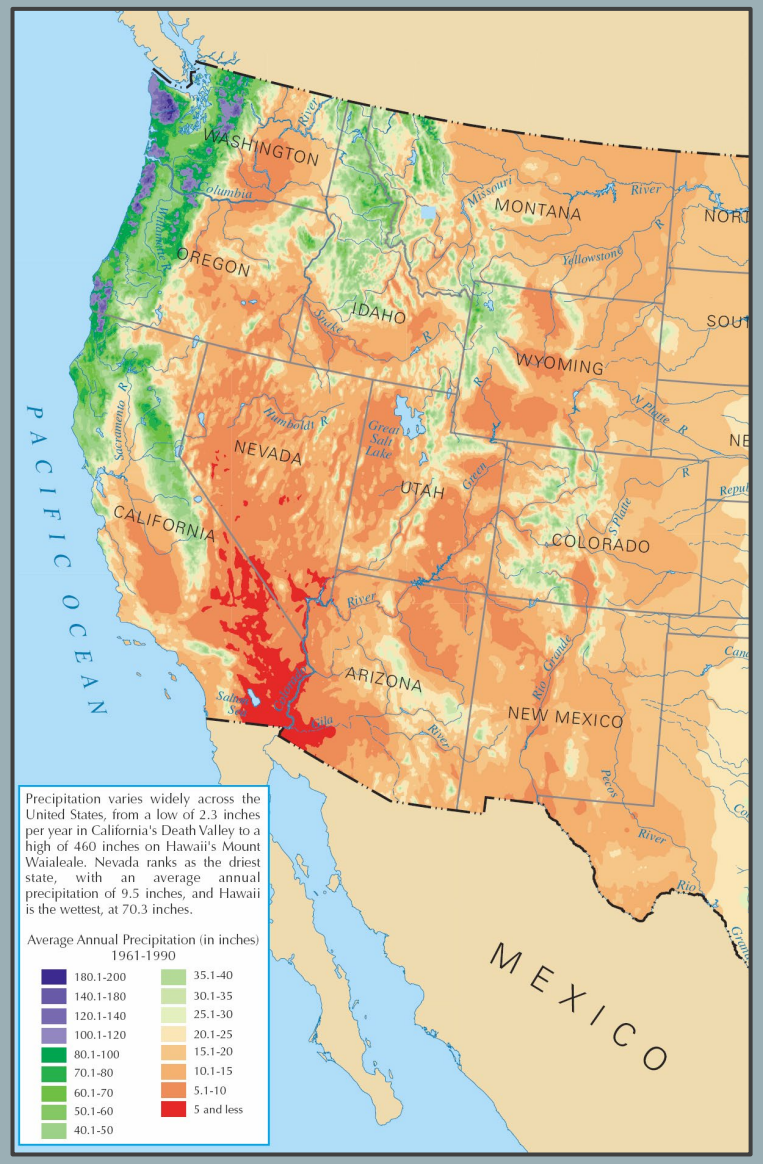
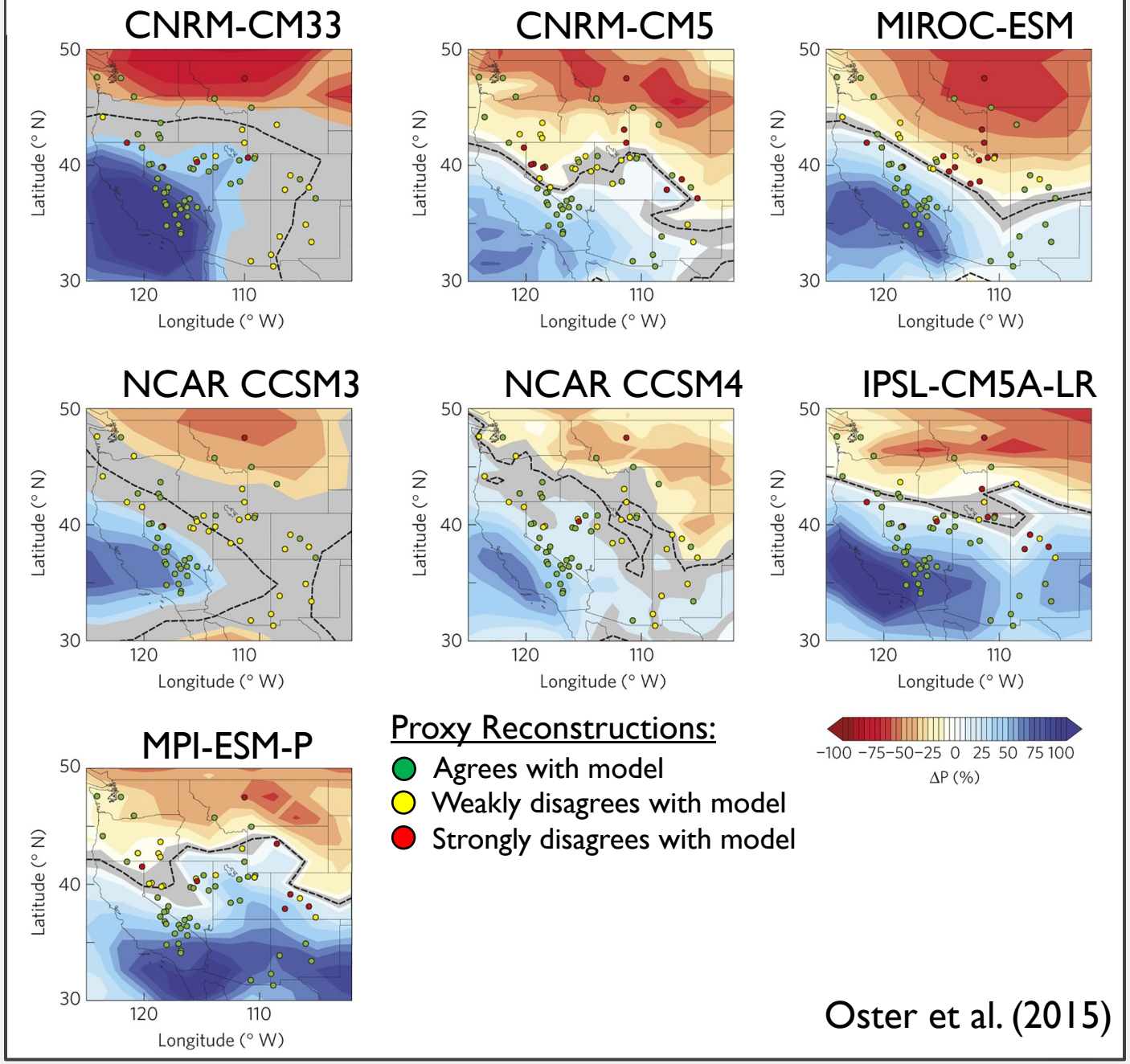
AIR-SEA COUPLING SHAPES NORTH AMERICAN HYDROCLIMATE RESPONSE TO LGM ICE SHEETS

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

CESM Paleoclimate Working Group Meeting
February 8, 2021

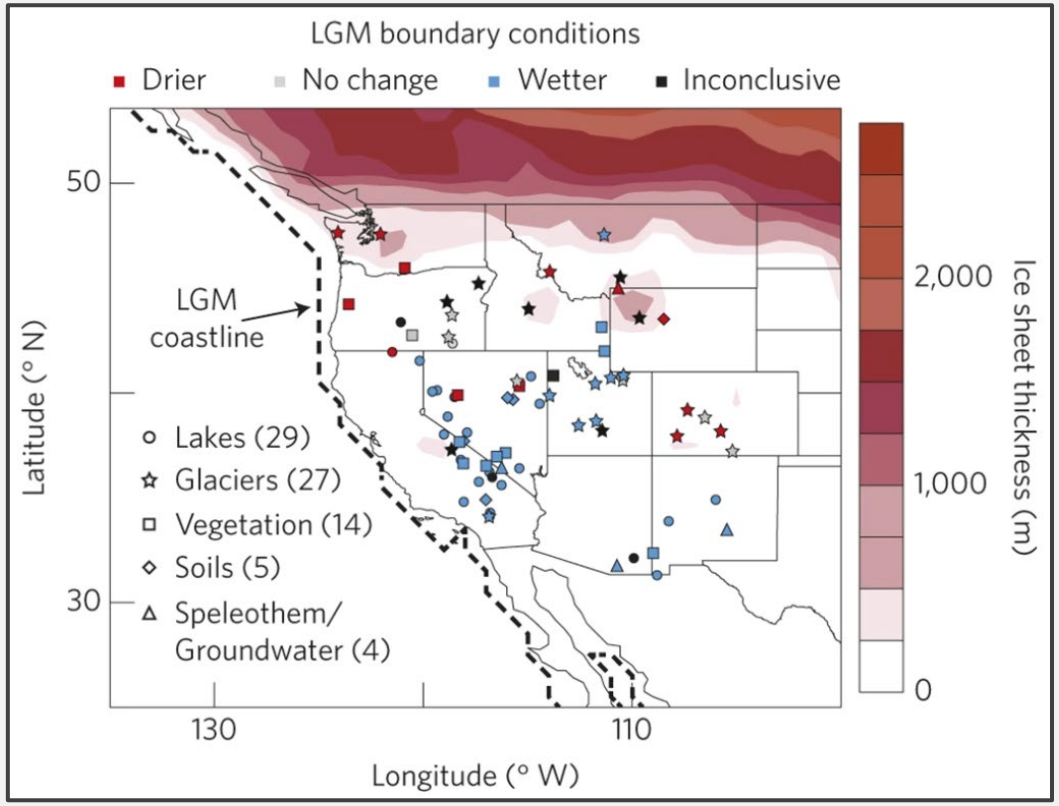


LGM precipitation difference in PMIP3 models



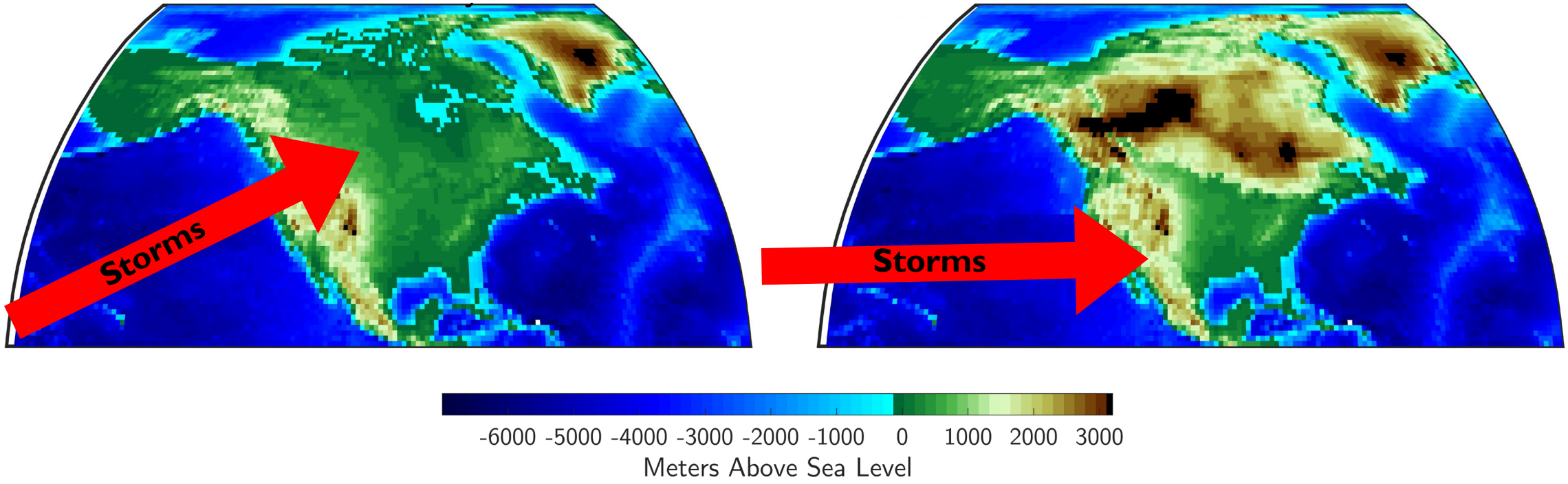
Oster et al. (2015)

