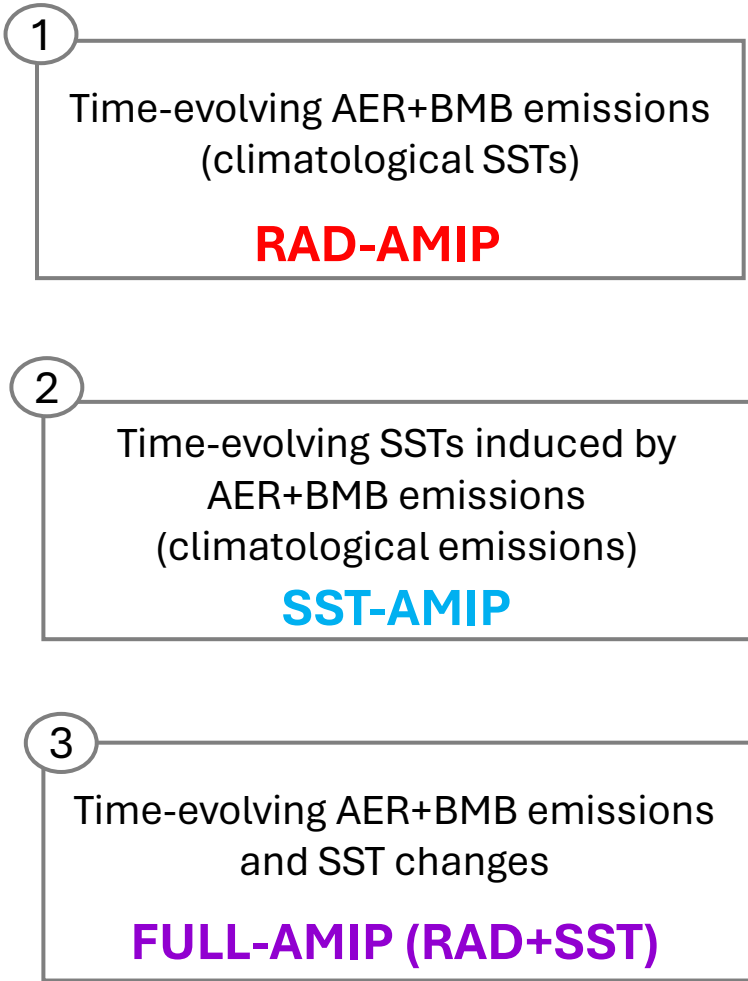
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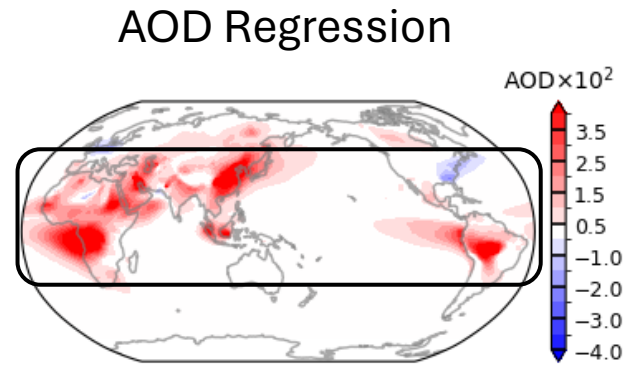
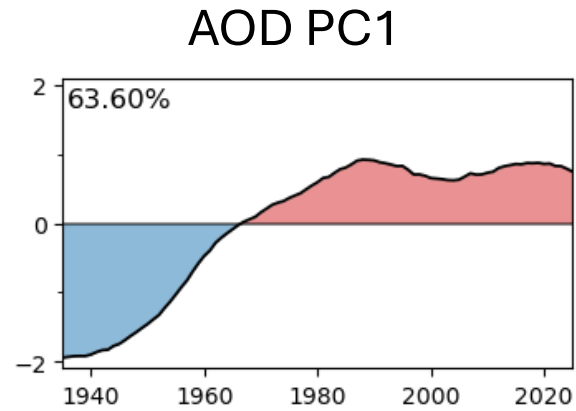
JJA Leading Forcing Patterns

(EOF analysis of AER+BMB aerosol optical depth)

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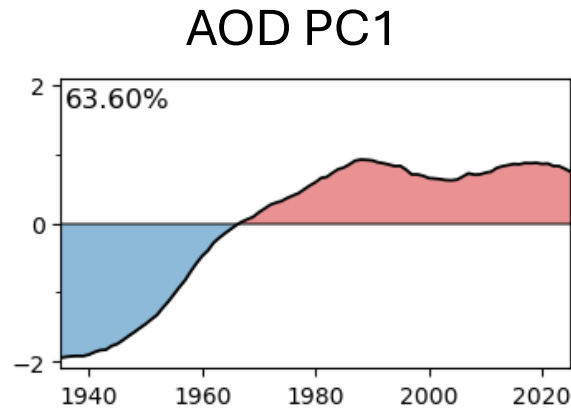
“Low-Latitude”
AOD mode



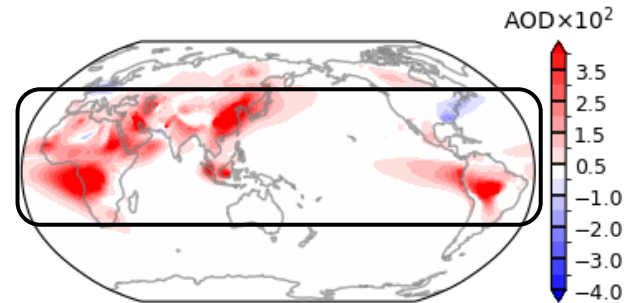
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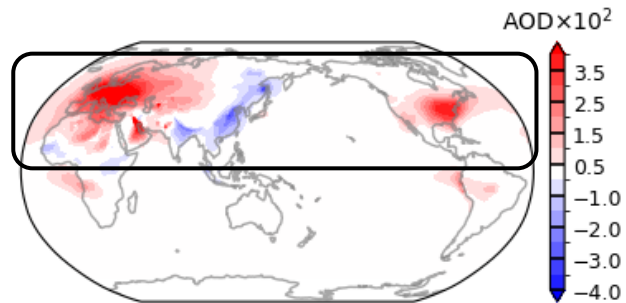
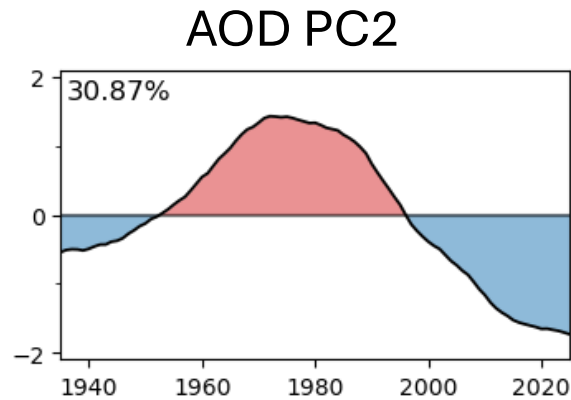
**“Low-Latitude”
AOD mode**



AOD Regression



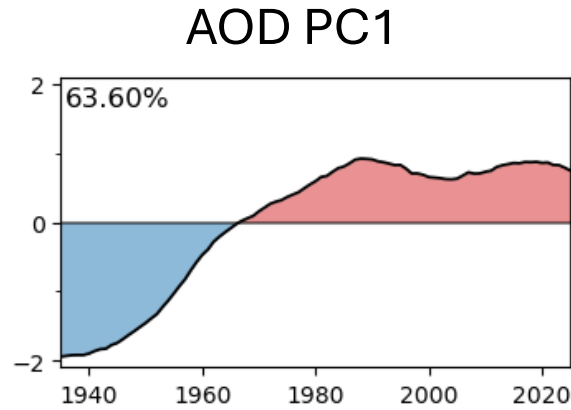
**“NH Mid-Latitude”
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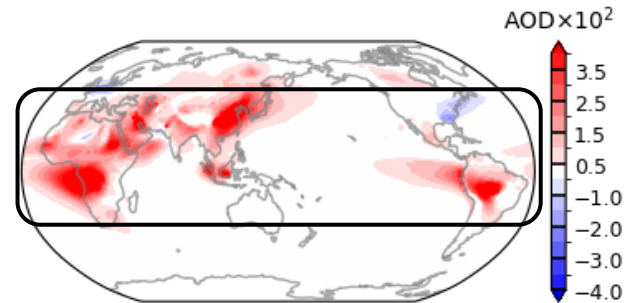
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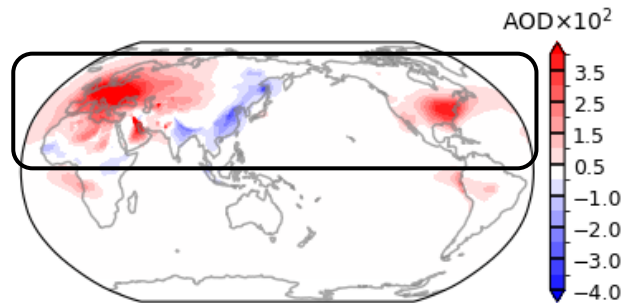
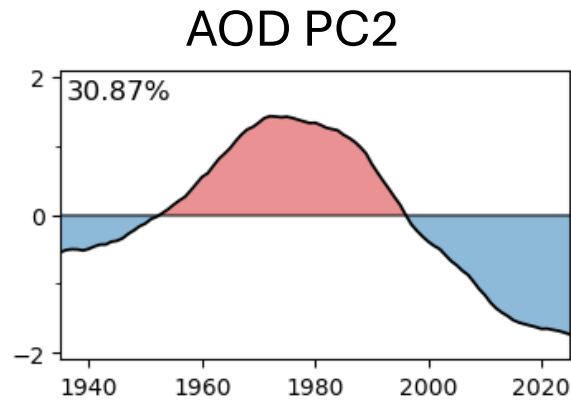
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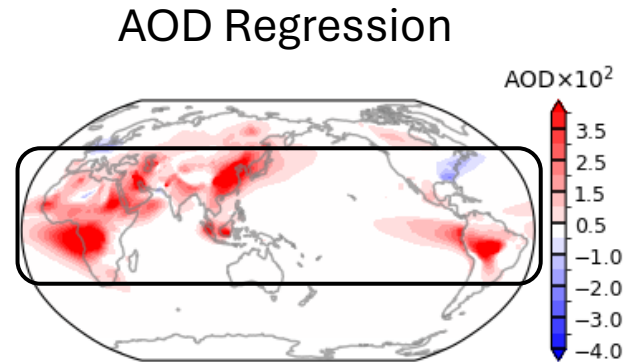
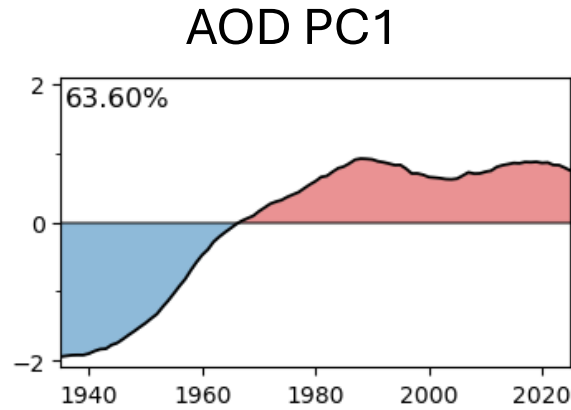


