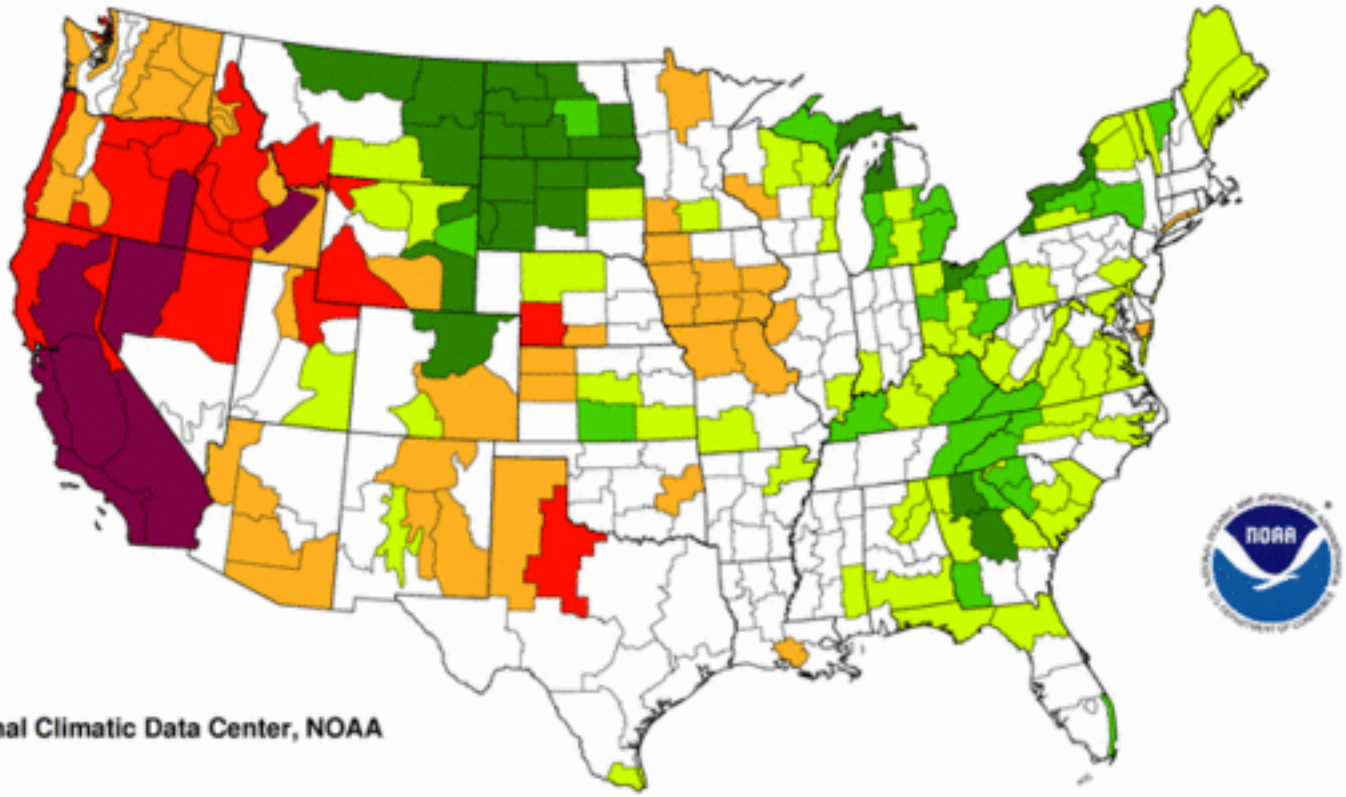
Were past warmings in the western US associated with drier conditions? A paleo-model-data comparison

Corinne I Wong[1], Gerald L. Potter[2], Isabel P. Montanez[1], Bette L. Otto-Bliesner[3], Pat Behling[4], Jessica L. Oster[5]

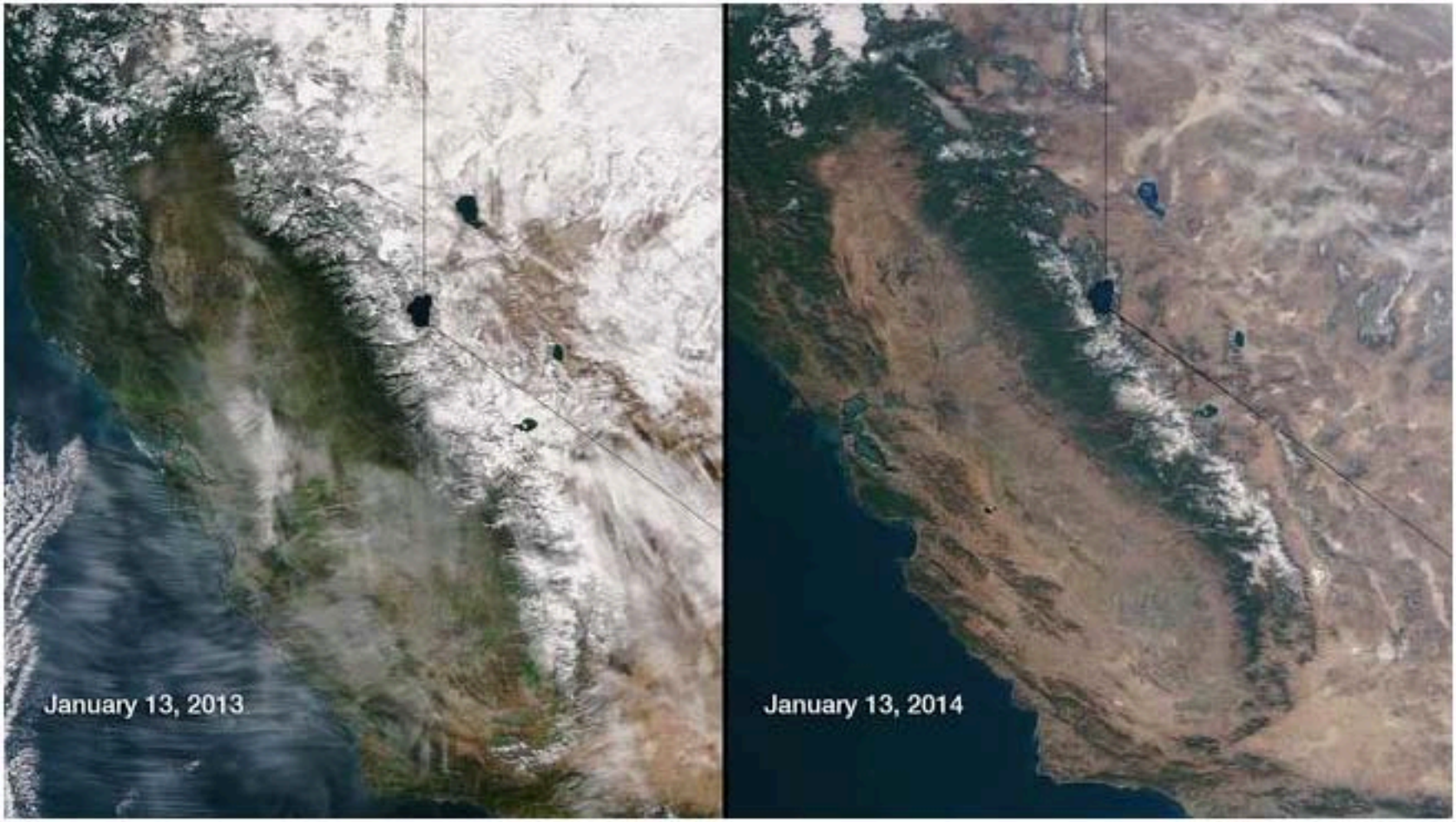
[1]UC Davis, [2]NASA, [3]NCAR, [4]Univ. Wisconsin, [5]Vanderbuilt Univ.