LGM HYDROCLIMATE



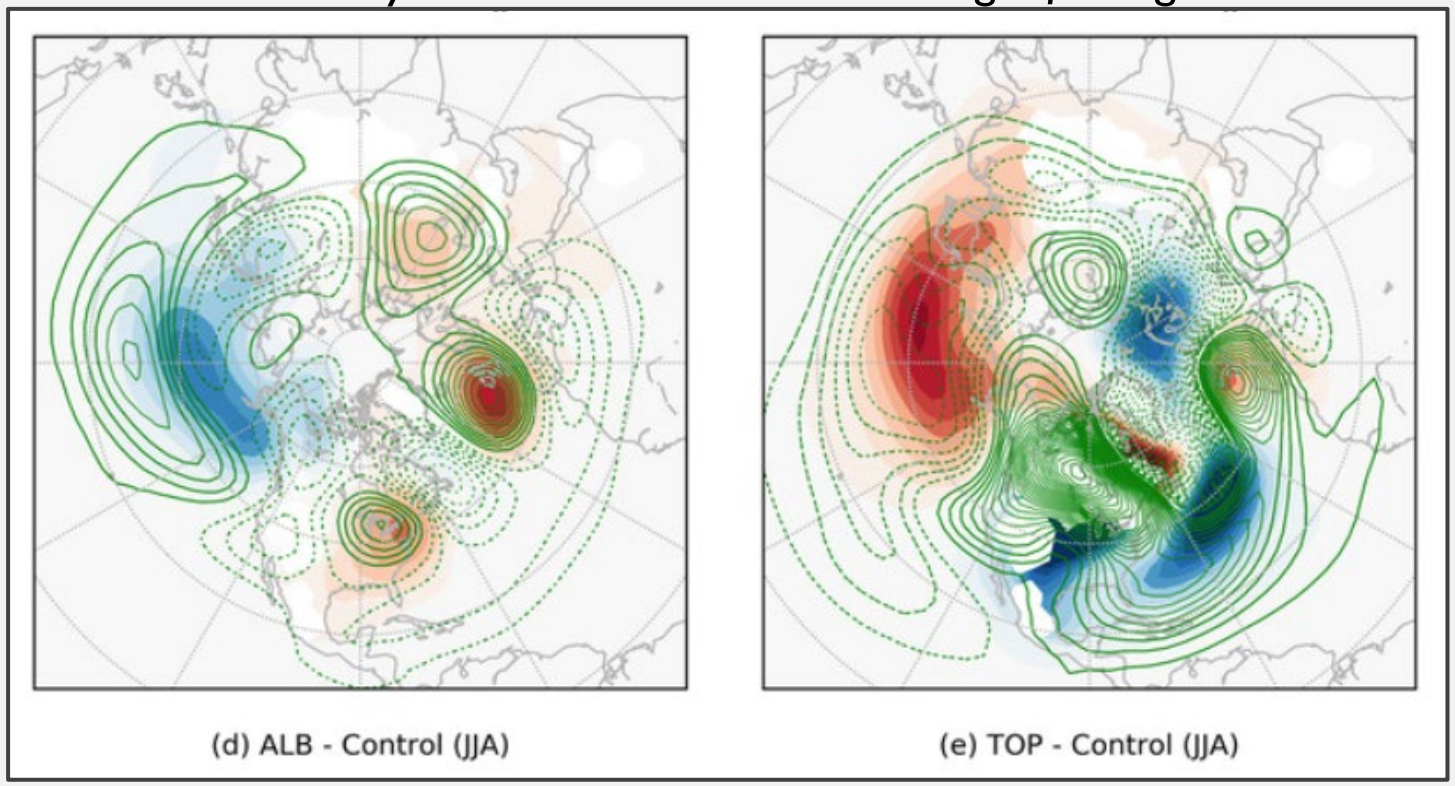
Proxies and models point to a wetter Southwest U.S. and drier Pacific Northwest during LGM

LGM HYDROCLIMATE



LGM HYDROCLIMATE

Summer stationary waves in LGM HadCM3 single forcing runs



Roberts et al. (2019)

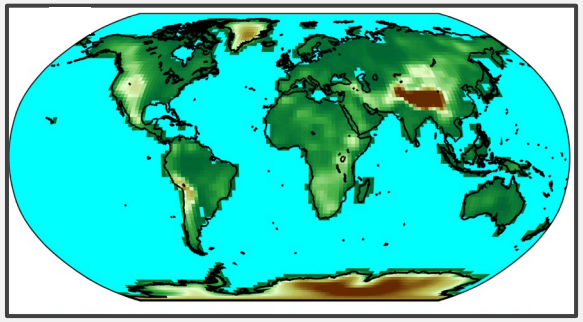
Research questions:

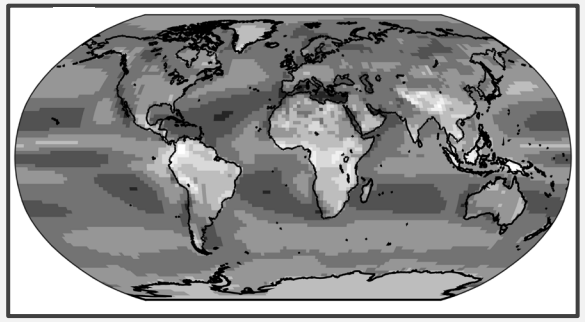
1. Mechanical (tall) vs thermodynamic (bright) influence of continental ice sheets on North American west coast hydroclimate?
   - Influence on North Pacific jet and downstream rainfall.
2. What role do air-sea interactions and/or ocean dynamics play in modulating that response?

CESM1 EXPERIMENTS

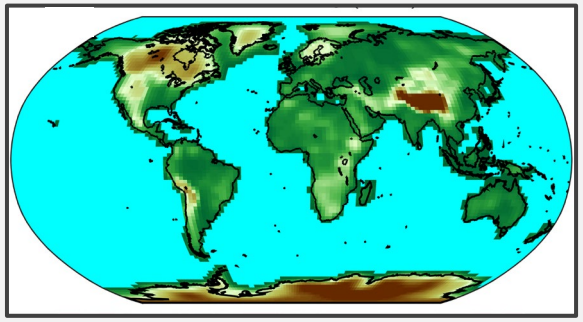
*See DiNezio et al. (2018) *Science Advances*, for complete model details

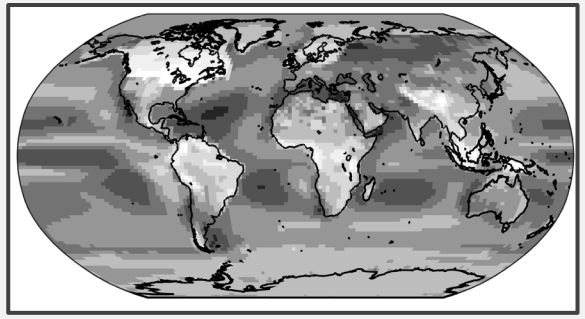
Pre-industrial Control (Ctl)

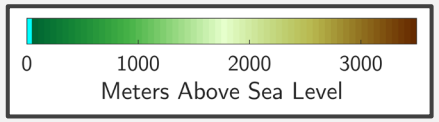




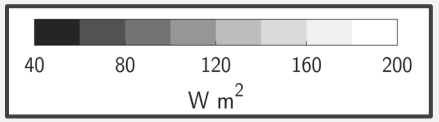
Full LGM Climate (LGM-Full)





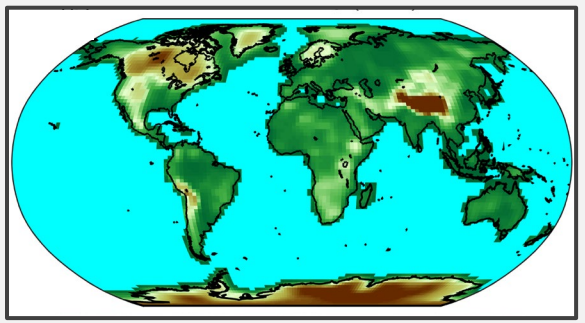


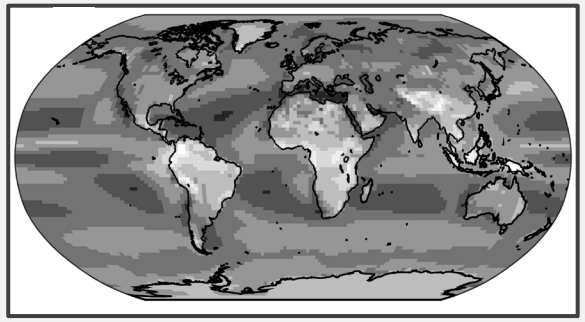
Surface Height



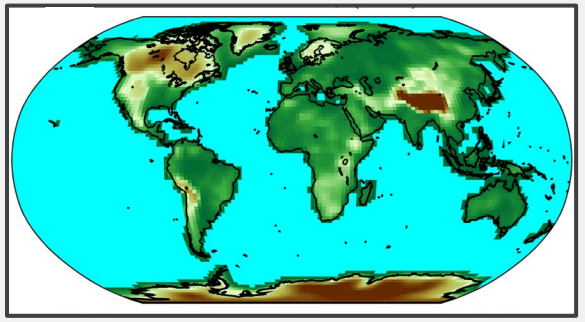
TOA Upward SW

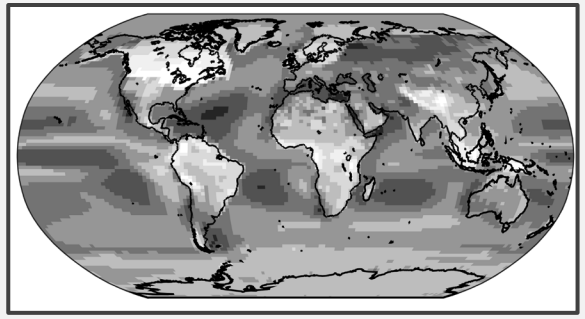
Green Mountain (GM; Mechanical forcing)

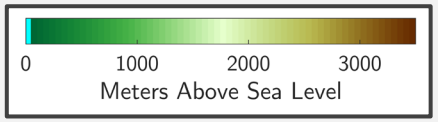




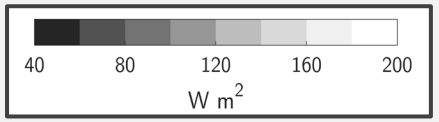
White Mountain (WM; Mech. + Therm. forcing)







Surface Height



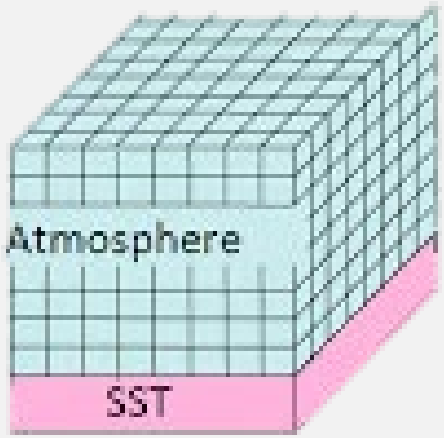
TOA Upward SW

CESM1 EXPERIMENTS

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

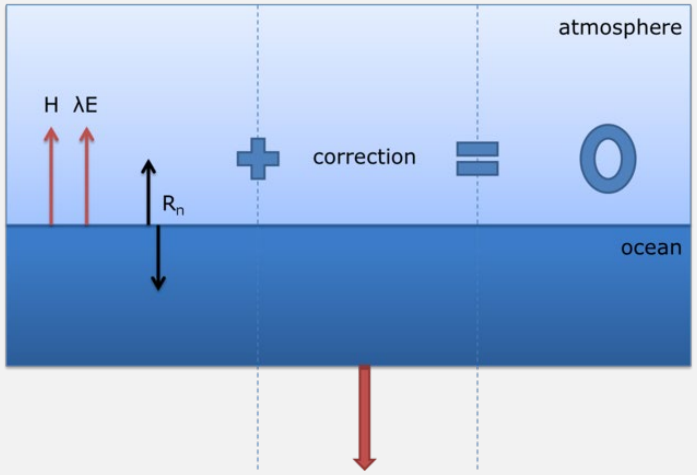
*All runs appropriately spun-up

AGCM-only



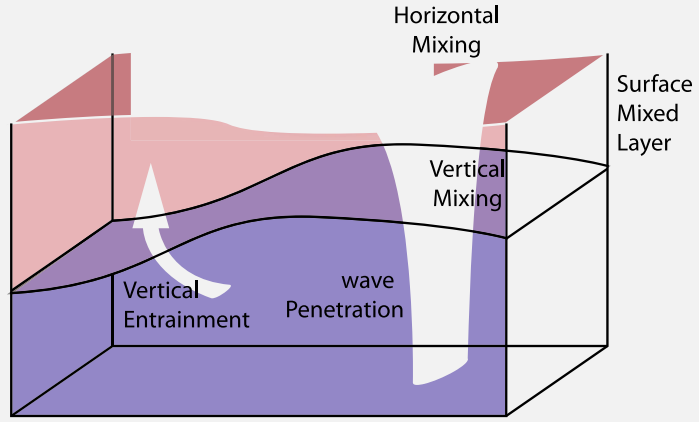
Forced at lower boundary by SSTs

Slab Ocean Model (SOM)