**Two modes:
95% variance explained**

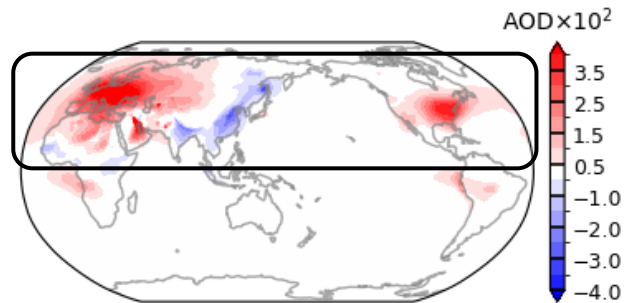
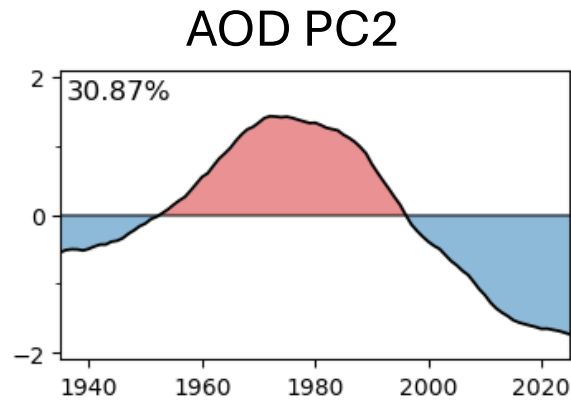
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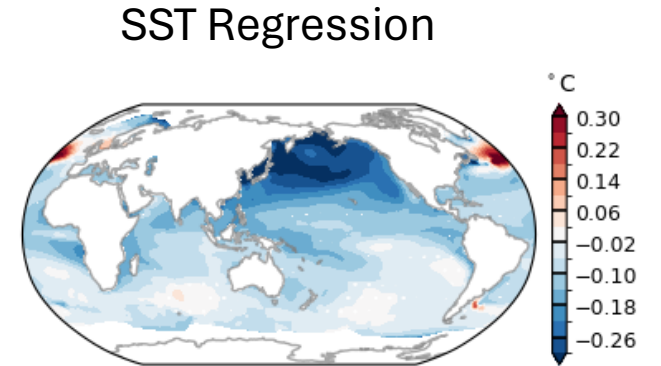
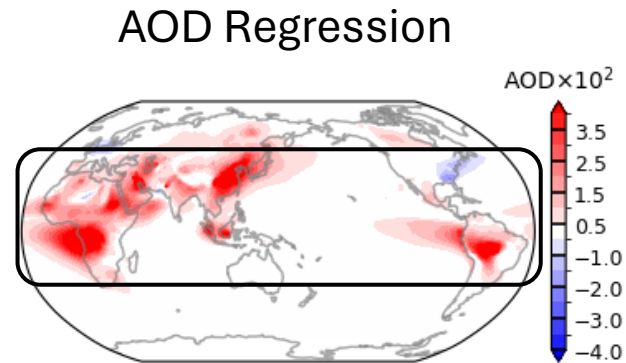
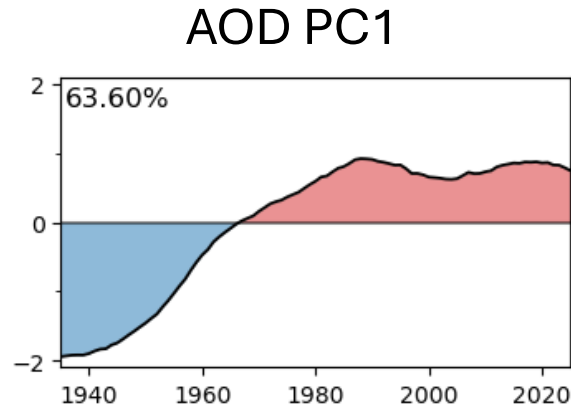
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Atmospheric radiative
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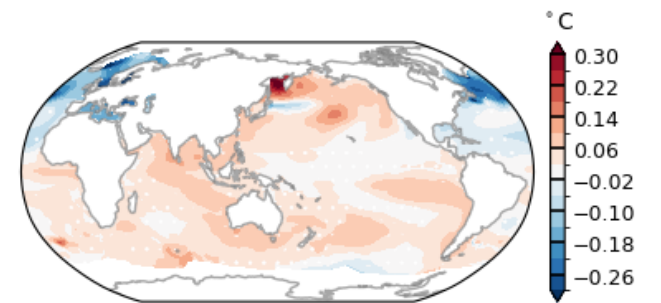
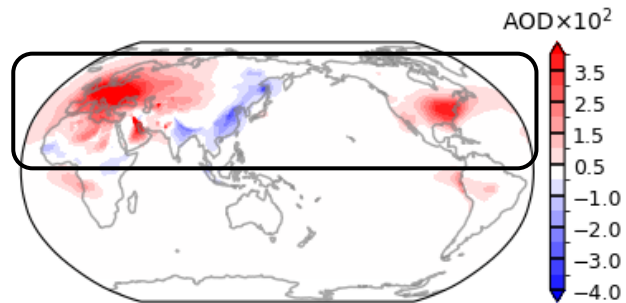
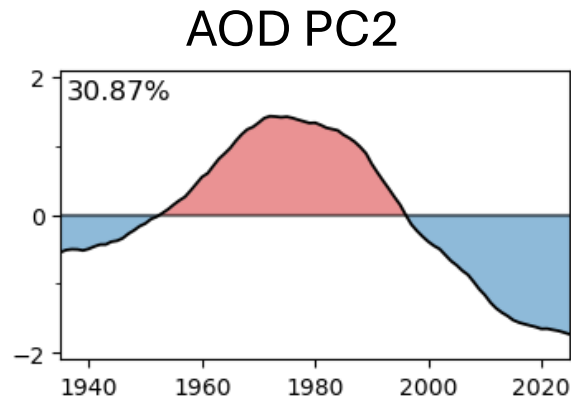
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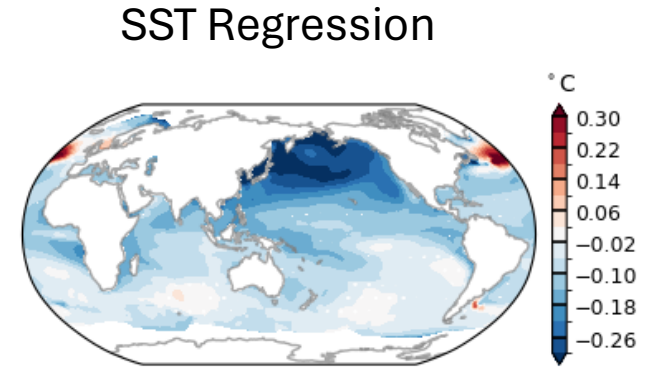
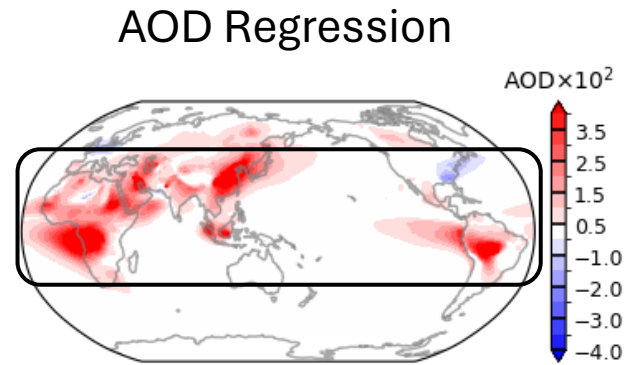
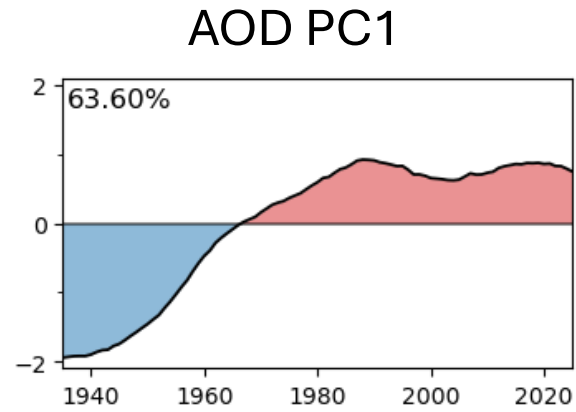
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SST forcing patterns

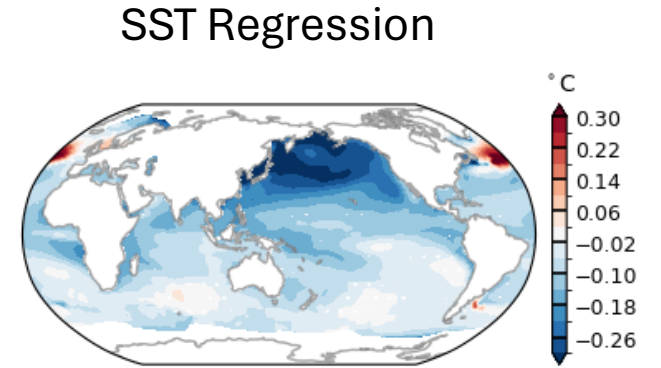
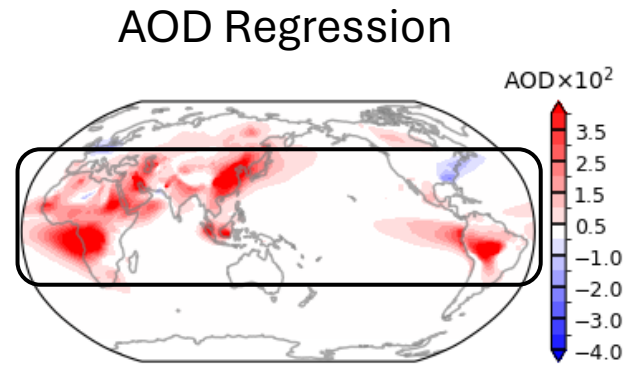
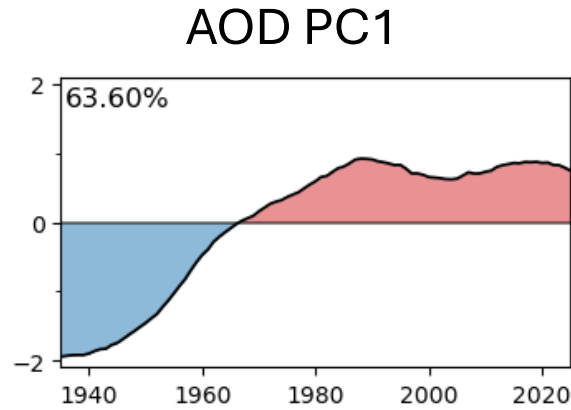
JJA Precipitation Response to “Low Latitude” AOD Mode

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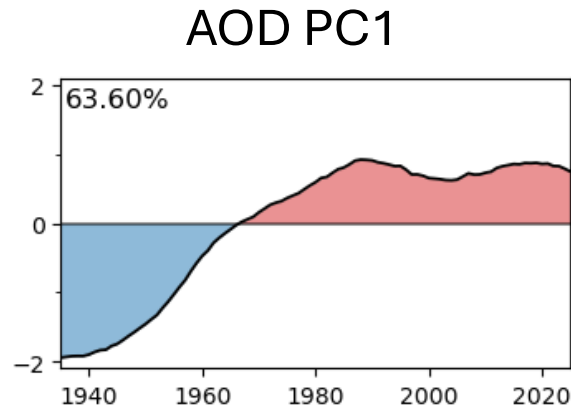


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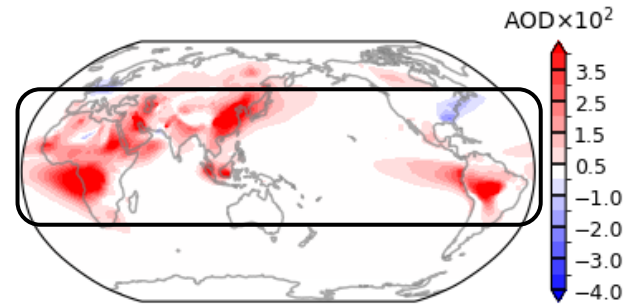


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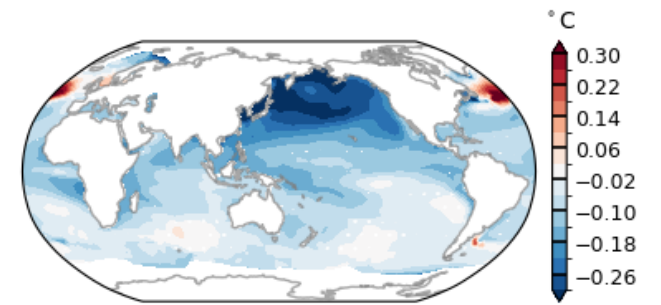
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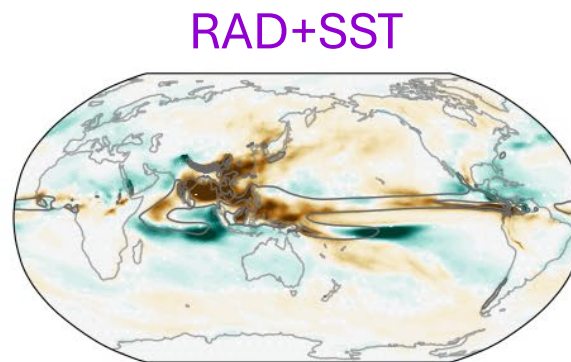
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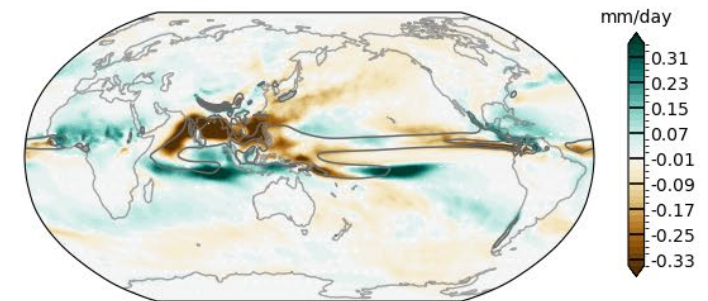
SST Regression



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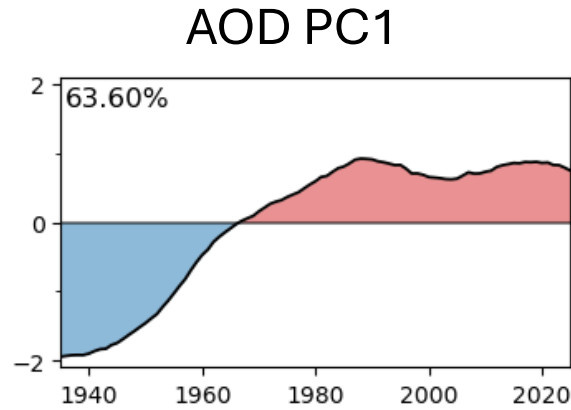


