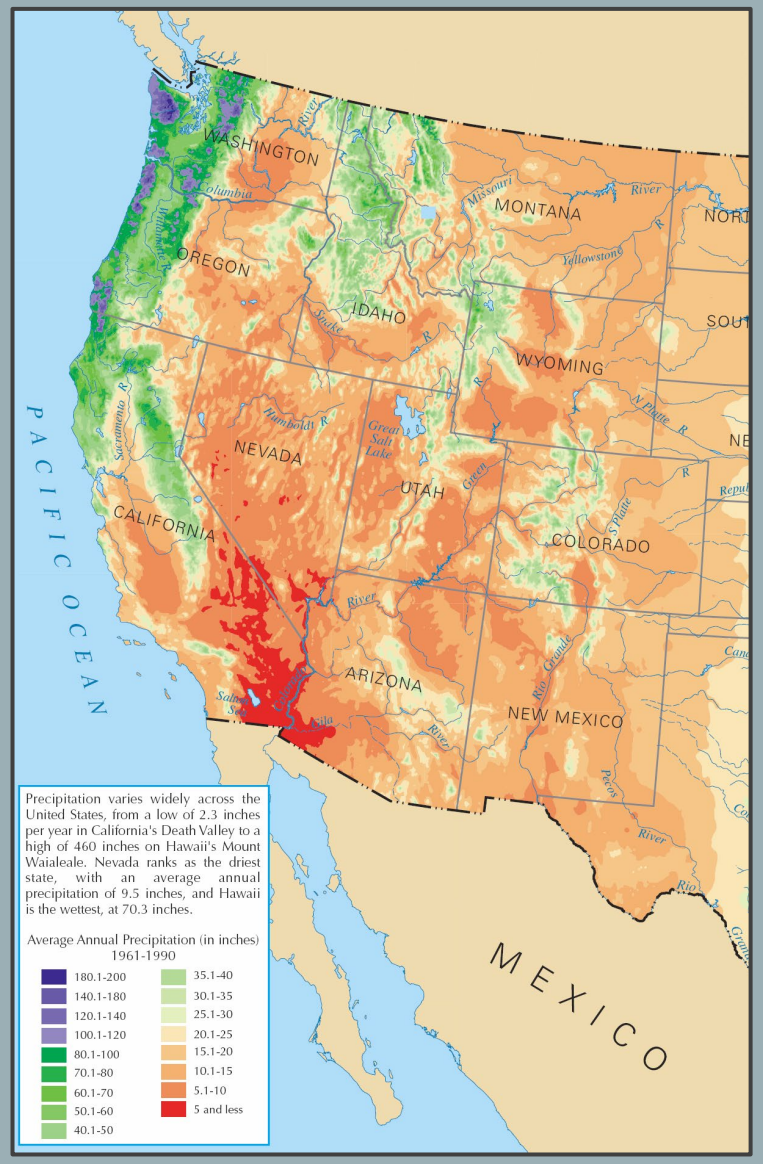
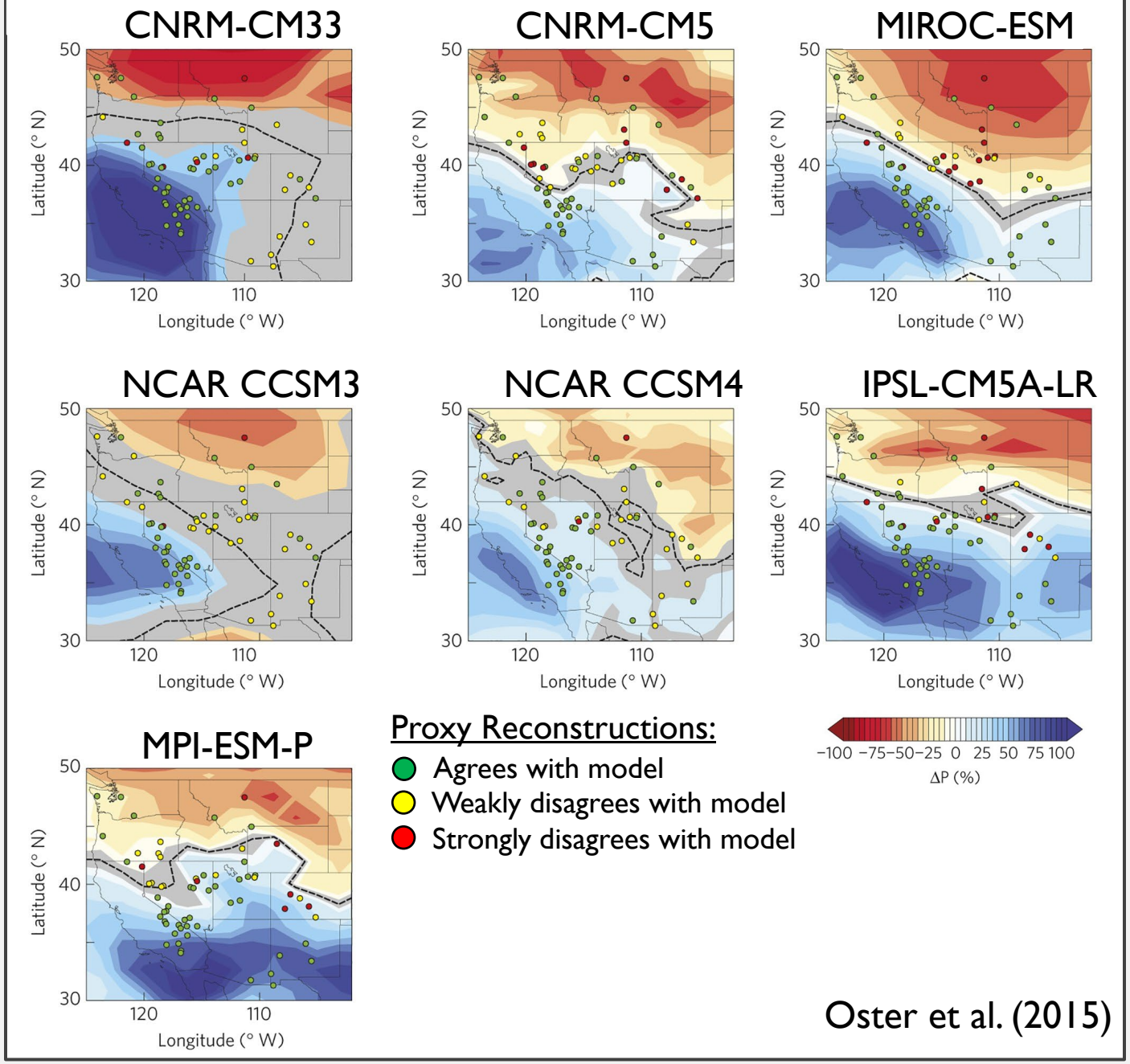
# AIR-SEA COUPLING SHAPES NORTH AMERICAN HYDROCLIMATE RESPONSE TO ICE SHEETS

**Dillon Amaya**, Alan Seltzer, Kris Karnauskas, Juan Lora, Xiyue Zhang, and Pedro DiNezio

CESM CVC Working Group Meeting
February 18, 2021

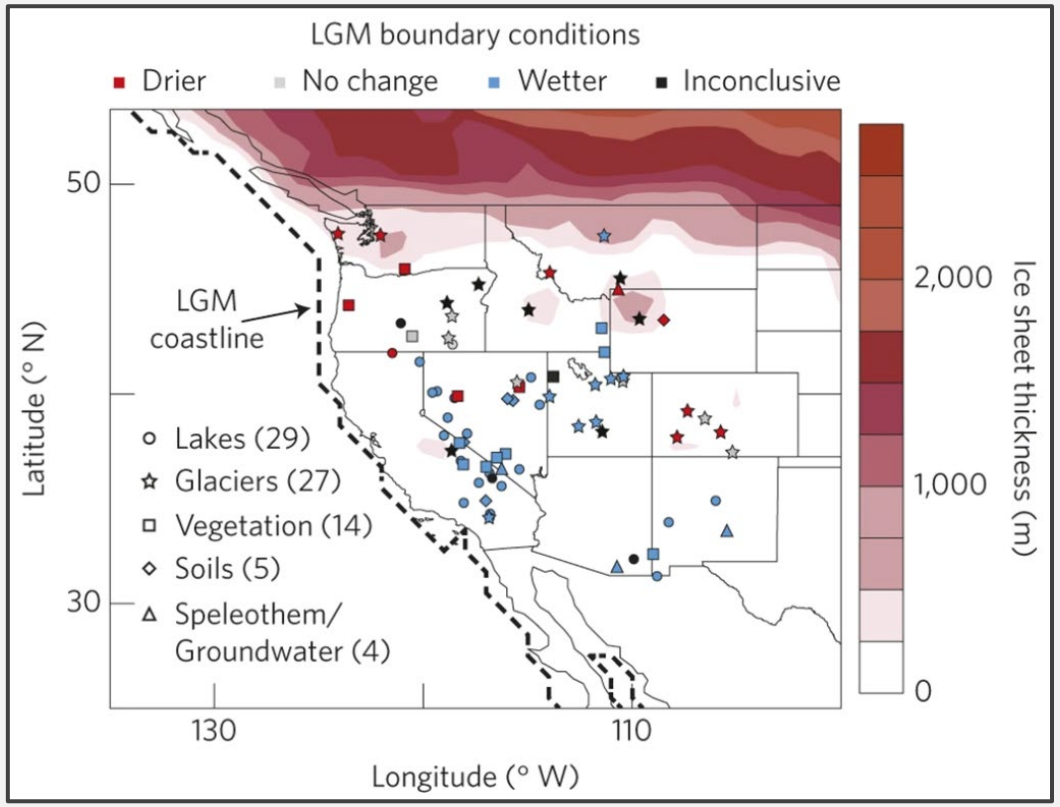



# LGM precipitation difference in PMIP3 models



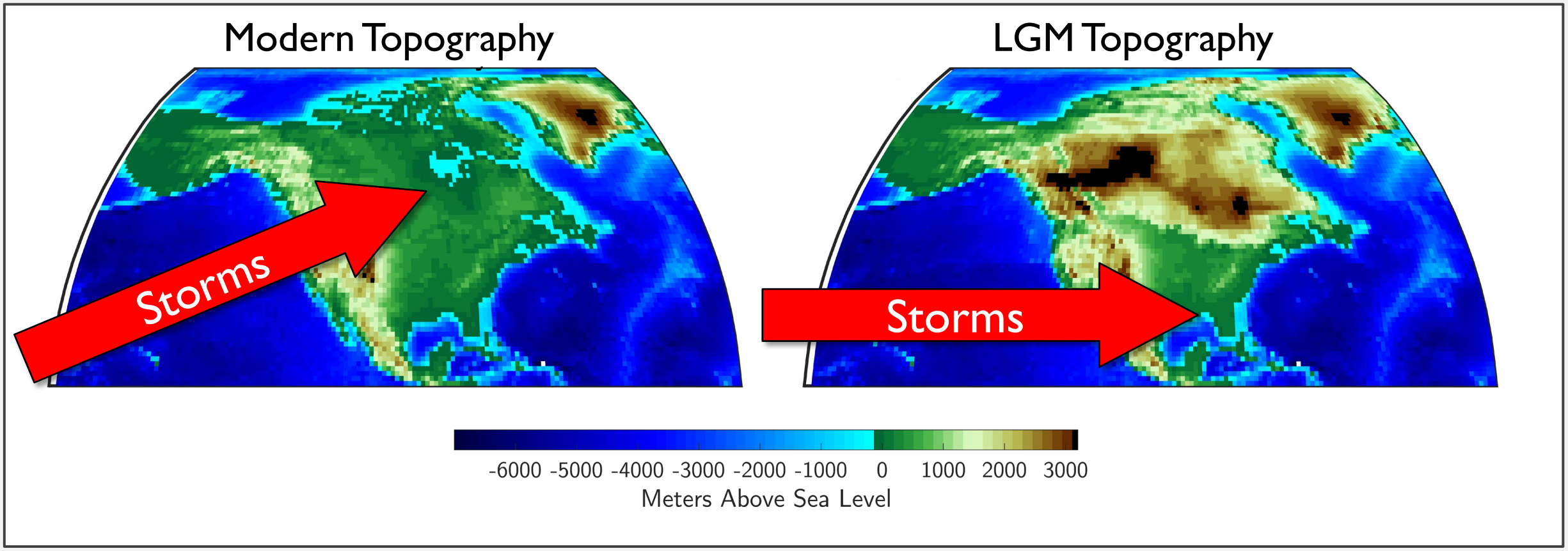

Oster et al. (2015)

# LGM HYDROCLIMATE



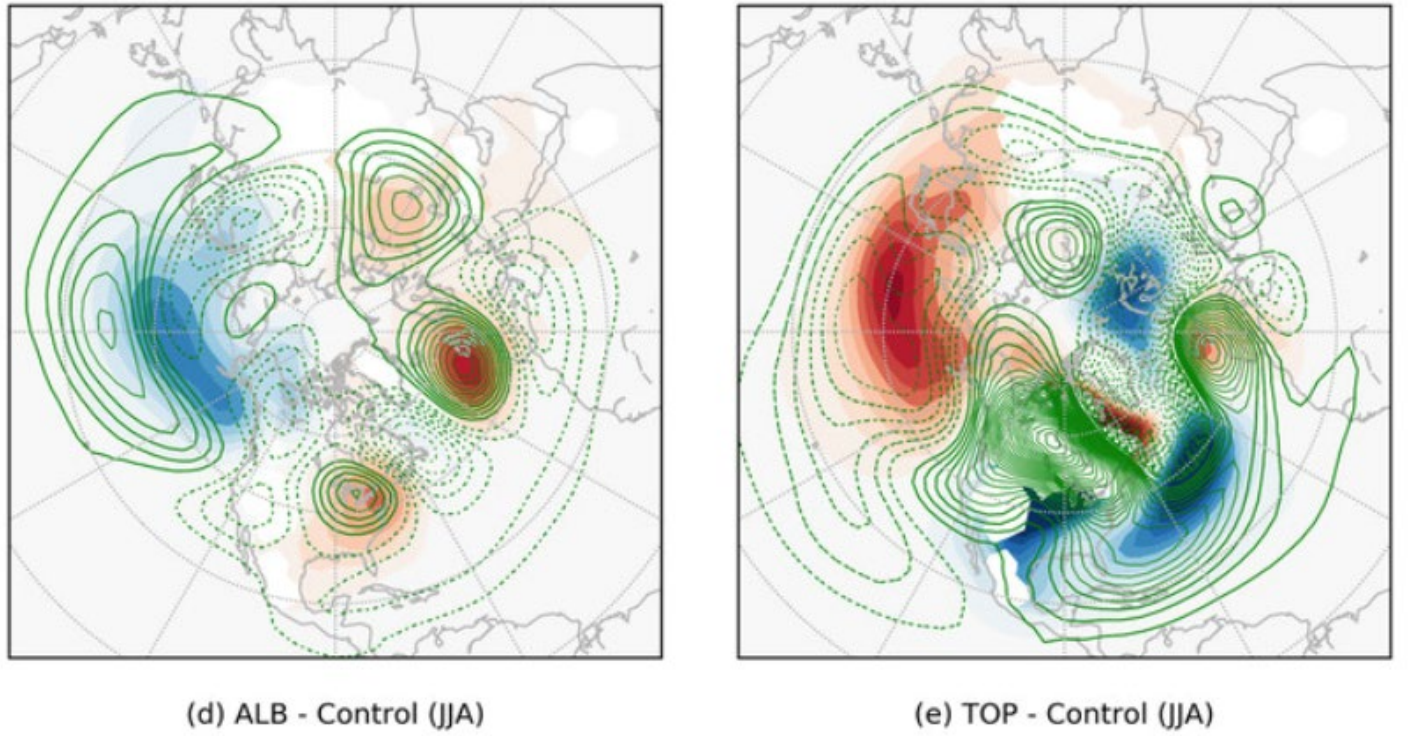

Proxies and models point to a wetter Southwest U.S. and drier Pacific Northwest during LGM

# LGM HYDROCLIMATE



# LGM HYDROCLIMATE

*Summer stationary waves in LGM HadCM3 single forcing runs*




Roberts et al. (2019)

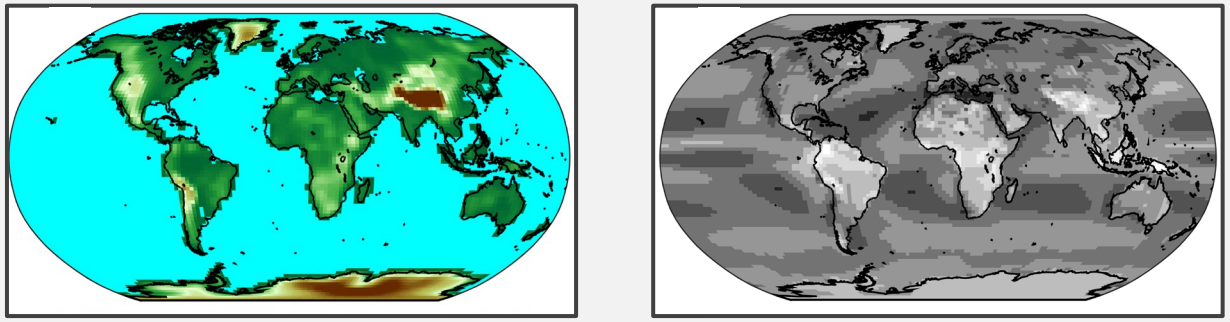
Research questions:

1. Mechanical (tall) vs thermodynamic (bright) influence of continental ice sheets on west coast hydroclimate?
   - Influence on North Pacific jet and downstream rainfall.
2. What role do air-sea interactions and/or ocean dynamics play in modulating that response?