Interactive mixed layer with air-sea heat exchange

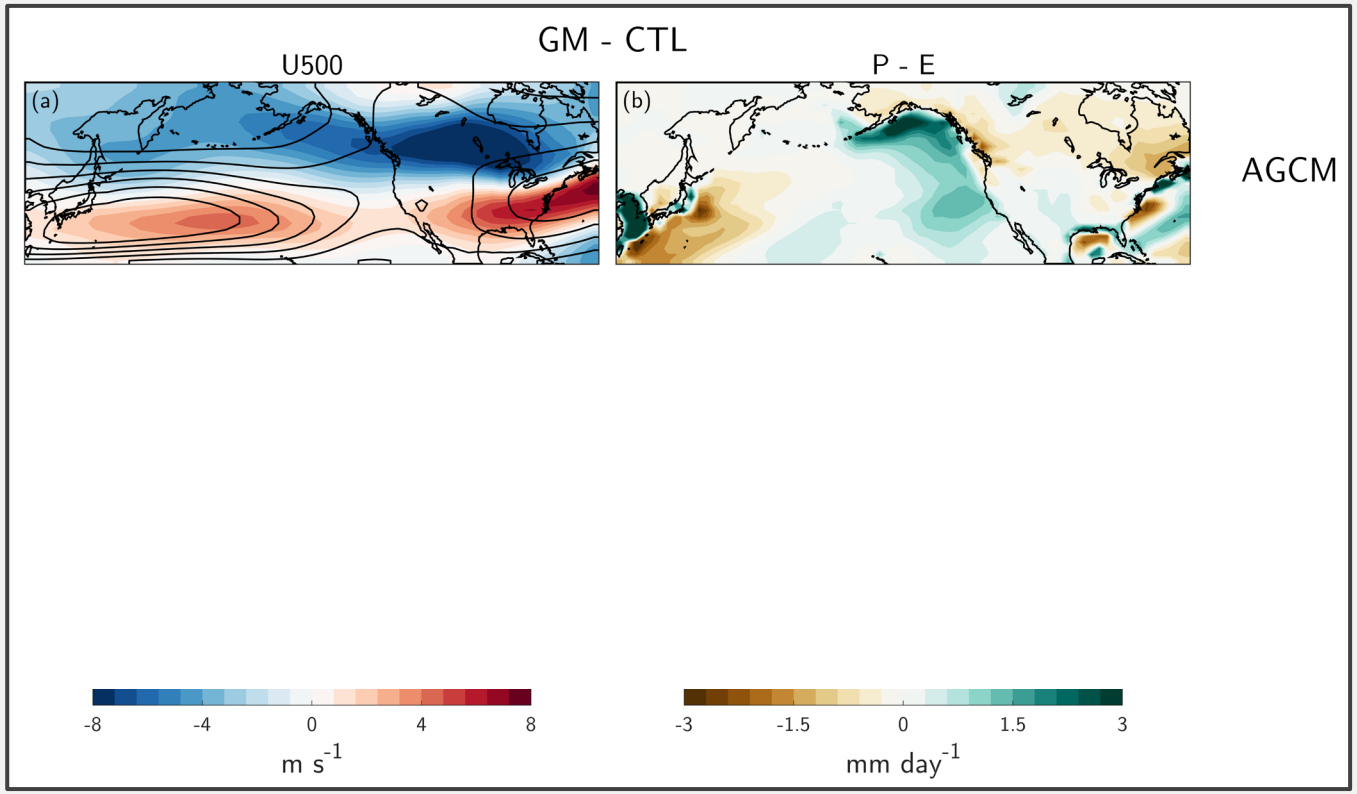
Dynamical Ocean Model (DOM)



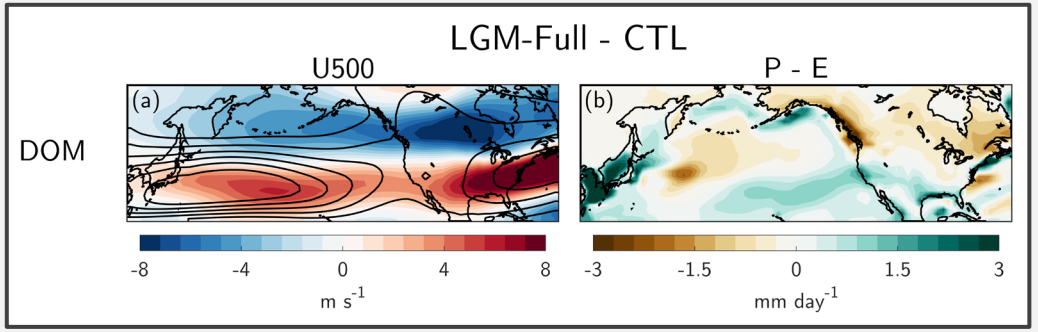
Fully dynamical ocean circulation

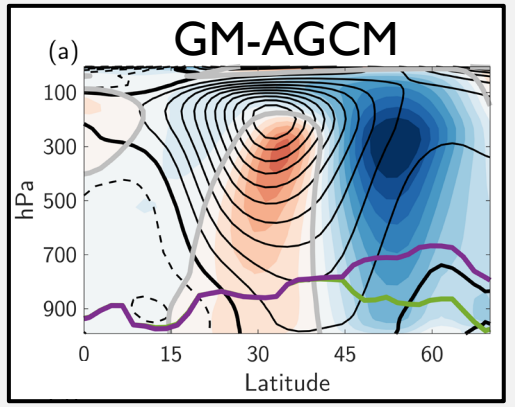
GREEN MOUNTAIN

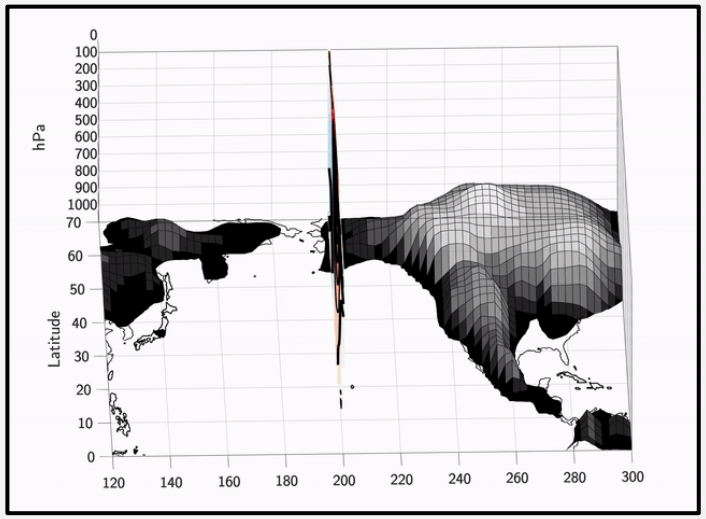
Mechanically forced shift of the N. Pacific jet, shift in west coast hydroclimate



Amaya et al. *in review*

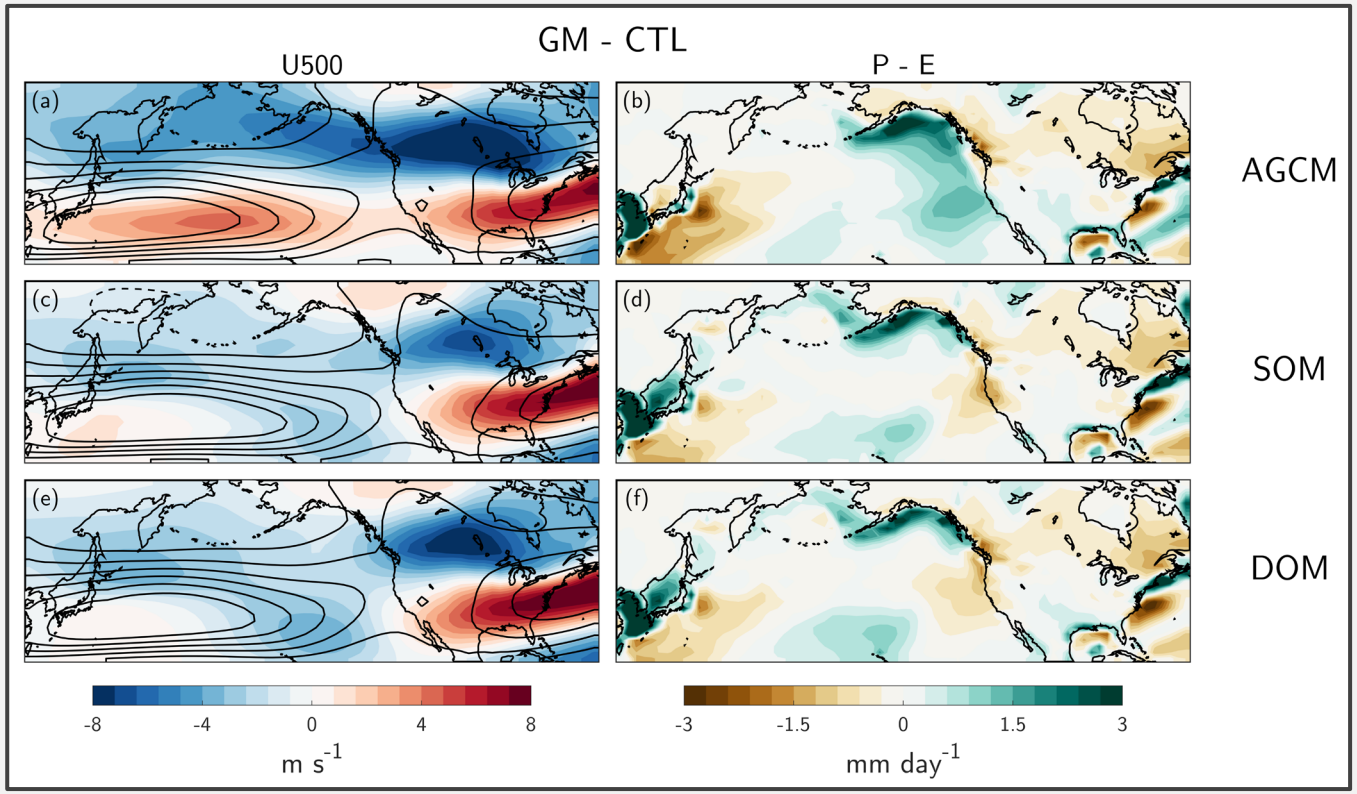


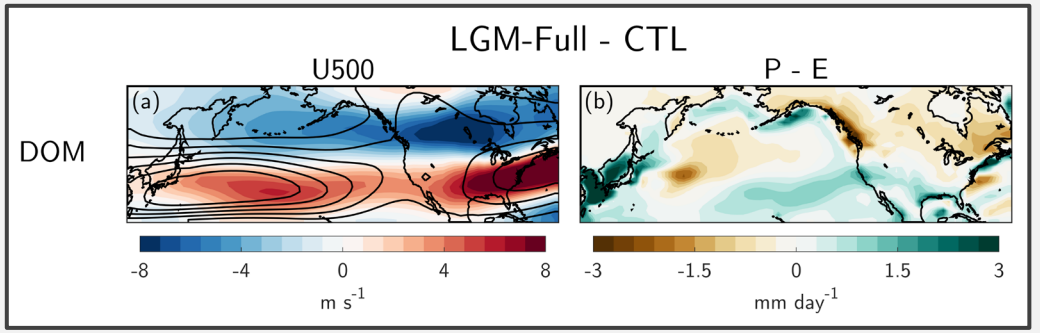


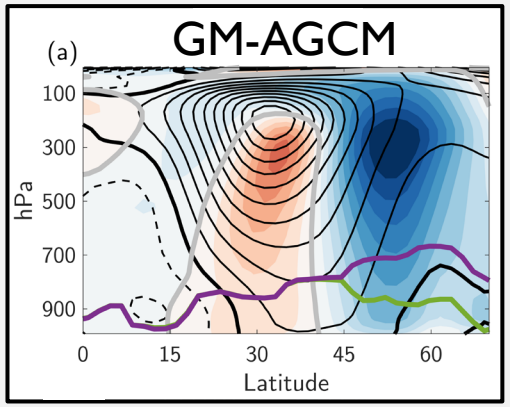


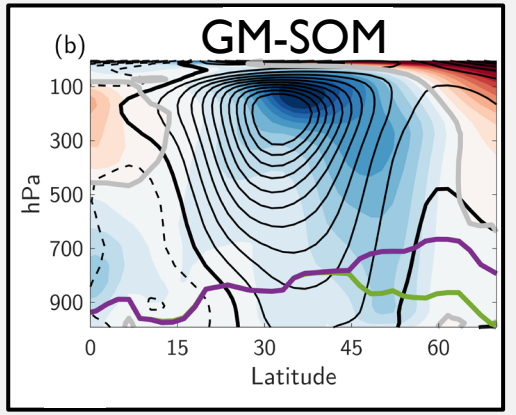
GREEN MOUNTAIN

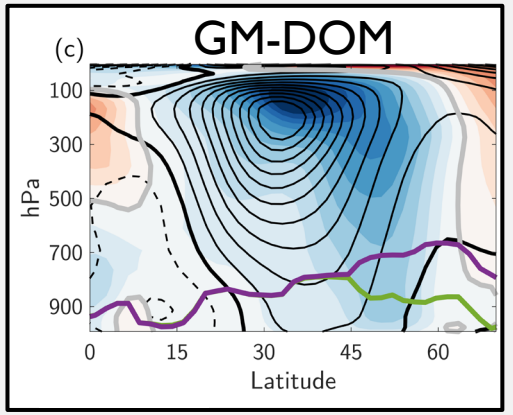
Including ocean-atmosphere interactions leads to opposite result







