

A process-based understanding of regional climate responses to CO₂ forcing

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and Noah Diffenbaugh



Objective

Introduce an ensemble of AGCM timeslice experiments designed to identify and better understand the mechanisms that shape the response of regional climate to CO₂ forcing.

Research Questions

1. How do regional climate responses in a coupled model arise from the combination of responses to CO₂ forcing?
 - DIRECT CO₂ EFFECT
 - PLANT PHYSIOLOGICAL EFFECT
 - UNIFORM SST WARMING
 - SST PATTERN CHANGE

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2. Which aspects are most important for causing inter-model uncertainty?

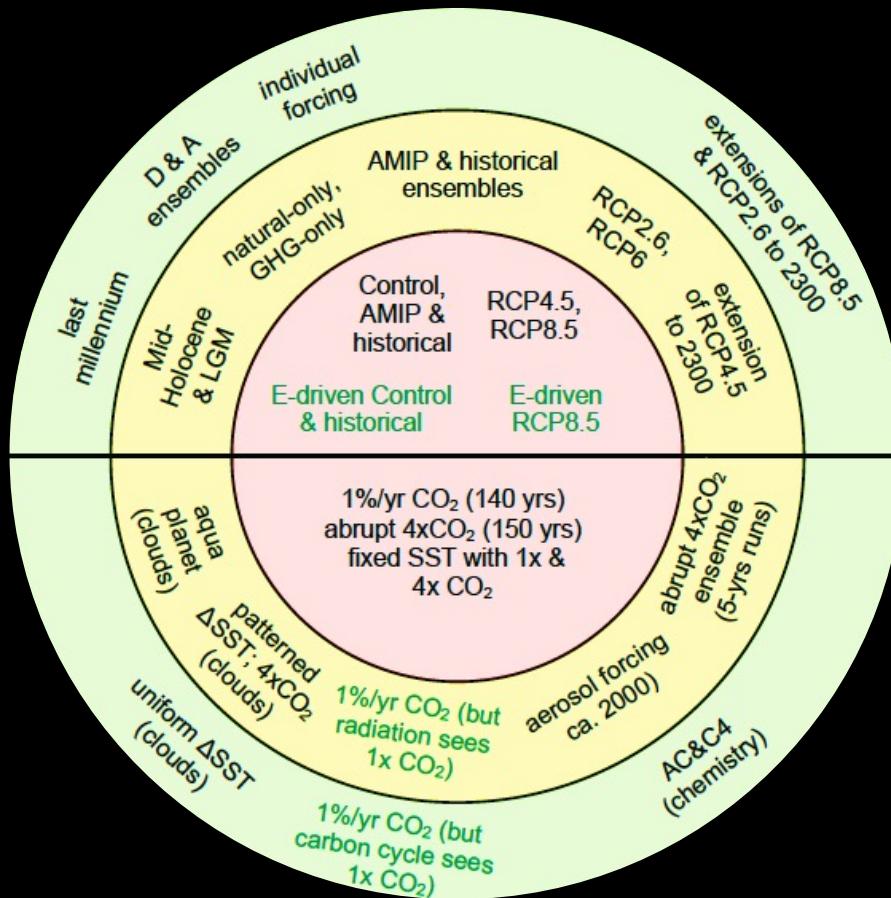
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2. Which aspects are most important for causing inter-model uncertainty?
3. What impact do coupled model SST biases have on regional climate projections?

Presentation Outline

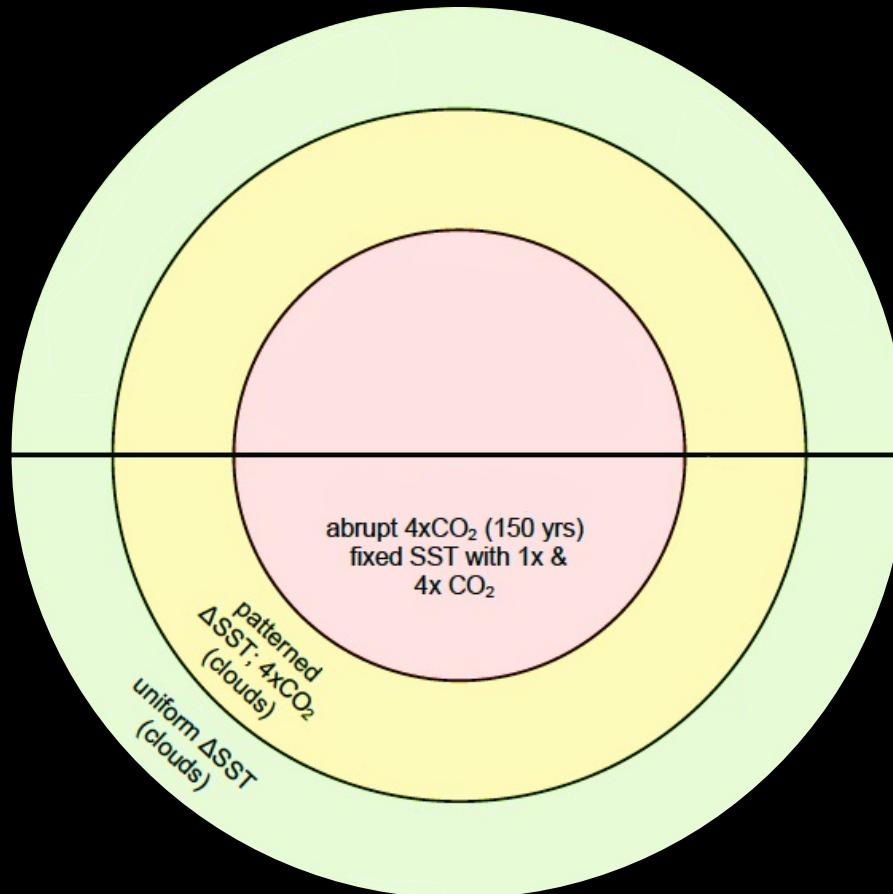
1. CFMIP2/CMIP5 idealized experiments
2. Framework of new idealized experiments
3. Preliminary results
4. Summary

CFMIP2/CMIP5 Experiments



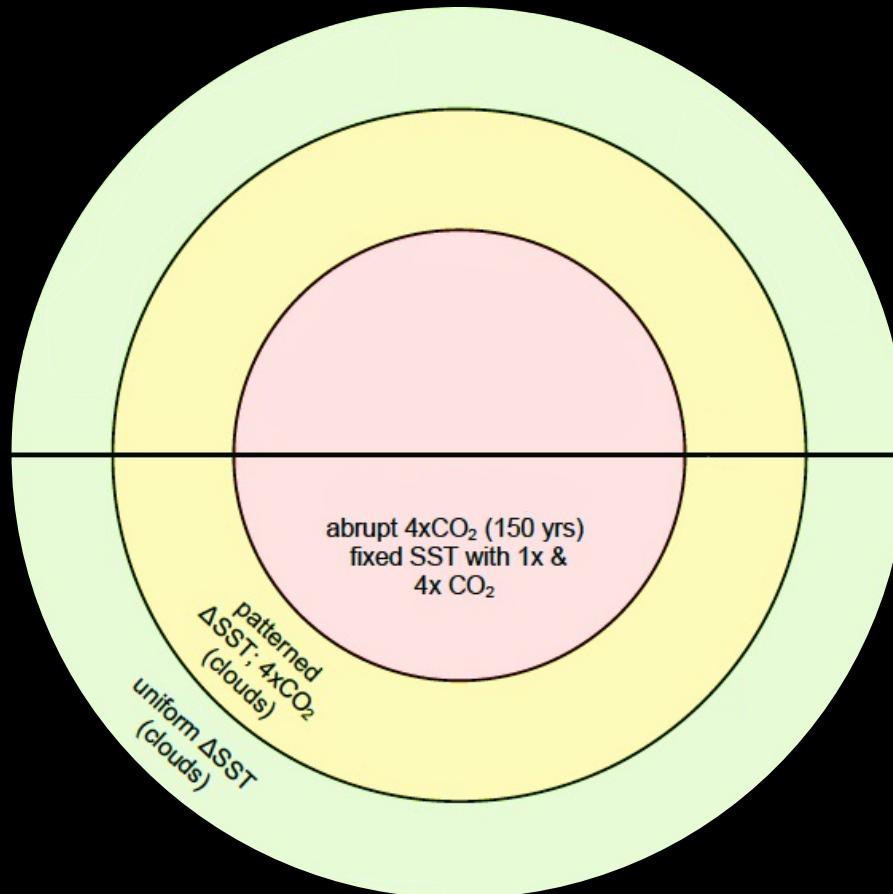
Idealized Experiments to Understand Complex Climate Change Signals