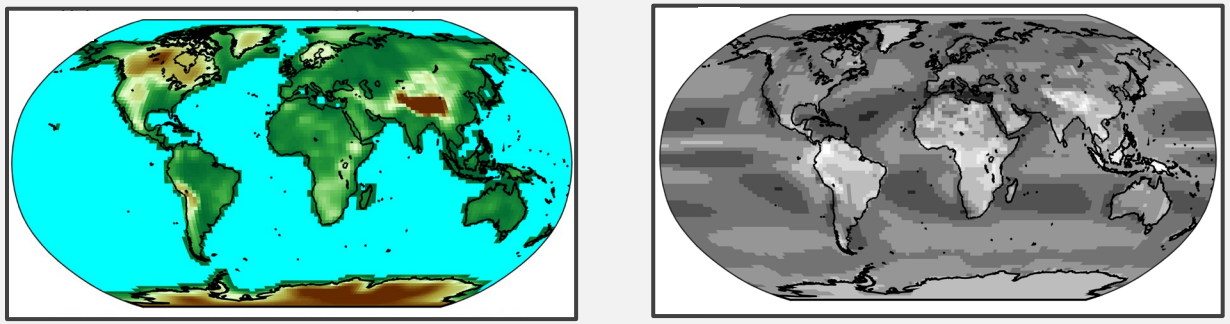
# CESM1 EXPERIMENTS

*See DiNezio et al. (2018) *Science Advances*, for complete model details

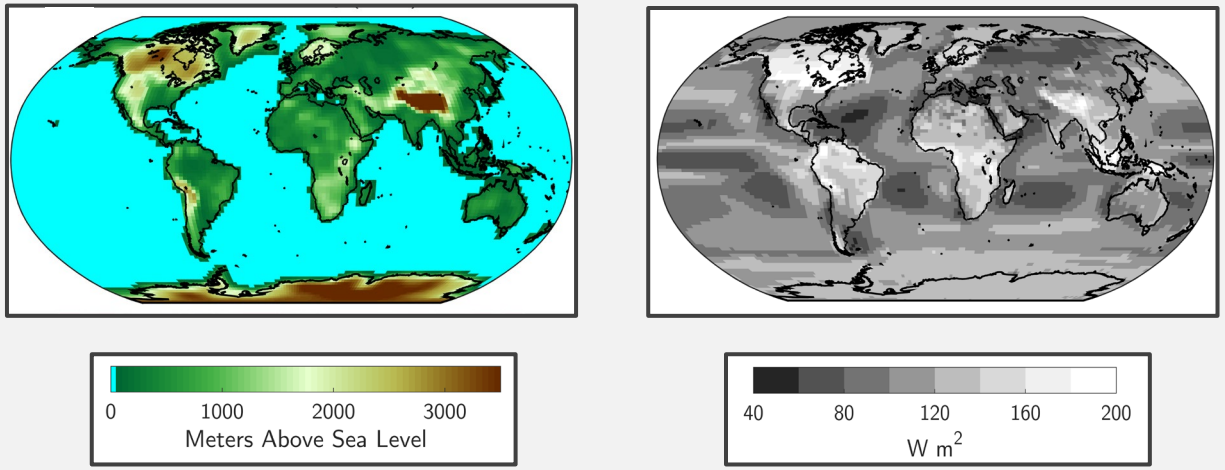
## Pre-industrial Control (Ctl)



## Green Mountain (GM; Mechanical forcing)



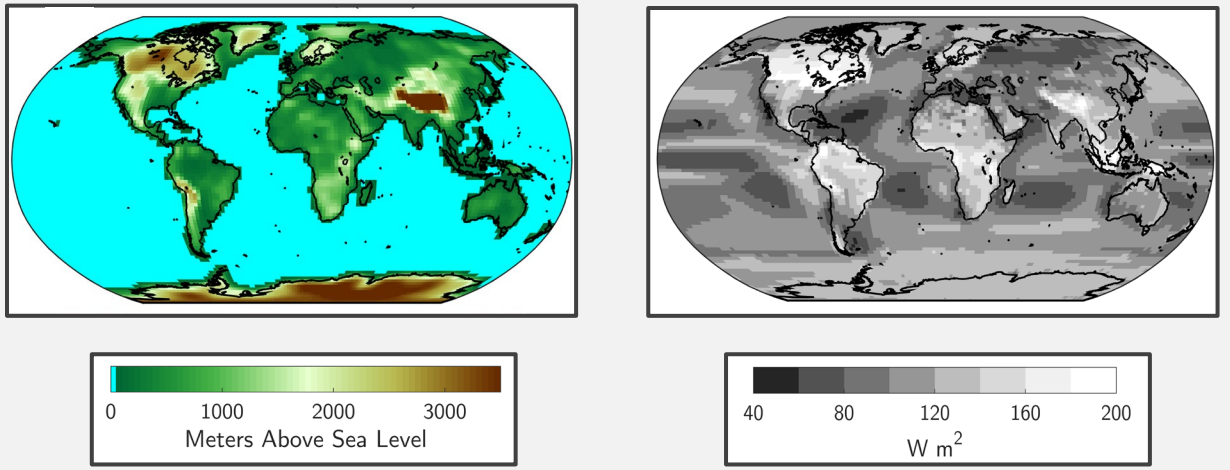
## Full LGM Climate (LGM-Full) + GHGs, orbital, etc.




Surface Height

TOA Upward SW

## White Mountain (WM; Mech. + Therm. forcing)




Surface Height

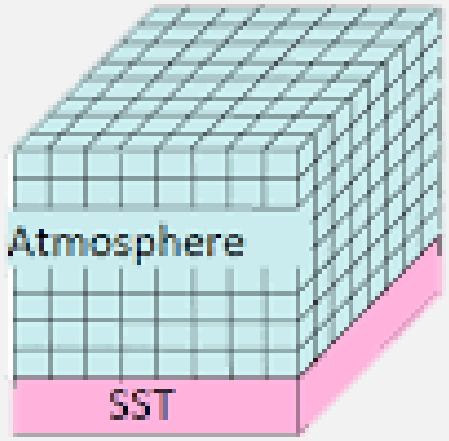
TOA Upward SW

# CESM1 EXPERIMENTS

White Mt and Green Mt experiments across hierarchy of ocean model configurations

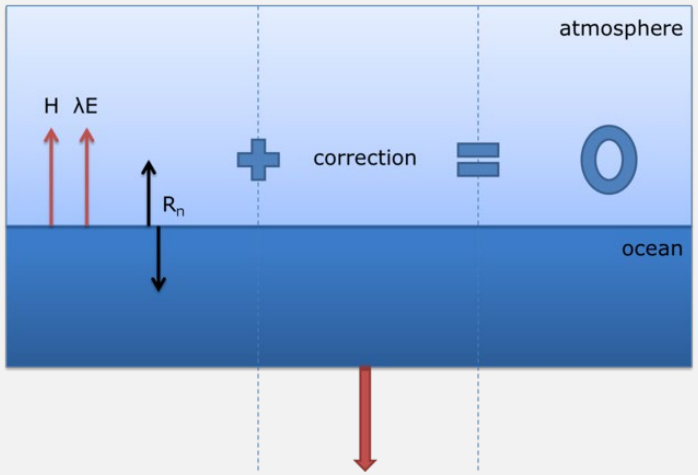
*All runs appropriately spun-up

## AGCM-only



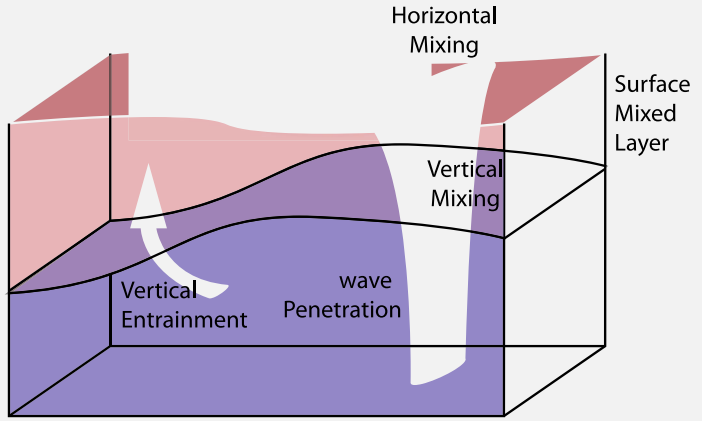

Forced by Ctl climatological SSTs

## Slab Ocean Model (SOM)




Interactive mixed layer with air-sea heat exchange

## Dynamical Ocean Model (DOM)



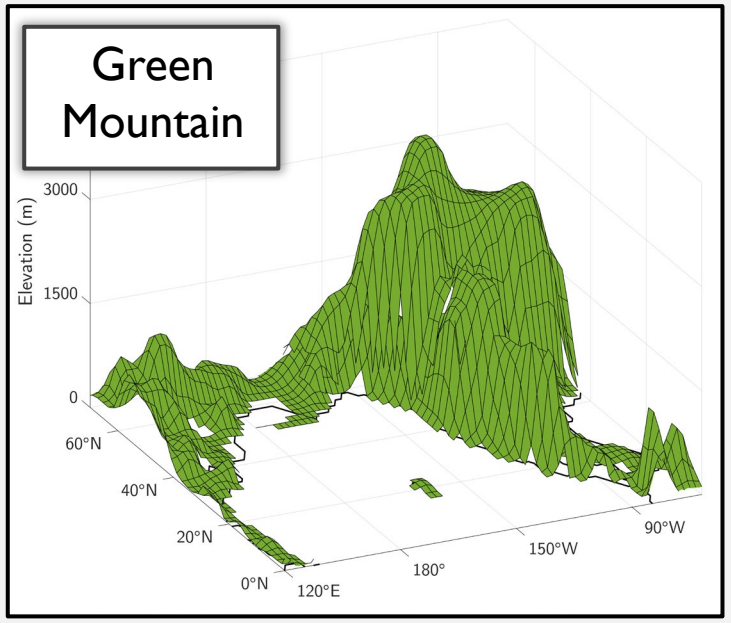

Fully dynamical ocean circulation

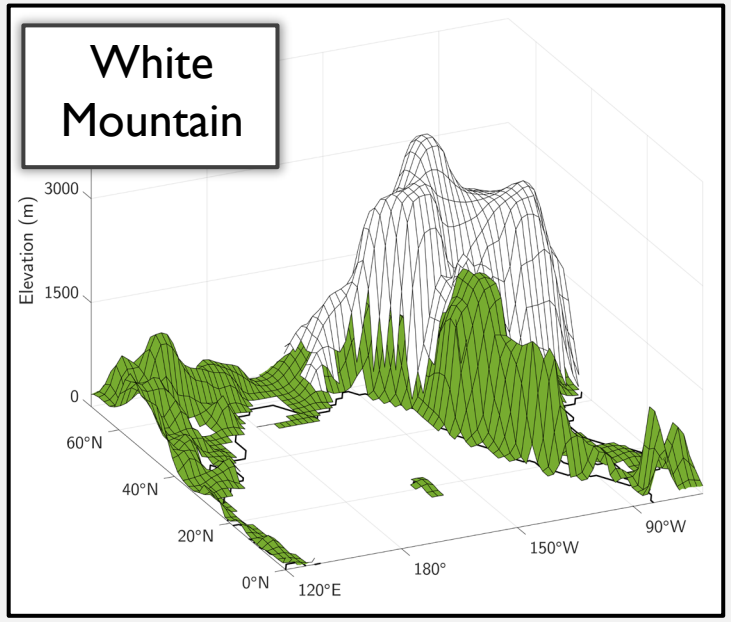
# CESM1 EXPERIMENTS

*Summary of experiments*

| | GHGs | Orbit | Land mask & bathymetry | Topography | Albedo |
|---|---|---|---|---|---|
| **LGM (DOM)** | X | X | X | X | X |
| **White Mountain (DOM, SOM, AGCM)** | | | | X | X |
| **Green Mountain (DOM, SOM, AGCM)** | | | | X | |

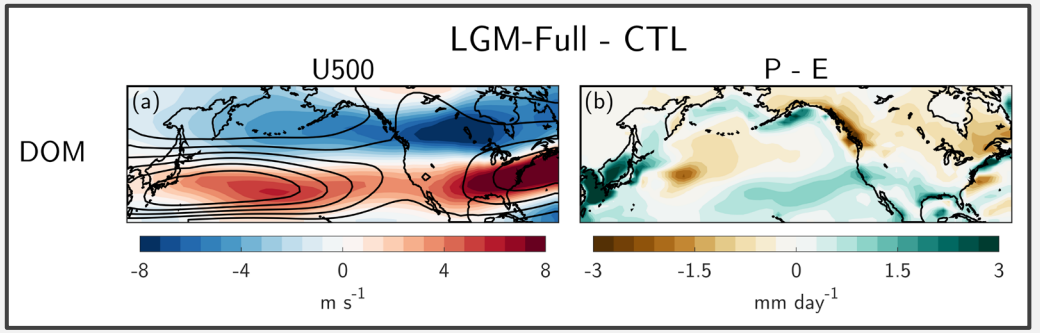
See DiNezio et al. (2018) for more details