SST forced

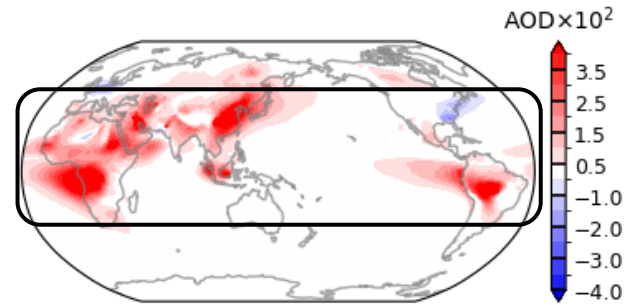


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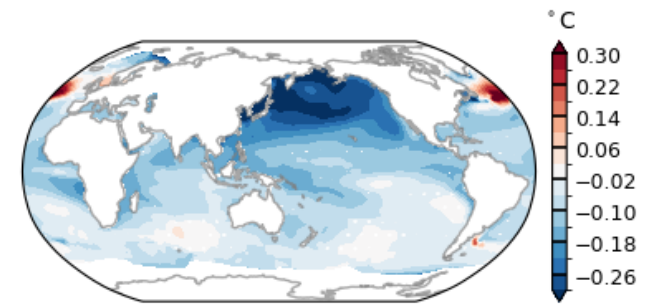
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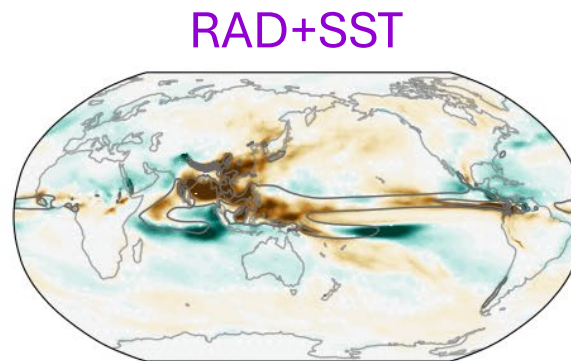
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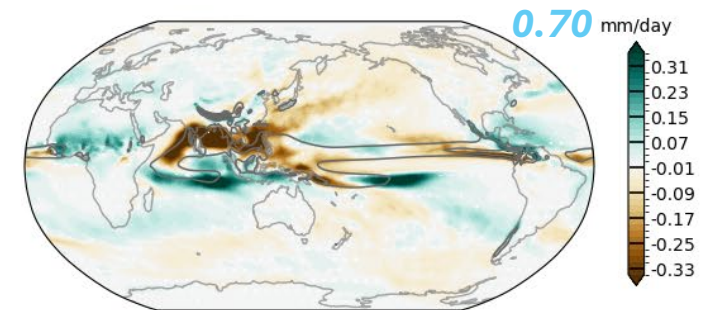
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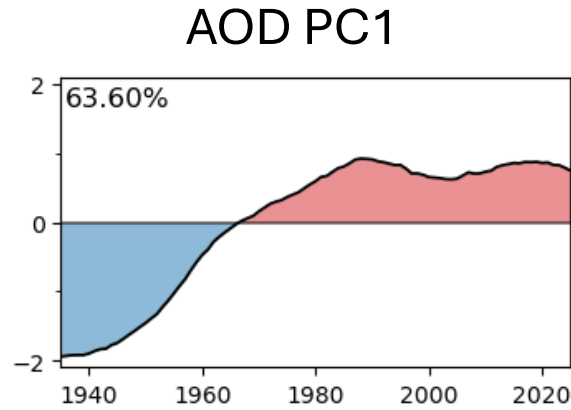


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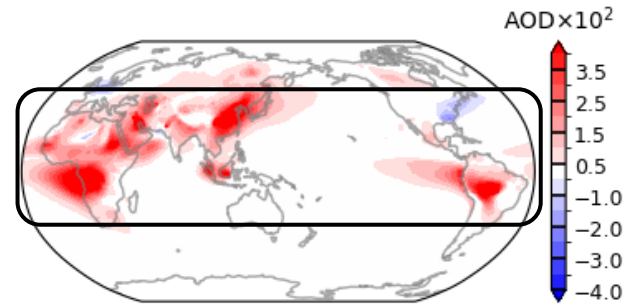


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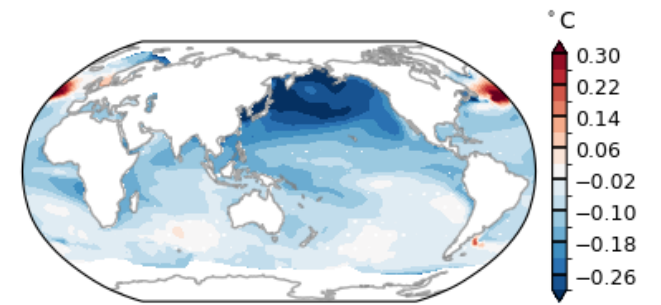
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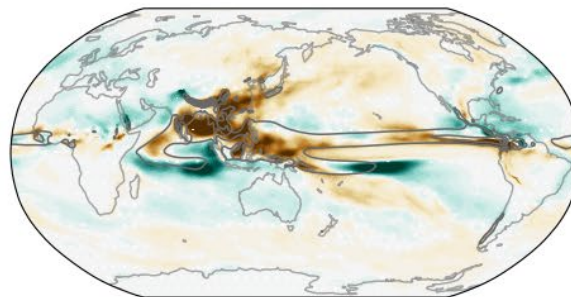
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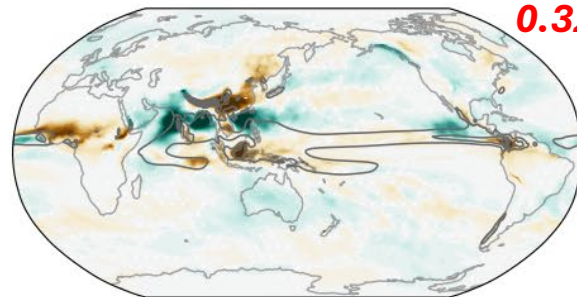
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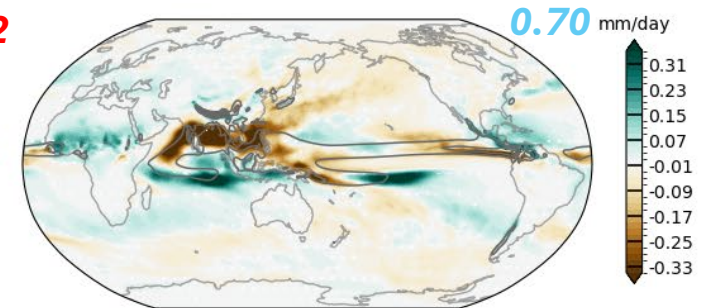
RAD+SST



Radiatively forced



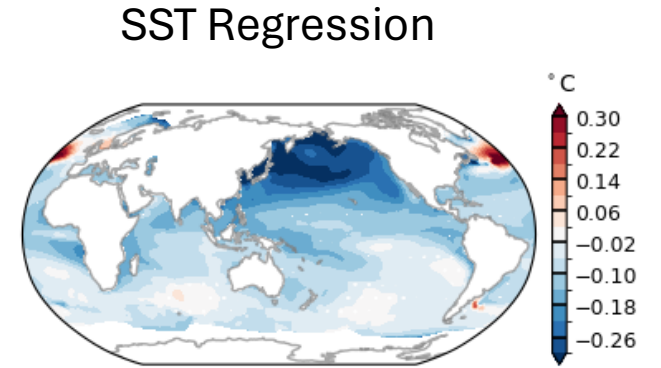
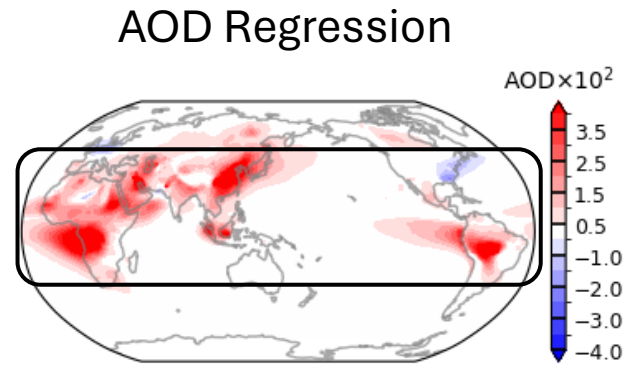
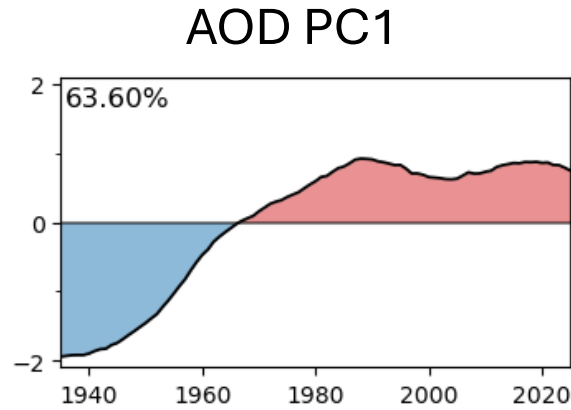
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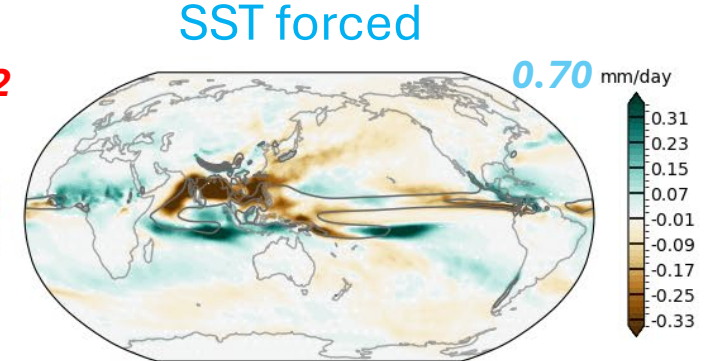
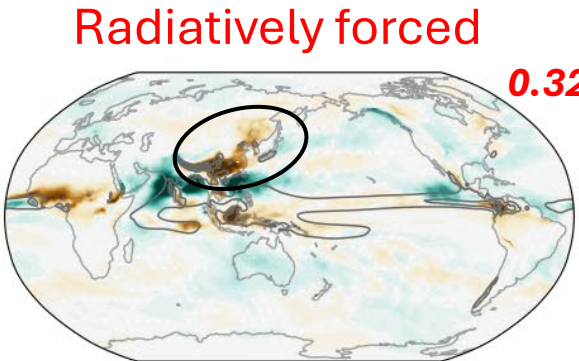
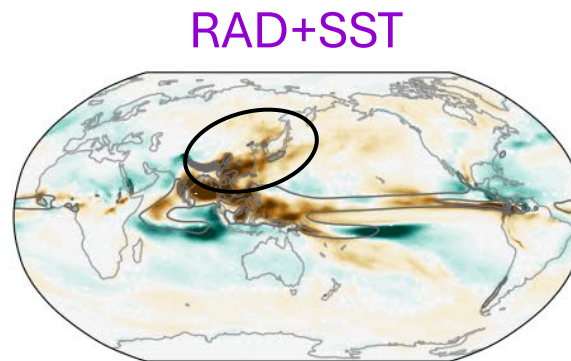
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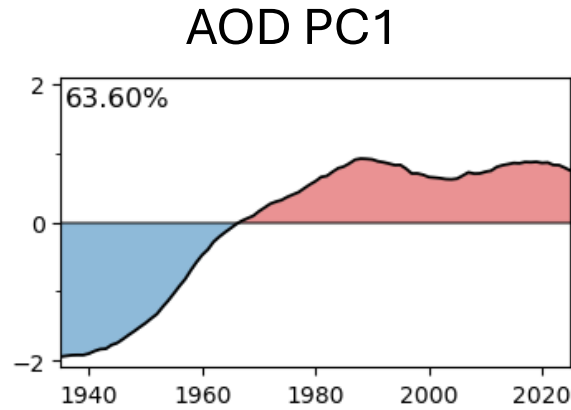


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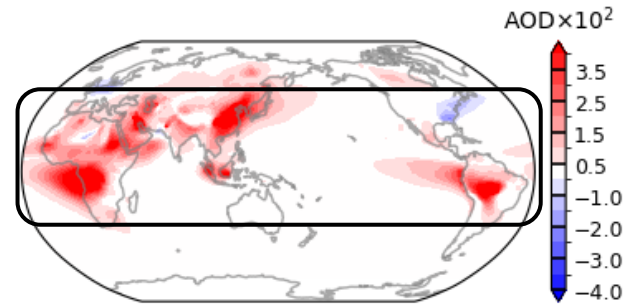


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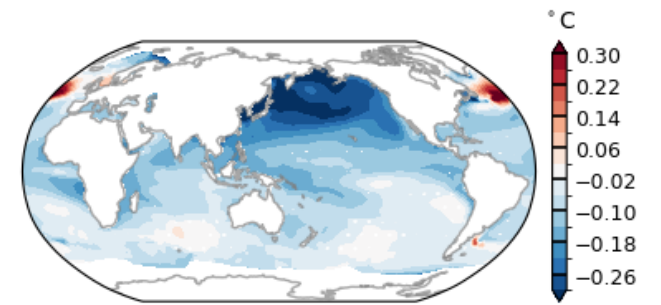
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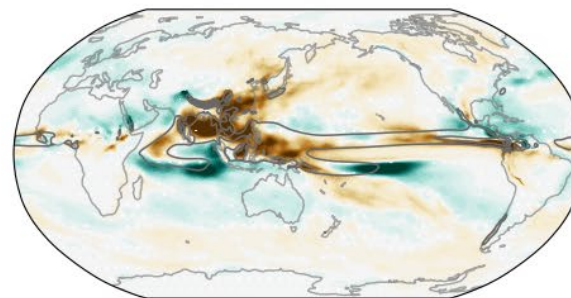
AOD Regression