sstClim
sstClim4xCO₂
amip
amip4xCO₂
amip4K
amipFuture



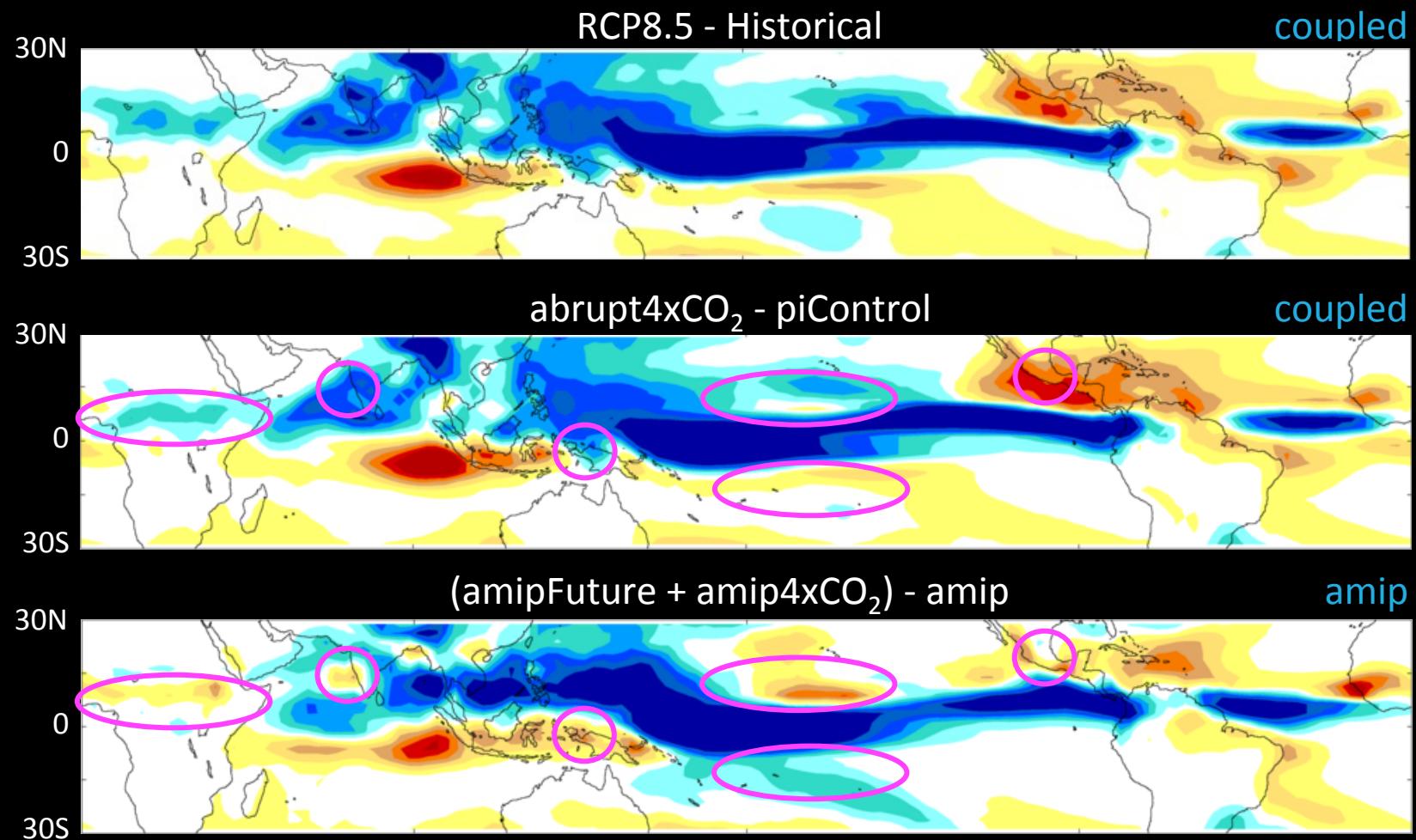
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Limitations?

CMIP5 Multi-model Mean Precipitation Change JJA (mm/day/K)



Current amip, amipFuture, etc... expts are useful, but **do not linearly sum to give the coupled AOGCM response** in many regions.

New Timeslice Experiments

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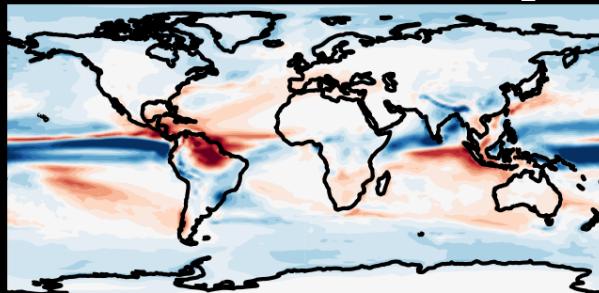
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sstPiTot	Combination of sstPiFuture and sstPi4xCO ₂ Veg to test for linearity of response.
amipTot	As sstPiTot but with amip baseline SSTs. Used to test influence of model SST biases on future projections.