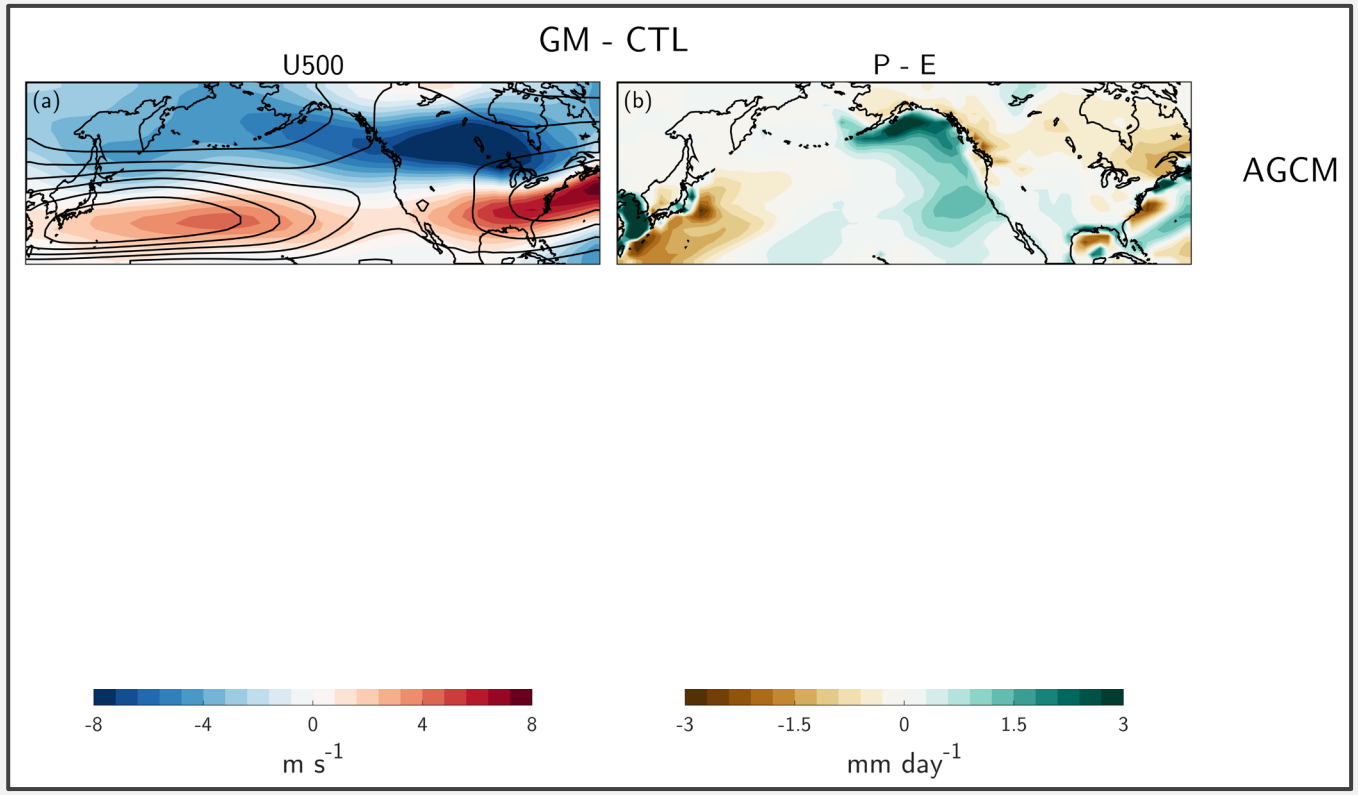



# GREEN MOUNTAIN

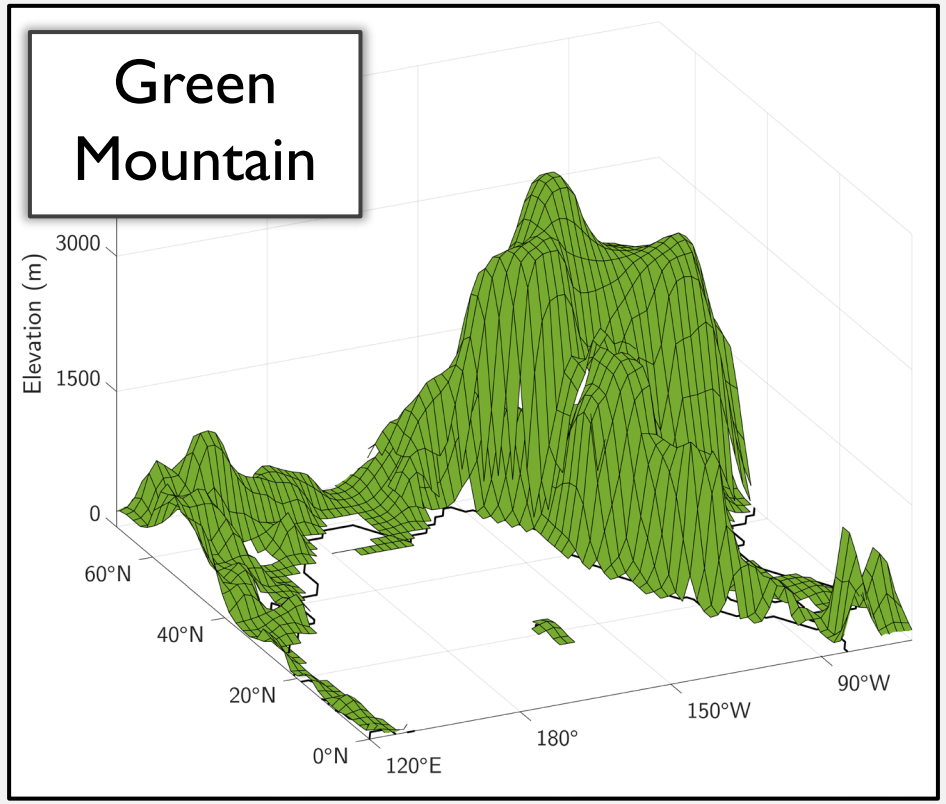
**Mechanically forced shift of the N. Pacific jet, shift in west coast hydroclimate**




*Dec-Feb averaged atmospheric circulation anomalies*




Amaya et al. *in revision*



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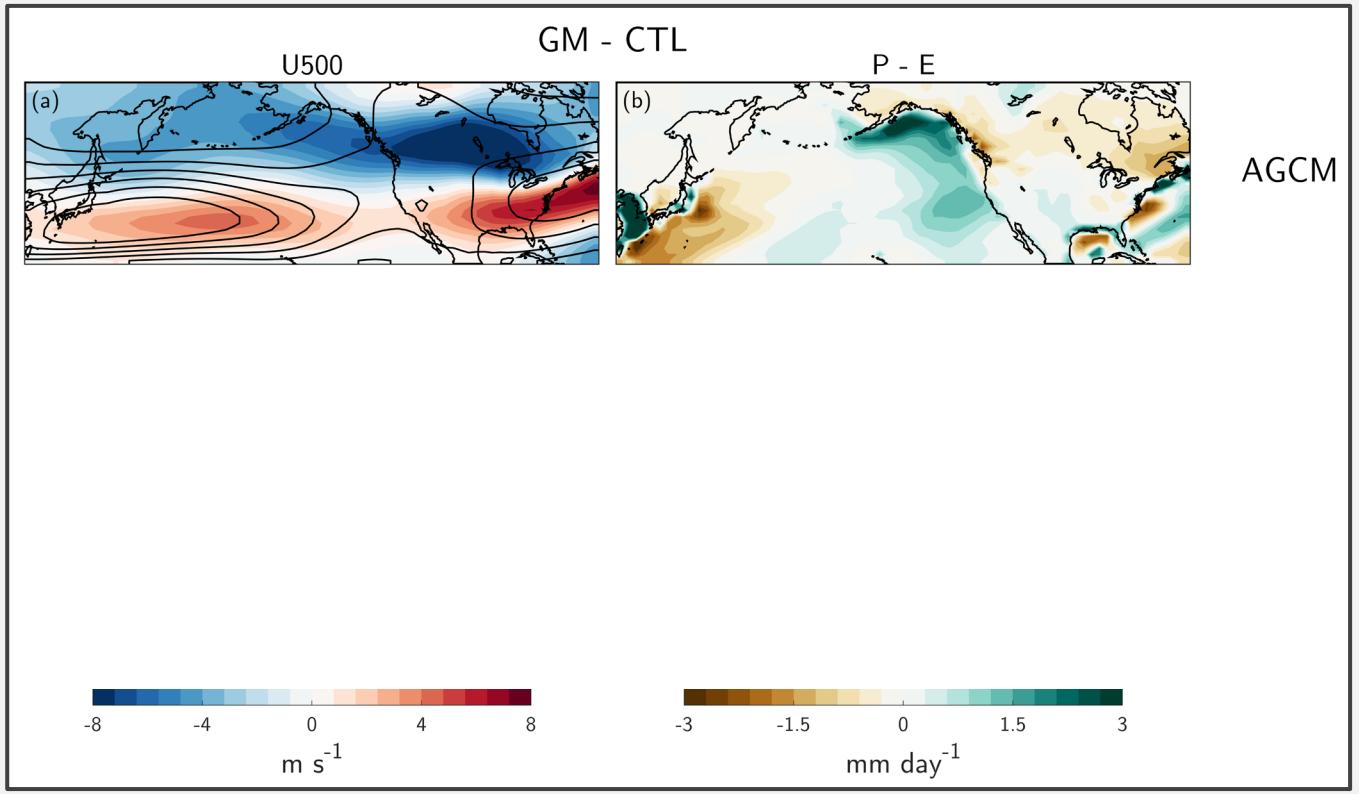
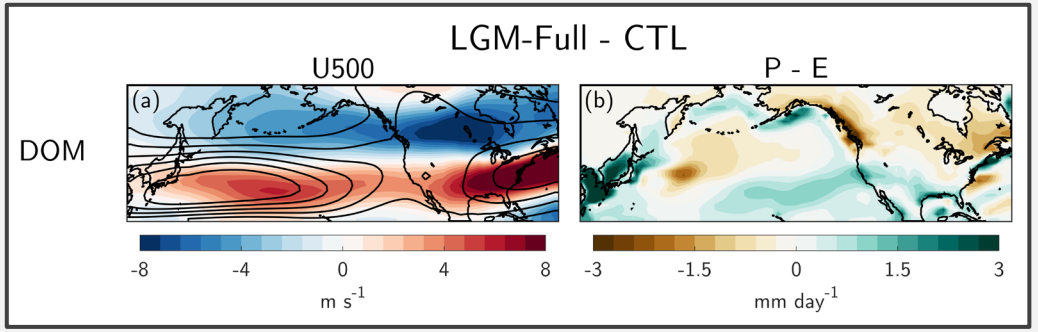



Amaya et al. *in revision*

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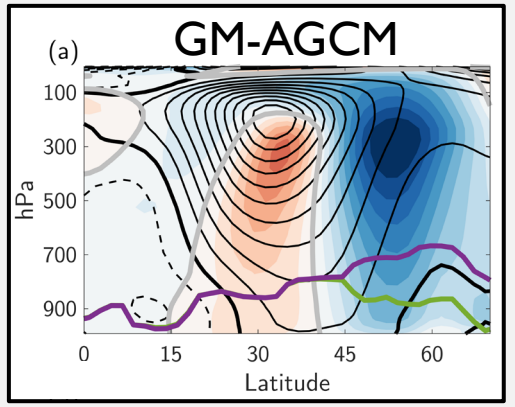
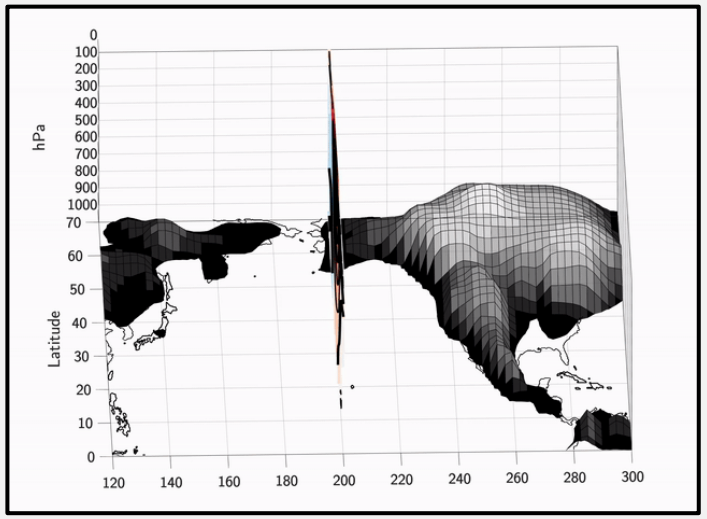
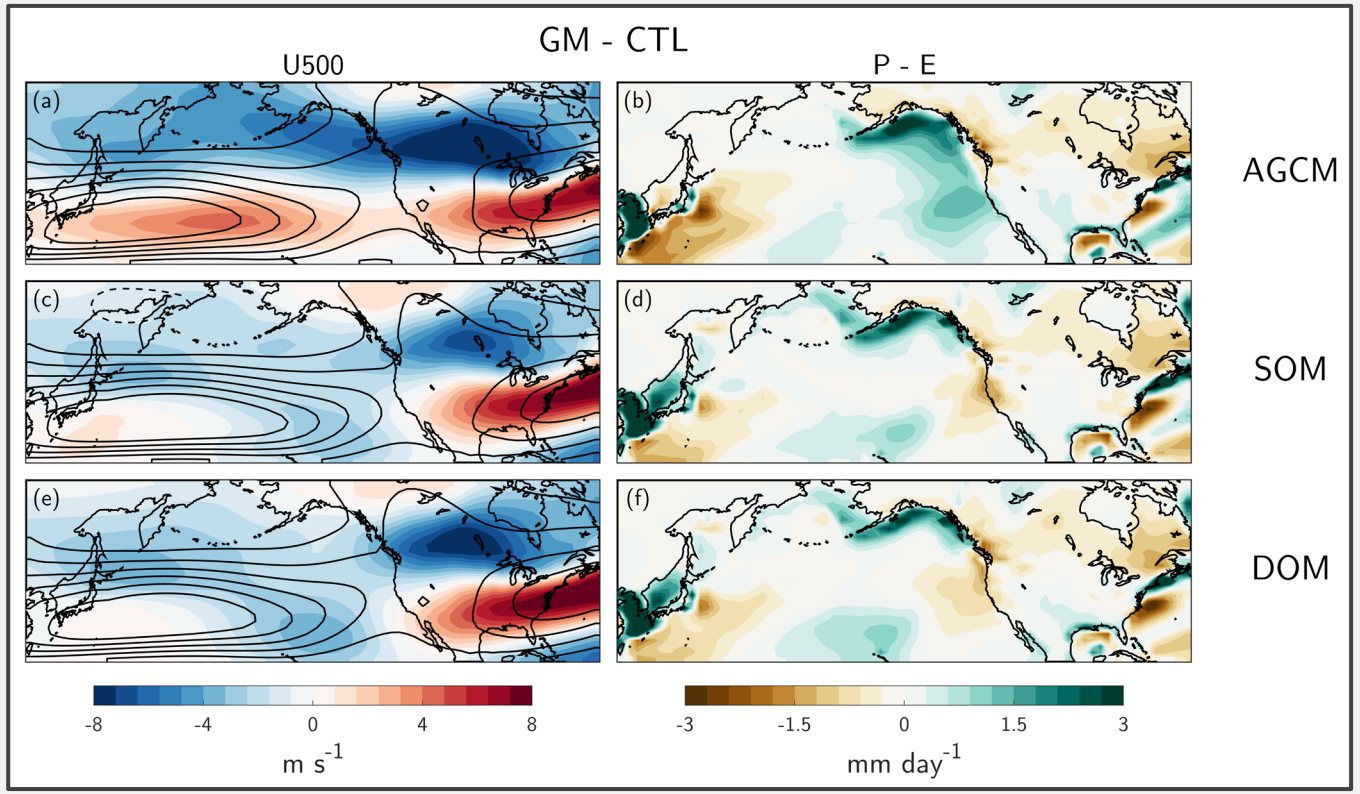


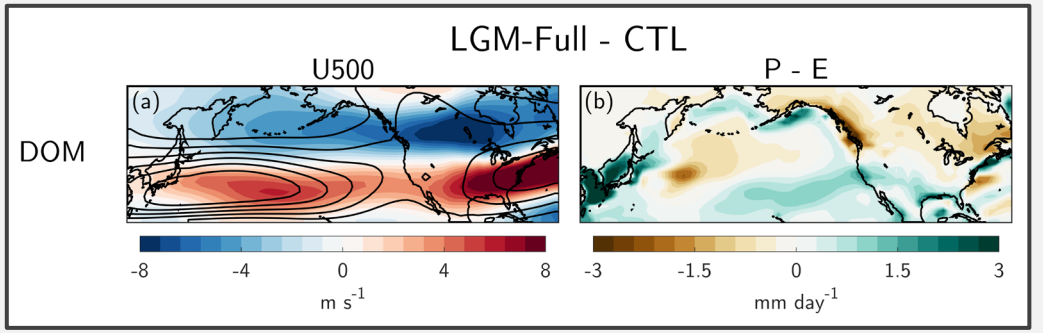



# GREEN MOUNTAIN

## Including ocean-atmosphere interactions leads to opposite result




Amaya et al. *in review*

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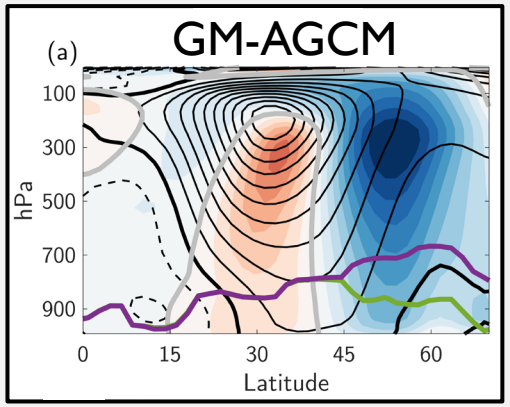