Palmer Drought Severity Index
January, 2014



National Climatic Data Center, NOAA

extreme drought	severe drought	moderate drought	mid–range	moderately moist	very moist	extremely moist
–4.00 and below	–3.00 to –3.99	–2.00 to –2.99	–1.99 to +1.99	+2.00 to +2.99	+3.00 to +3.99	+4.00 and above

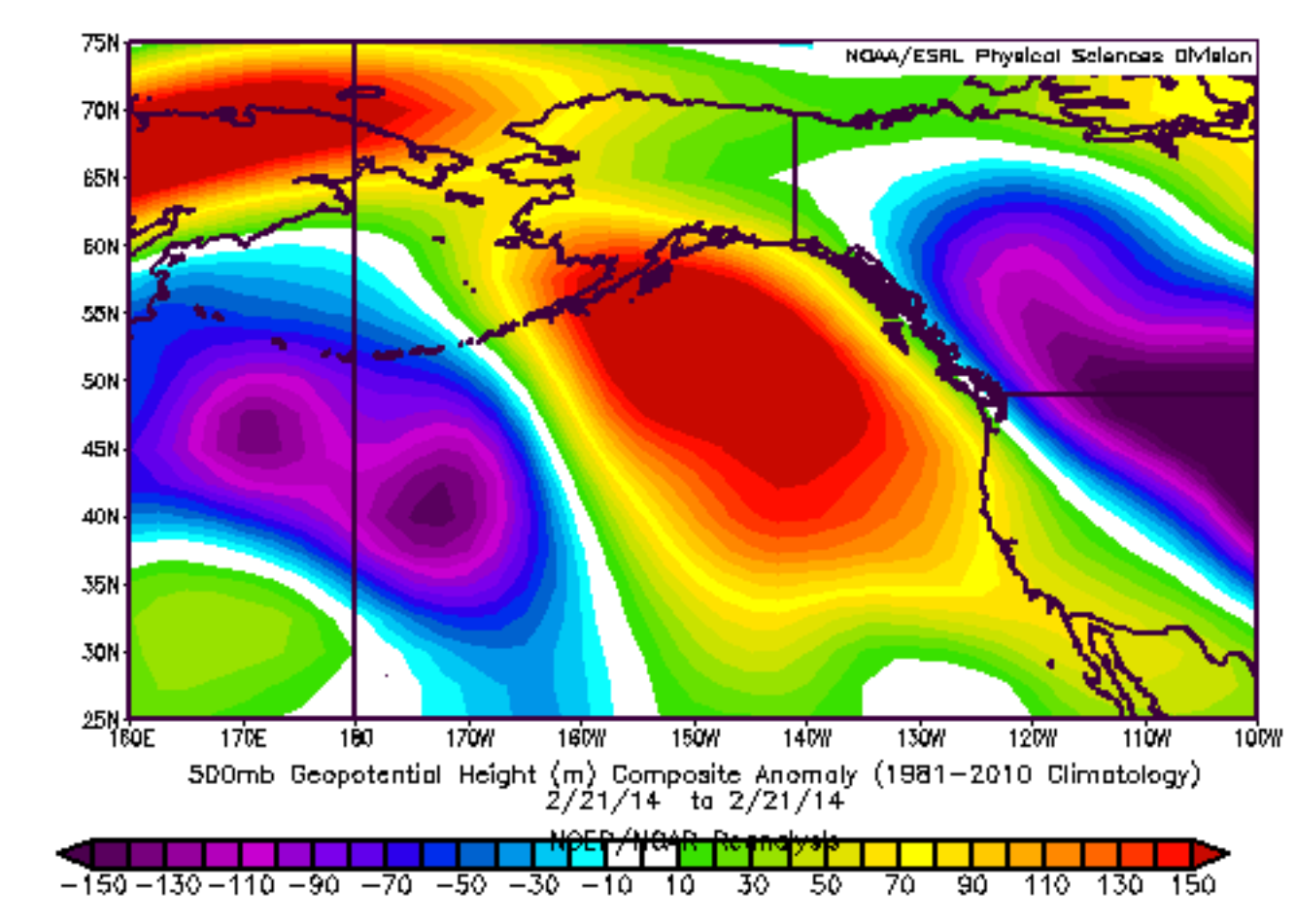


NOAA

The drought in California as seen from space. The lack of snow at Lake Tahoe and in the Sierras is pronounced.