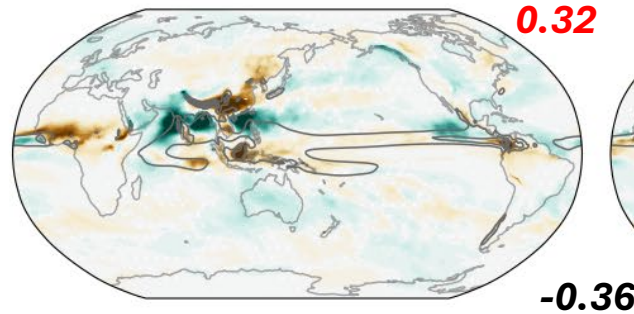
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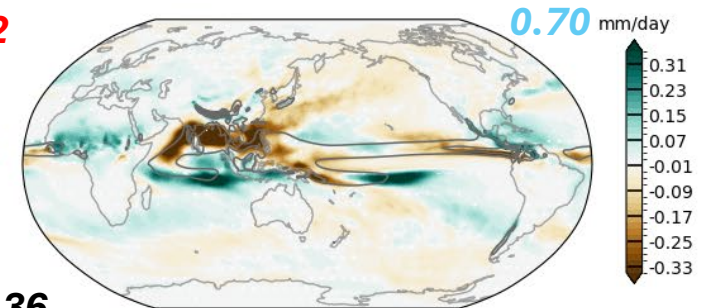
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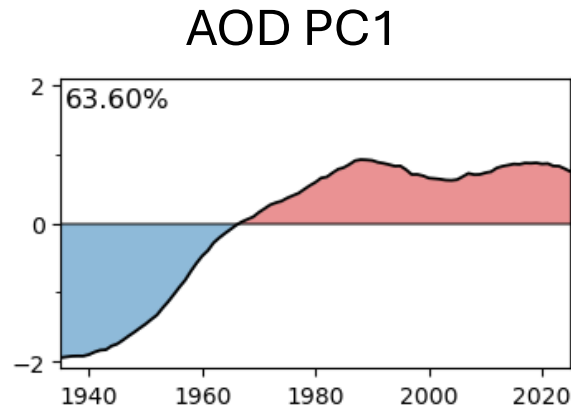
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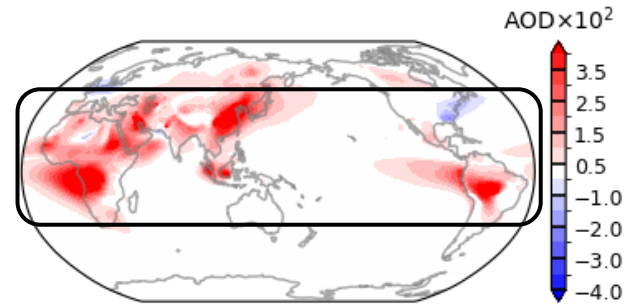
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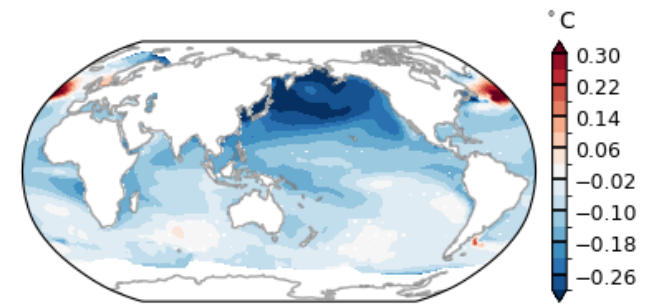
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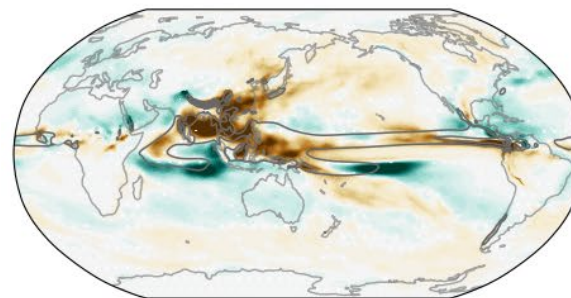
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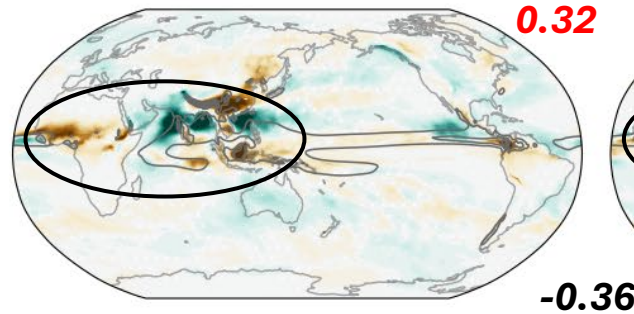
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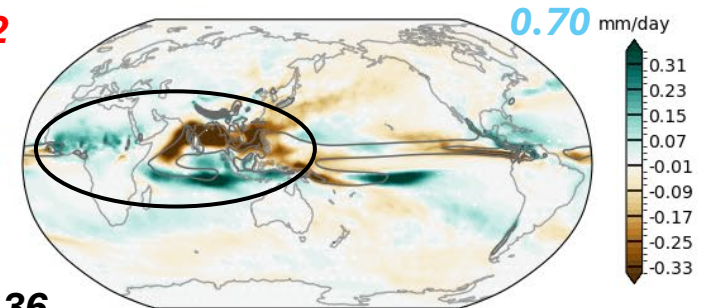
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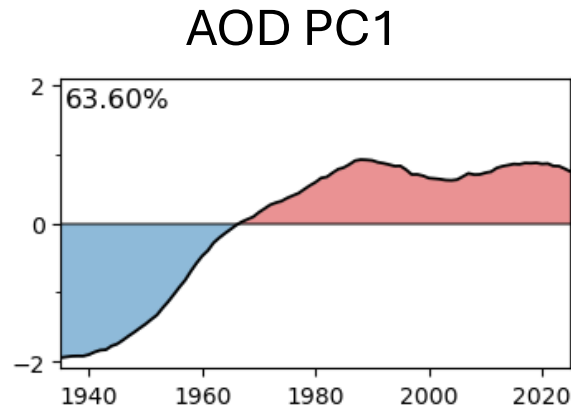
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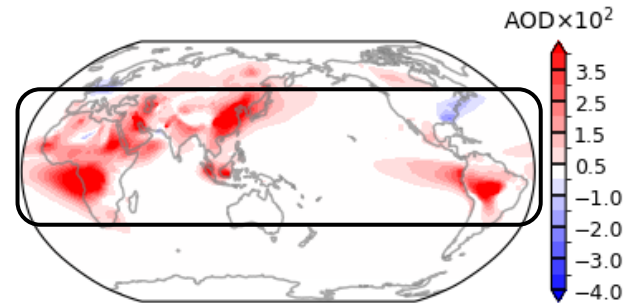
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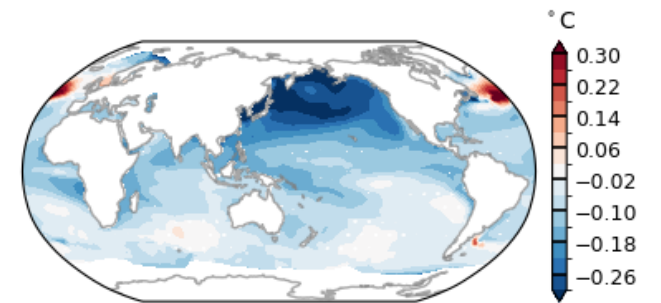
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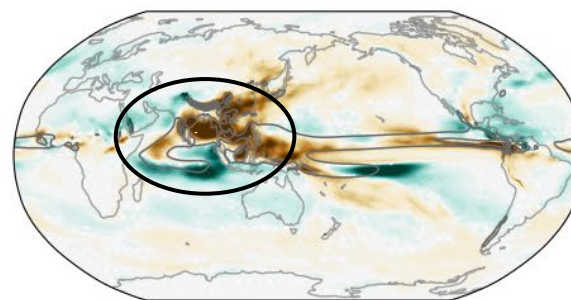
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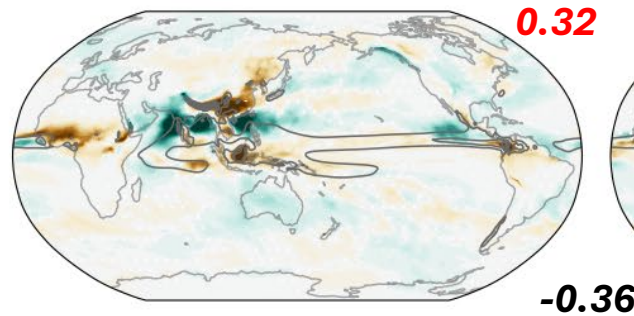
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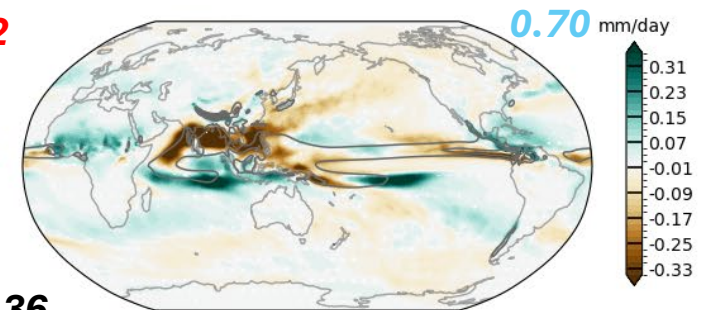
RAD+SST



Radiatively forced



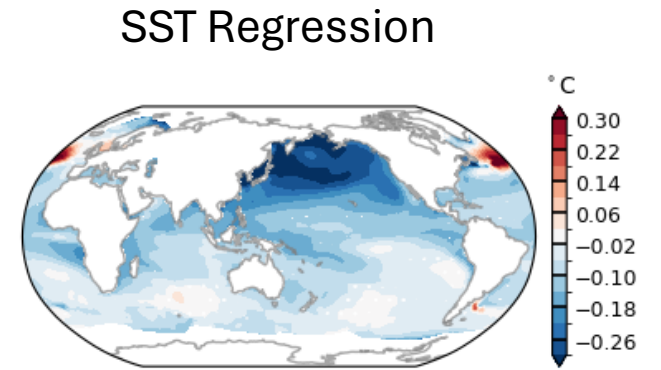
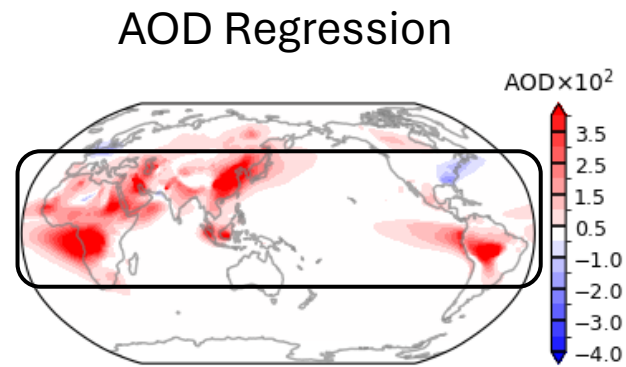
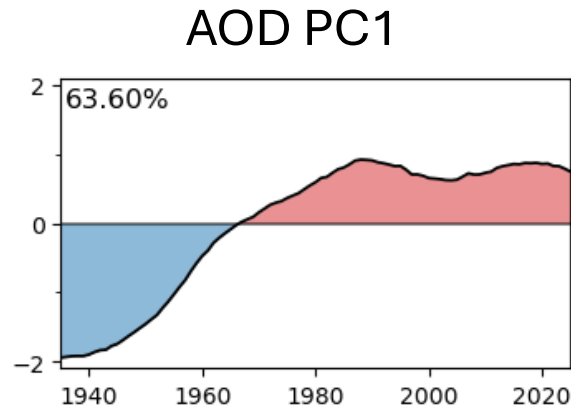
SST forced



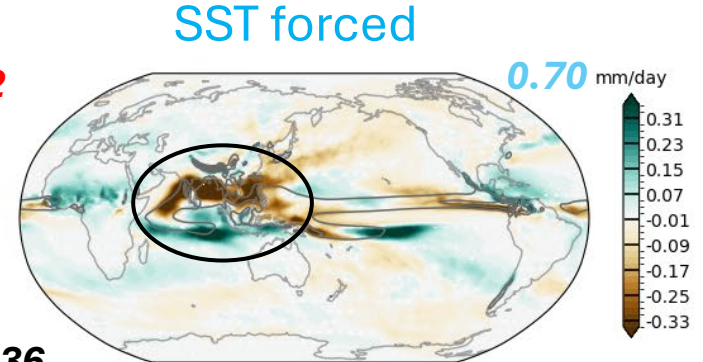
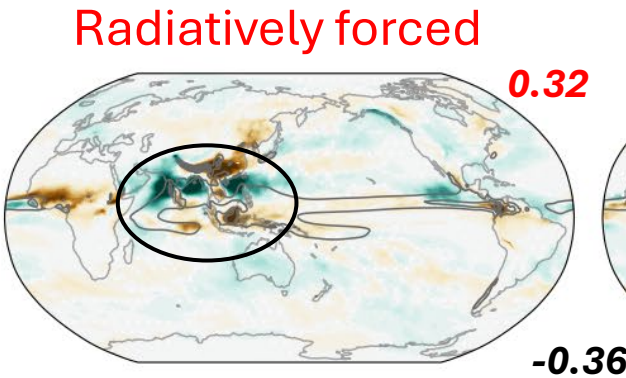
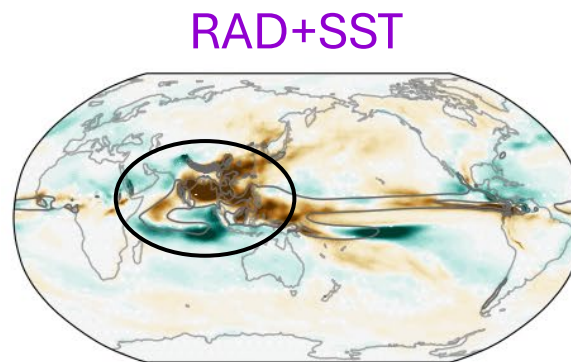
Precipitation
Response