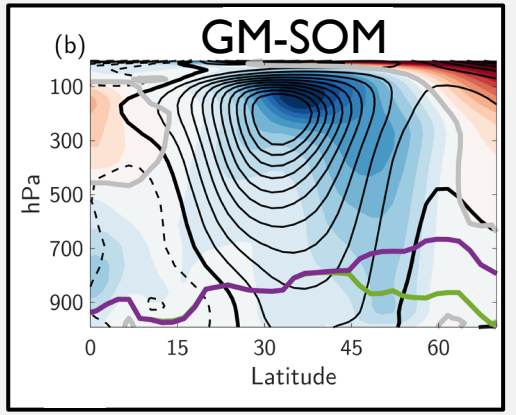


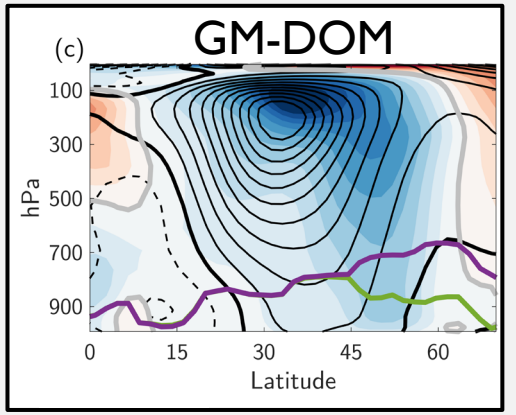

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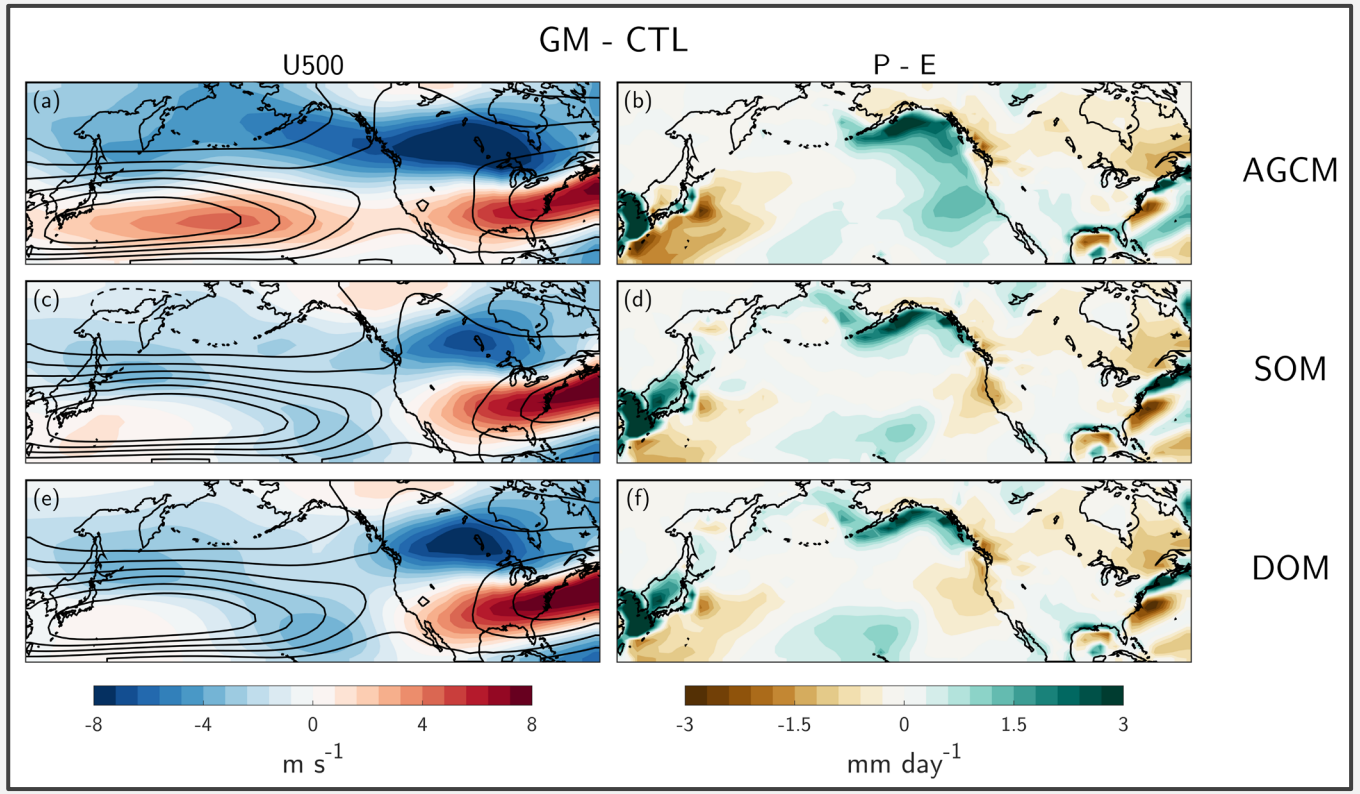


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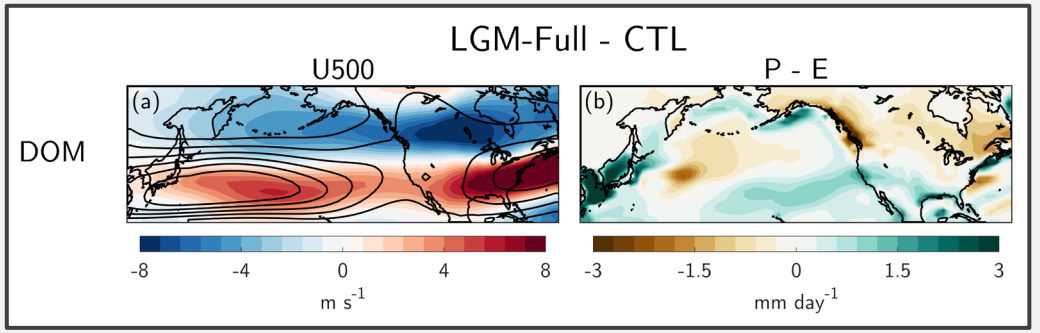
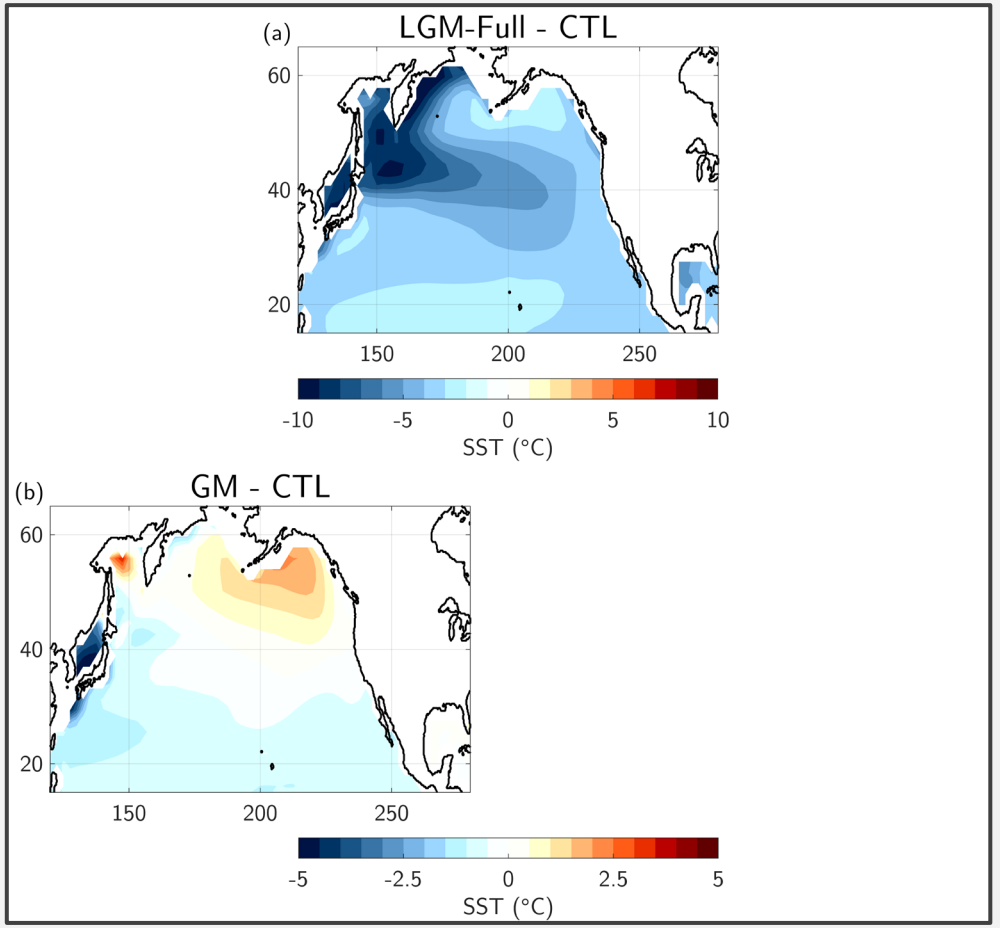



*DOM SST response*



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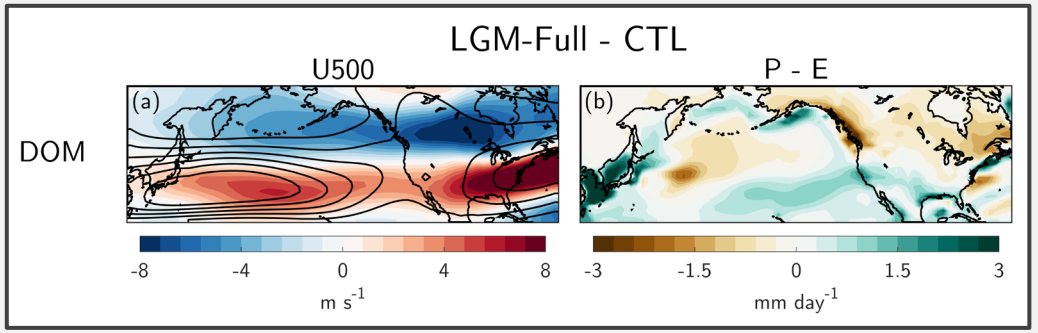


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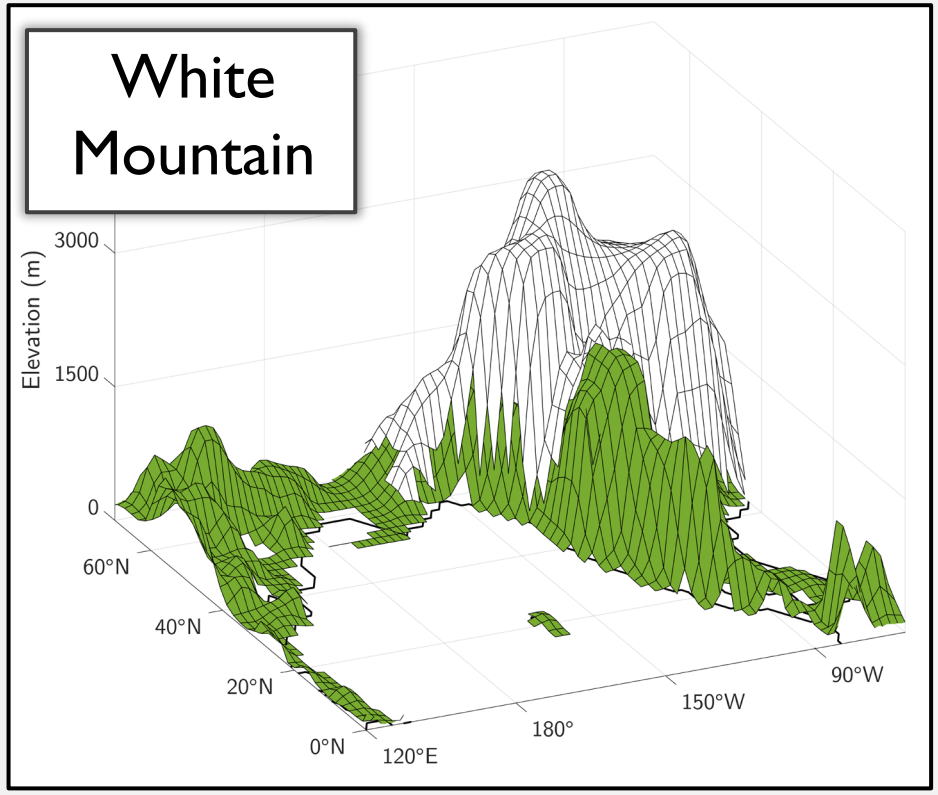


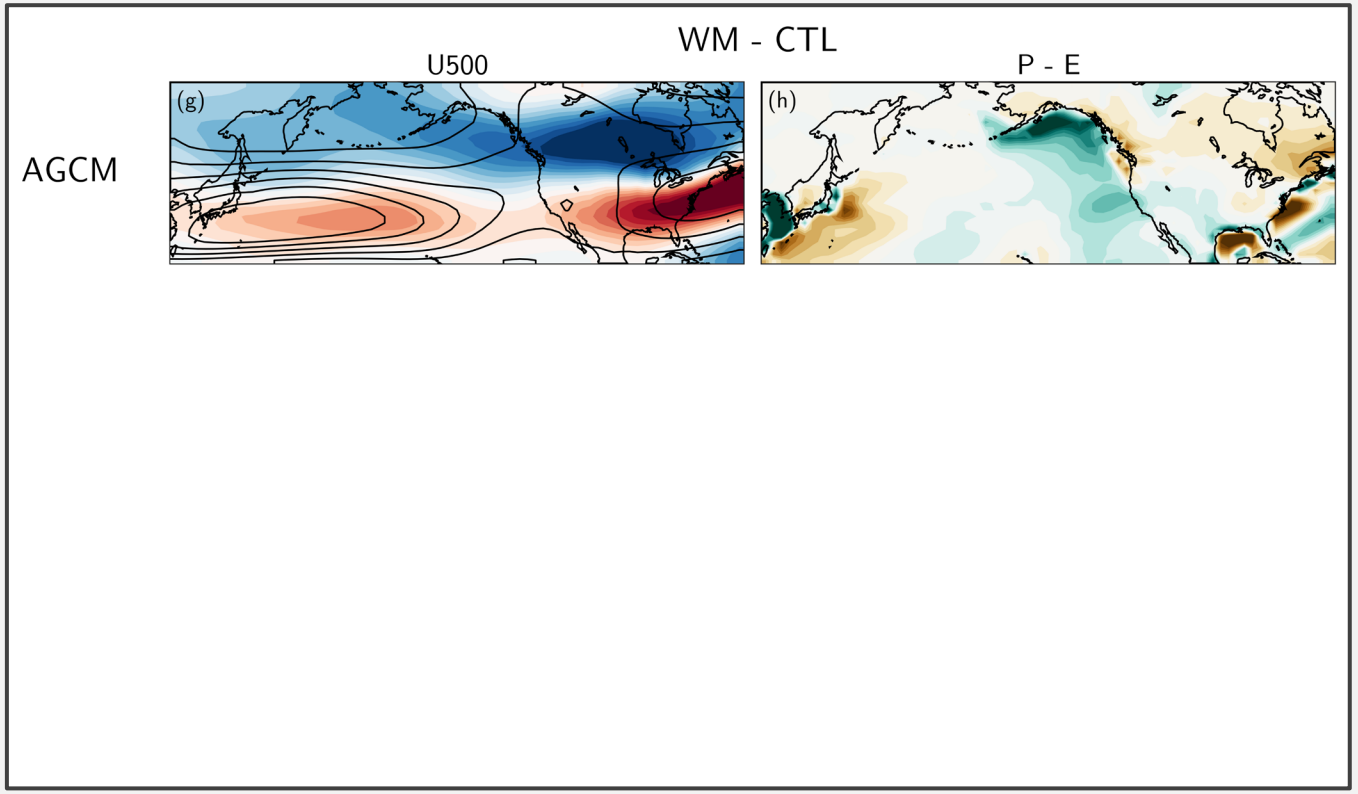


Amaya et al. *in revision*

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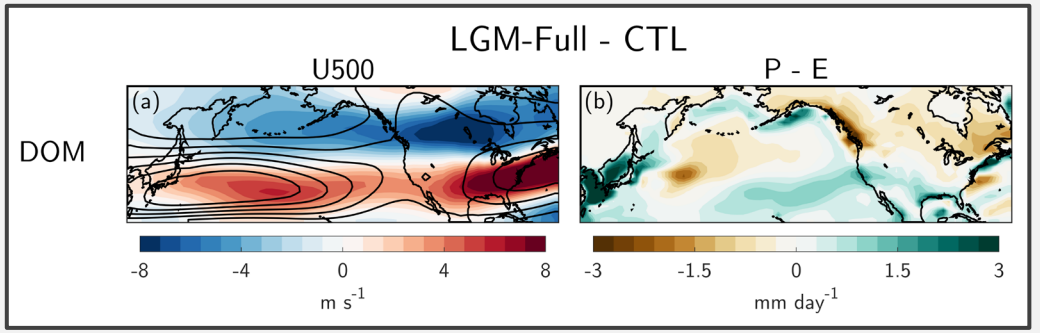
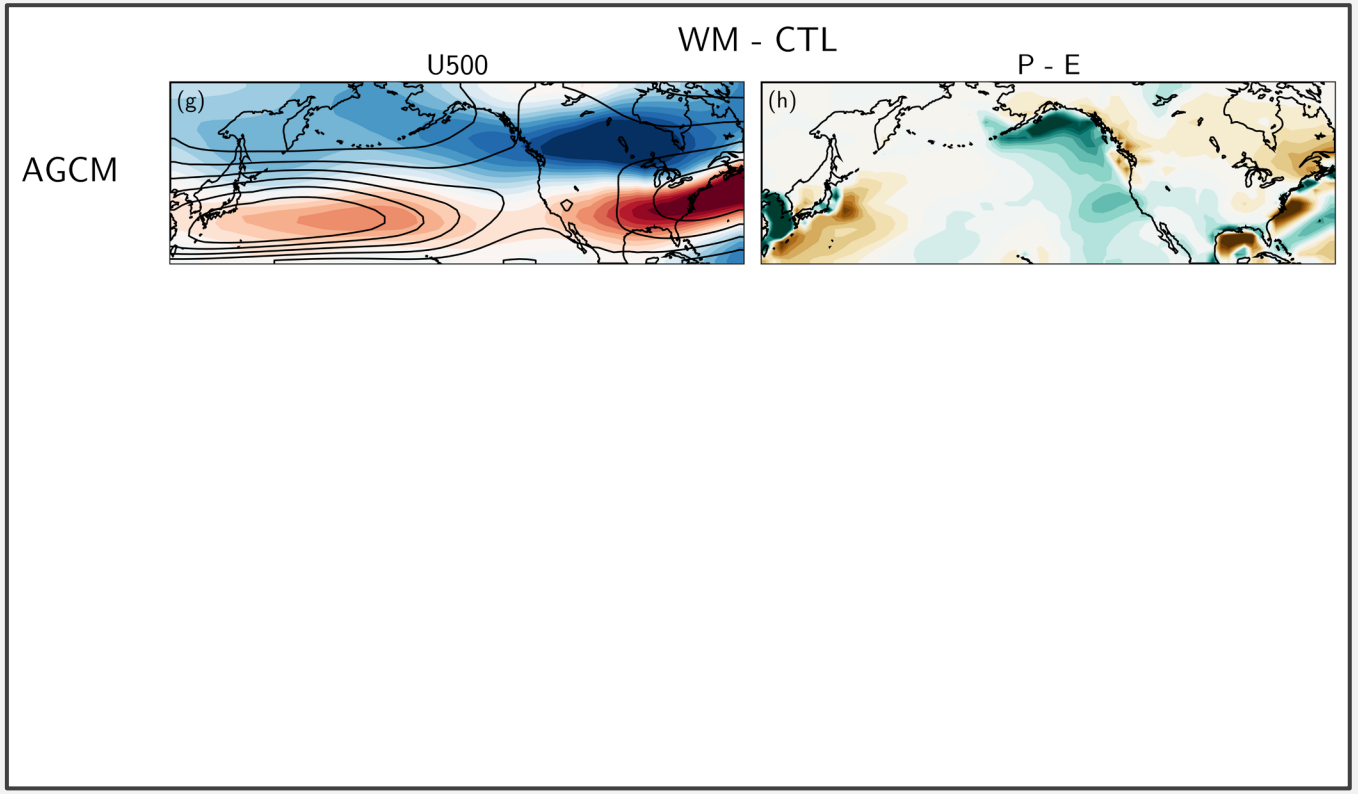