NBC BAY AREA

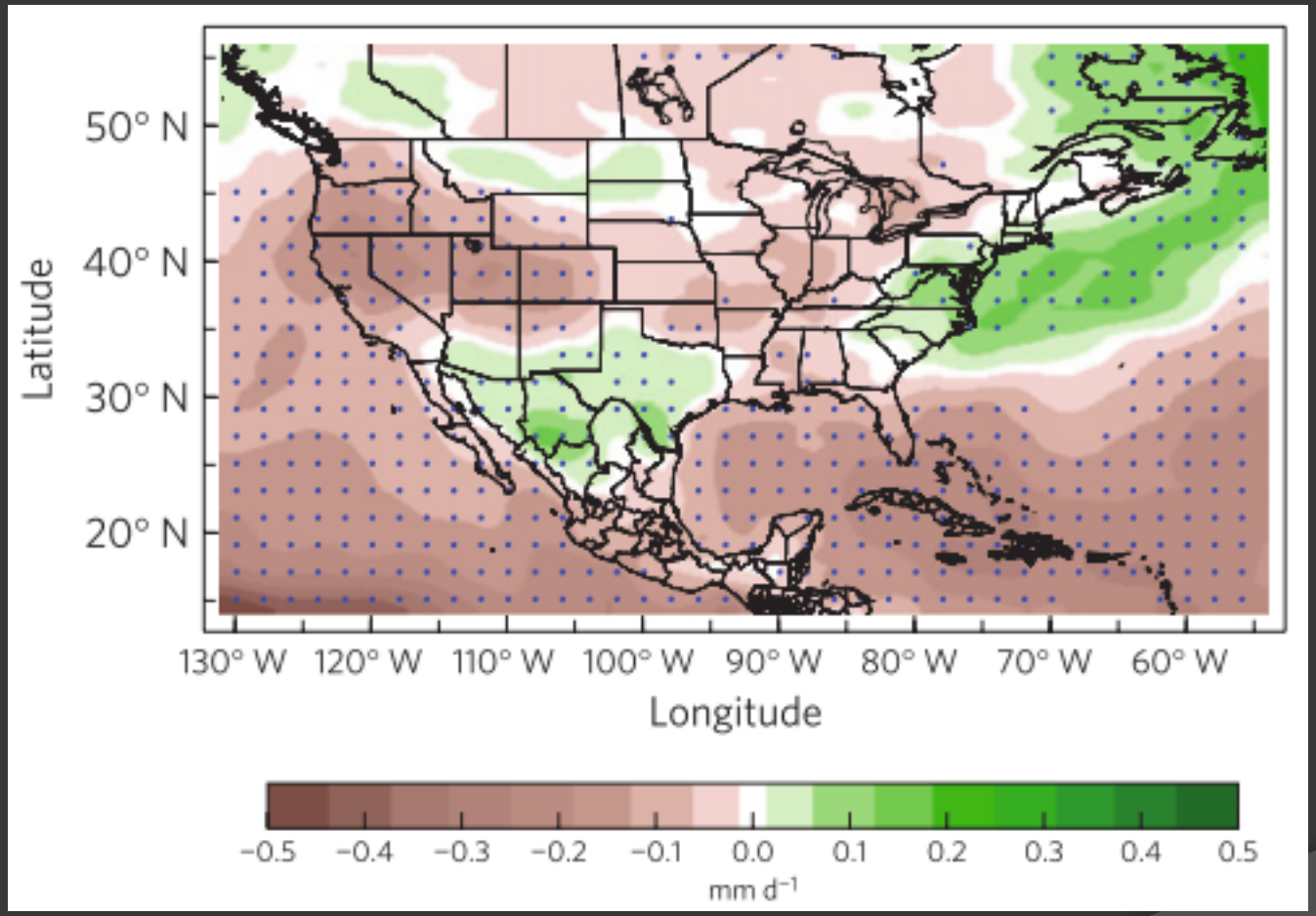
Ridiculously Resilient Ridge



California Weather Blog

brought to you by Weather West

Forecasted declines in water availability



Average AMJ change in P-E for 2021-2040 minus 1951-2000 across CMIP5 models

Seager et al., 2012

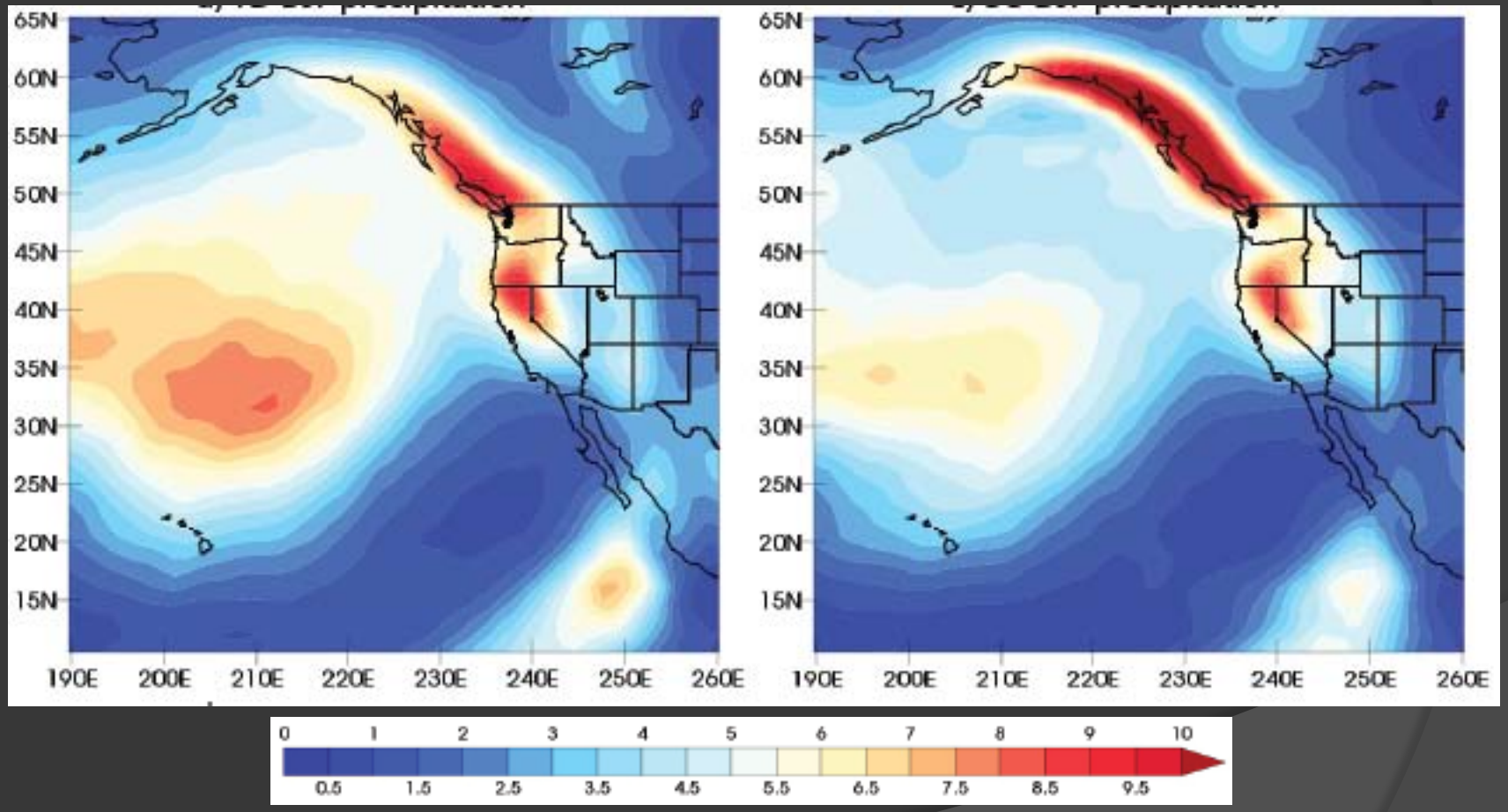
Research Question

- What climate processes control the response of precipitation to changes in temperature?
- Reconstruction of moisture conditions from distinct warm and cool intervals
- Paleoclimate modeling to test hypotheses about teleconnections

Paleoclimate model approach

Younger Dryas Cold Stadial

Bølling Warm Interstadial



DJF precipitation (mm/d)

Key results

- Intensification of winter storm track during Younger Dryas
- No support for existing hypothesis
  - Shift of westerlies
  - Tropical moisture source
- Northward expansion of storm track during Bølling

Outline

- What teleconnections link N. Atlantic temperature to western US moisture conditions?
- Model approach
- Results
  - Intensification of storm track under cool conditions
  - Northward expansion of storm under warm conditions
  - Variable North Pacific High but no evidence for tropical moisture source