Annual Precipitation Change

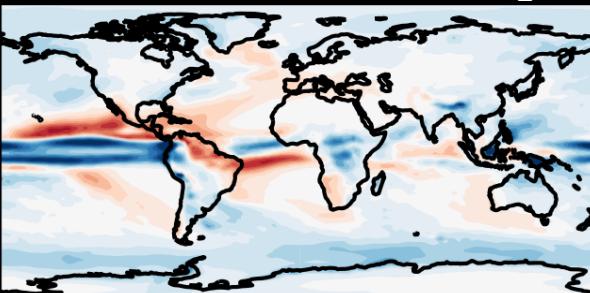
HadGEM2

Coupled abrupt4xCO₂



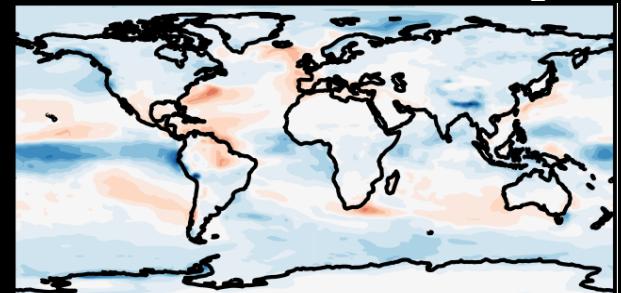
CCSM4

Coupled abrupt4xCO₂

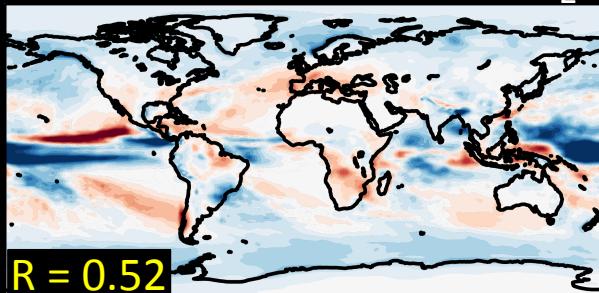


CNRM

Coupled abrupt4xCO₂

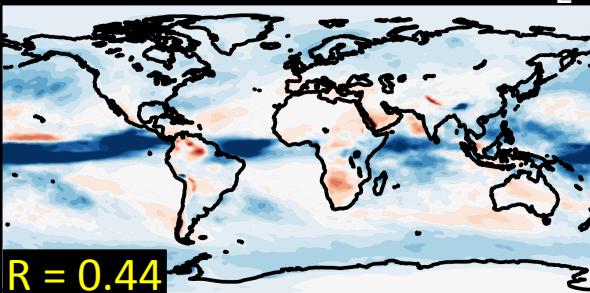


amipFuture + amip4xCO₂



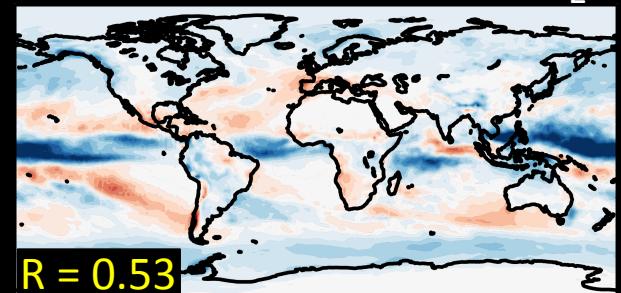
R = 0.52

amipFuture + amip4xCO₂



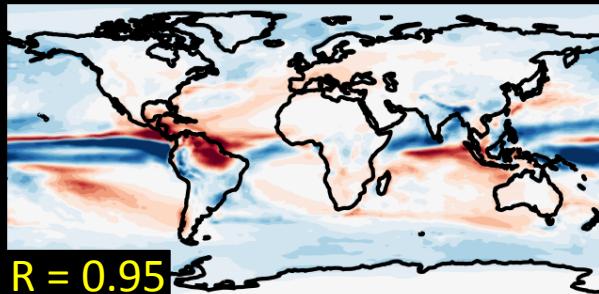
R = 0.44

amipFuture + amip4xCO₂



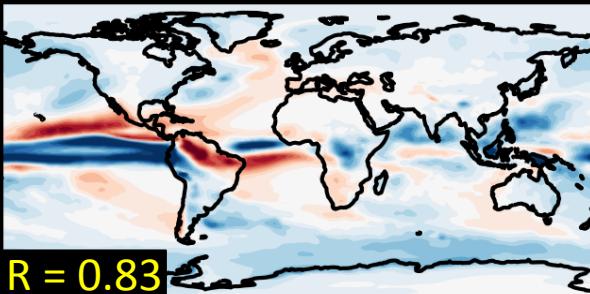
R = 0.53

*sstPiTot



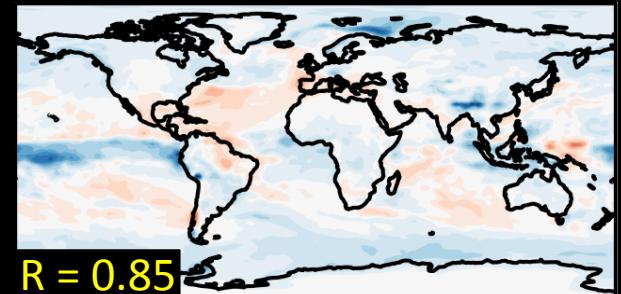
R = 0.95

*sstPiTot



R = 0.83

*sstPiTot



R = 0.85

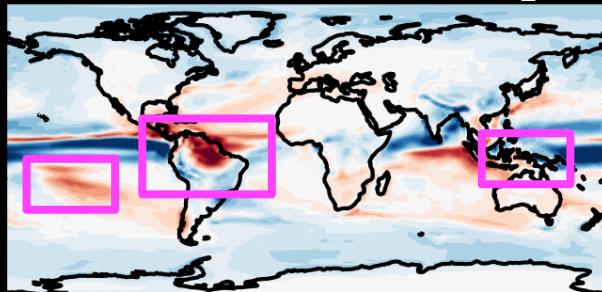


* = New Experiment

Annual Precipitation Change

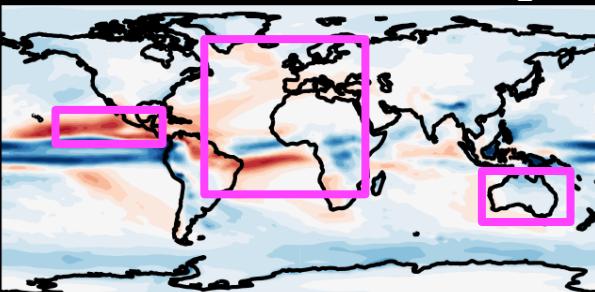
HadGEM2

Coupled abrupt4xCO₂



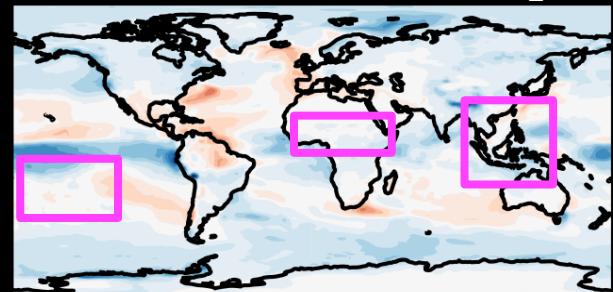
CCSM4

Coupled abrupt4xCO₂

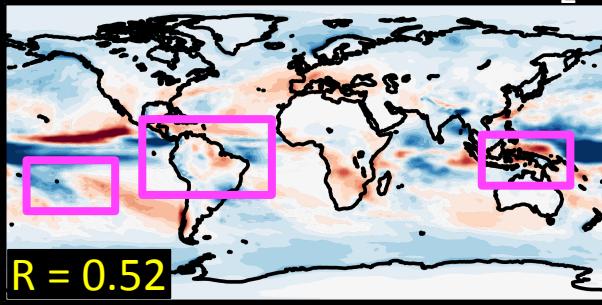


CNRM

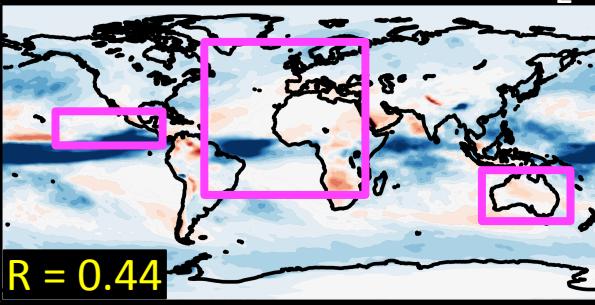
Coupled abrupt4xCO₂



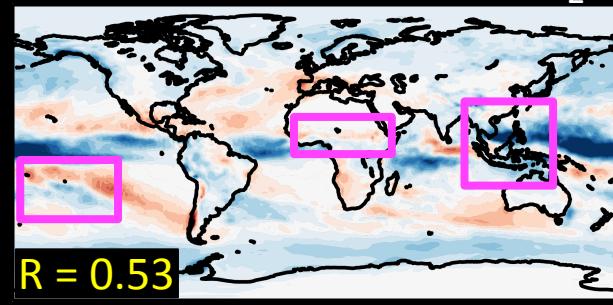
amipFuture + amip4xCO₂



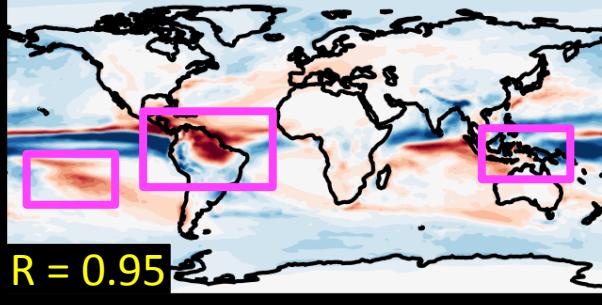
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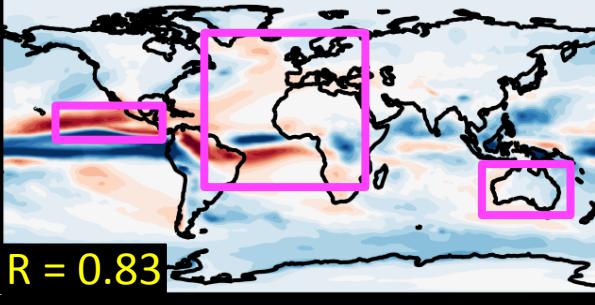
amipFuture + amip4xCO₂



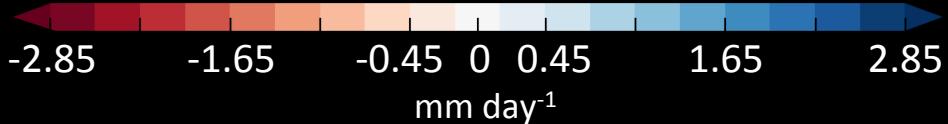
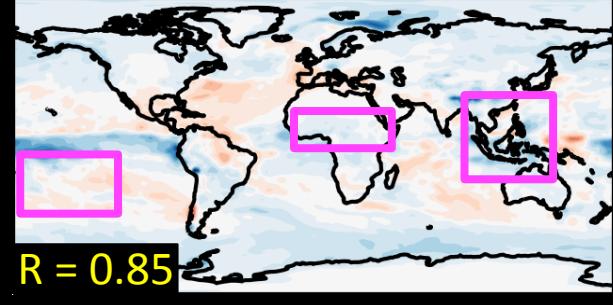
*sstPiTot



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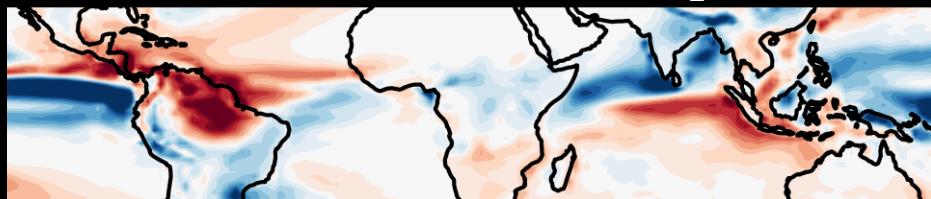
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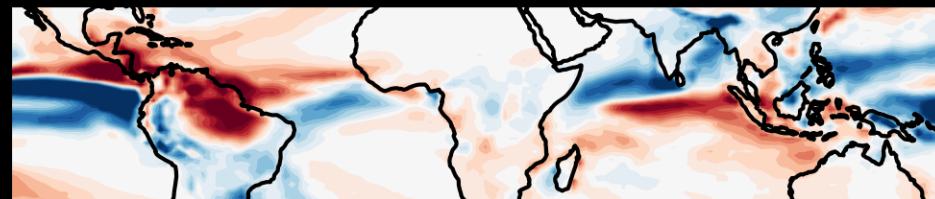
* = New Experiment