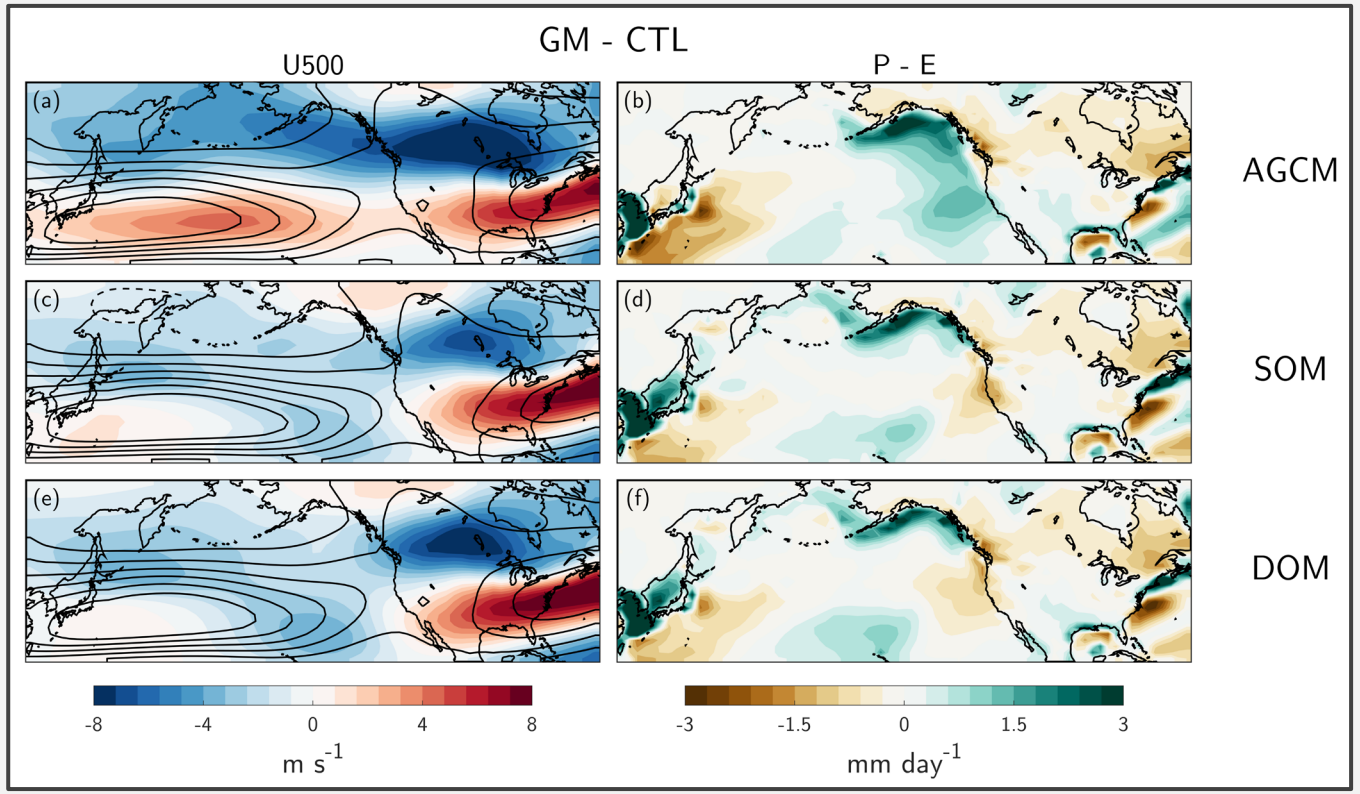




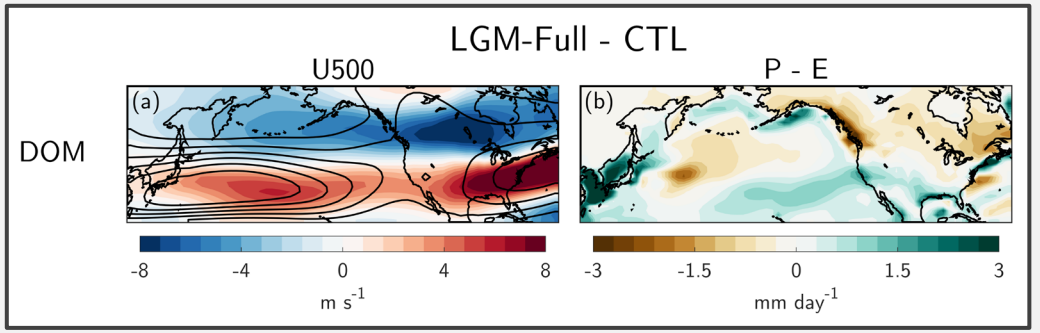
Amaya et al. *in review*

GREEN MOUNTAIN

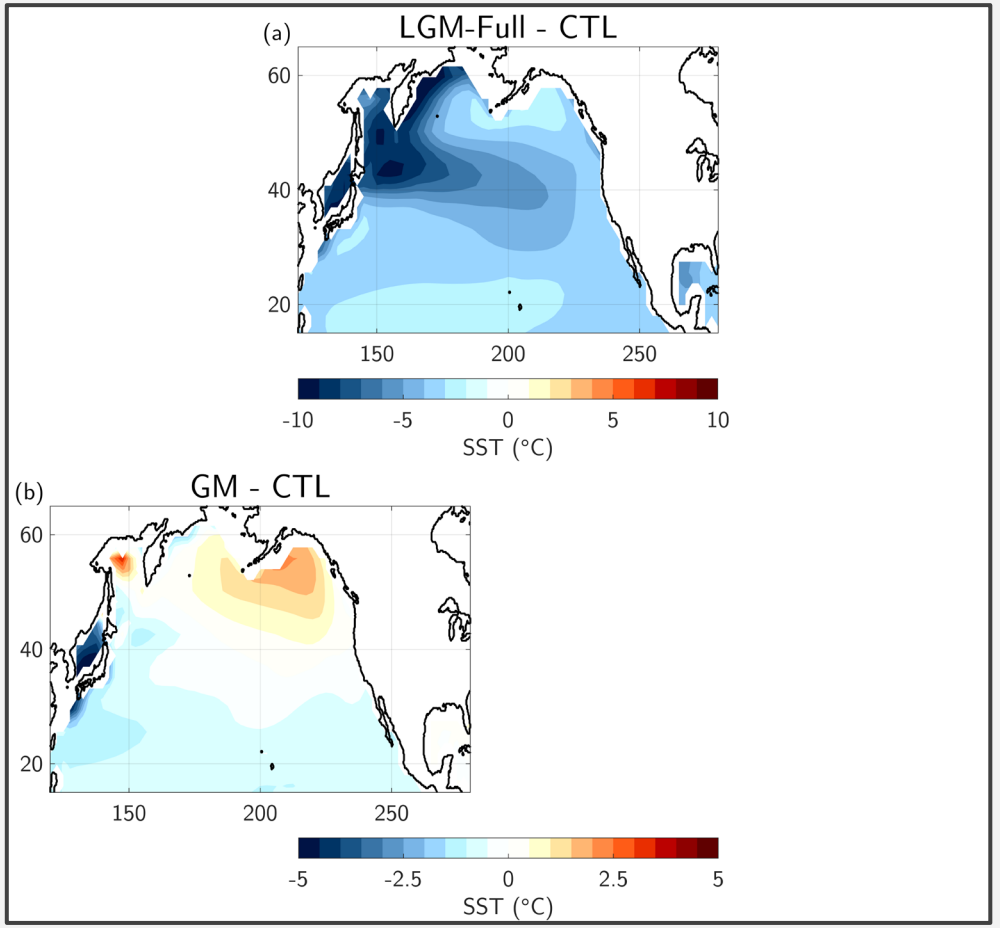
Including ocean-atmosphere interactions leads to opposite result