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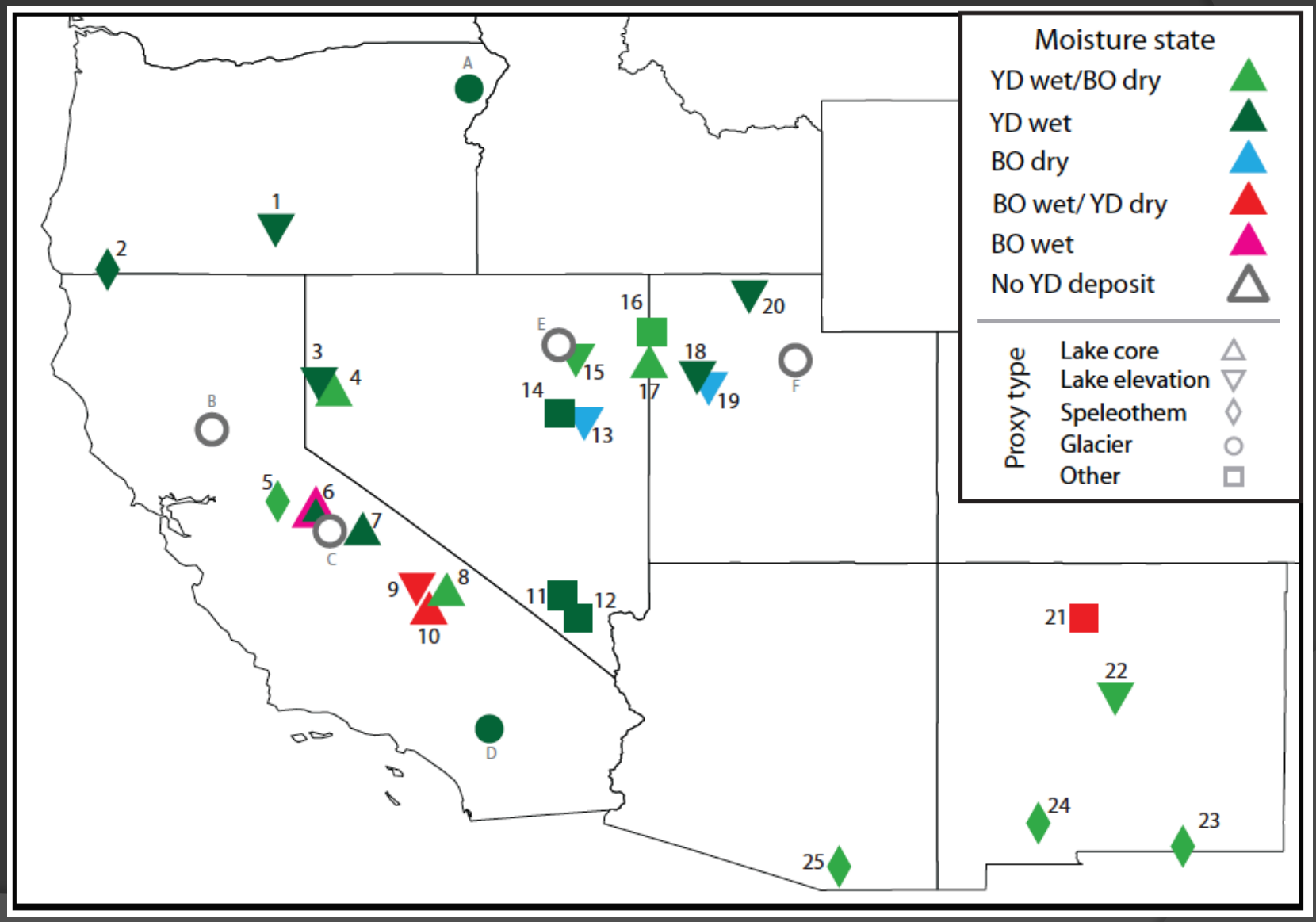
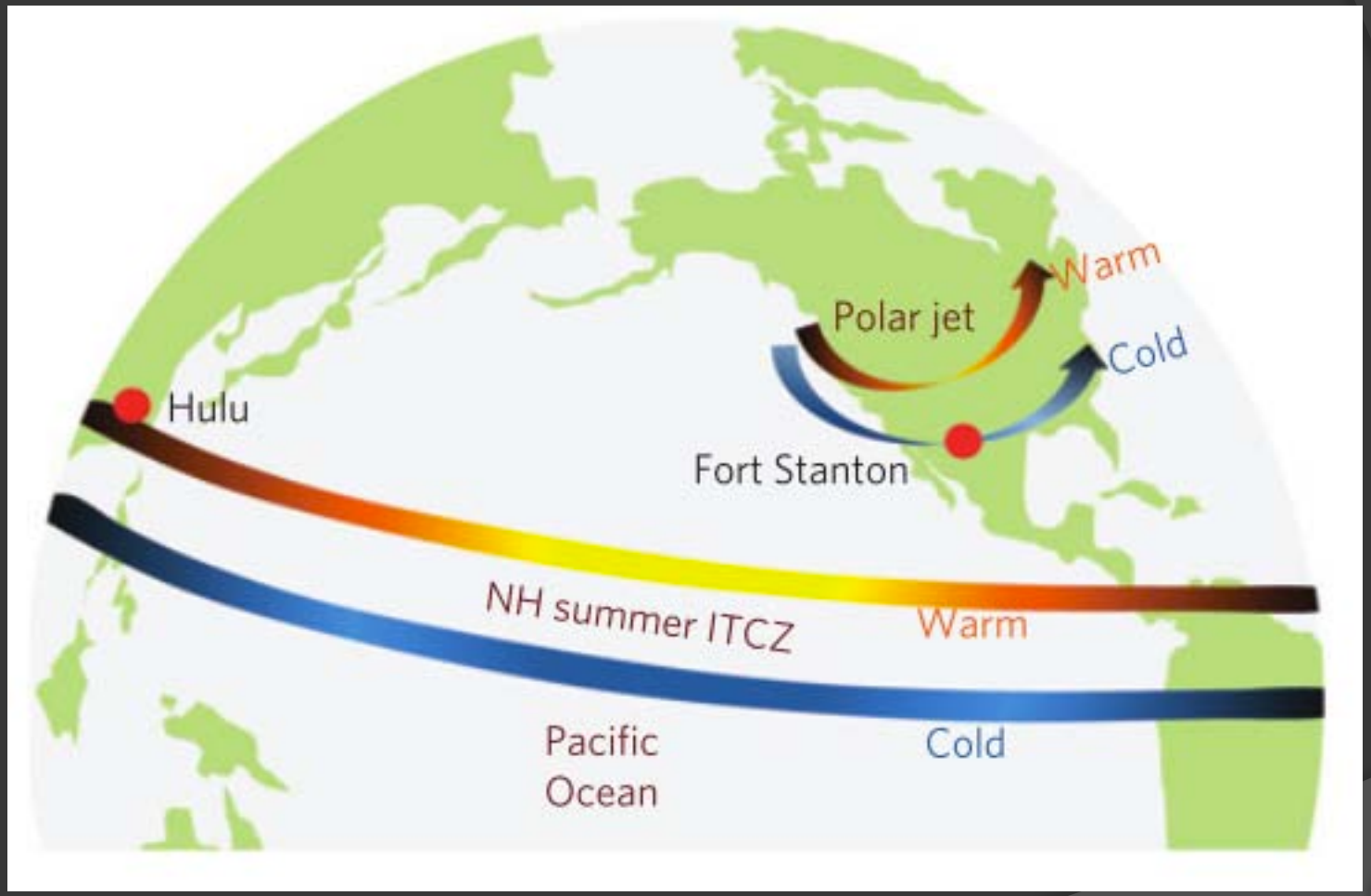
Paleomoisture reconstructions suggest wetter Younger Dryas