Annual Precipitation Change HadGEM2

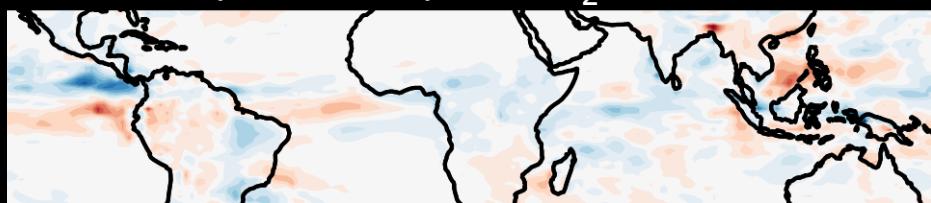
Coupled abrupt4xCO₂



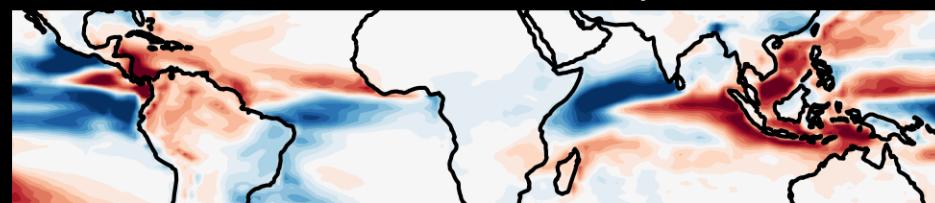
sstPiTot



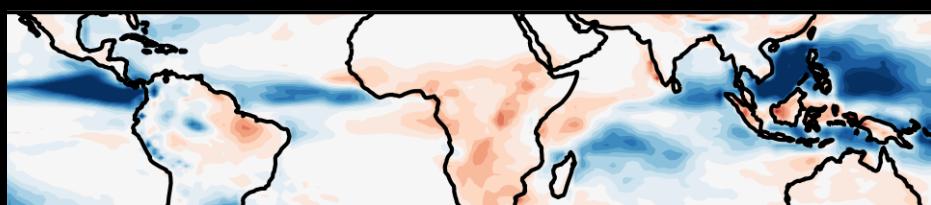
Coupled abrupt4xCO₂ - sstPiTot



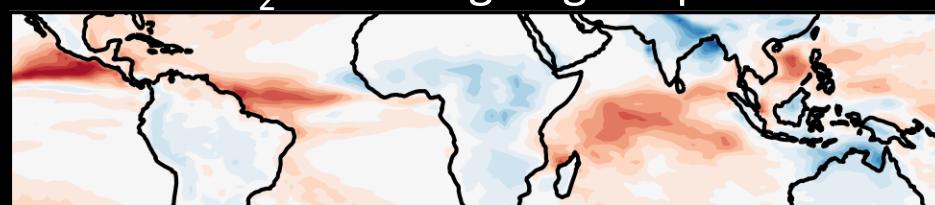
SST Pattern-Only



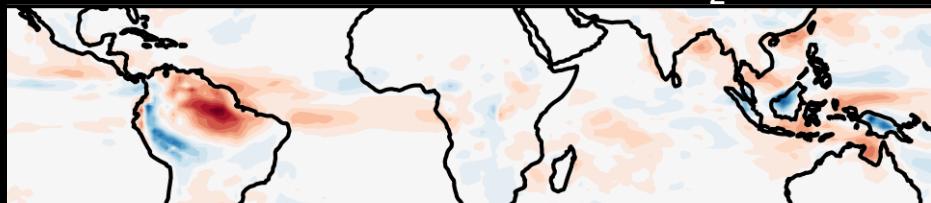
SST Uniform +4K



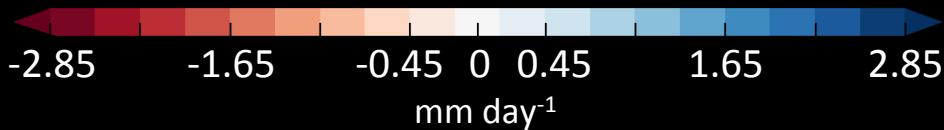
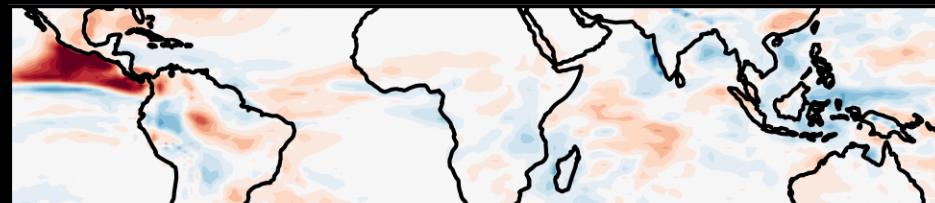
4xCO₂ Excluding Veg Response



Veg Response to 4xCO₂



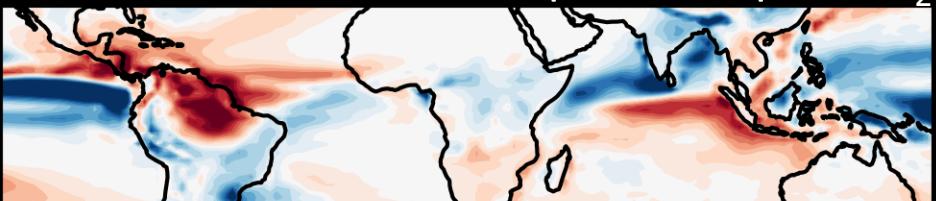
Nonlinear Response



Annual Precipitation Change

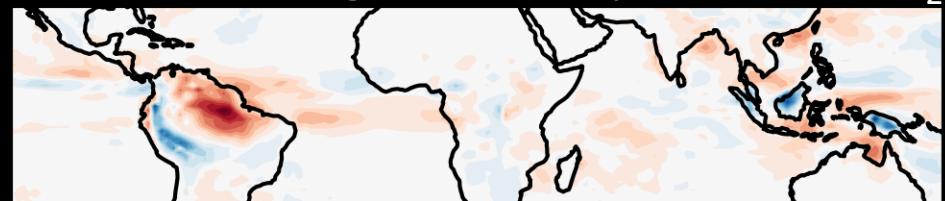
HadGEM2

Coupled abrupt4xCO₂



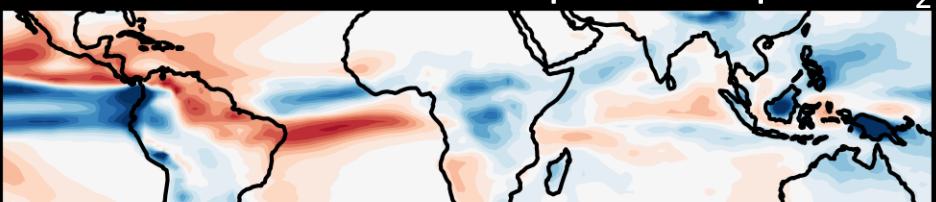
HadGEM2

Vegetation Response to 4xCO₂



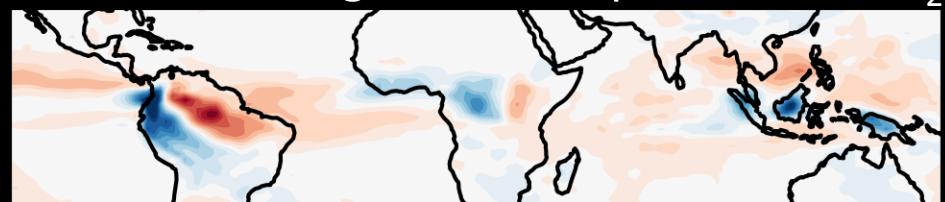
CCSM4

Coupled abrupt4xCO₂



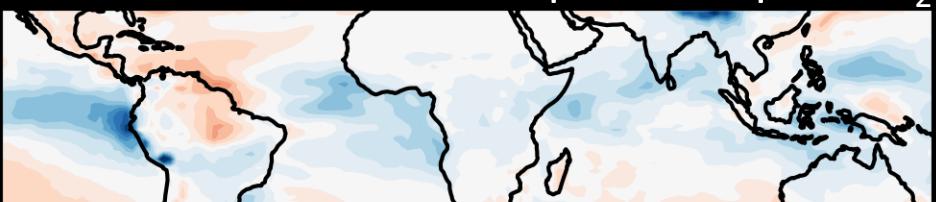
CCSM4

Vegetation Response to 4xCO₂



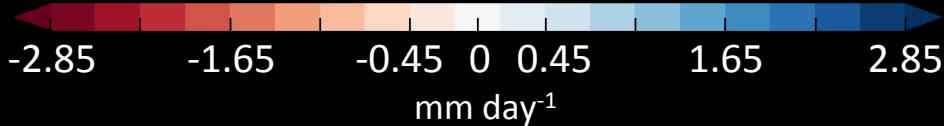
CNRM

Coupled abrupt4xCO₂



CNRM

Vegetation Response to 4xCO₂



Annual Precipitation Change

HadGEM2

Coupled abrupt4xCO₂

HadGEM2

Vegetation Response to 4xCO₂

CCSM4

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Vegetation Response to 4xCO₂