JJA Precipitation Response to “Low Latitude” AOD Mode

“Low-Latitude”
AOD mode

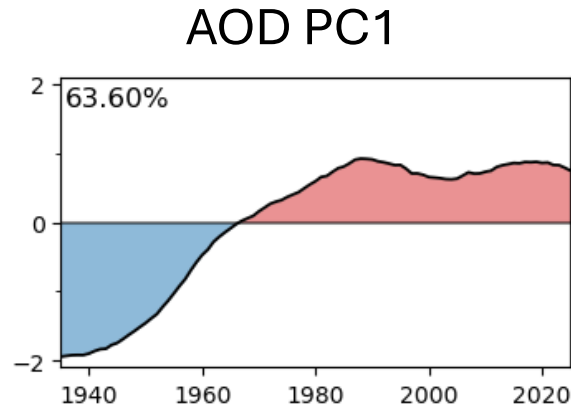


Precipitation
Response

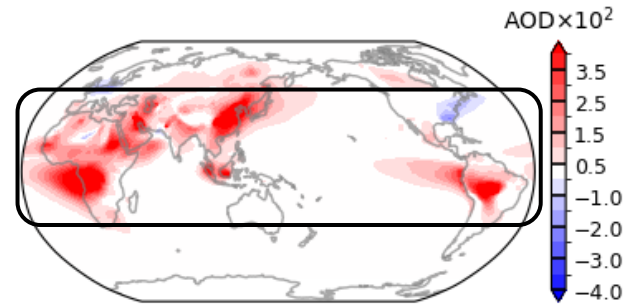


JJA Precipitation Response to “Low Latitude” AOD Mode

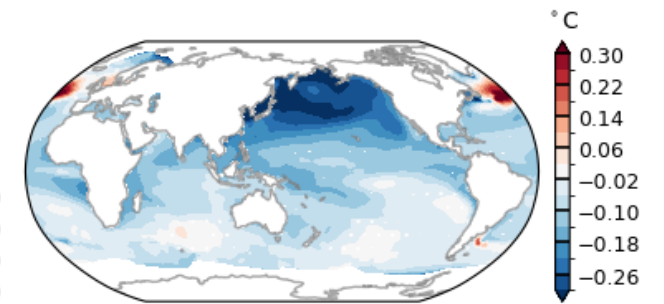
“Low-Latitude”
AOD mode



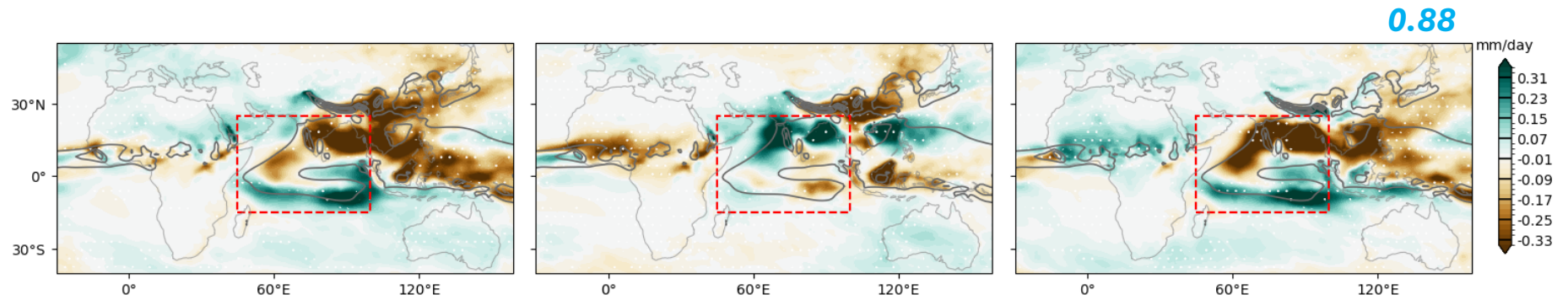
AOD Regression



SST Regression



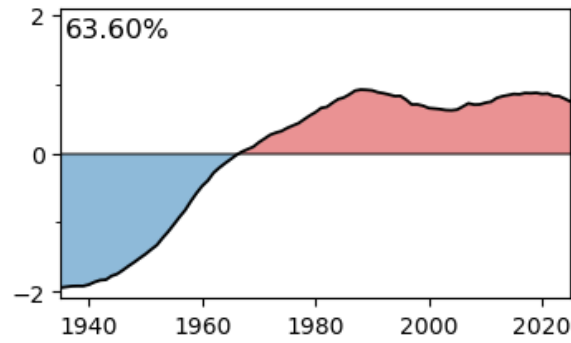
Precipitation
Response



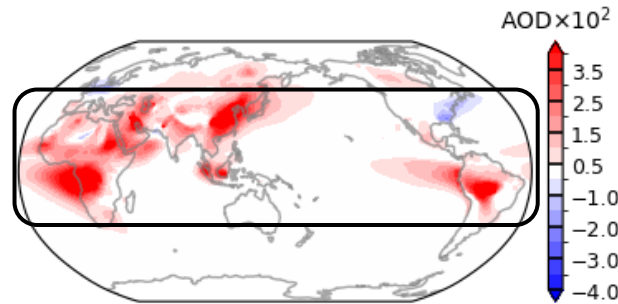
JJA Precipitation Response to “Low Latitude” AOD Mode

“Low-Latitude”
AOD mode

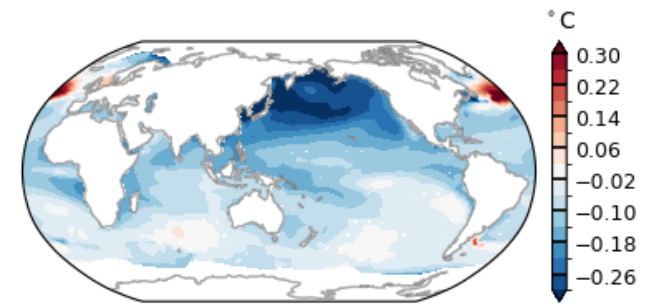
AOD PC1



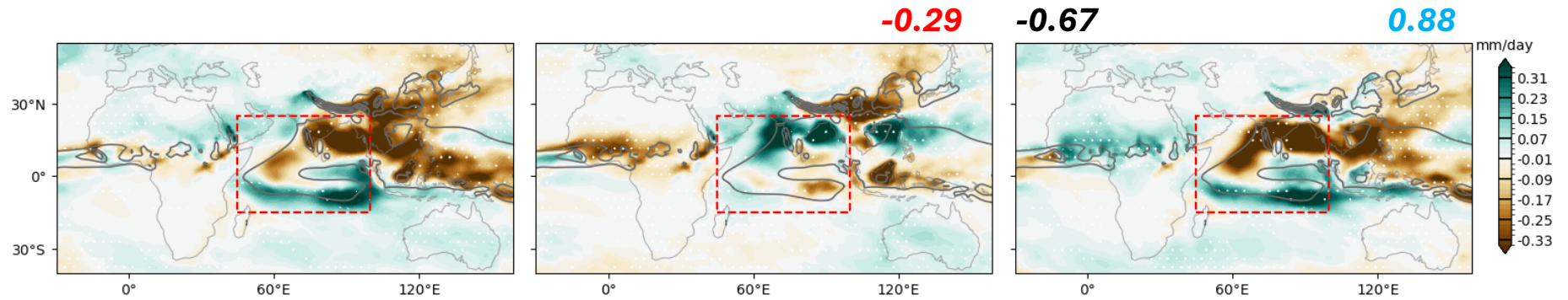
AOD Regression



SST Regression

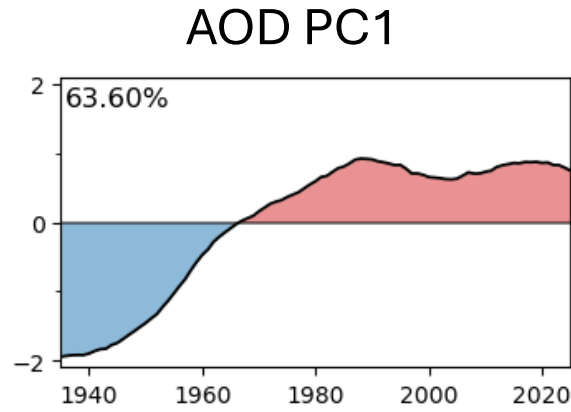


Precipitation
Response

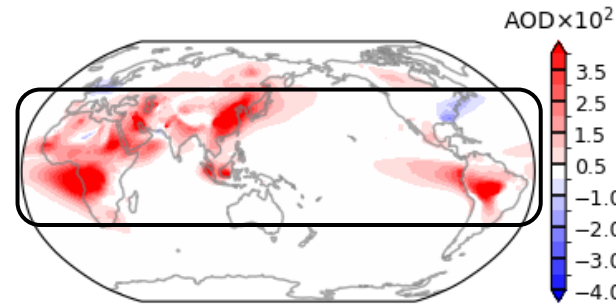


JJA Precipitation Response to “Low Latitude” AOD Mode

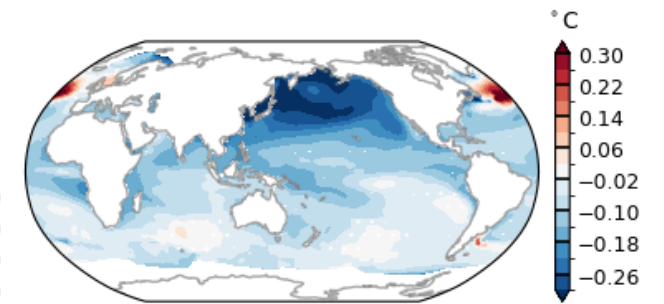
“Low-Latitude”
AOD mode



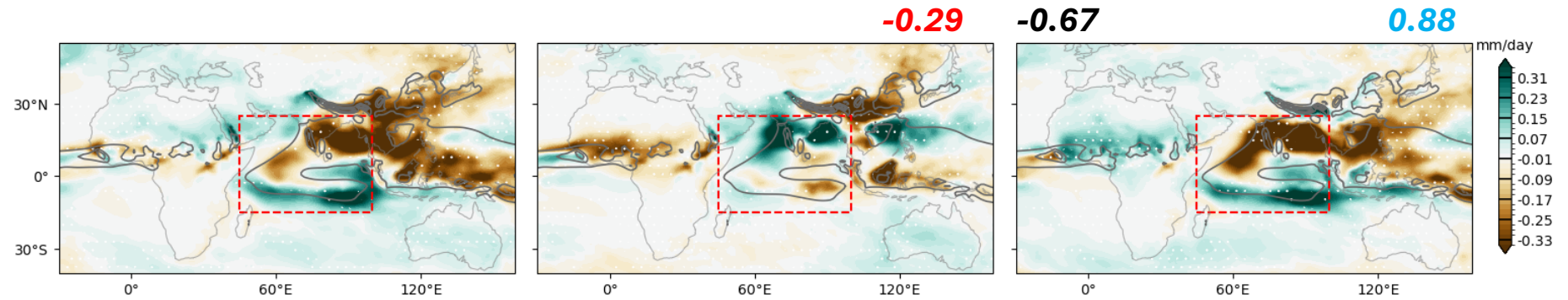
AOD Regression



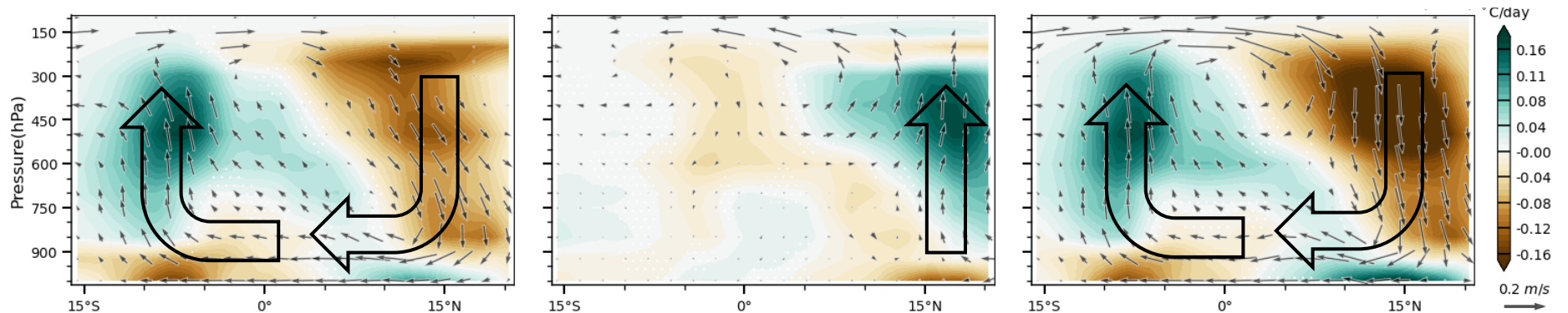
SST Regression



Precipitation
Response



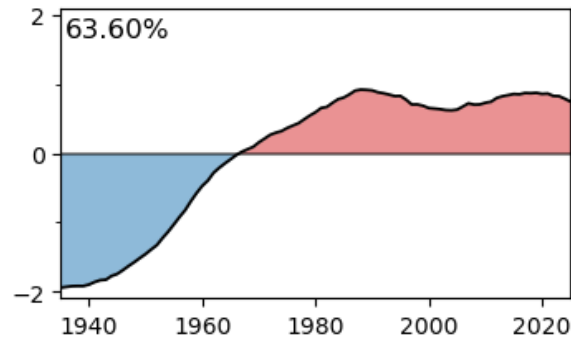
Latitude-Height
Cross Section
Condensational
Heating