*Dec-Feb averaged atmospheric circulation anomalies*

Same as GM-AGCM, direct response to mechanical forcing

Ocean coupling reinforces mechanically forced jet shift

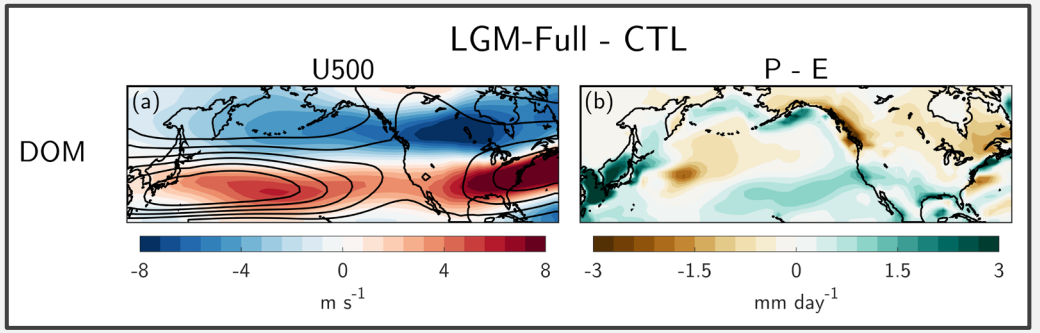
Similarity between SOM/DOM suggests ocean dynamics play secondary role



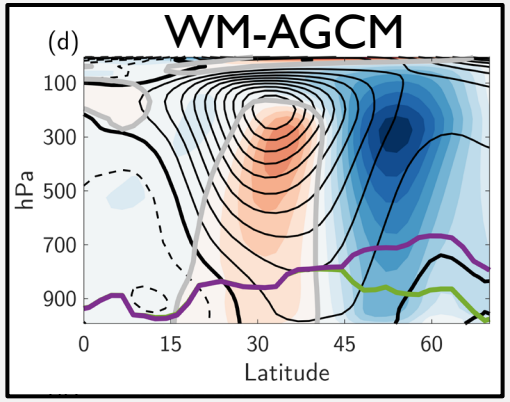

Amaya et al. *in revision*

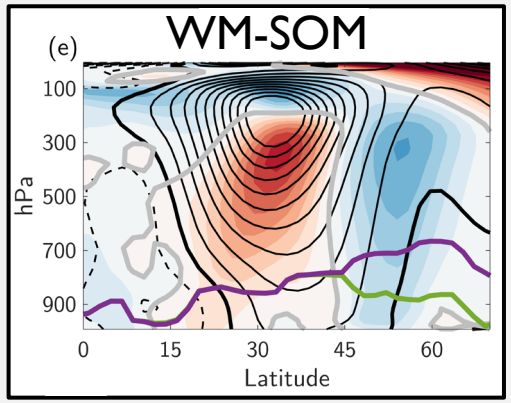
# WHITE MOUNTAIN

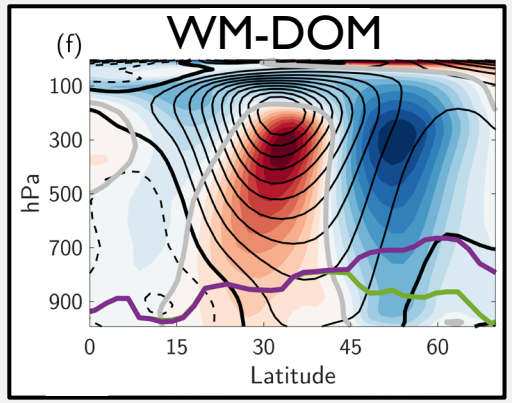
**Mechanical + thermodynamic ice sheet effects reproduce LGM-Full**

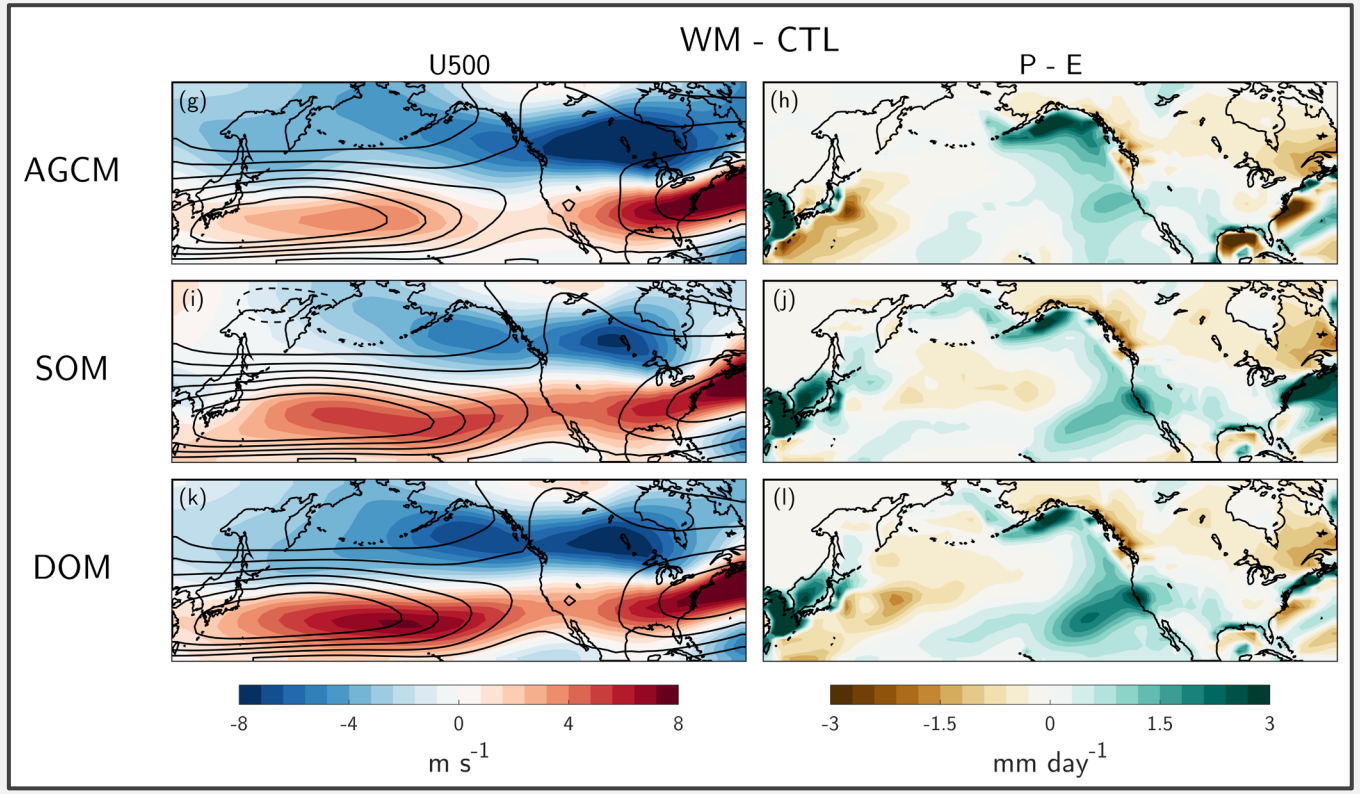



*Dec-Feb averaged atmospheric circulation anomalies*



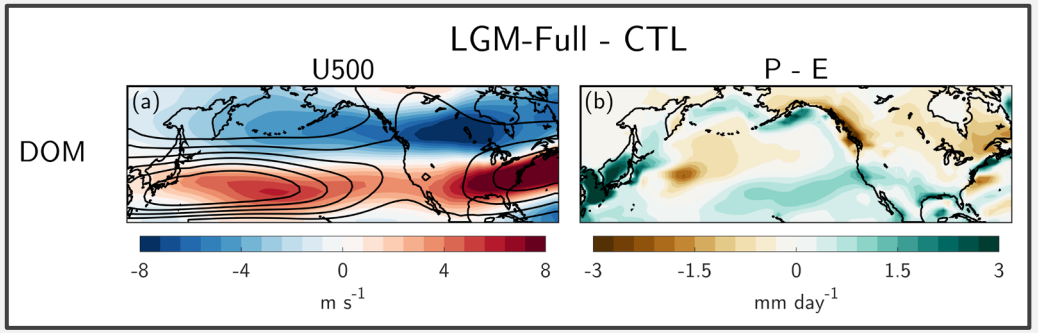




Amaya et al. *in revision*

# WHITE MOUNTAIN

## Thermodynamic forcing and subsequent air-sea interactions critical

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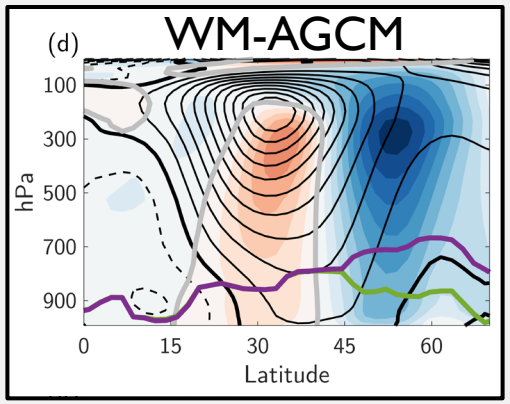


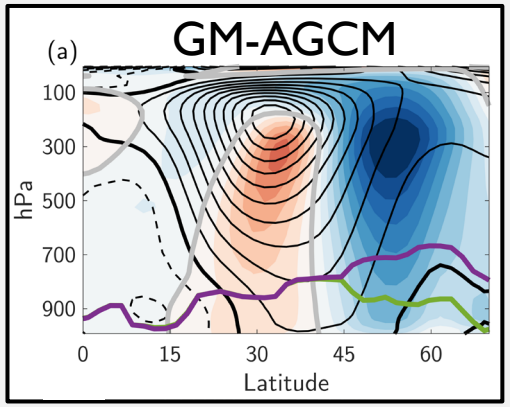


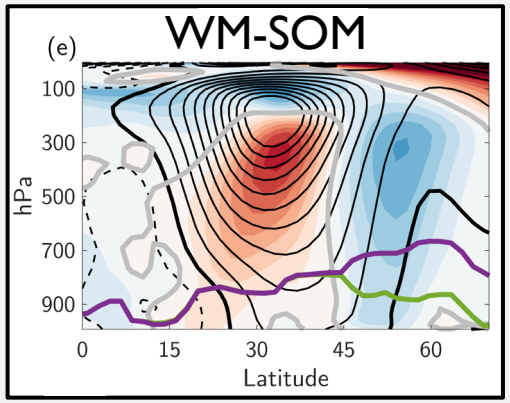


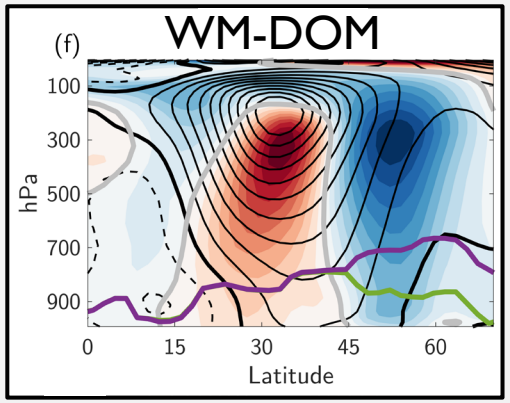


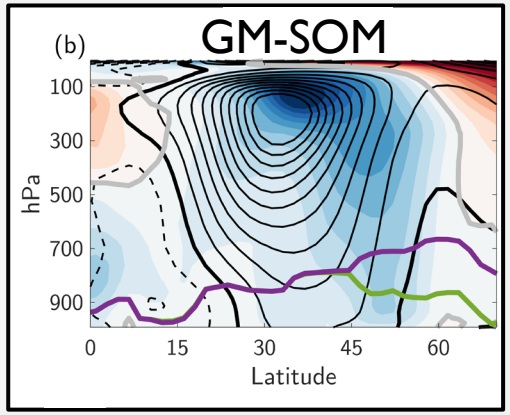


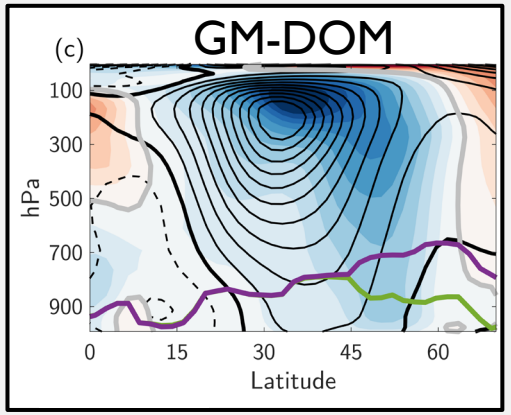


Amaya et al. *in revision*

# WHITE MOUNTAIN

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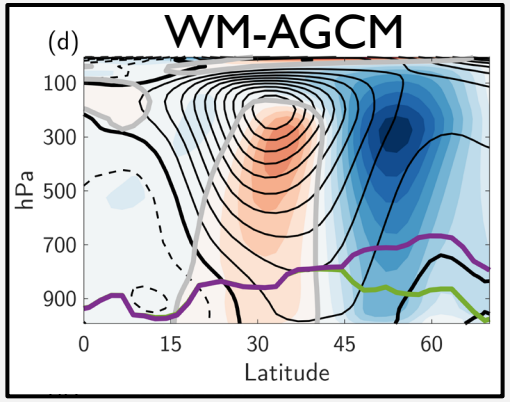
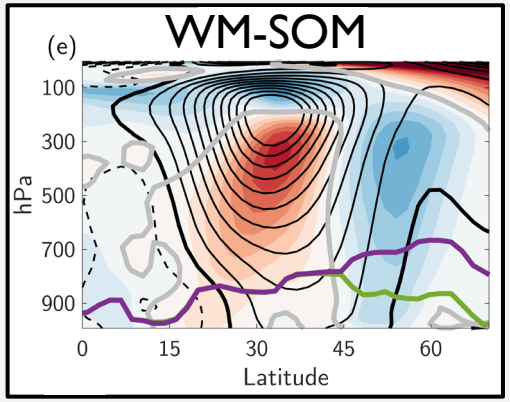
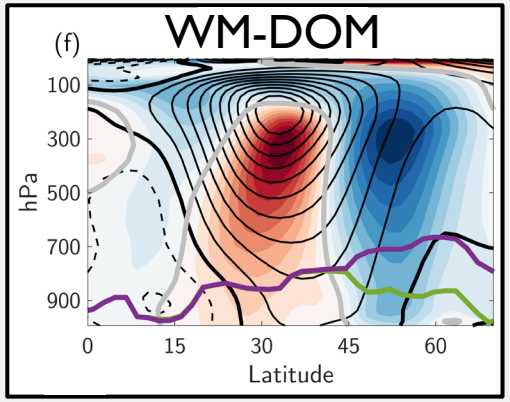
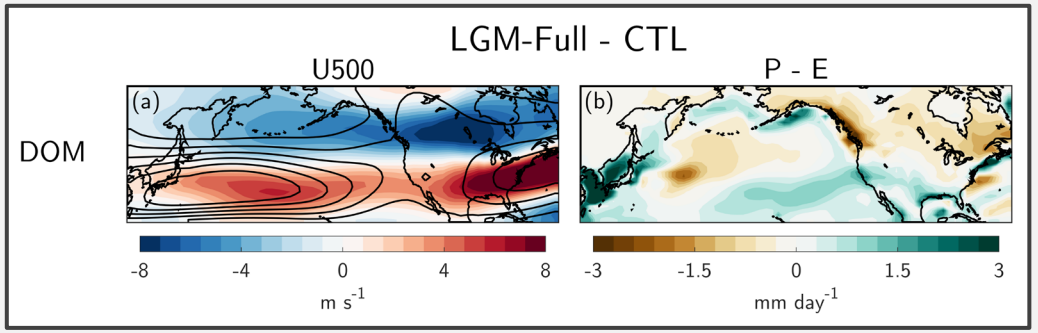