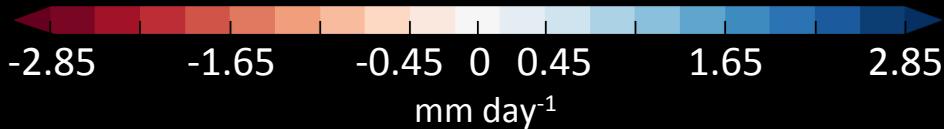
CNRM

Coupled abrupt4xCO₂

CNRM

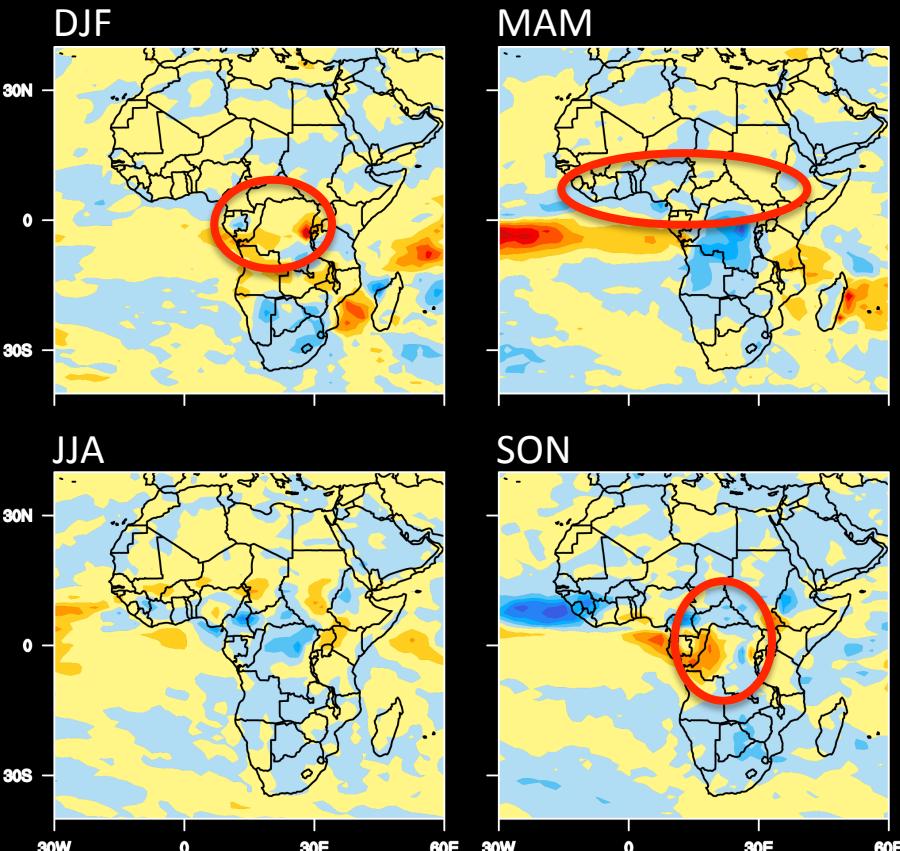
Vegetation Response to 4xCO₂

TO BE INCLUDED IN CMIP6

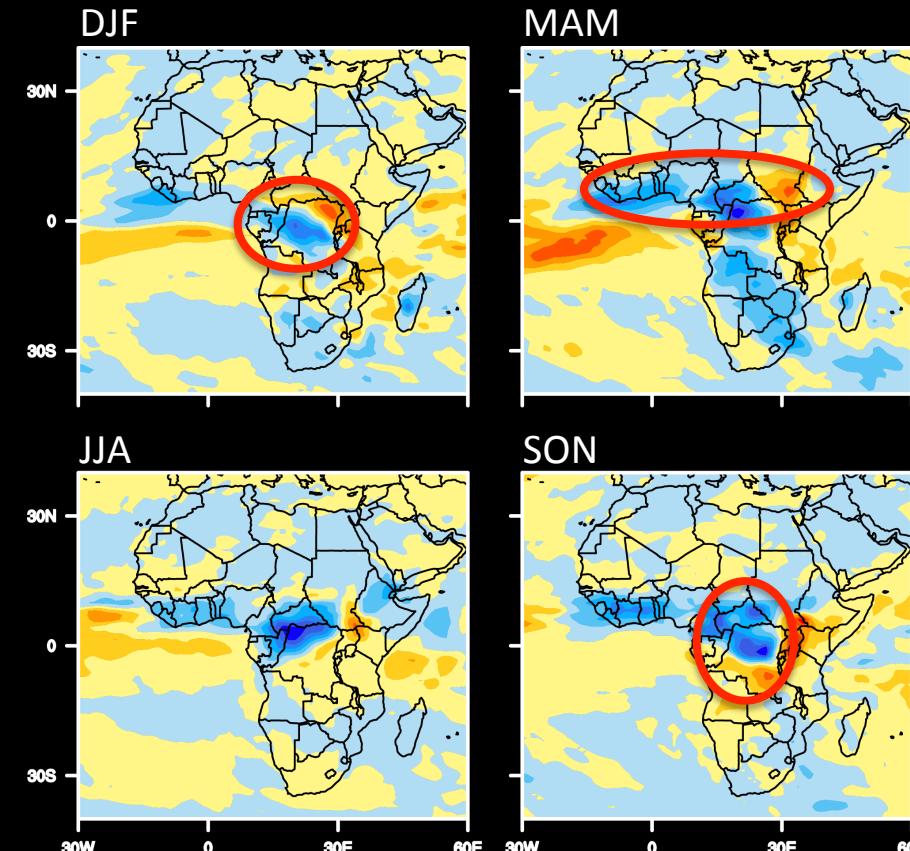


Seasonal Precipitation Change Vegetation Response to 4xCO₂

HadGEM2



CCSM4

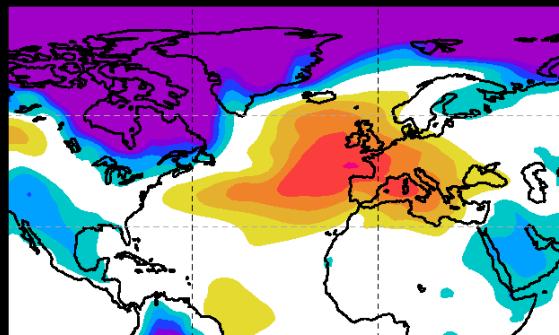


REMARKABLY DIFFERENT PATTERN

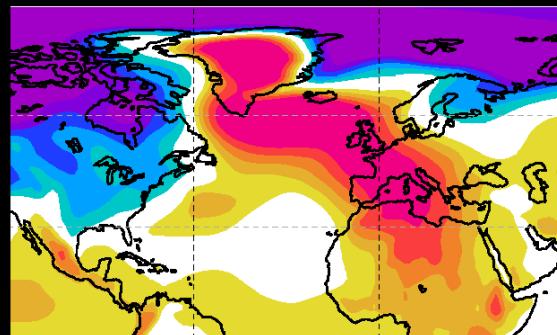
sstPi4xCO2Veg – sstPi4xCO2

Sea Level Pressure Change DJFM (hPa)