Amaya et al. *in review*

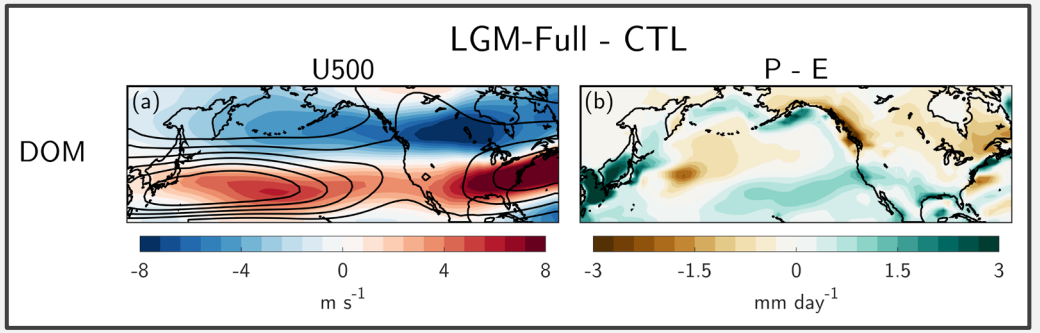


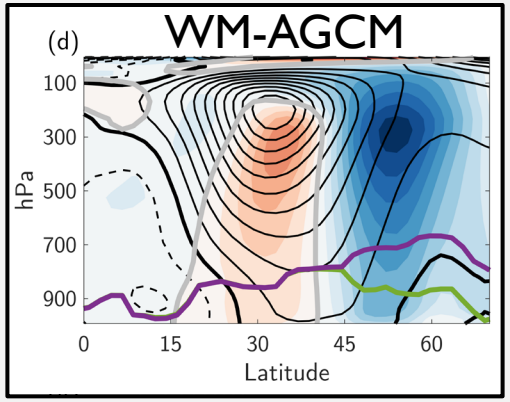
DOM SST response

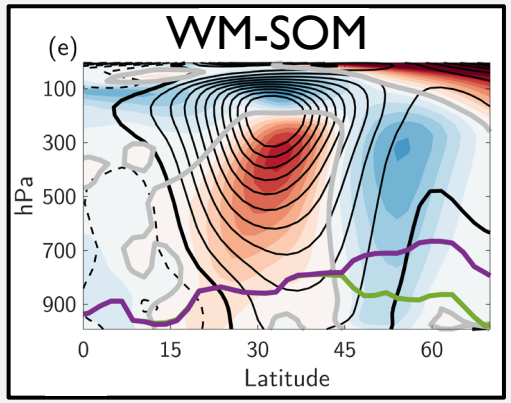


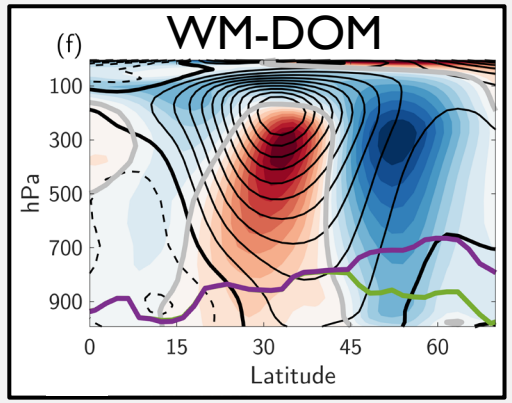
WHITE MOUNTAIN

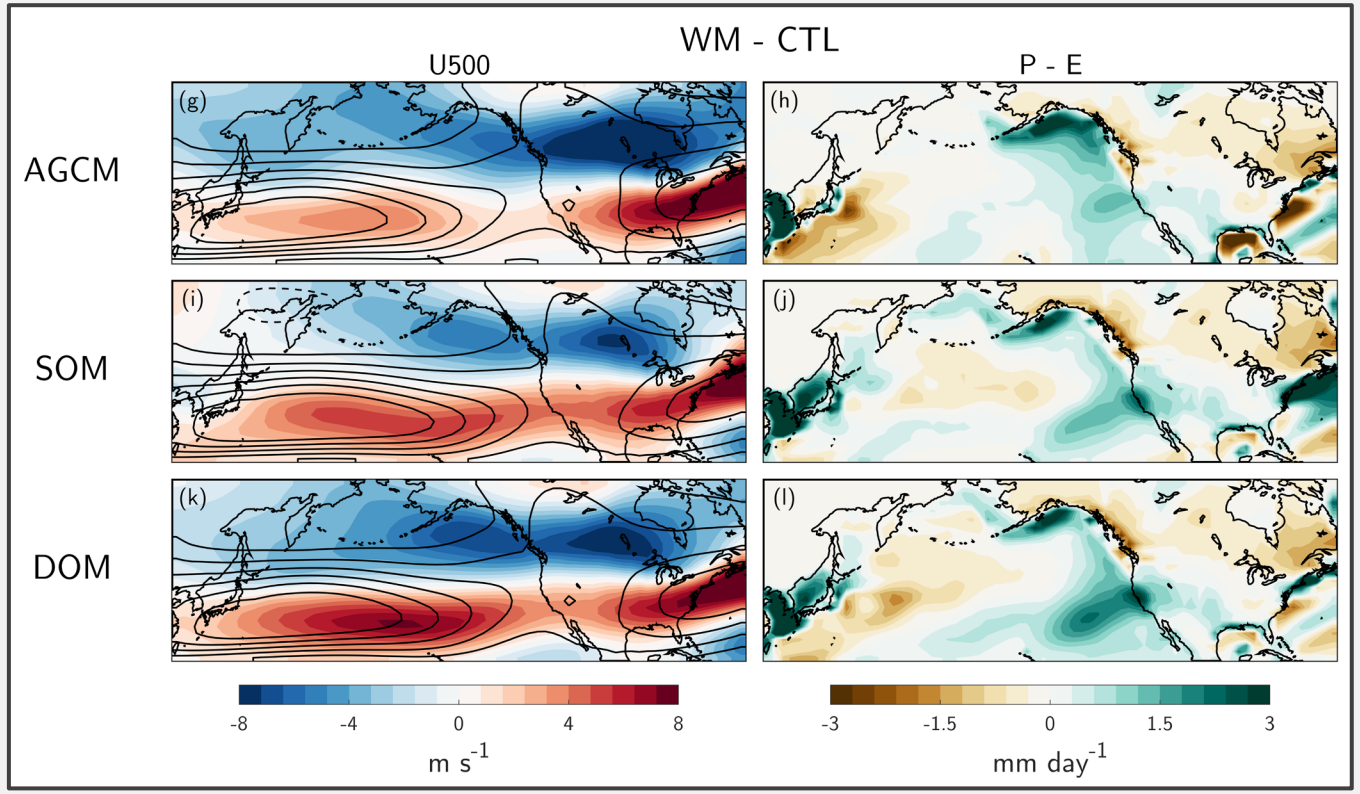
Mechanical + thermodynamic ice sheet effects reproduce LGM-Full







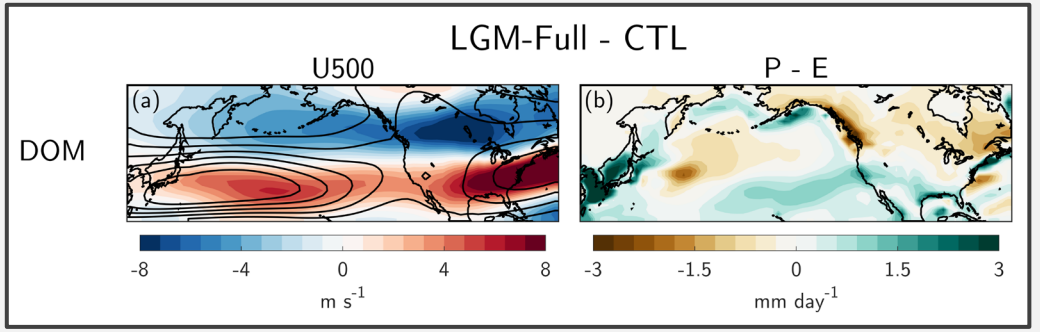


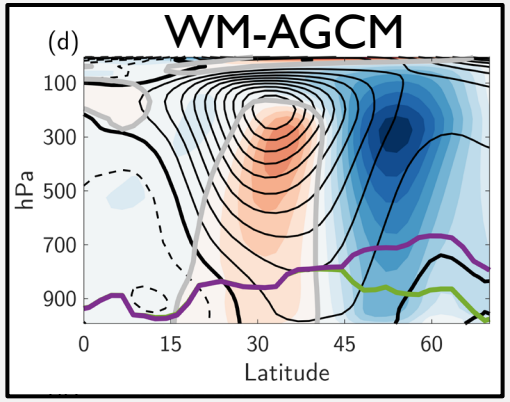


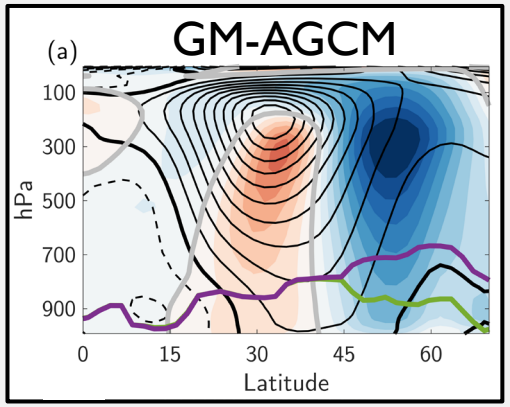
Amaya et al. *in review*

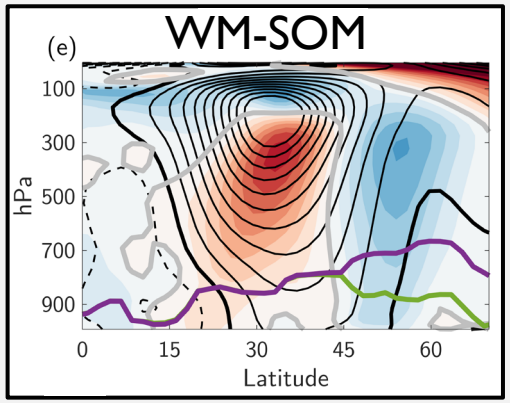
WHITE MOUNTAIN

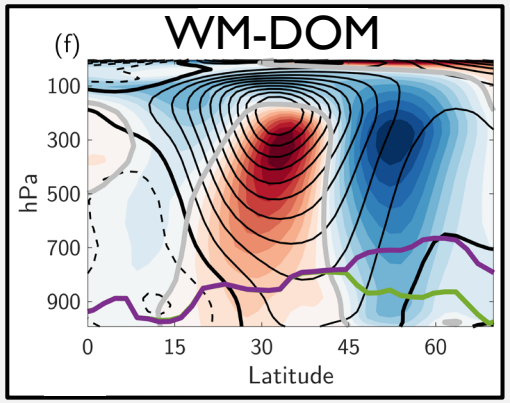
Thermodynamic forcing and subsequent air-sea interactions critical

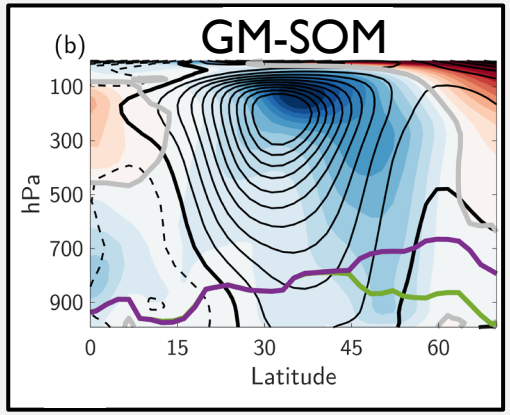


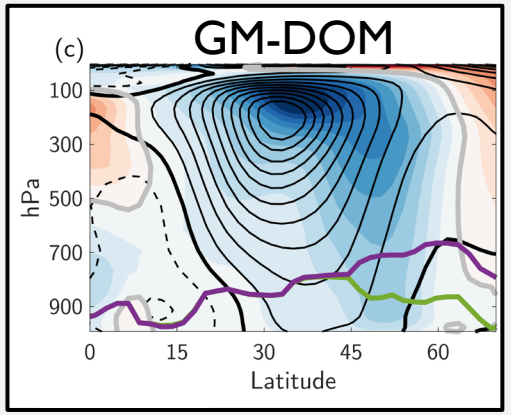








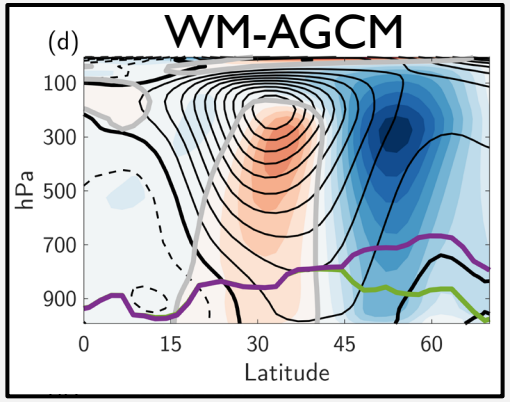


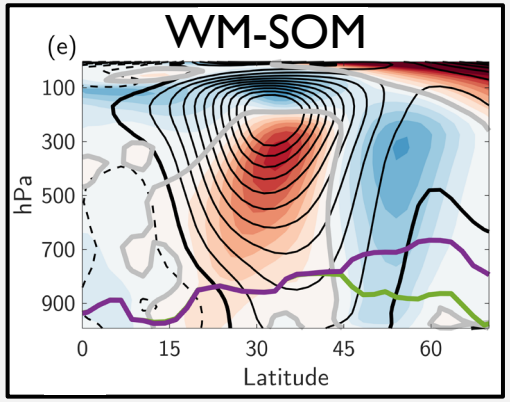


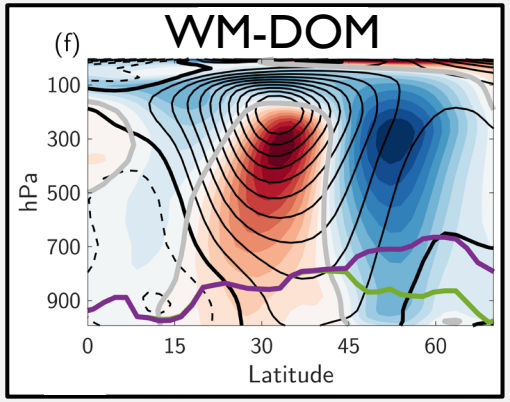
Amaya et al. *in review*

WHITE MOUNTAIN

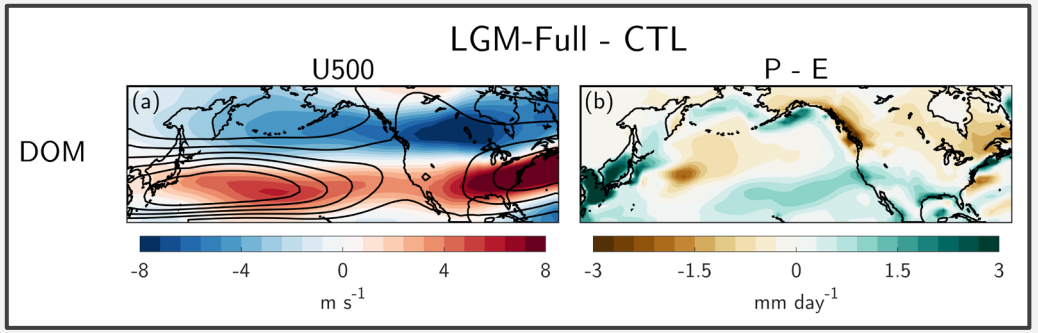
Thermodynamic forcing and subsequent air-sea interactions critical