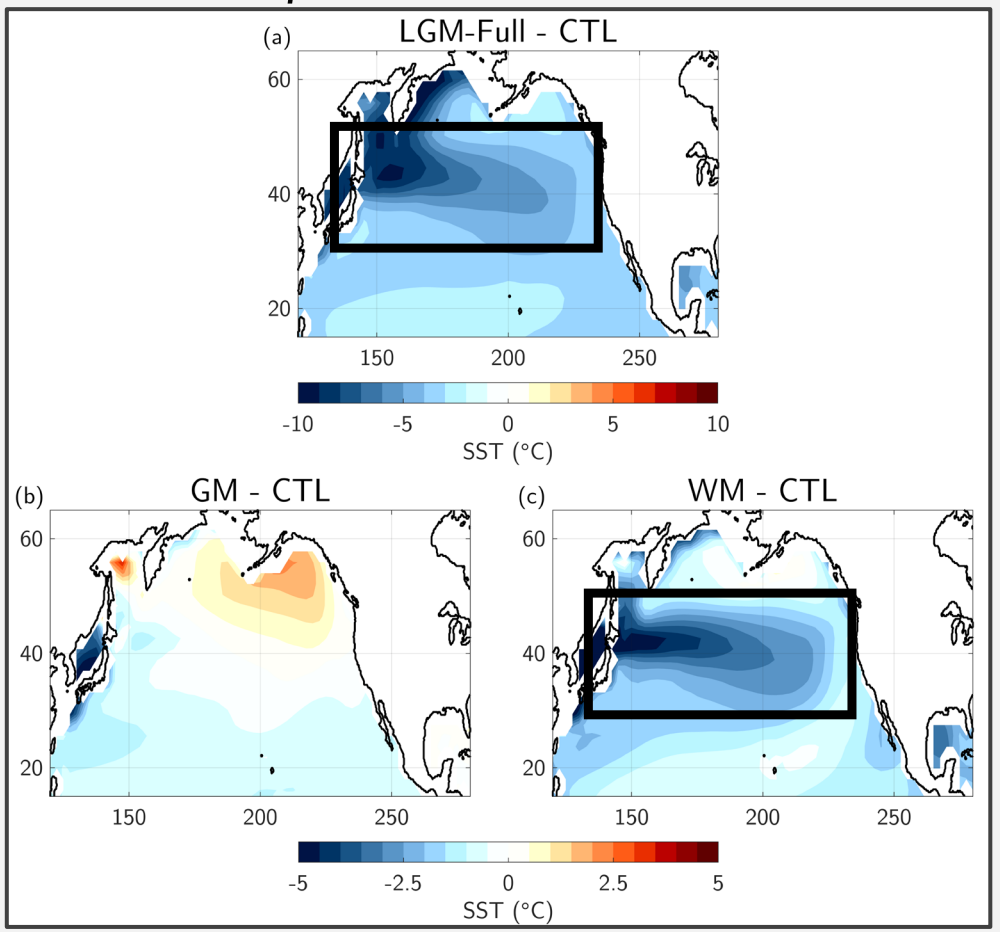




Amaya et al. *in review*




*DOM SST response*



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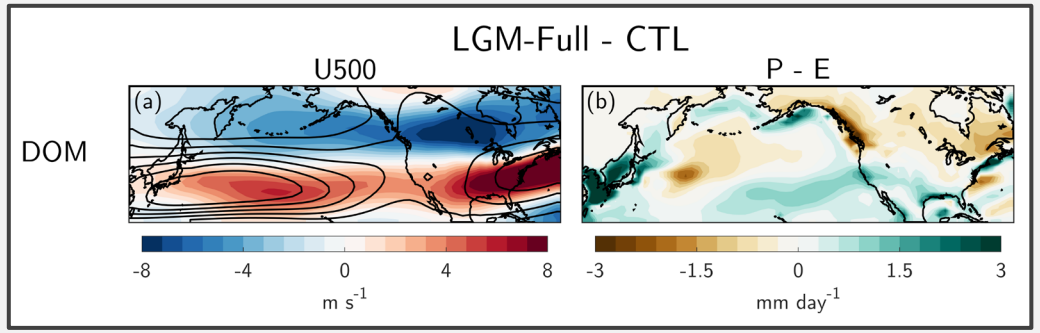
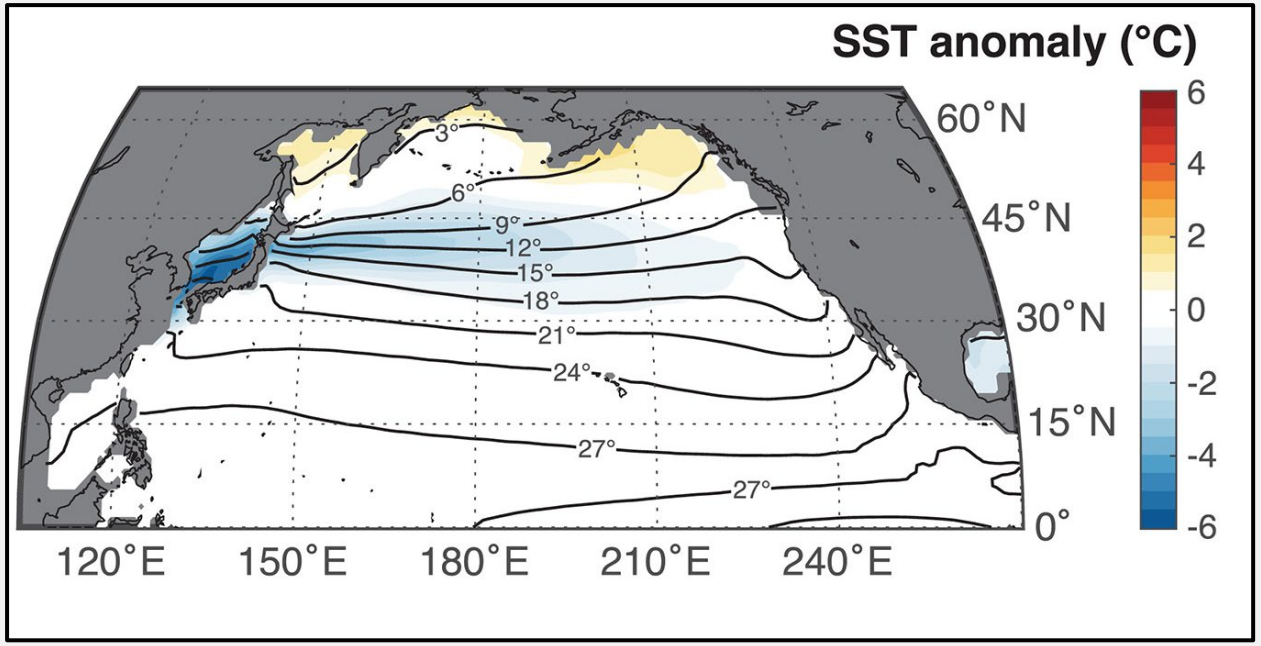
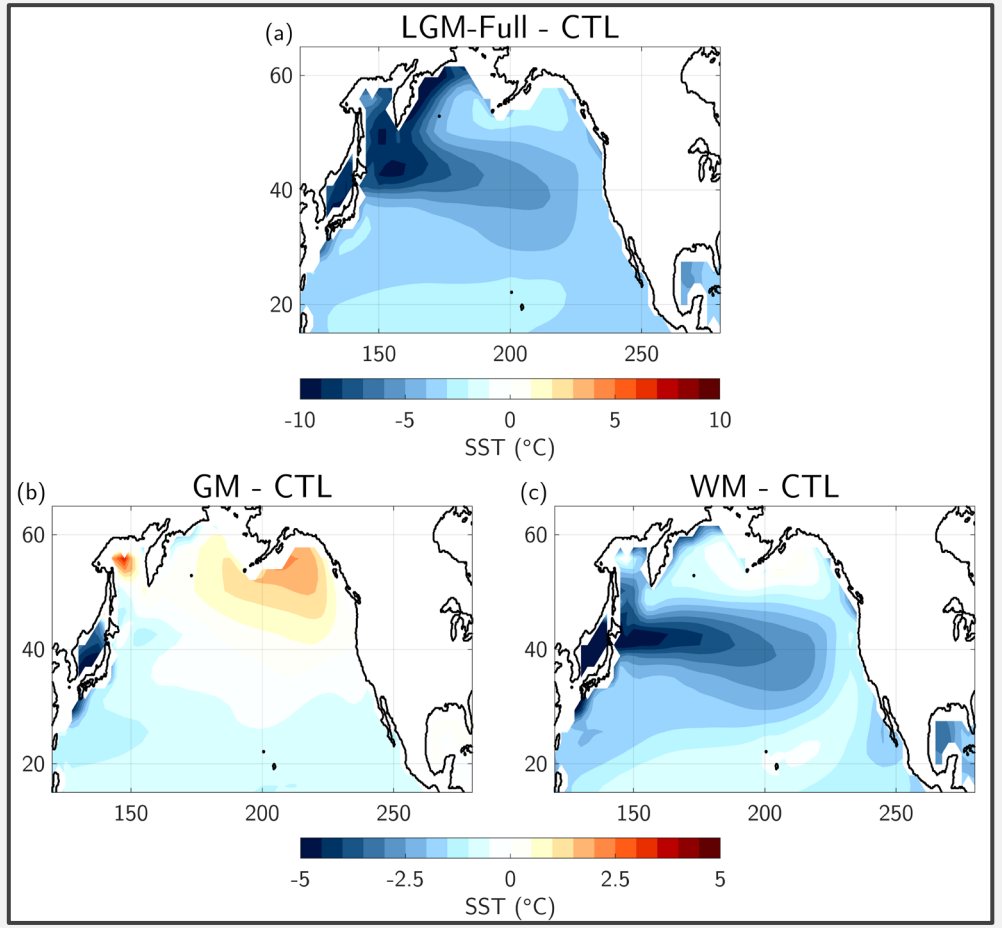



*PMIP3 Ensemble mean LGM - CTL*




Gray et al. (2020)

*DOM annual mean SST response*

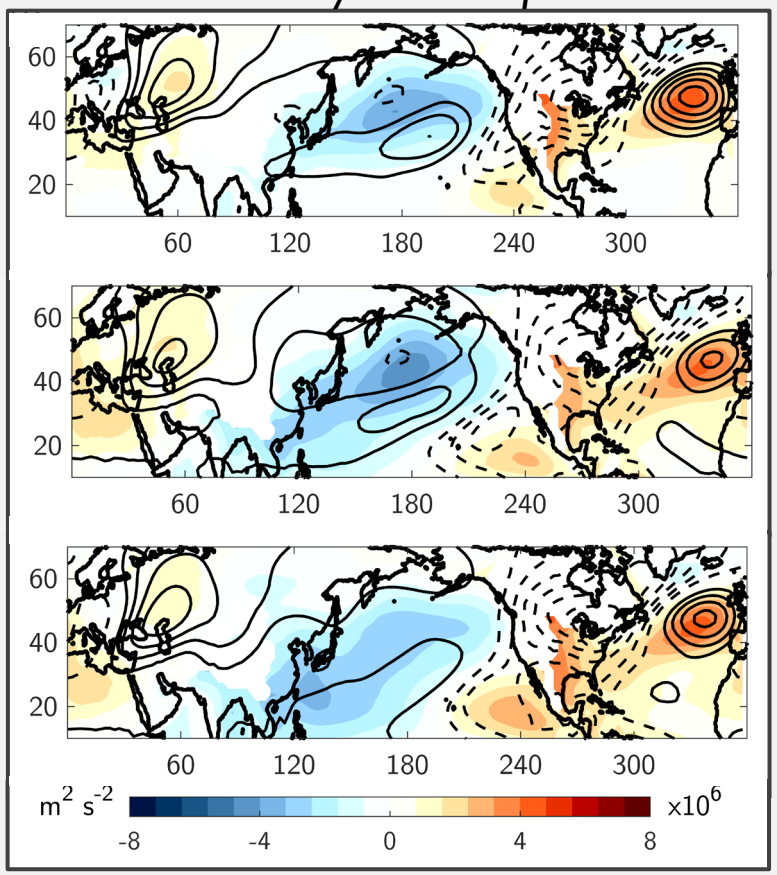



Amaya et al. *in revision*

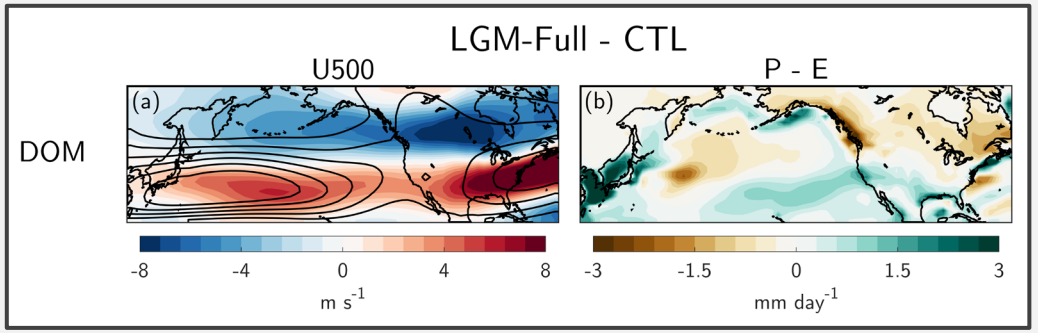
# WHITE MOUNTAIN

## Summer large-scale atmospheric circulation uncoupled from the ocean

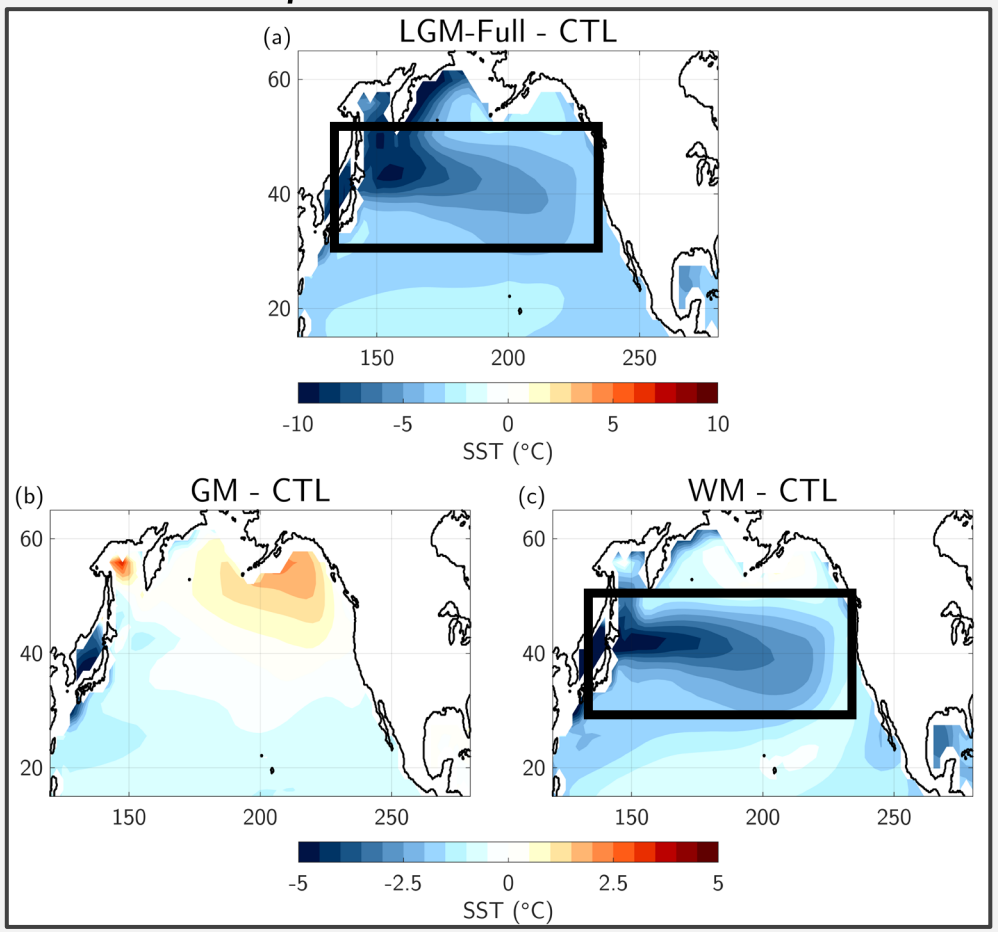
*Summer stationary wave response*




Shading: 850mb
Contours: 200mb

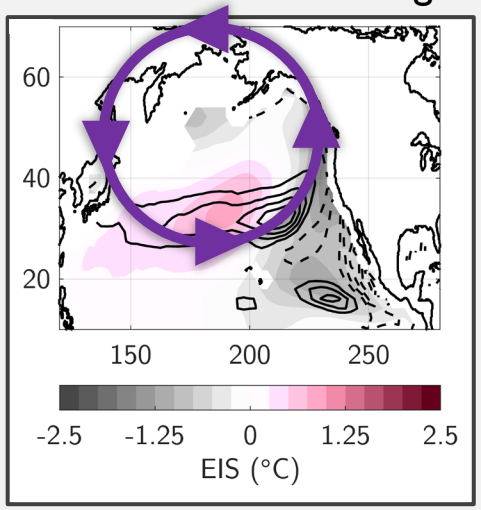



*DOM SST response*



# WHITE MOUNTAIN

Estimated Inversion Strength (EIS)