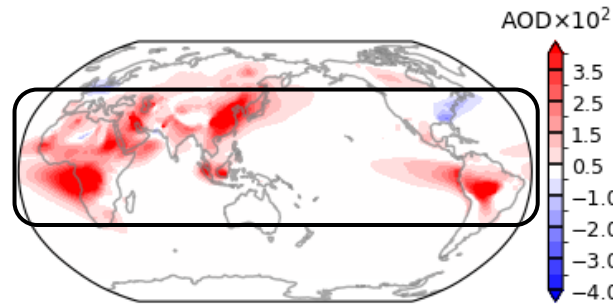
JJA Precipitation Response to “Low Latitude” AOD Mode

“Low-Latitude”
AOD mode

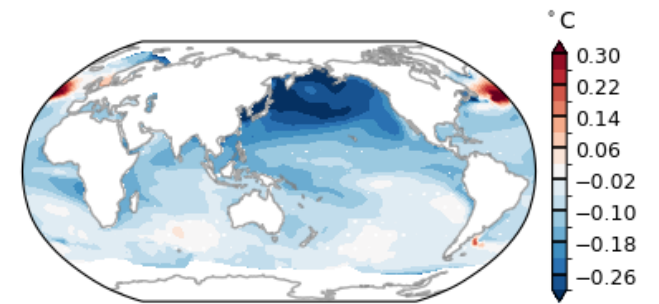
AOD PC1



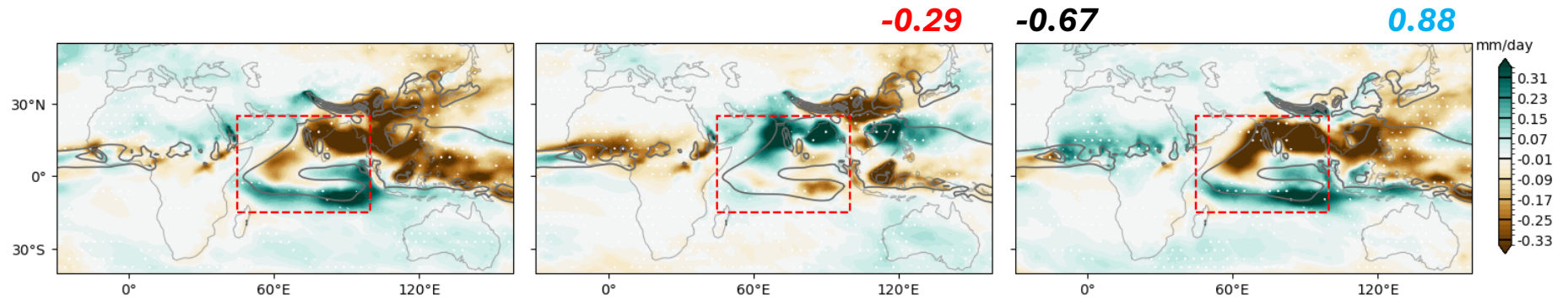
AOD Regression



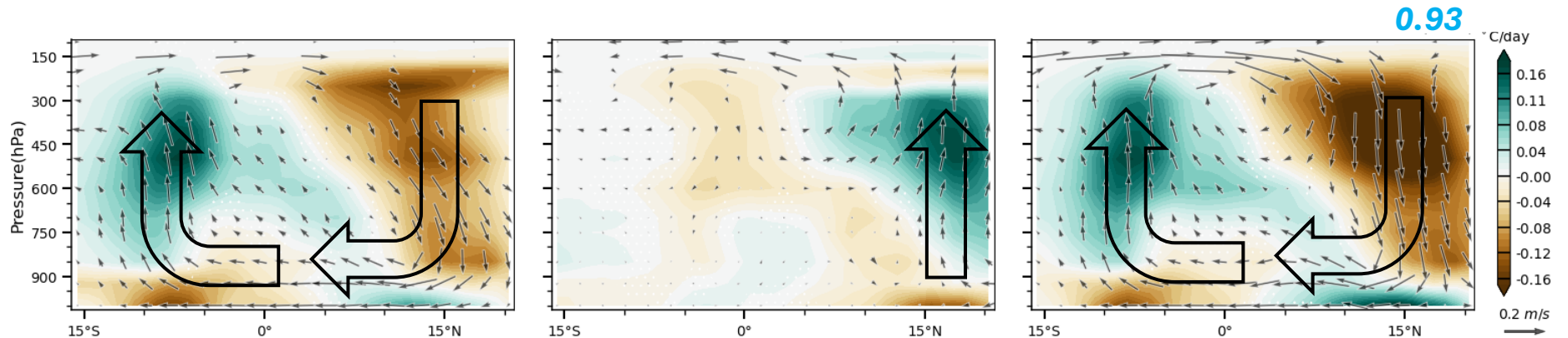
SST Regression



Precipitation
Response

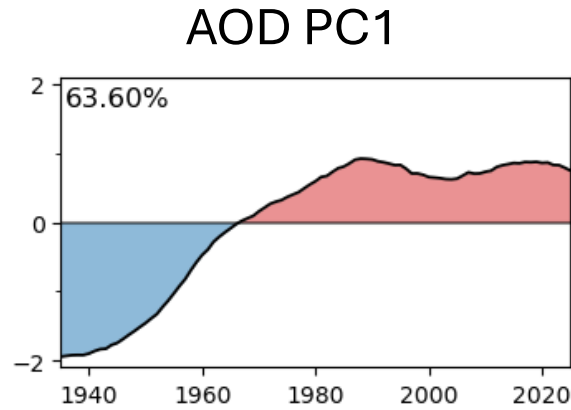


Latitude-Height
Cross Section
Condensational
Heating

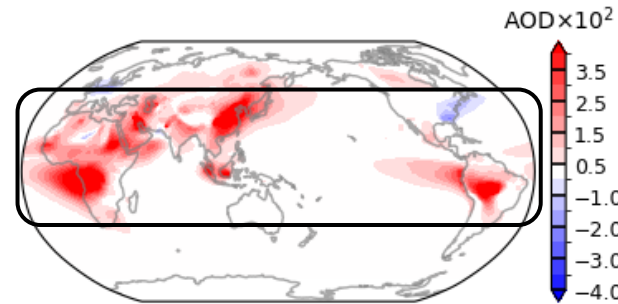


JJA Precipitation Response to “Low Latitude” AOD Mode

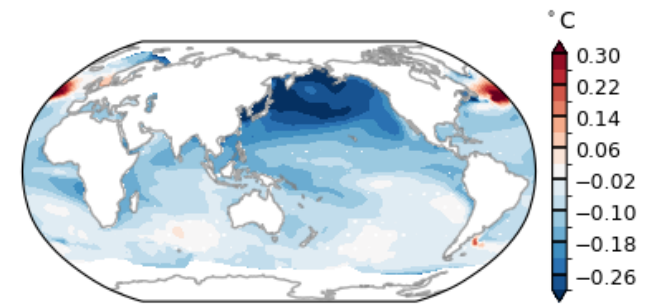
“Low-Latitude”
AOD mode



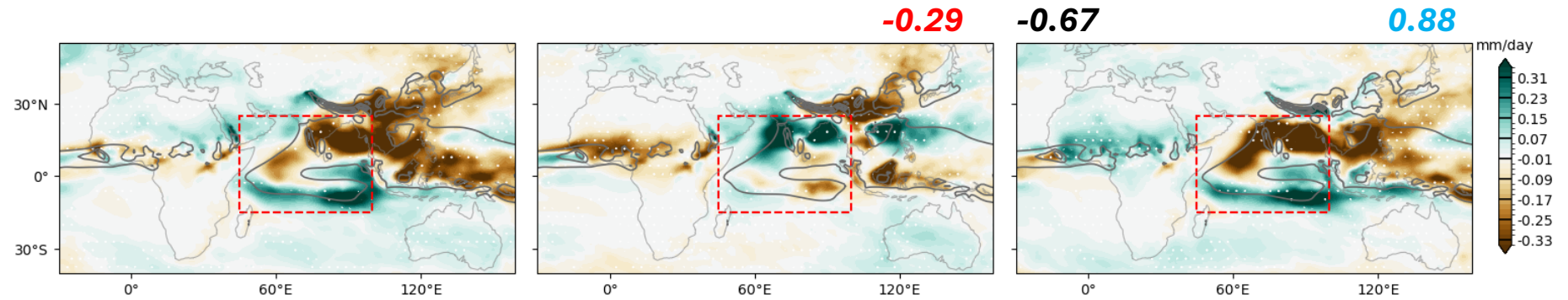
AOD Regression



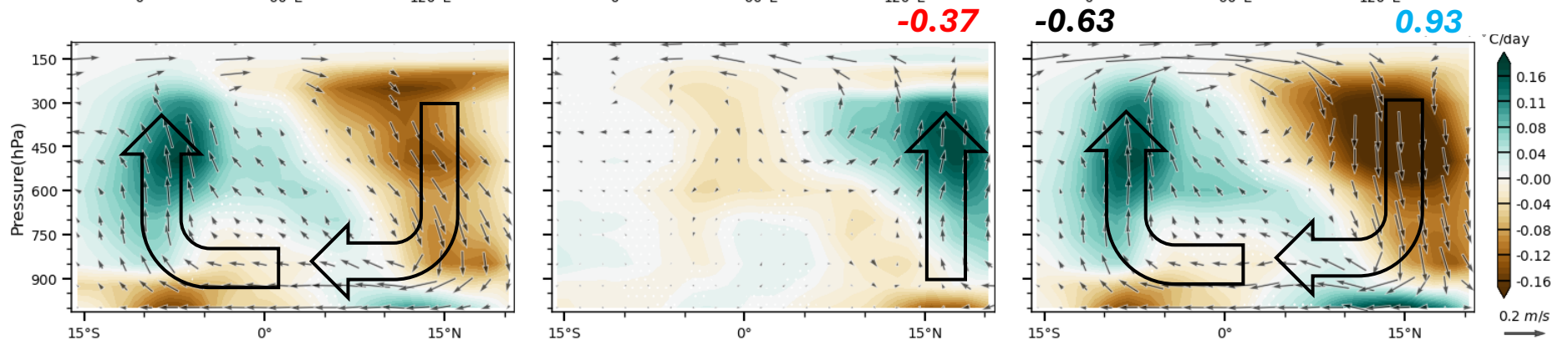
SST Regression



Precipitation
Response



Latitude-Height
Cross Section
Condensational
Heating



Take-home Messages

- Historical anthropogenic aerosol emissions can be decomposed into two dominant modes of variability:
 - **“Low-Latitude” AOD mode (64%)** ← industrial AER and tropical BMB
 - **“NH Mid-Latitude” AOD mode (31%)** ← industrial AER
- Large-scale atmospheric response to these modes is dominated by **SST forcing**, while **radiative forcing** contributes mostly locally.
- Regional responses over the Indian Ocean are impacted by both **local emissions** through **radiative forcing** and **remote emissions** through **radiative** and **SST** forced dynamical pathways.