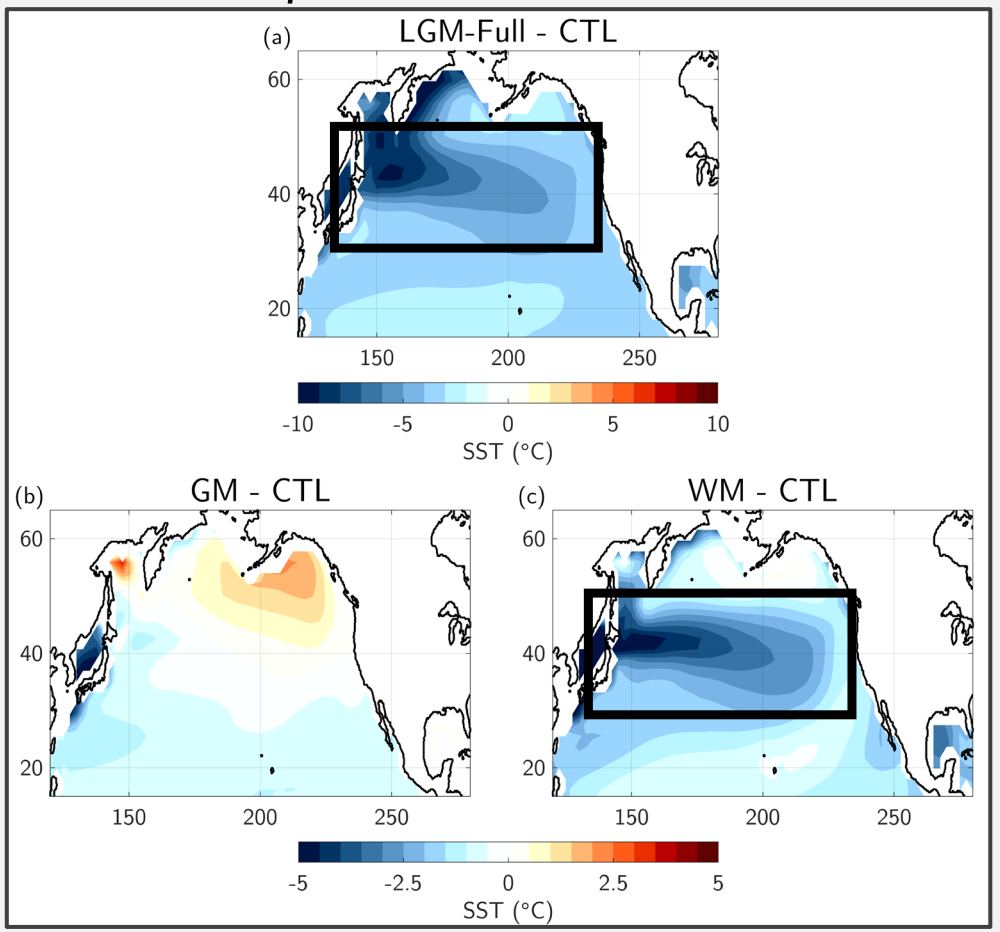




Amaya et al. *in review*



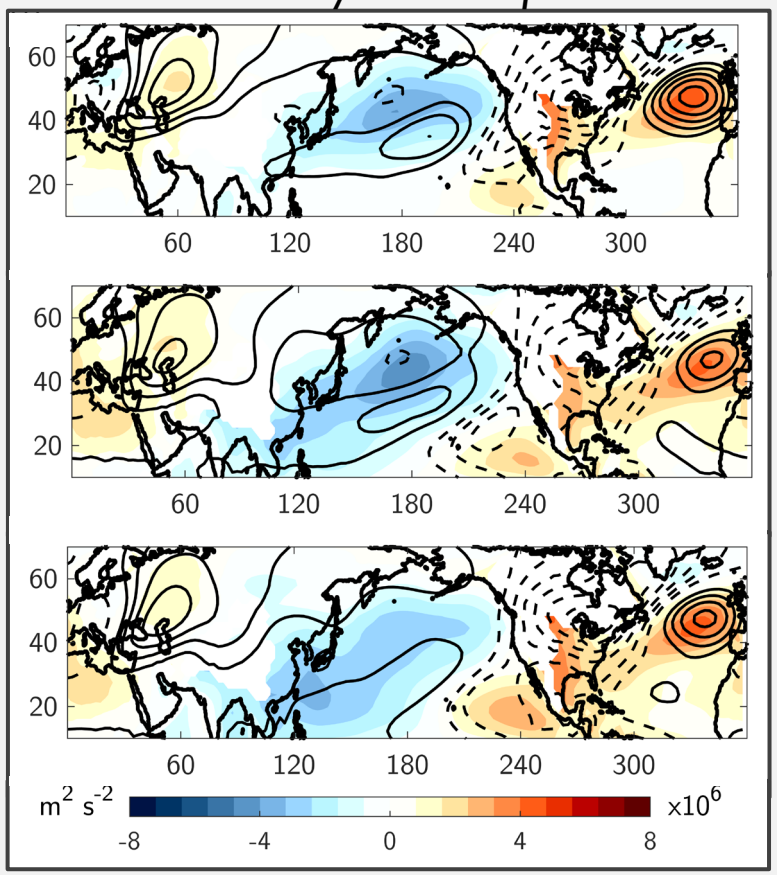
DOM SST response



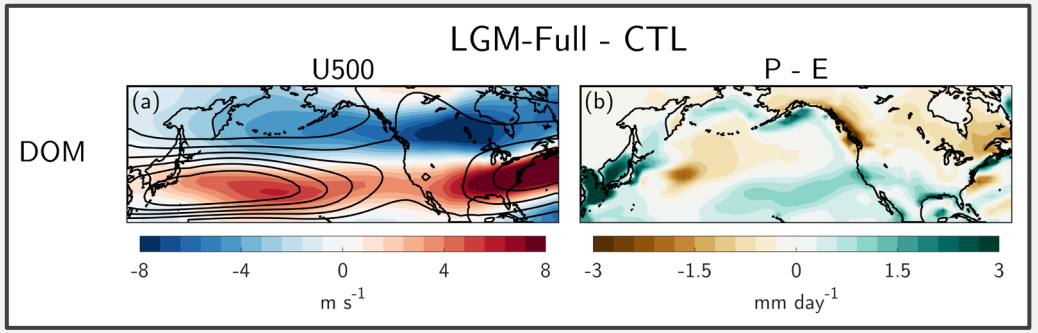
WHITE MOUNTAIN

Summer large-scale atmospheric circulation uncoupled from the ocean

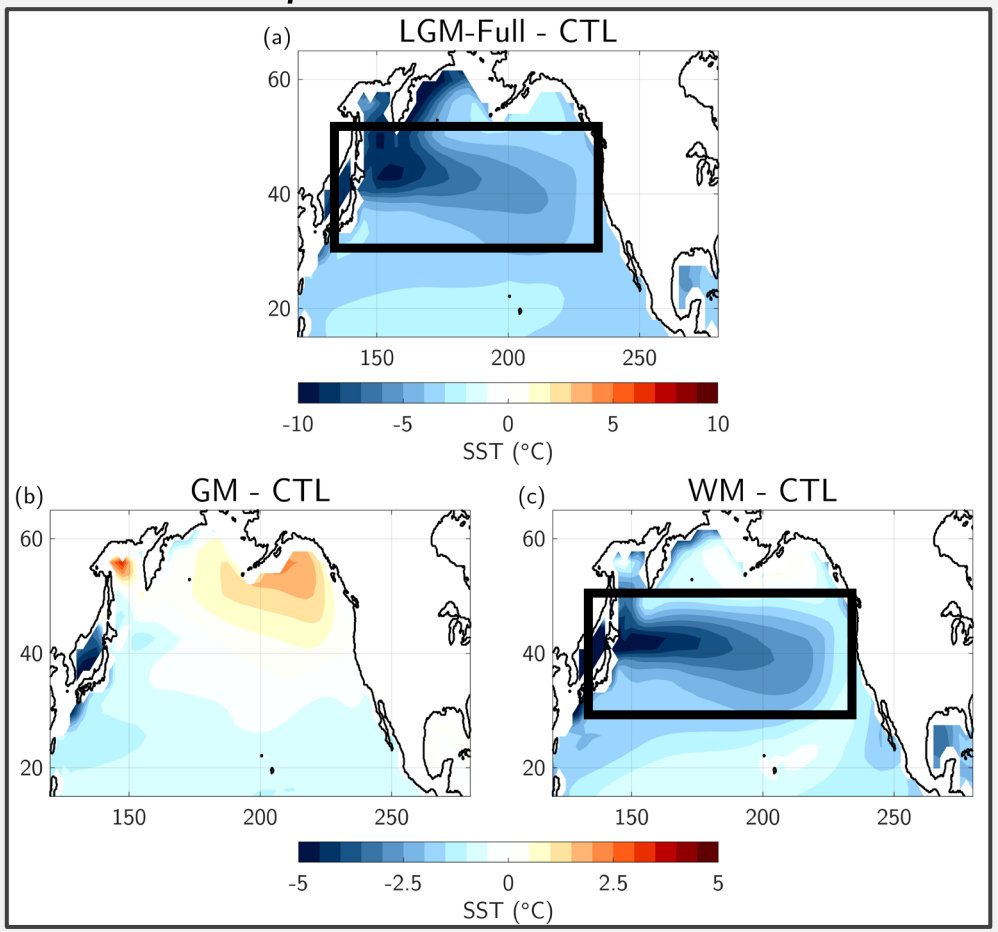
Summer stationary wave response



Shading: 850mb
Contours: 200mb

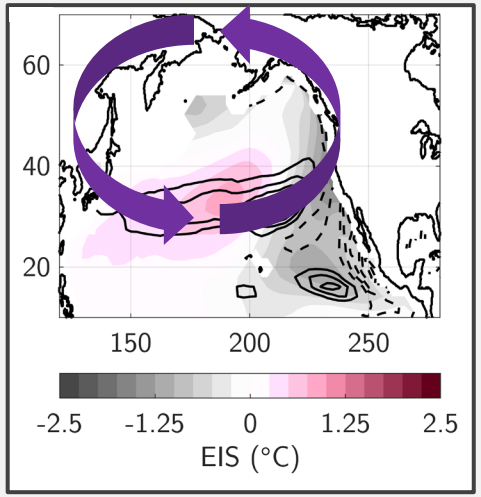


DOM SST response



WHITE MOUNTAIN

Estimated Inversion Strength (EIS)