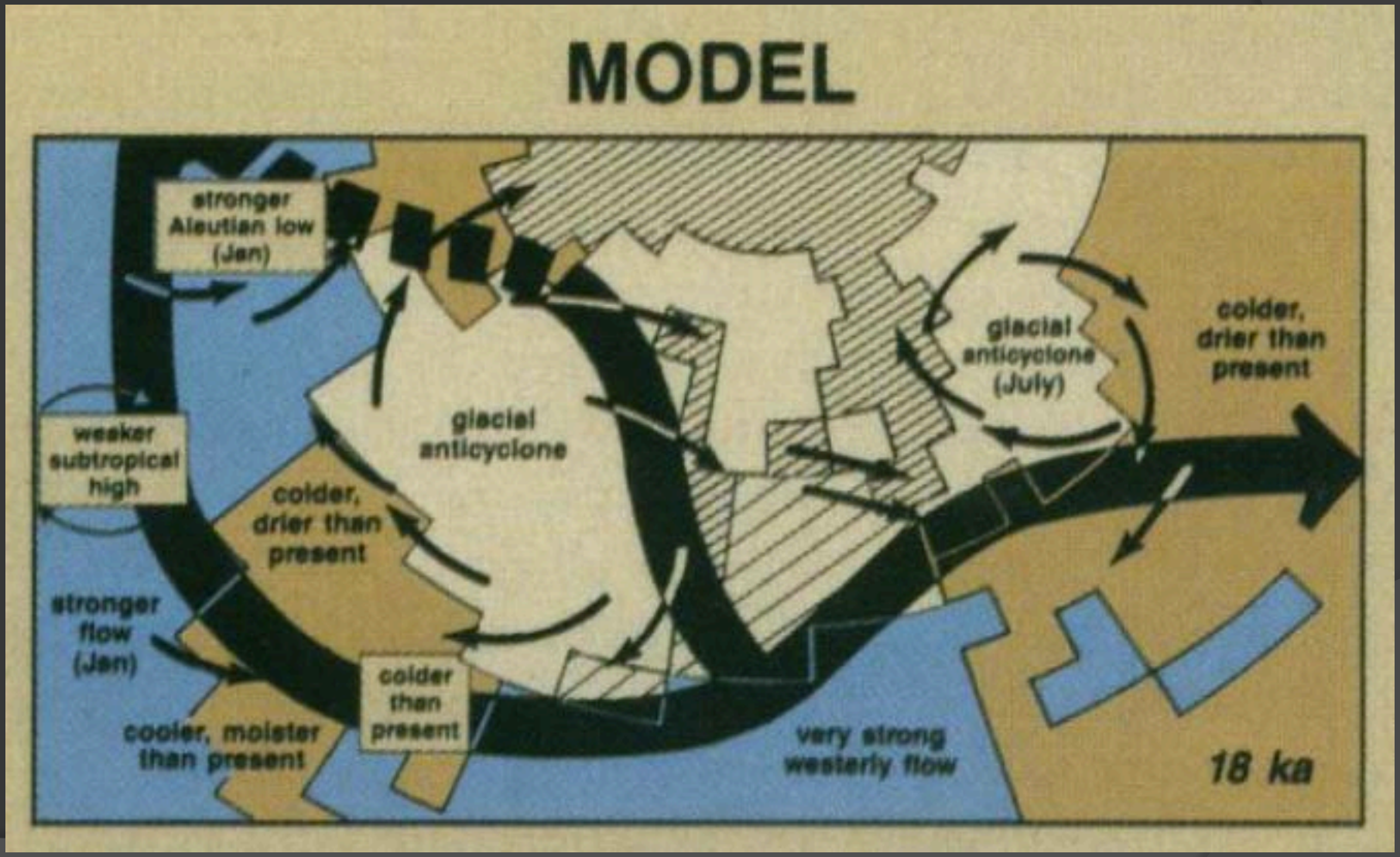
Wong et al., in prep

Shift of the westerlies hypothesis



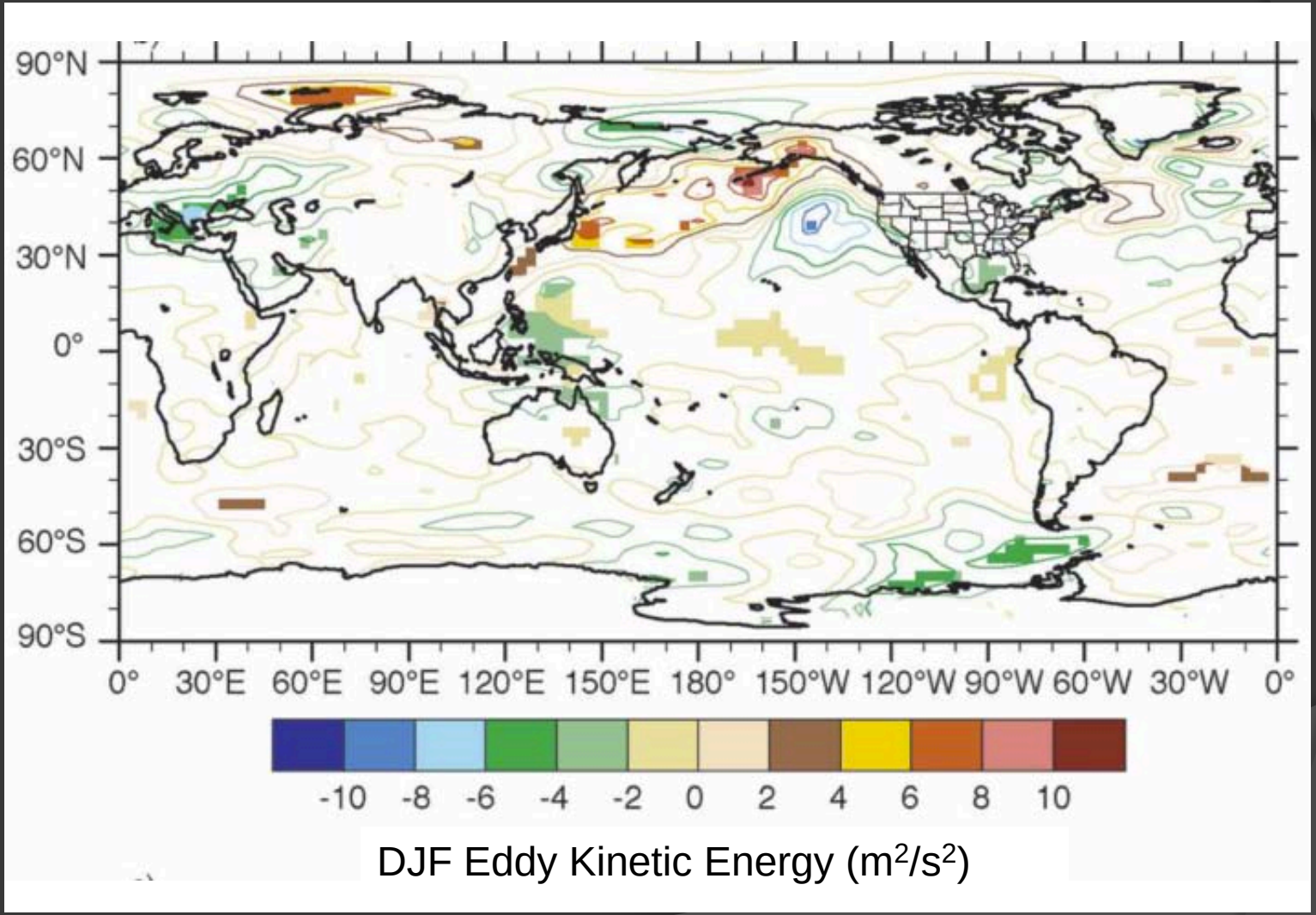
Asmerom et al., 2010

Split jet stream during Last Glacial Maximum



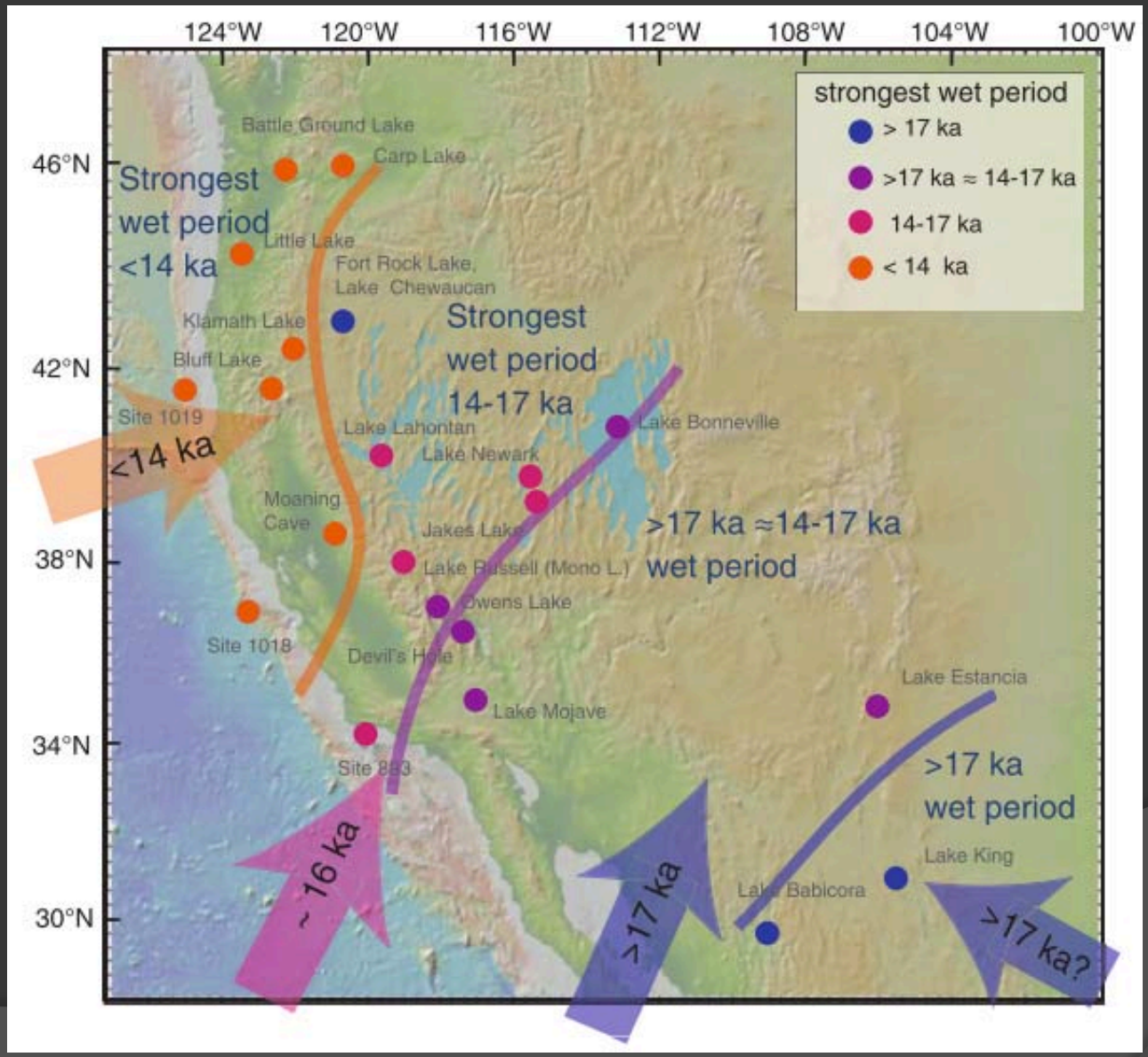