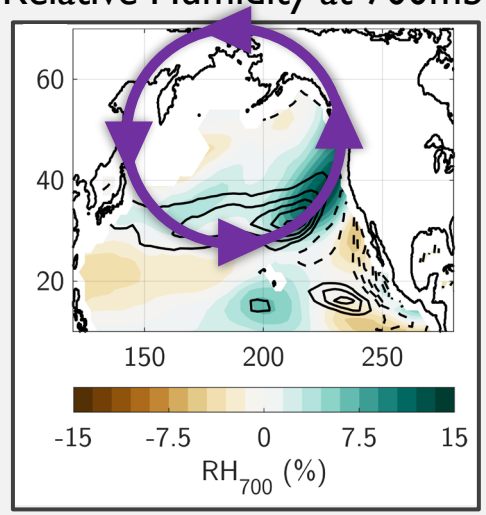



DOM

AGCM

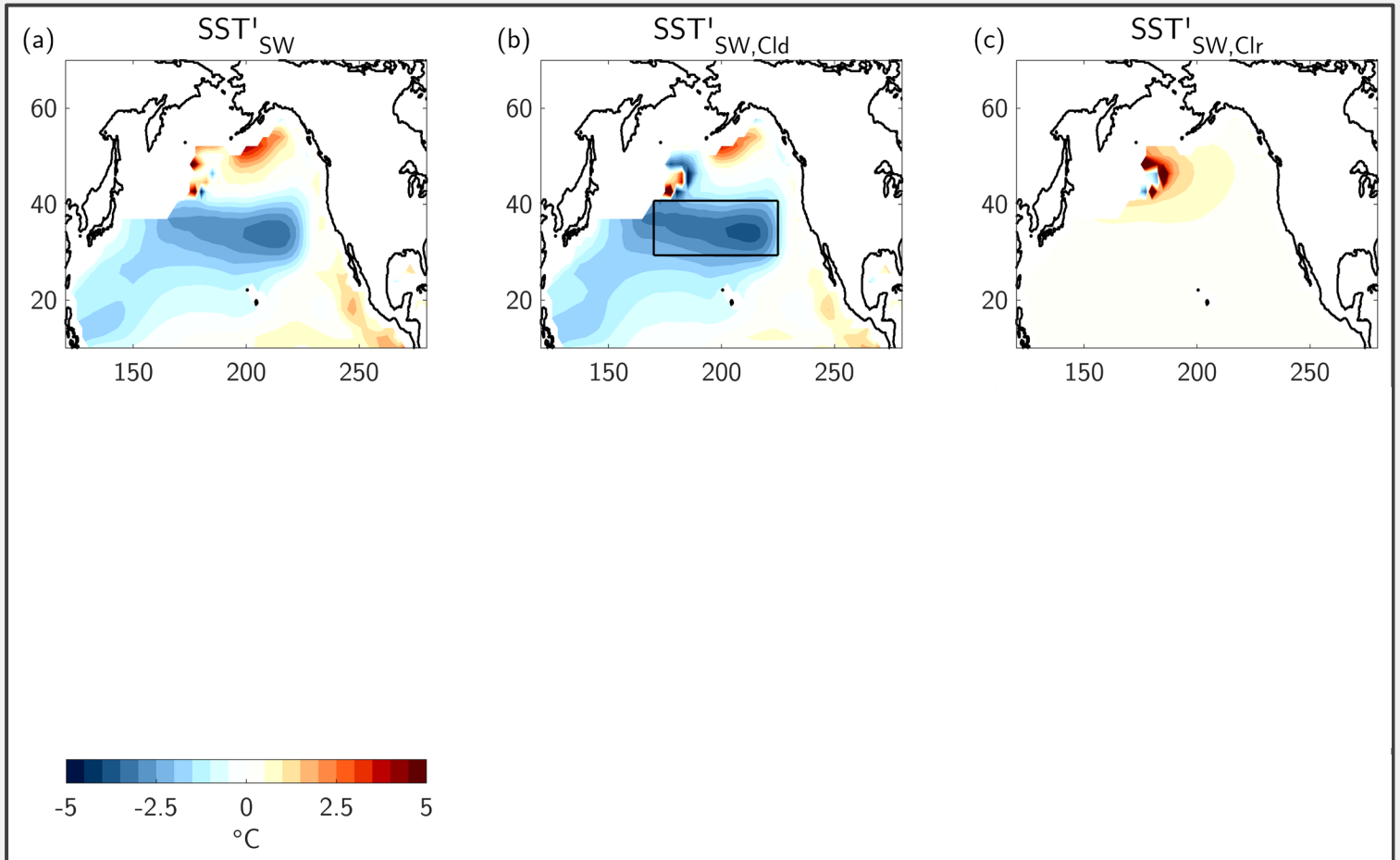
EIS > 0 = more stable

Relative Humidity at 700mb




Summertime low cloud ingredients WM-AGCM

*SST anomalies implied by changes in shortwave*




WM – CTL summer cloud response

# SUMMARY

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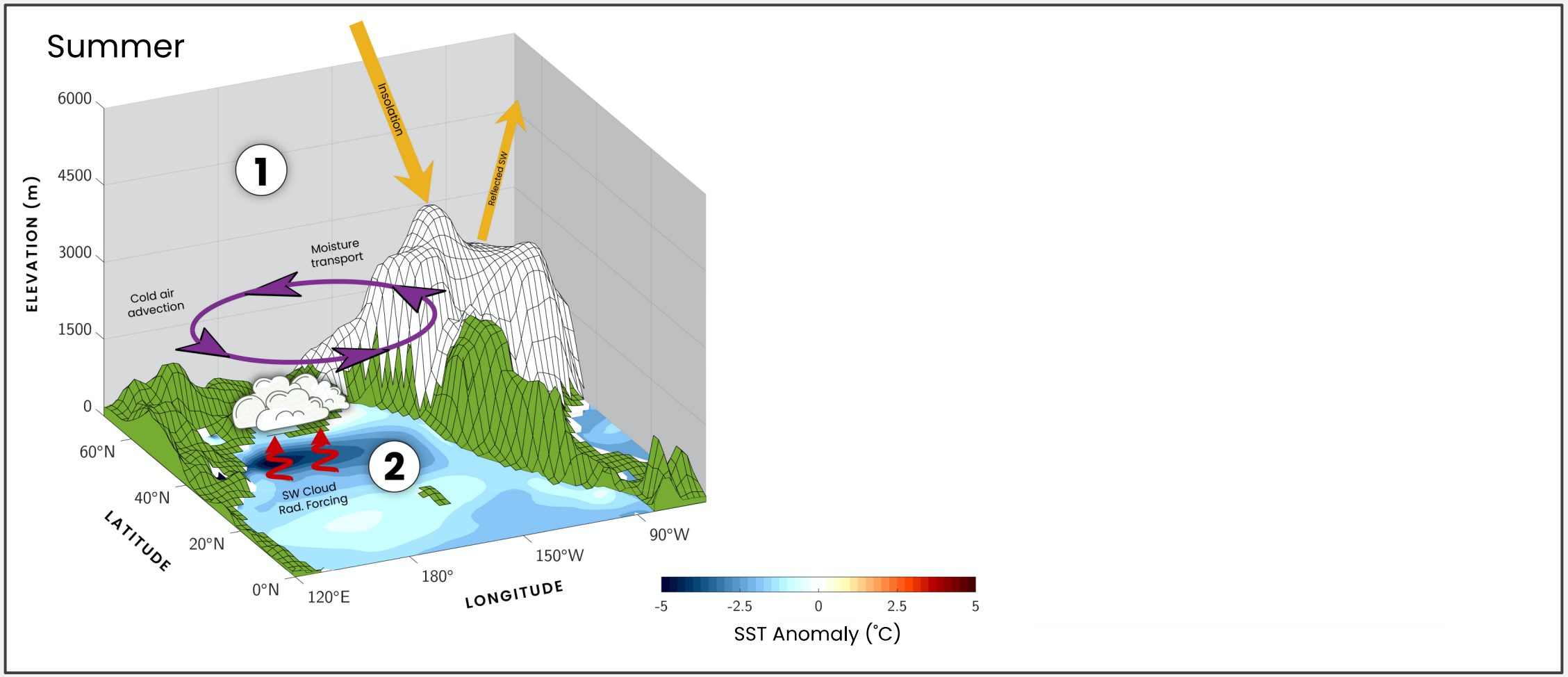
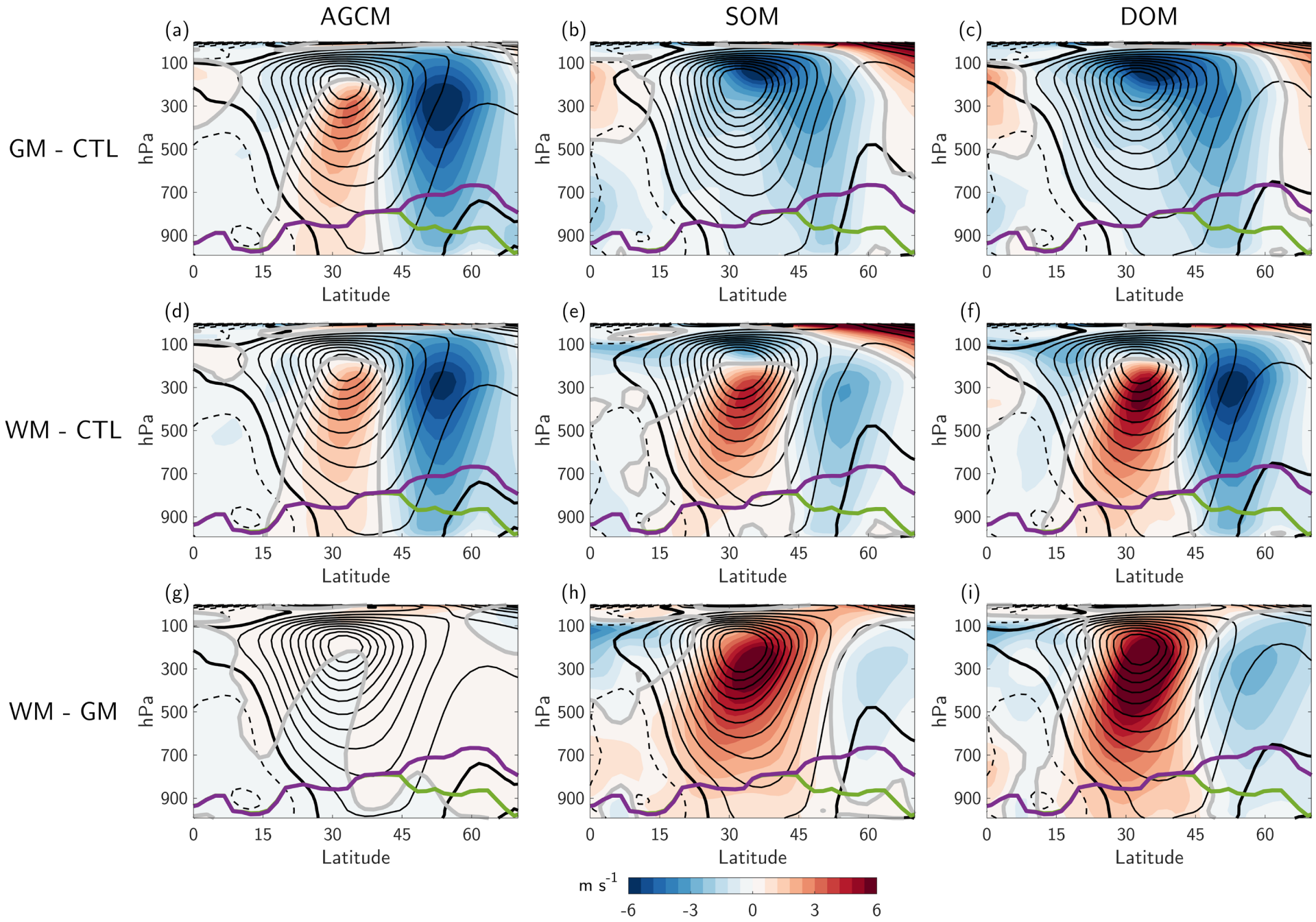
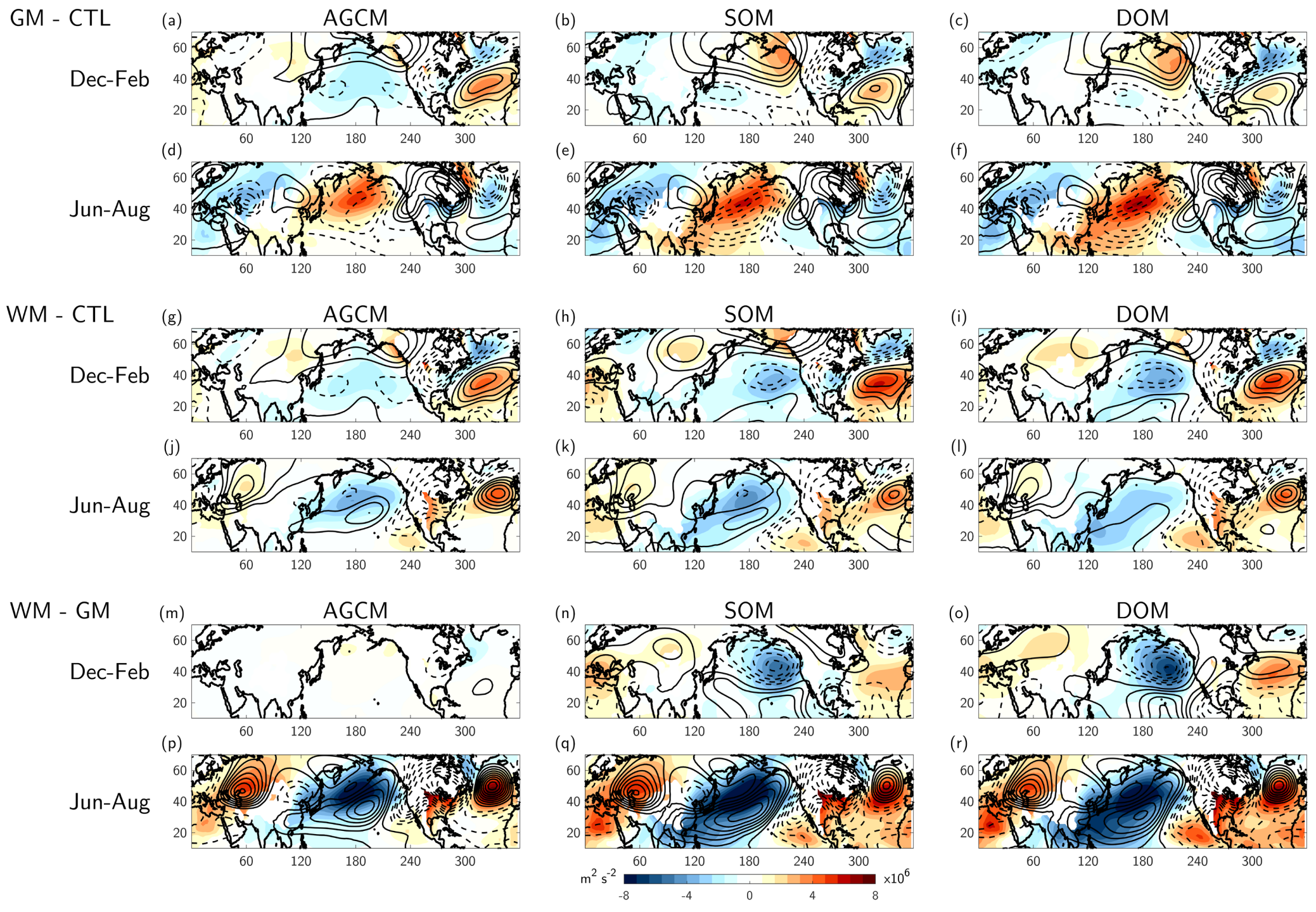
# QUESTIONS?