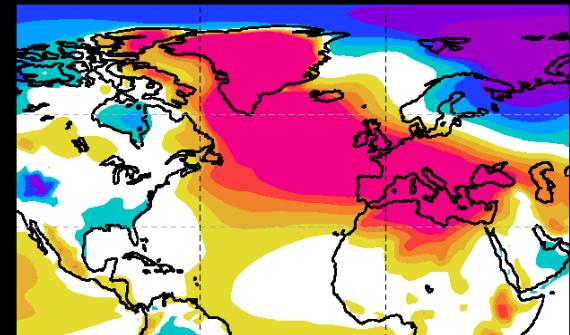
HadGEM2
Coupled abrupt4xCO₂



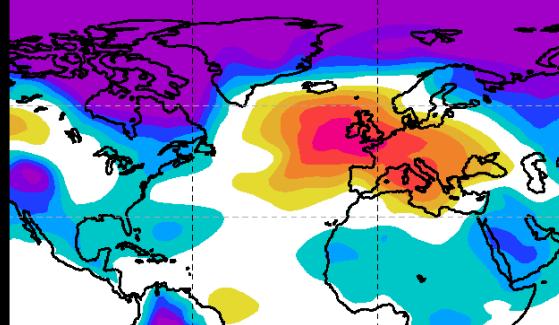
CNRM
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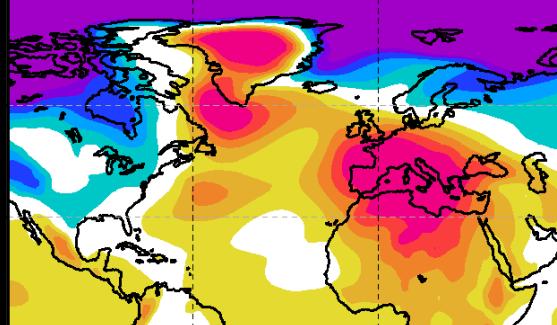
CCSM4
Coupled abrupt4xCO₂



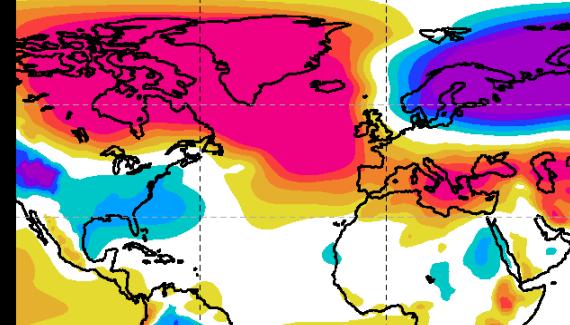
sstPiTot R = 0.87



sstPiTot R = 0.89



sstPiTot R = 0.74



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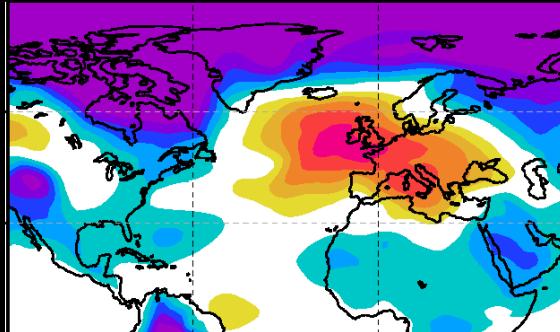
- Can successfully decompose the coupled model response into individual responses to CO₂ forcing
- Use of model's own SST patterns and inclusion of vegetation response to CO₂ greatly improves agreement with coupled model response.
- Vegetation response to CO₂ may contribute substantially to inter-model spread in precipitation projections within tropical forest regions.
- SST pattern change largely responsible for the pattern of precipitation responses over oceans

Extra Slides

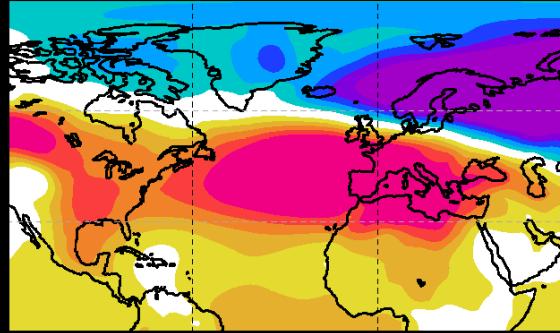
Sea Level Pressure Change DJFM (hPa)