Extra Slides

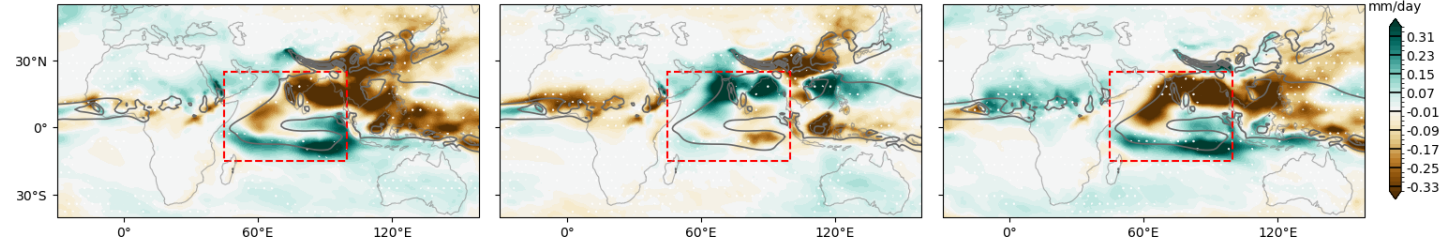
JJA Regional Responses to leading patterns

RAD+SST

Radiatively forced

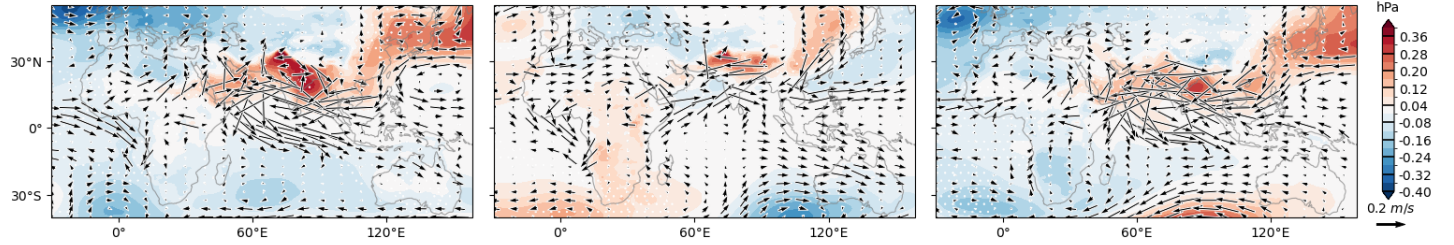
SST forced

Precipitation regressions

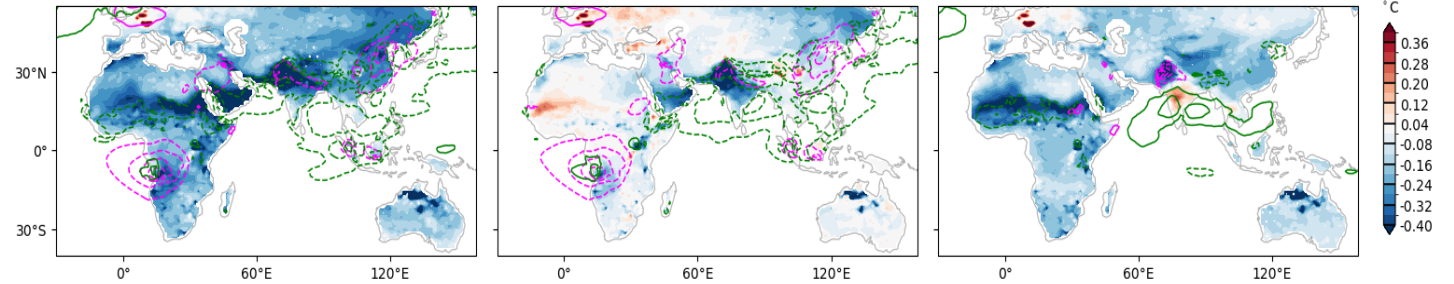


“Low-Latitude”
AOD mode

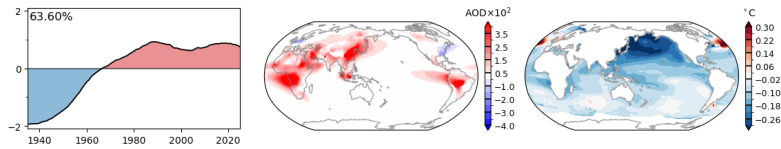
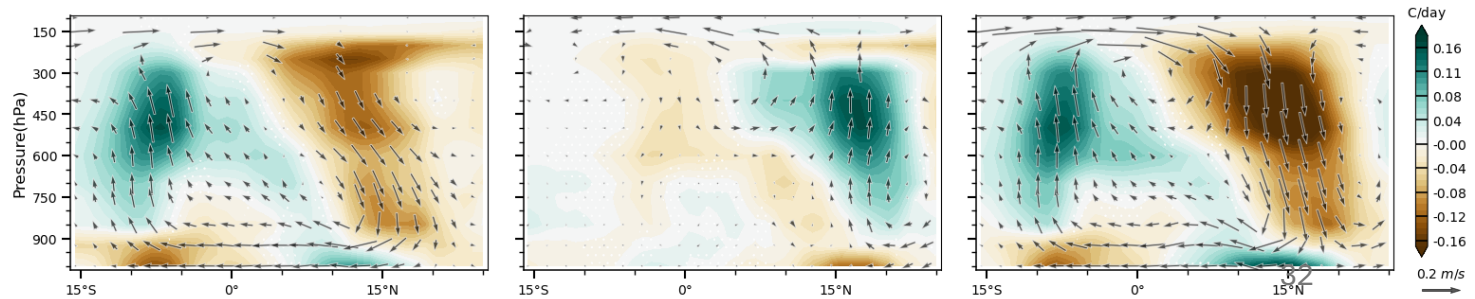
SLP & 850wind regressions



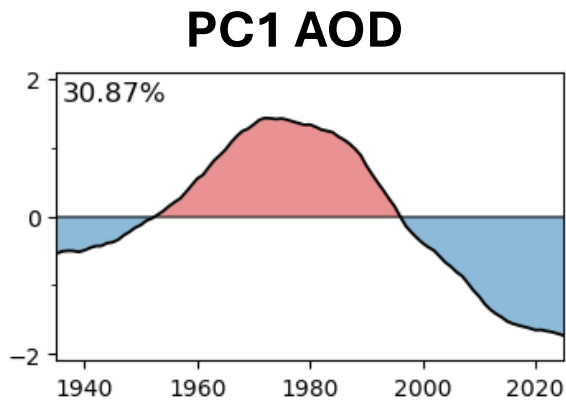
TREFHT regressions



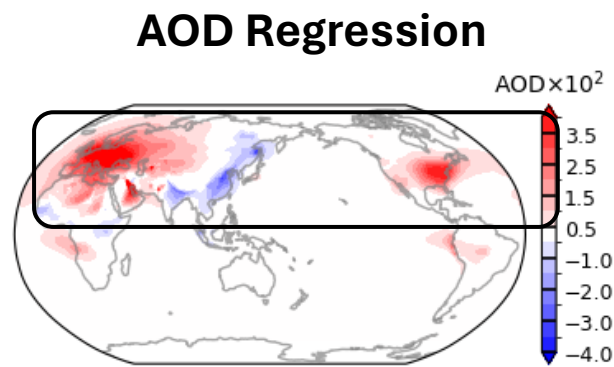
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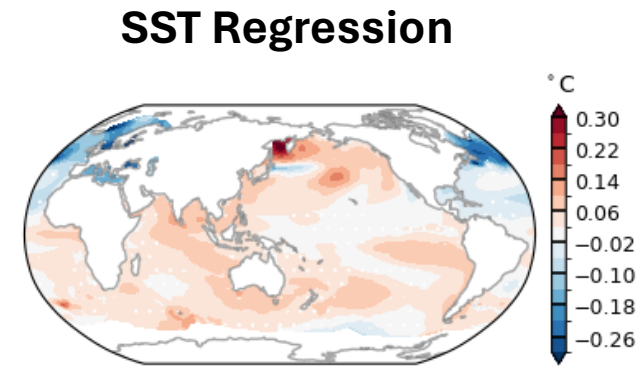
JJA Regional Response to “NH Mid-Latitude” AOD mode



RAD+SST

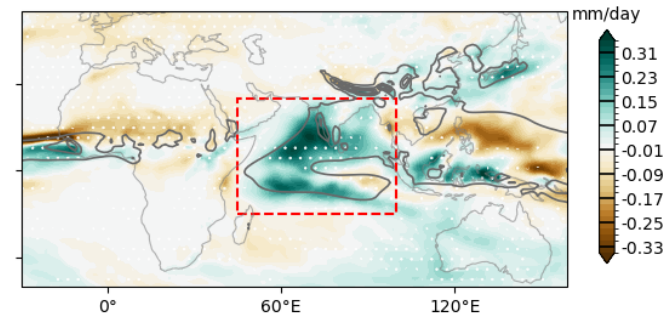
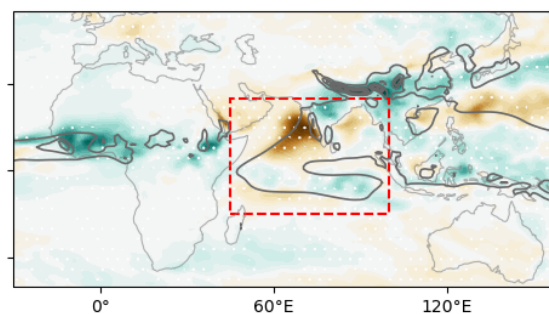
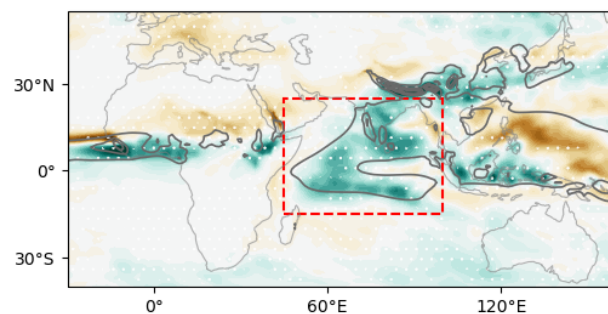


Radiatively forced



SST forced

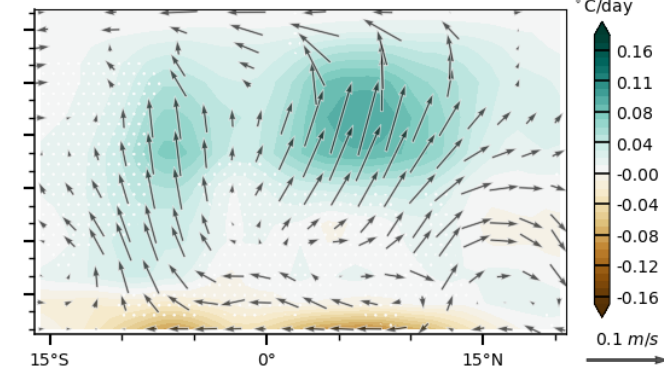
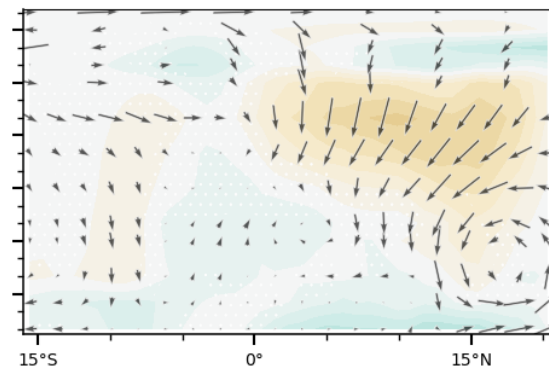
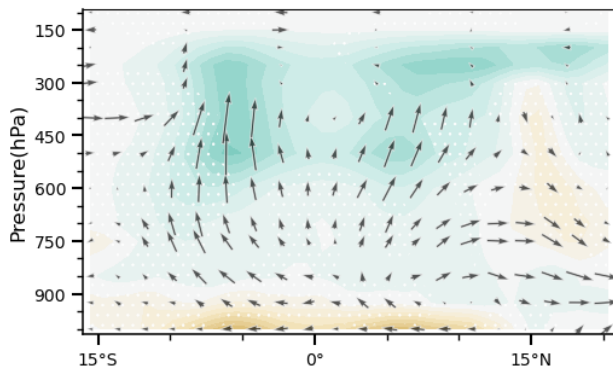
Precipitation Response



-0.01

0.71

Latitude-Height Cross Section Condensational Heating

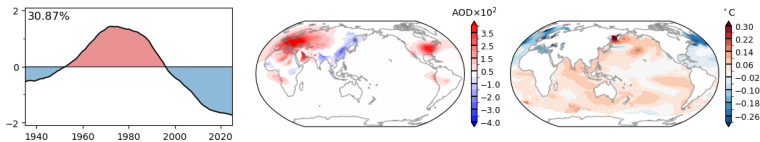


-0.17

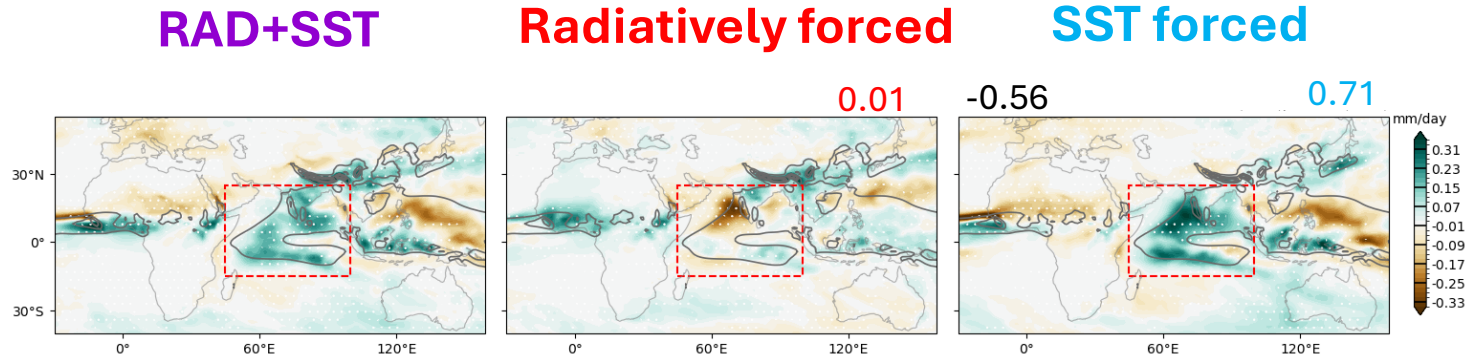
0.86

JJA Regional Responses to leading patterns

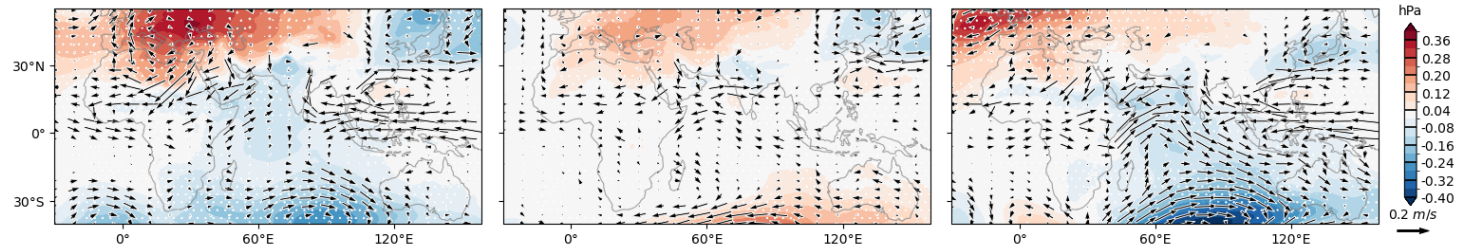
“NH Mid-Latitude”
AOD mode.