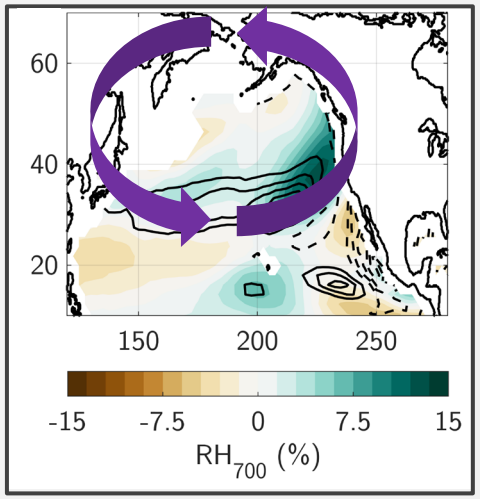


DOM

AGCM

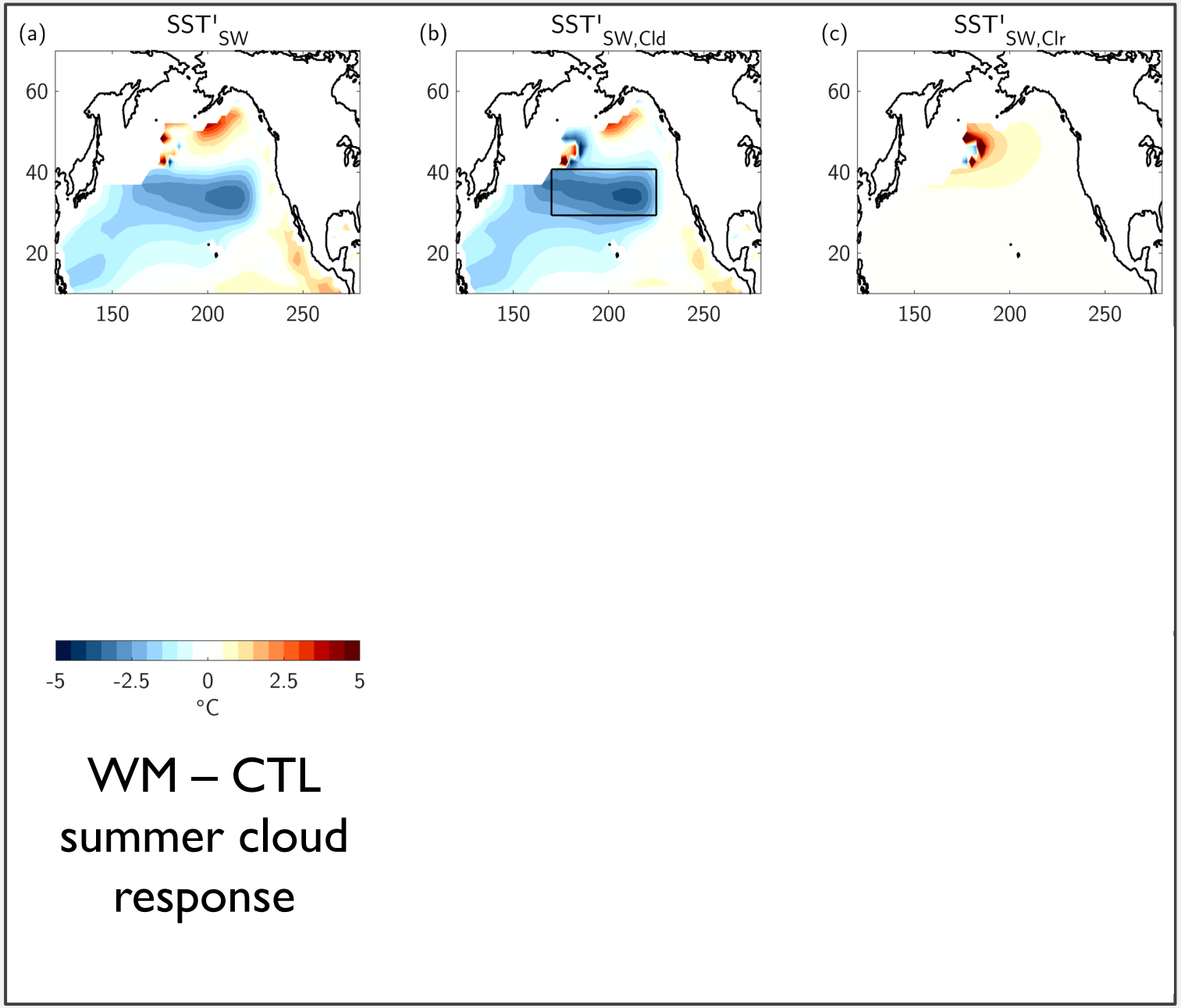
EIS > 0 = more stable

Relative Humidity at 700mb



Summertime low cloud ingredients WM-AGCM

SST anomalies implied by changes in shortwave

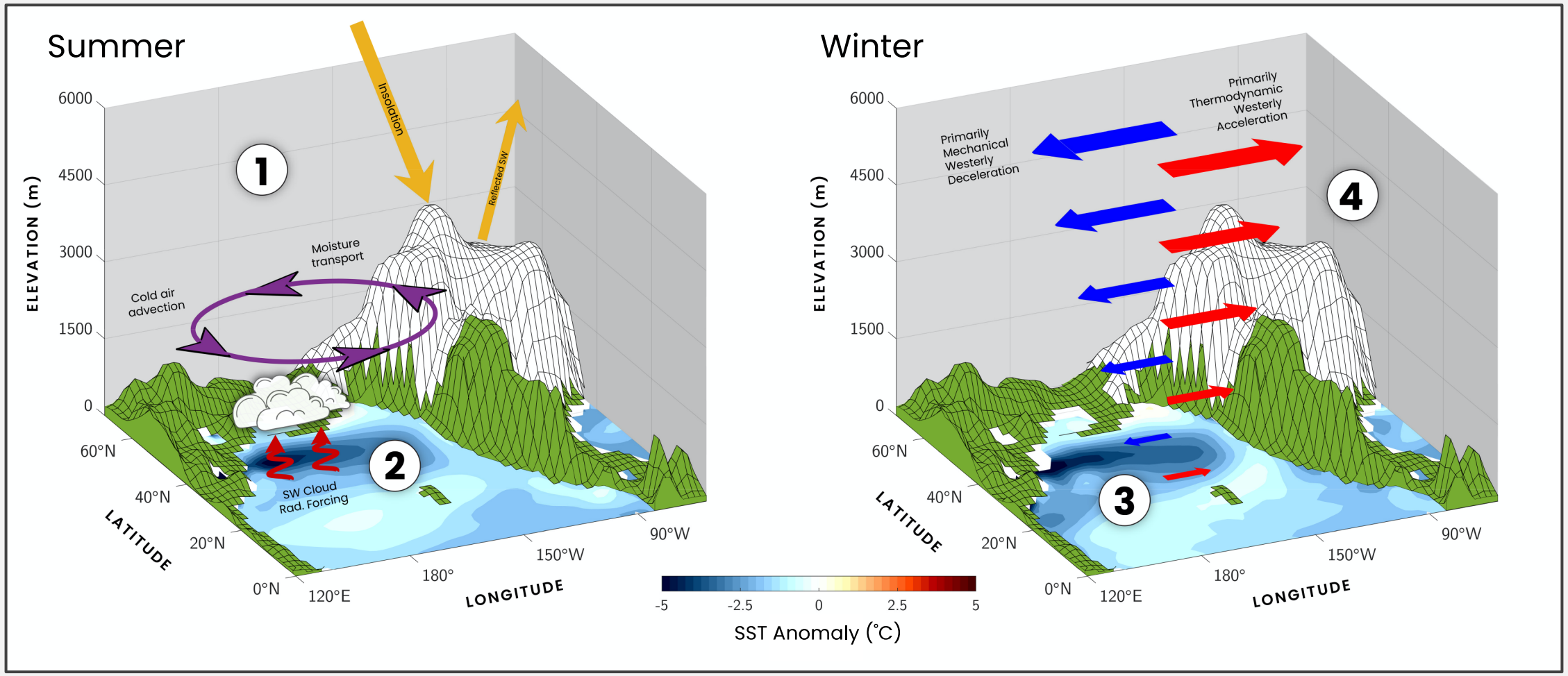


WM – CTL summer cloud response

SUMMARY

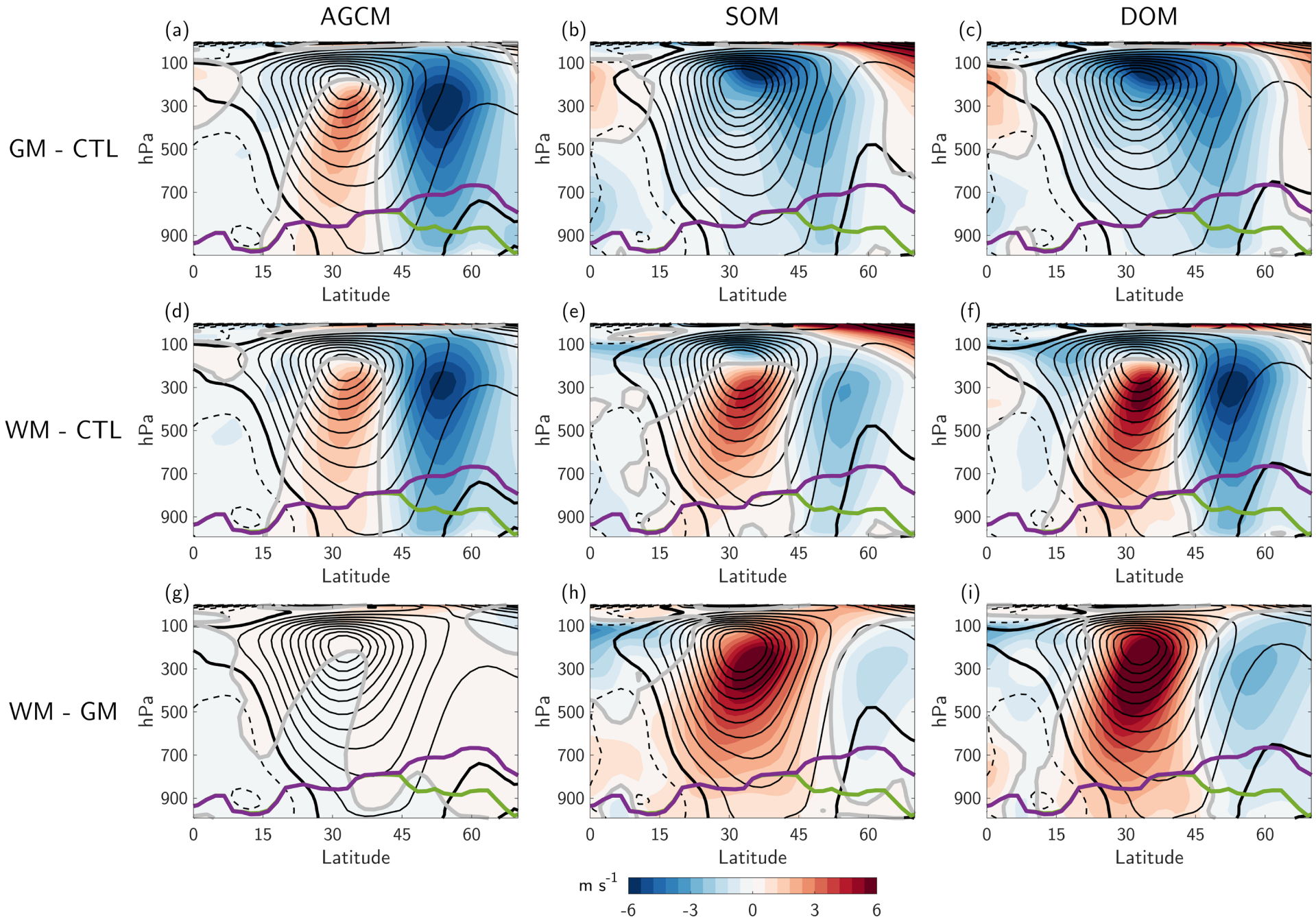
Email: dillon.amaya@colorado.edu

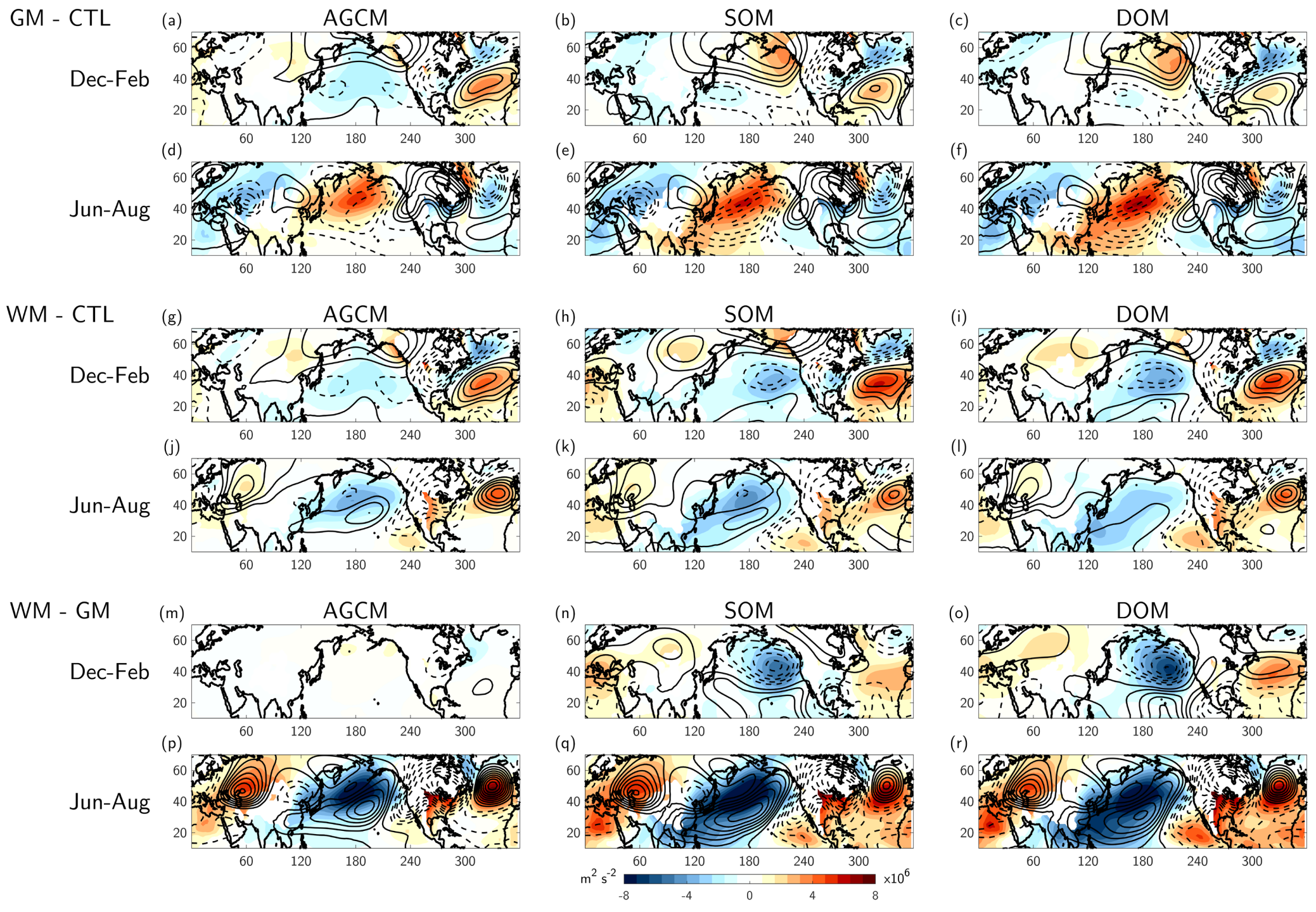
QUESTIONS?