HadGEM2

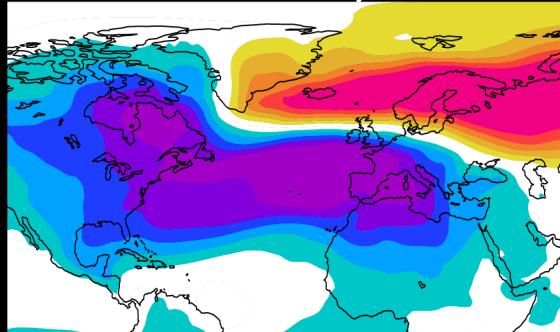
sstPiTot



SST Uniform +4K

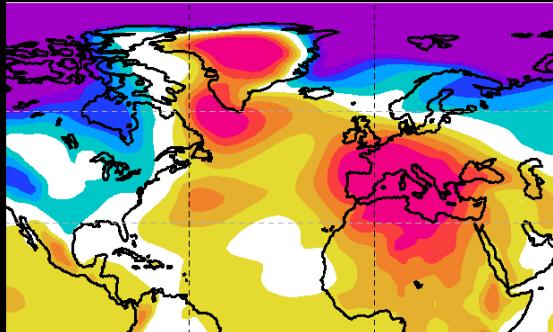


SST Pattern-Only

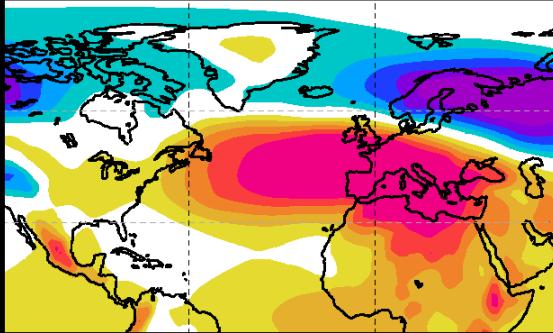


CNRM

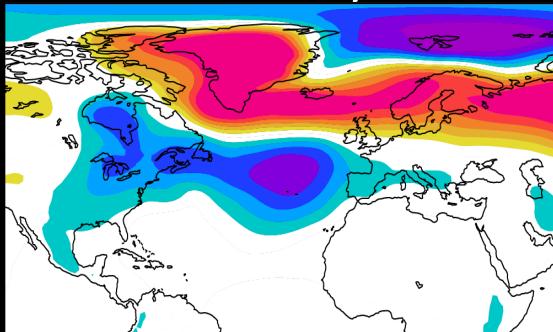
sstPiTot



SST Uniform +4K

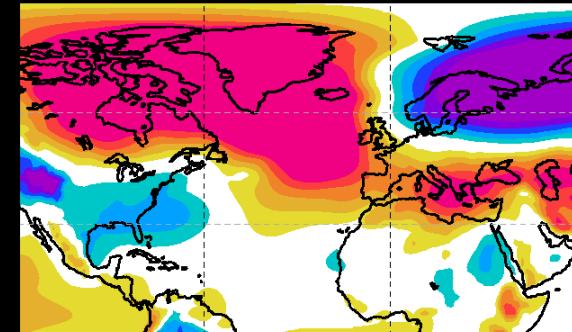


SST Pattern-Only

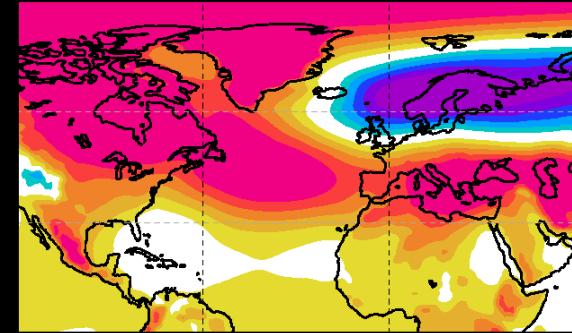


CCSM4

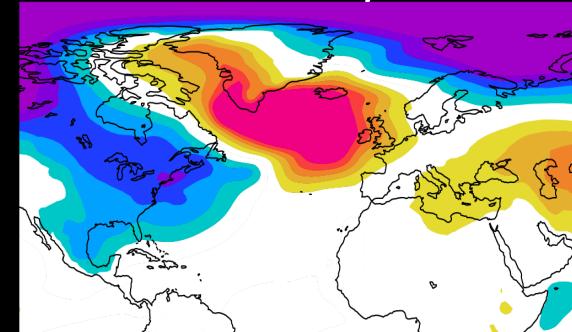
sstPiTot



SST Uniform +4K

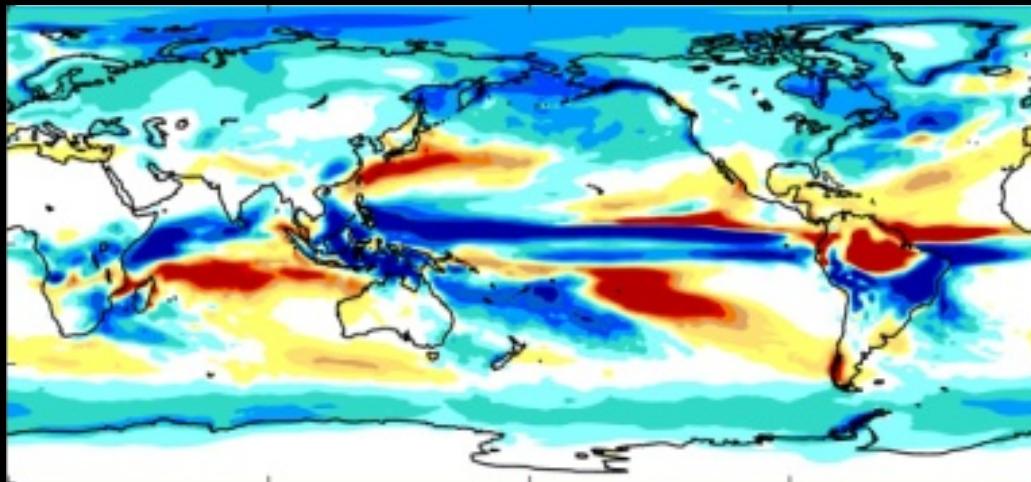


SST Pattern-Only

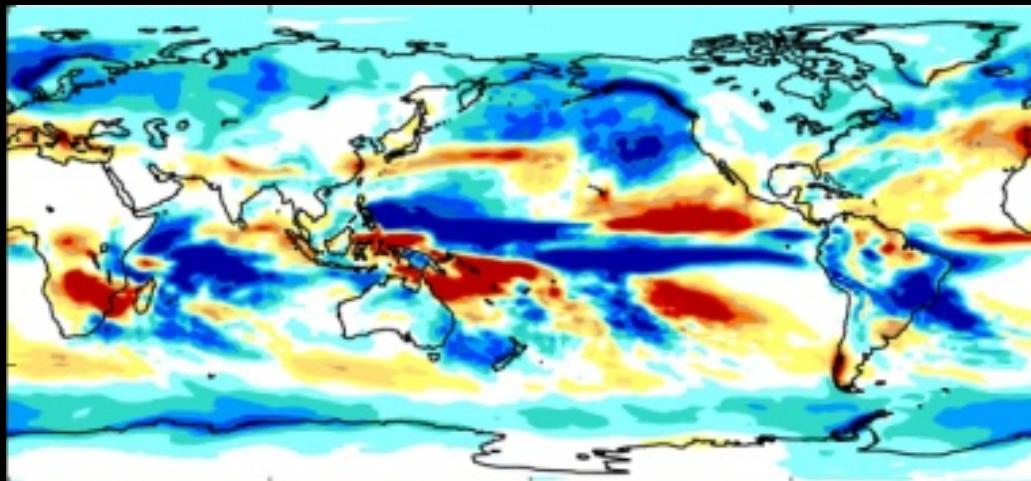


HadGEM2 Mean Precipitation Change DJF (mm/day)