COHMAP, 1988

Northward storm track shift simulated in scenarios of future warming



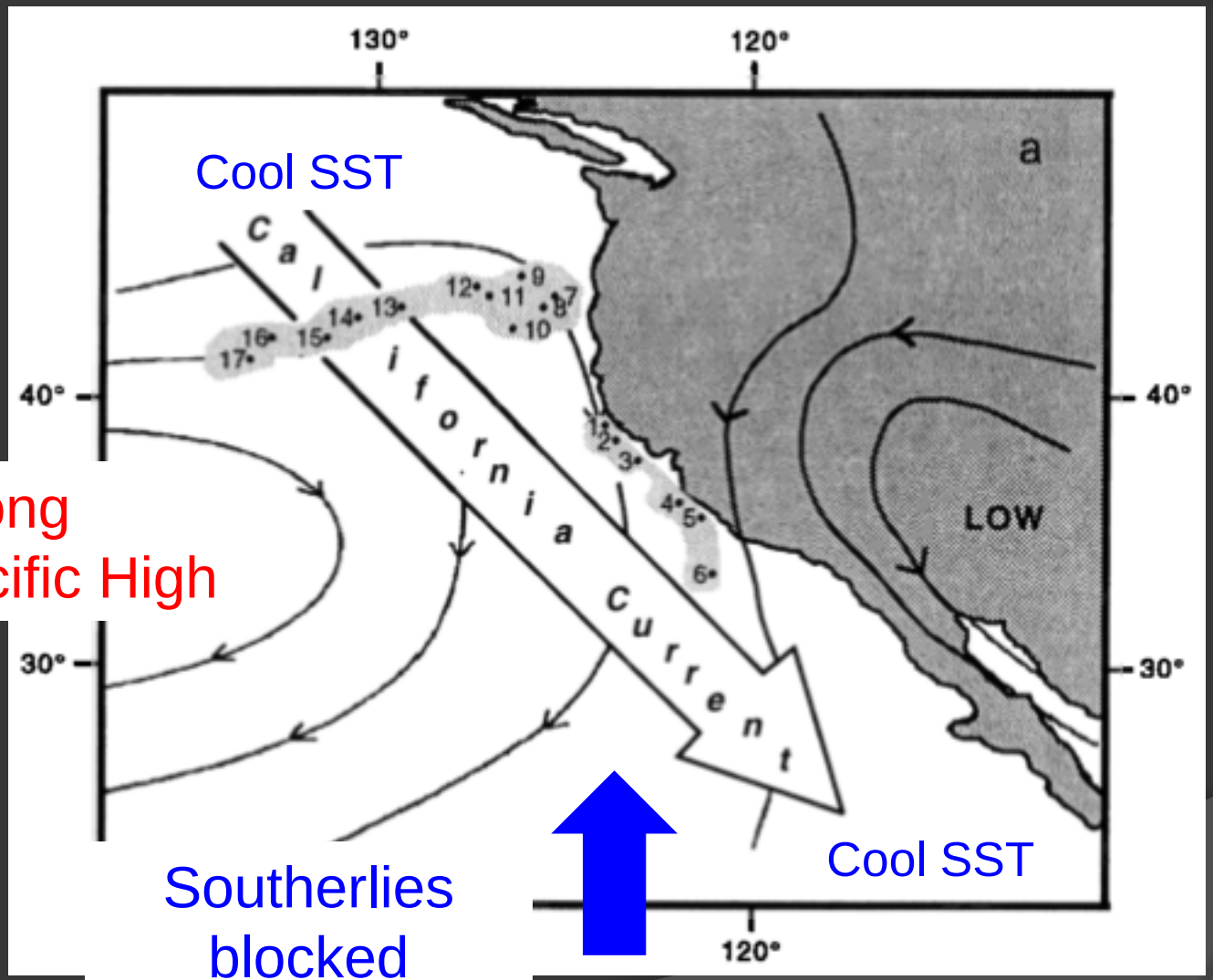
Sewall, 2005

Alternative hypothesis
Tropical Pacific moisture source



Lyle et al., 2012