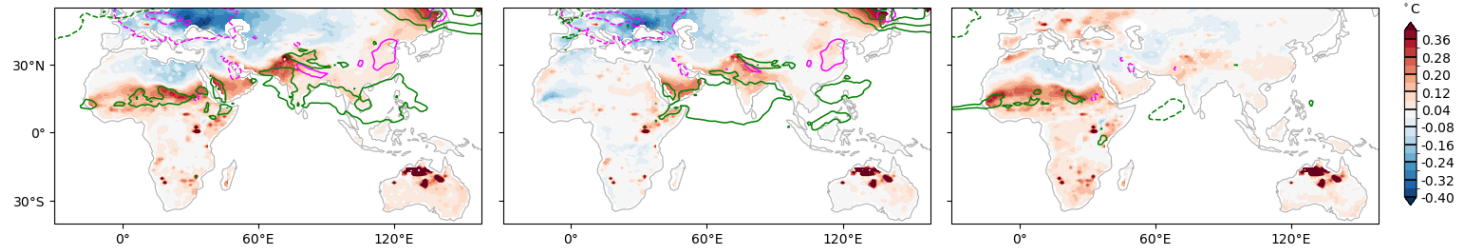
Precipitation regressions



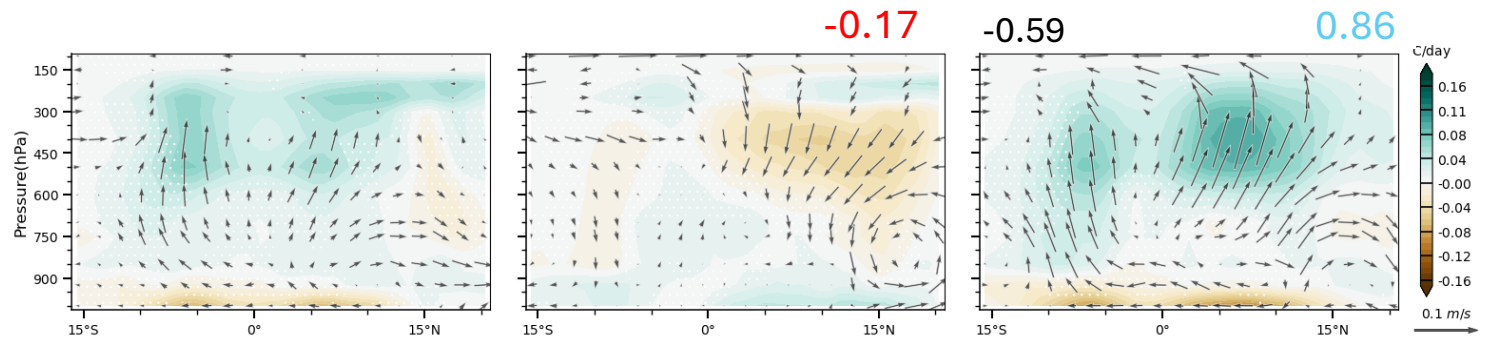
SLP & 850wind regressions



TREFHT regressions

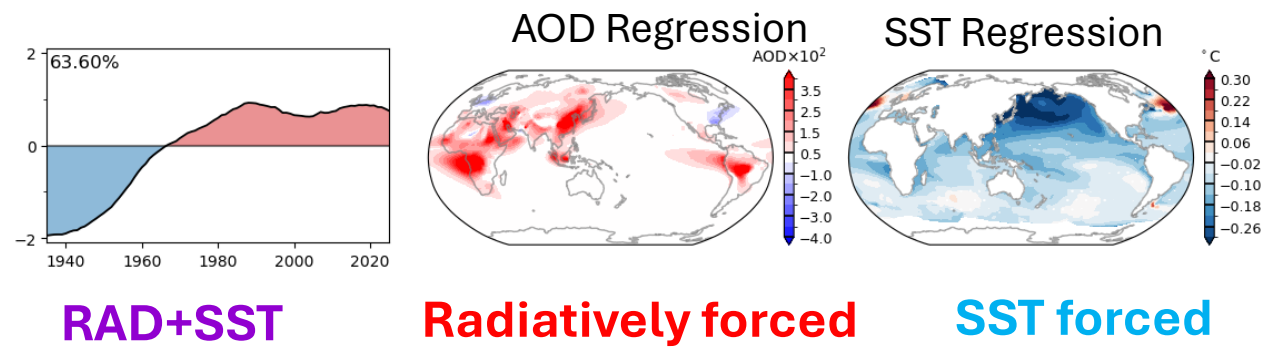


Latitude-Height Cross Section Condensational Heating

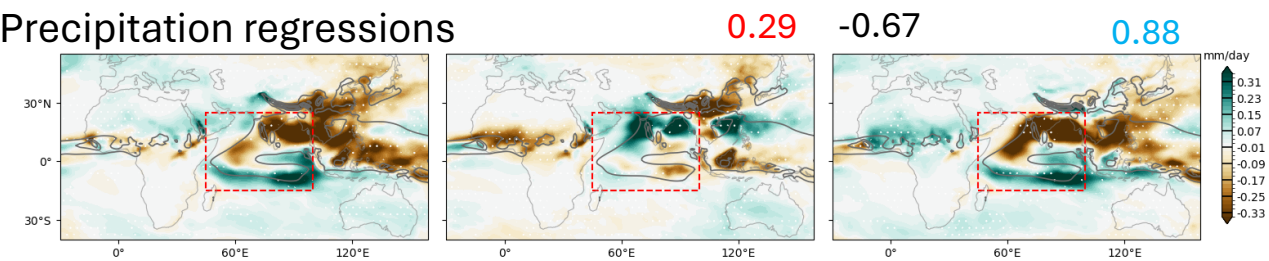


JJA Regional Responses to leading patterns

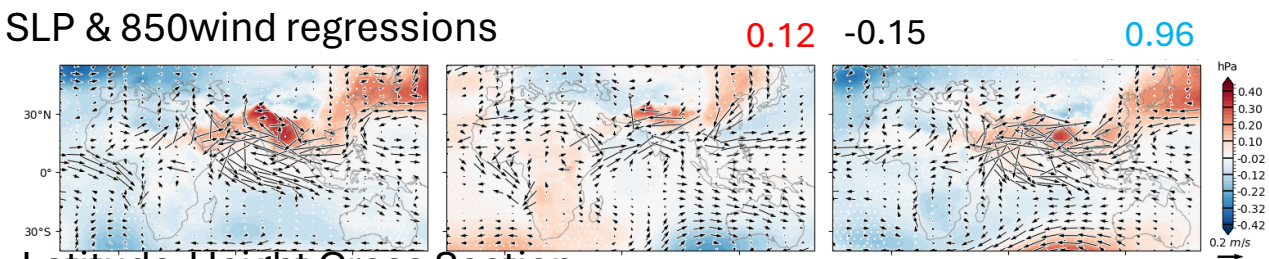
“Low-Latitude” AOD mode



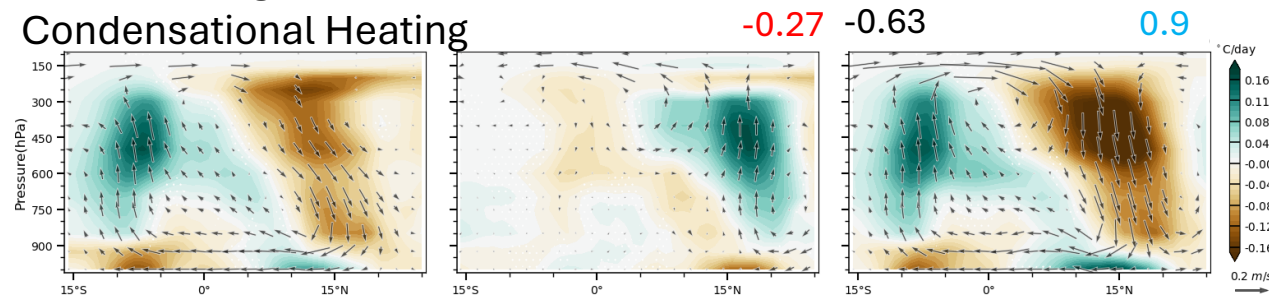
Precipitation regressions



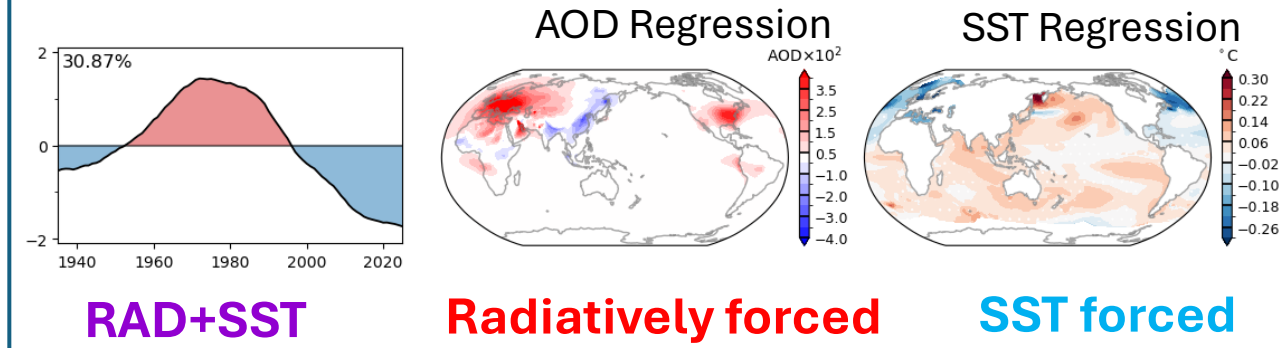
SLP & 850wind regressions



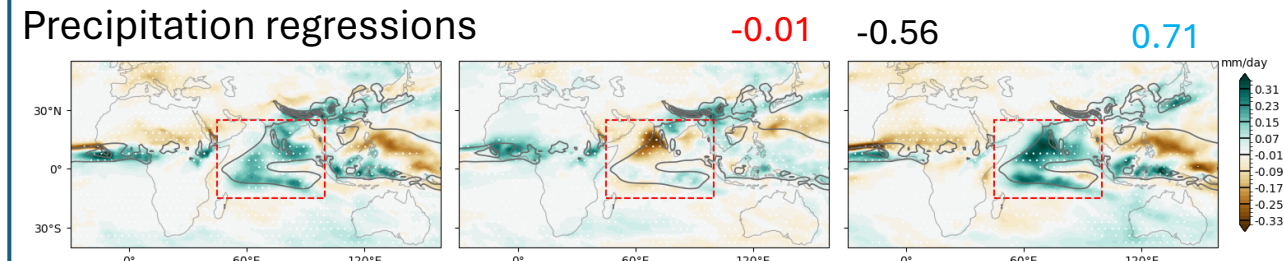
Latitude-Height Cross Section



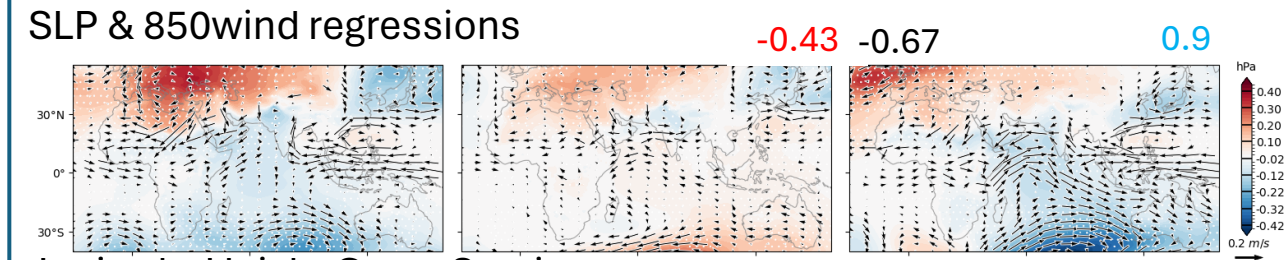
“NH Mid-Latitude” AOD mode.



Precipitation regressions



SLP & 850wind regressions



Latitude-Height Cross Section