abrupt4xCO₂



amipFuture (CMIP3 Pattern) + amip4xCO₂



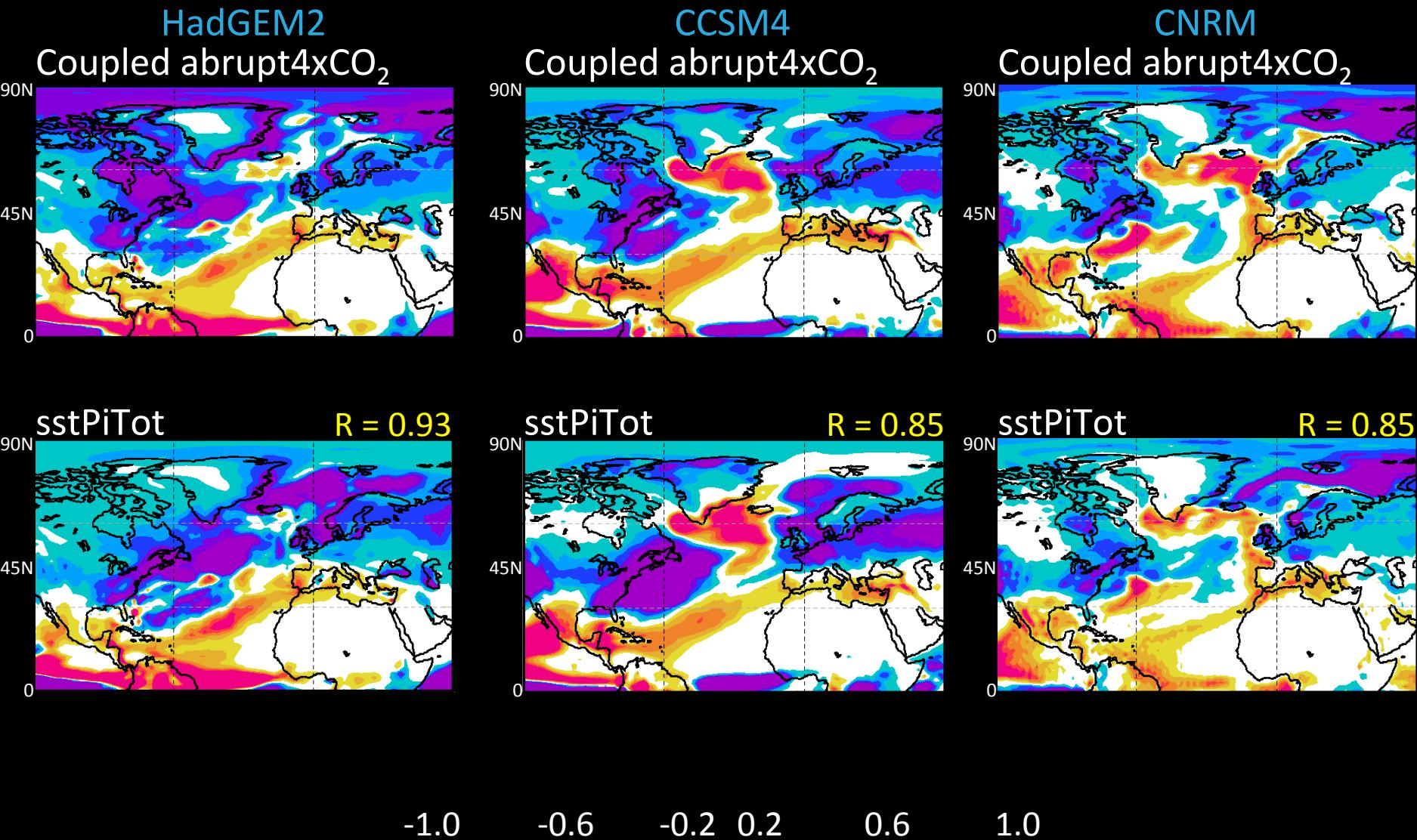
R = 0.34

Poor pattern
agreement

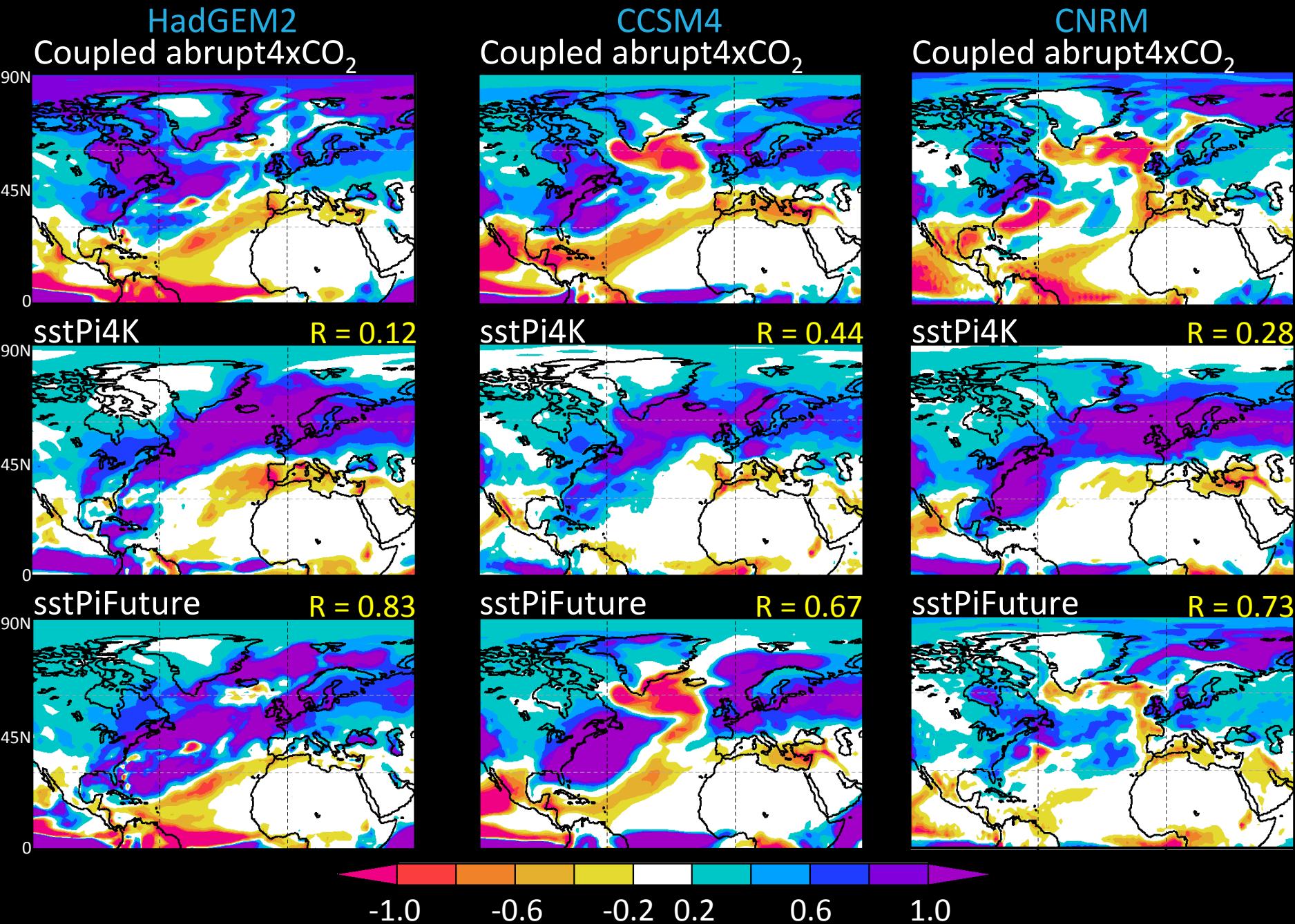


-1.8 -1 -0.2 .2 1 1.8

Precipitation Change DJFM (mm/day)

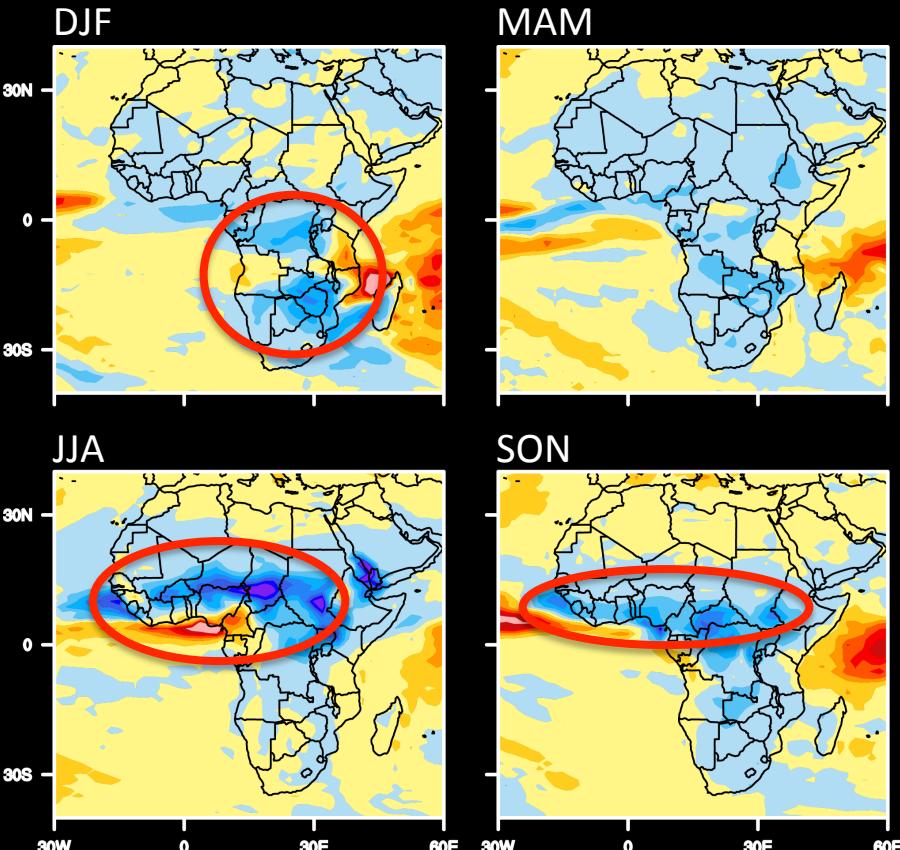


Precipitation Change DJFM (mm/day)

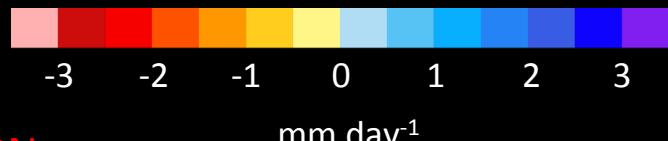
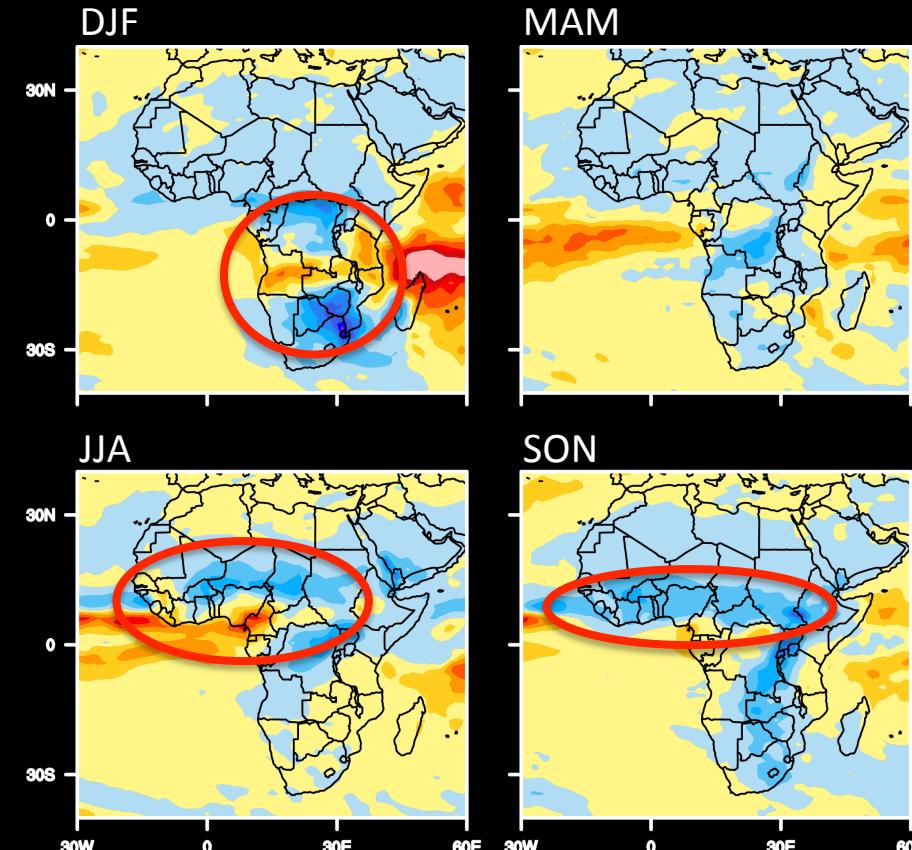


Direct CO₂ Effect (w/o Vegetation Physiological Effect) Seasonal Precipitation Change

HadGEM2



CCSM4



REMARKABLY SIMILAR PATTERN

sstPi4xCO₂ - sstPi

Potential Refinement of Experiments

- Rather than 4K warming, use global mean SST anomaly from each model's own coupled abrupt4xCO₂ run.
 - Use in all “future” sst experiment runs

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- Rather than 4K warming, use global mean SST anomaly from each model's own coupled abrupt4xCO₂ run.
 - Use in all “future” sst experiment runs
- Rather than add the 50-year mean anomaly of future SSTs to the time-varying preindustrial SSTs, use the time-varying monthly SSTs from the coupled abrupt4xCO₂ run.
 - Use in sstPiFuture and sstPiTot runs
 - Include future sea ice concentrations?