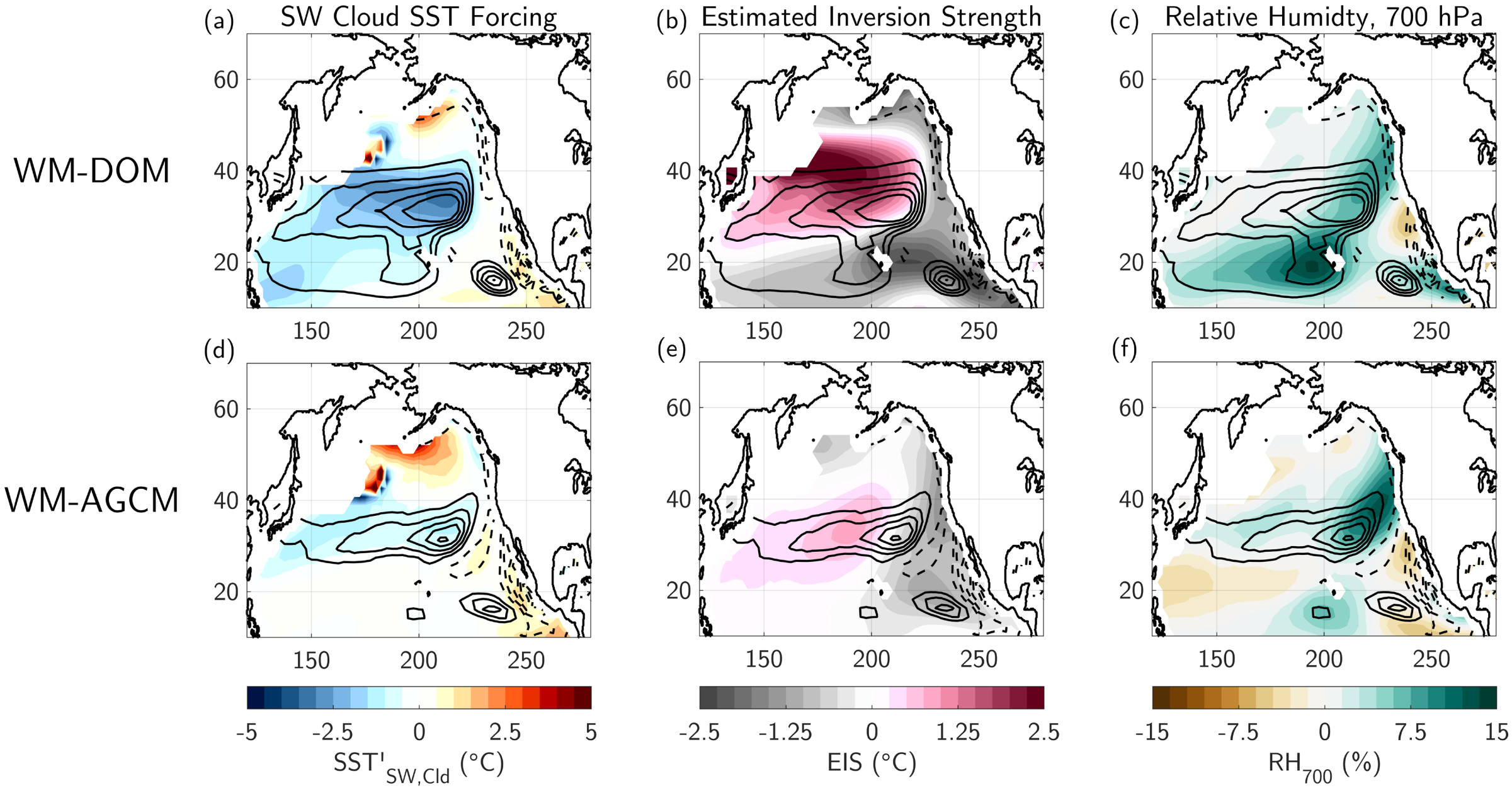


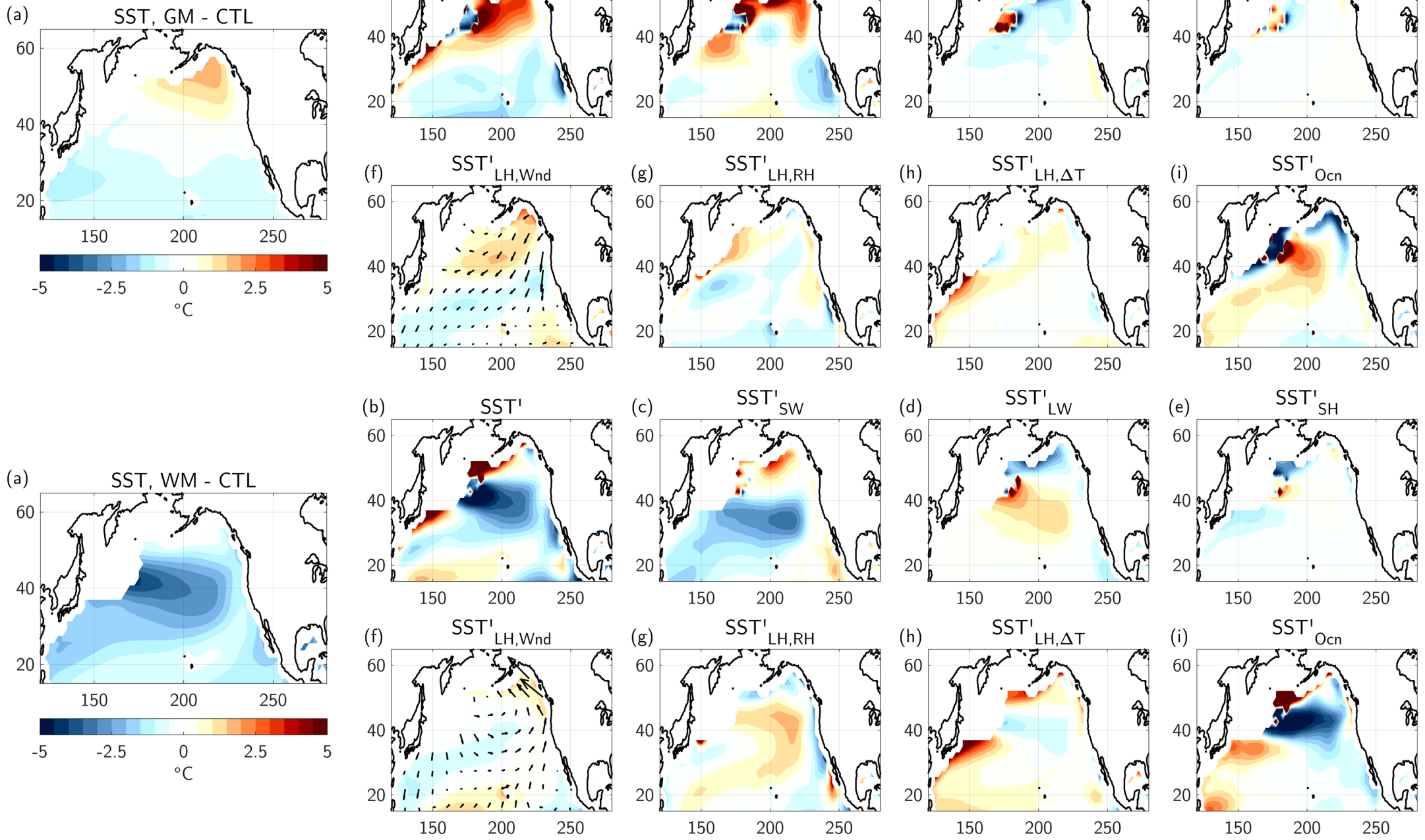

Amaya DJ, AM Seltzer, KB Karnauskas, JM Lora, X Zhang, and P DiNezio. Air-sea feedbacks shape North American hydroclimate response to ice sheets. *In revision*. Pre-print at www.dillonamaya.com

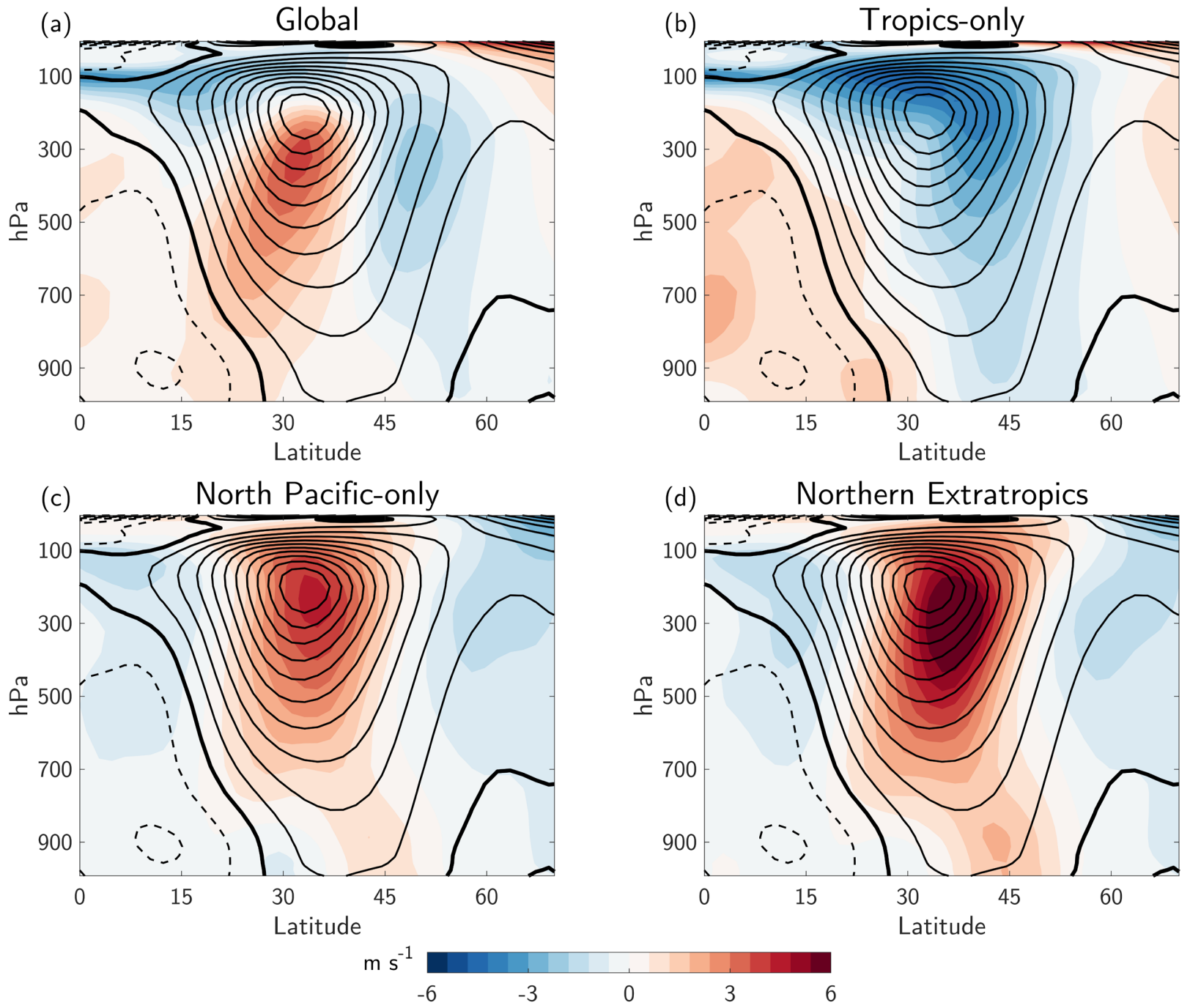
# EXTRA SLIDES


AGCM
SOM
DOM
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
GM - CTL
WM - CTL
WM - GM
hPa
100
300
500
700
900
0
15
30
45
60
Latitude
m s-1
-6
-3
0
3
6


GM - CTL
WM - CTL
WM - GM
Dec-Feb
Jun-Aug
AGCM
SOM
DOM
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
(j)
(k)
(l)
(m)
(n)
(o)
(p)
(q)
(r)
60
40
20
60
120
180
240
300
m2 s-2
x10^6
-8
-4
0
4
8


WM-DOM
WM-AGCM
(a) SW Cloud SST Forcing
(b) Estimated Inversion Strength
(c) Relative Humidty, 700 hPa
(d)
(e)
(f)
60
40
20
150
200
250
-5
-2.5
0
2.5
5
SST'SW,Cld (°C)
-2.5
-1.25
0
1.25
2.5
EIS (°C)
-15
-7.5
0
7.5
15
RH700 (%)

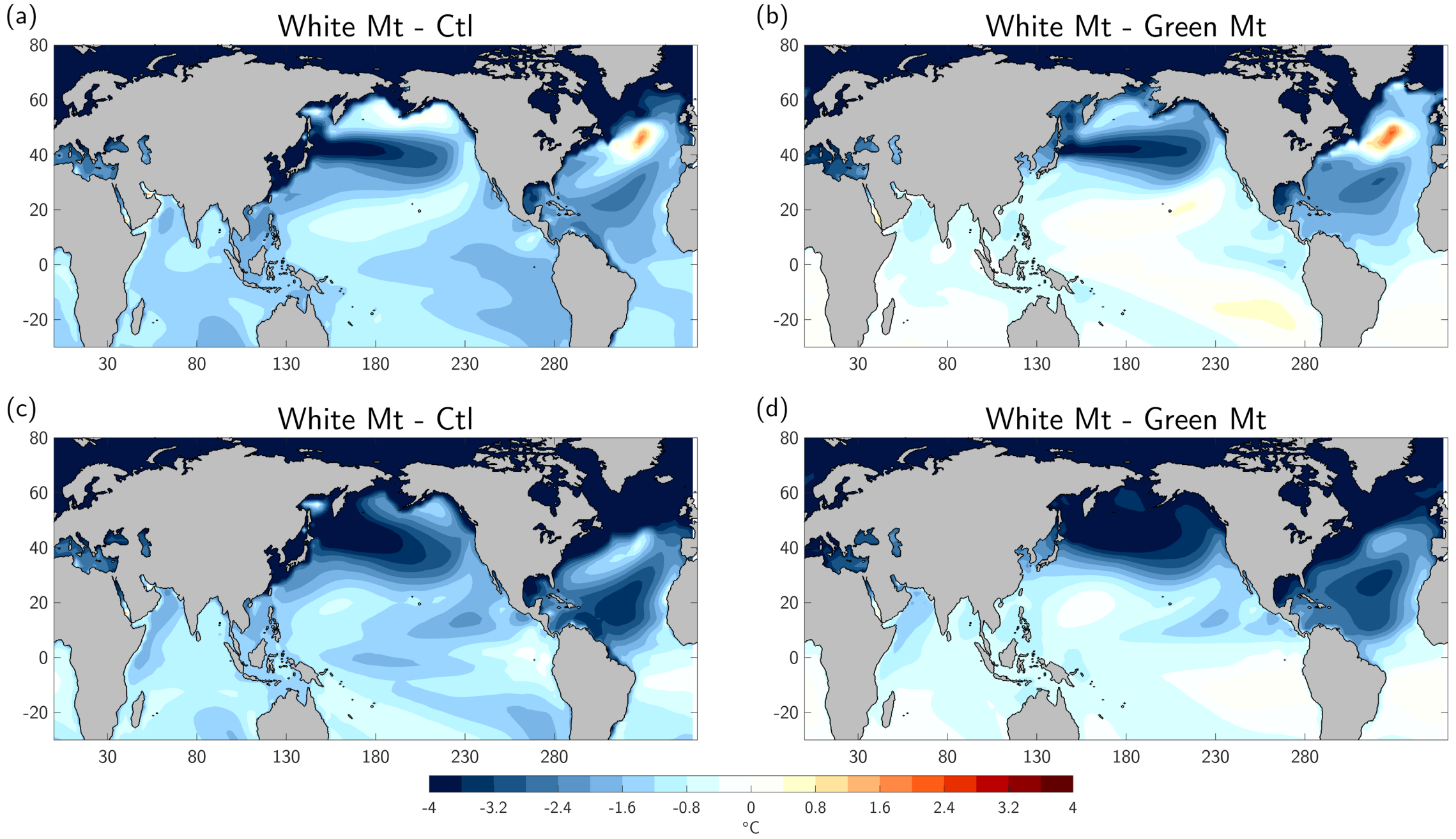

(a)
SST, GM - CTL
(b)
SST'
(c)
SST'SW
(d)
SST'LW
(e)
SST'SH
(f)
SST'LH,Wnd
(g)
SST'LH,RH
(h)
SST'LH,ΔT
(i)
SST'Ocn
(a)
SST, WM - CTL
(b)
SST'
(c)
SST'SW
(d)
SST'LW
(e)
SST'SH
(f)
SST'LH,Wnd
(g)
SST'LH,RH
(h)
SST'LH,ΔT
(i)
SST'Ocn
60
40
20
150
200
250
-5
-2.5
0
2.5
5
°C


(a)
Global
(b)
Tropics-only
(c)
North Pacific-only
(d)
Northern Extratropics
hPa
100
300
500
700
900
0
15
30
45
60
Latitude
m s-1
-6
-3
0
3
6

# Full SST anomalies, DJF

DOM

SOM



# SST anomalies relative to tropical mean (30°S-30°N), DJF

DOM

SOM