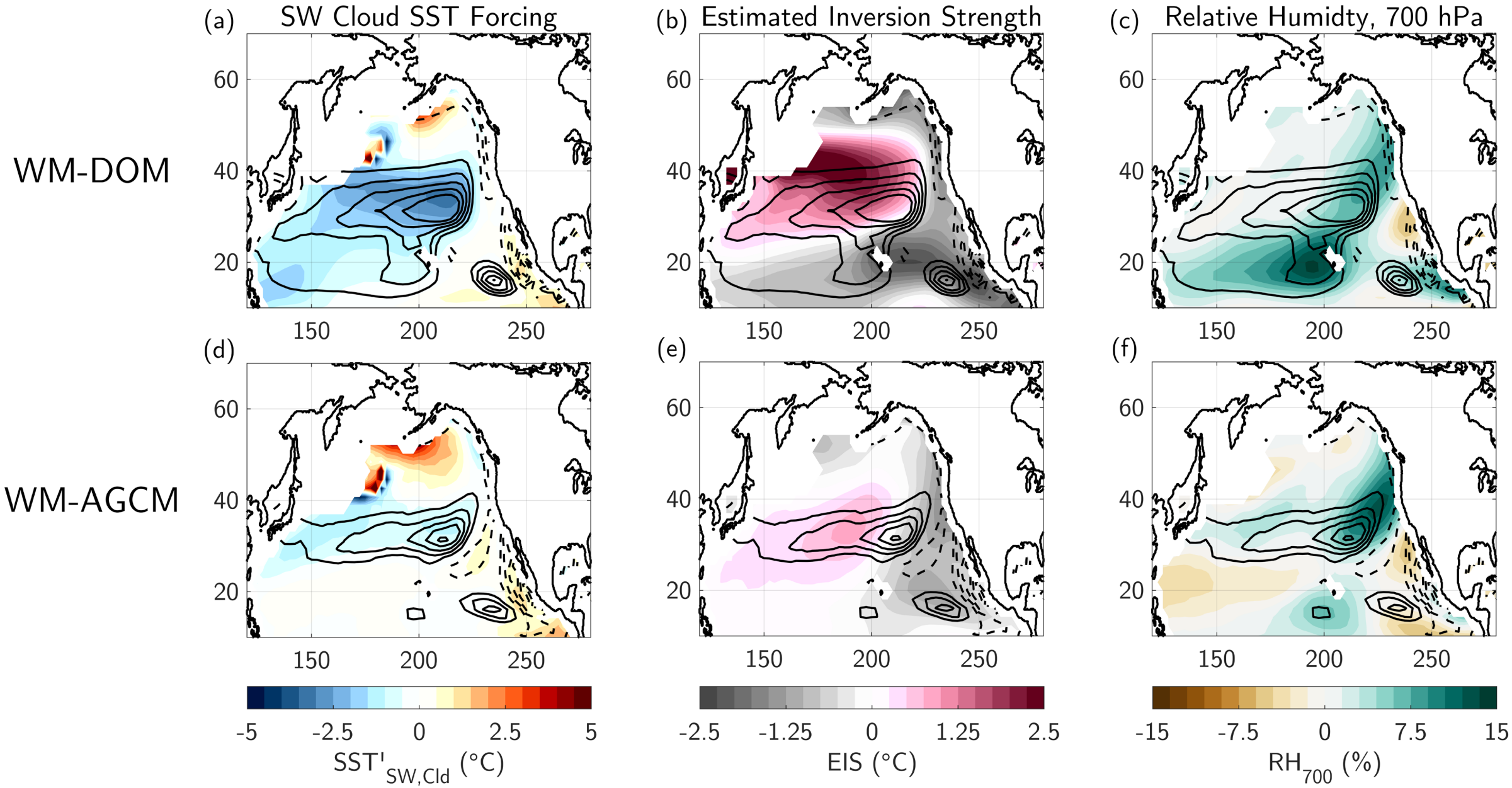


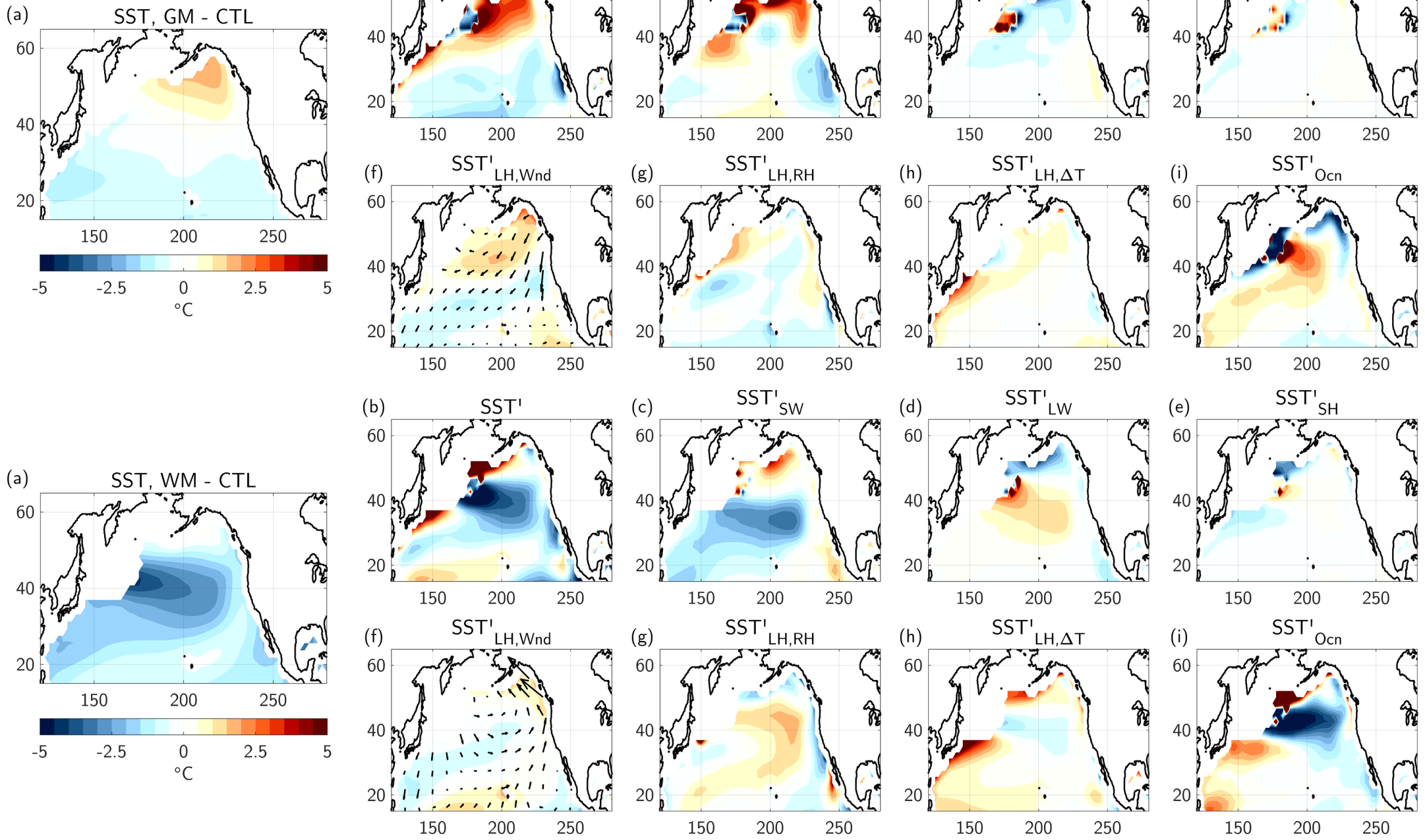
Amaya DJ, AM Seltzer, KB Karnauskas, JM Lora, X Zhang, and P DiNezio. Air-sea feedbacks shape North American hydroclimate response to ice sheets during the Last Glacial Maximum. *Under Review*. Pre-print at www.dillonamaya.com

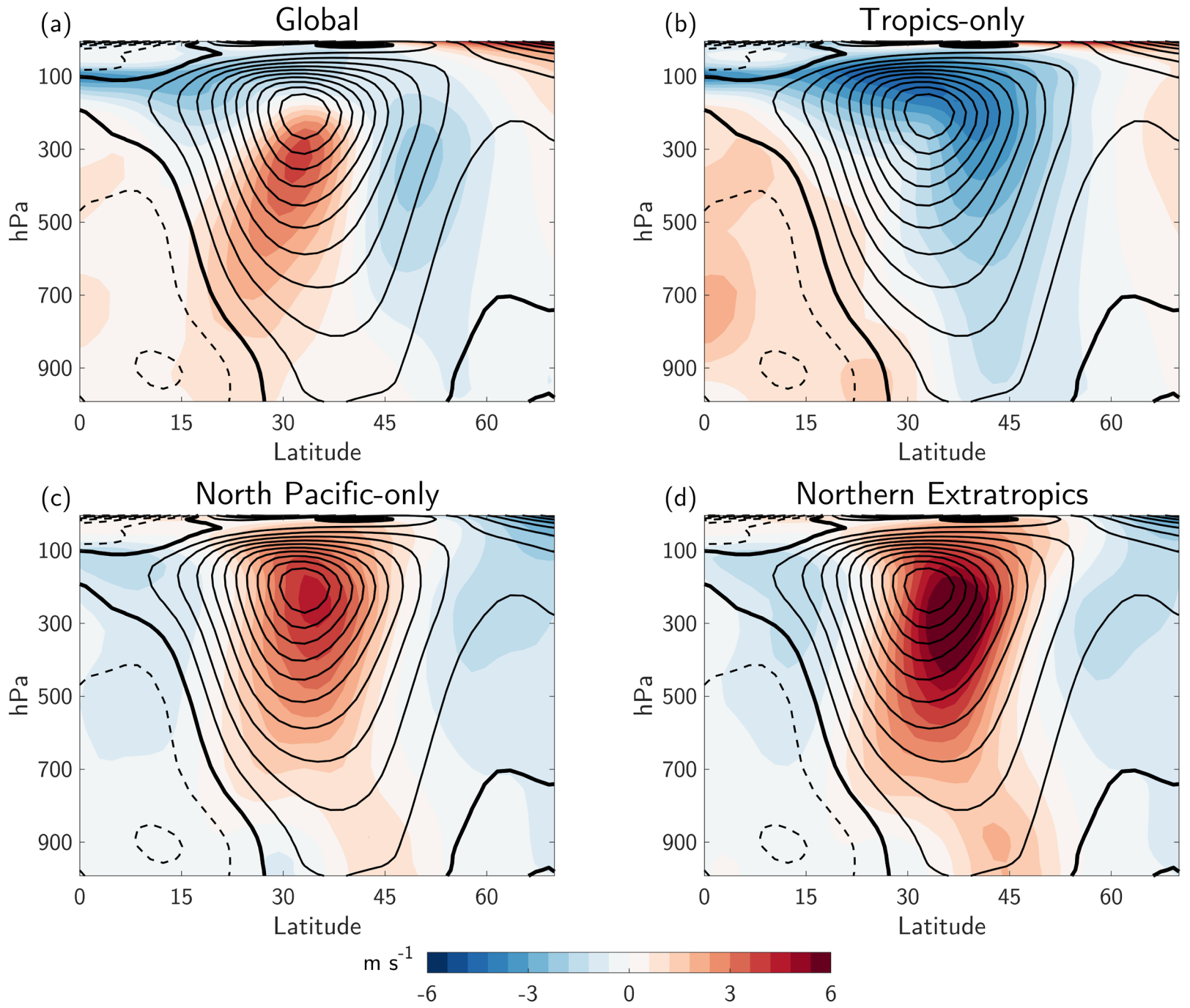
EXTRA SLIDES


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