Alternative hypothesis – tropical Pacific moisture source variability driven by North Pacific High



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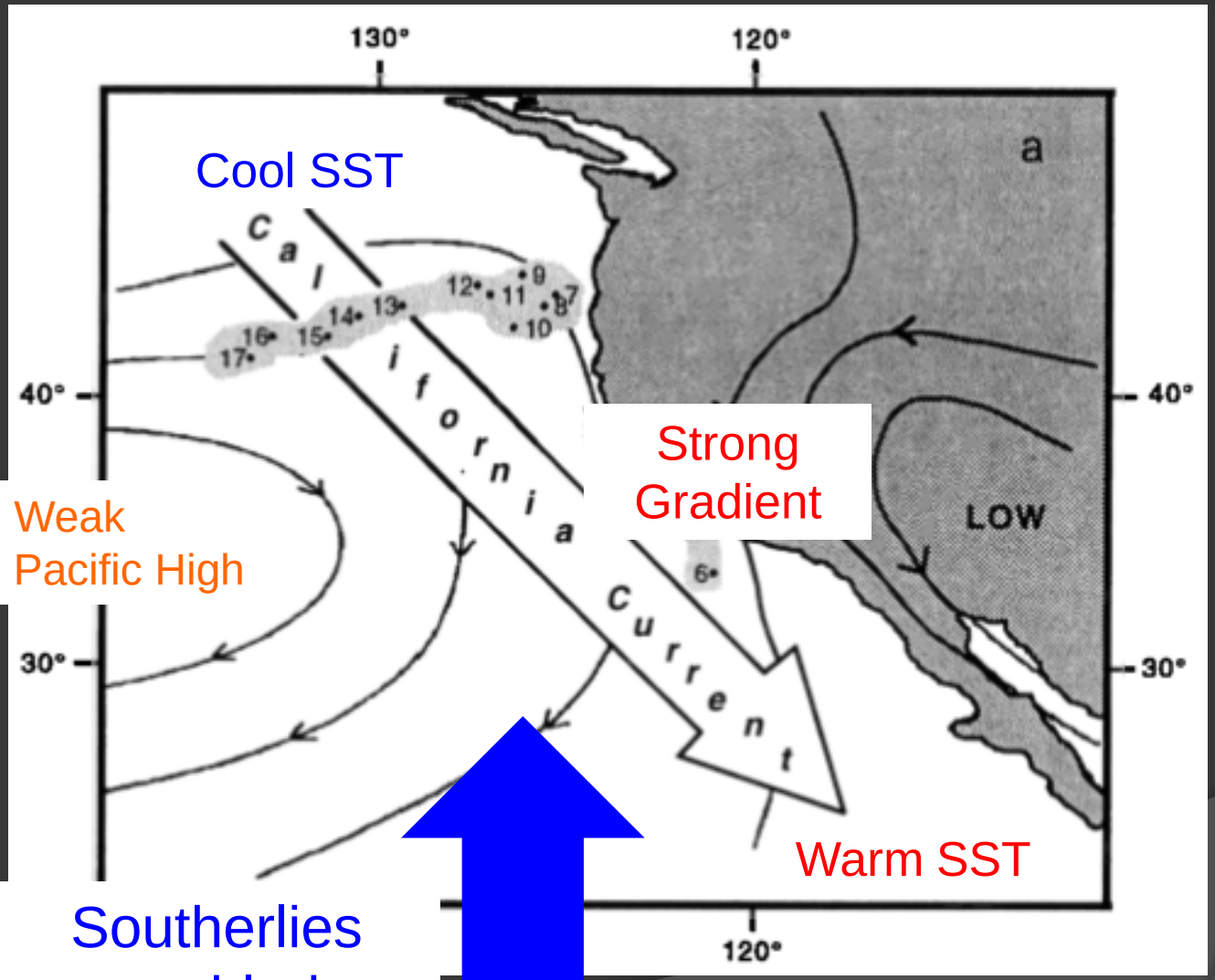

Modified from Doose et al., 1995

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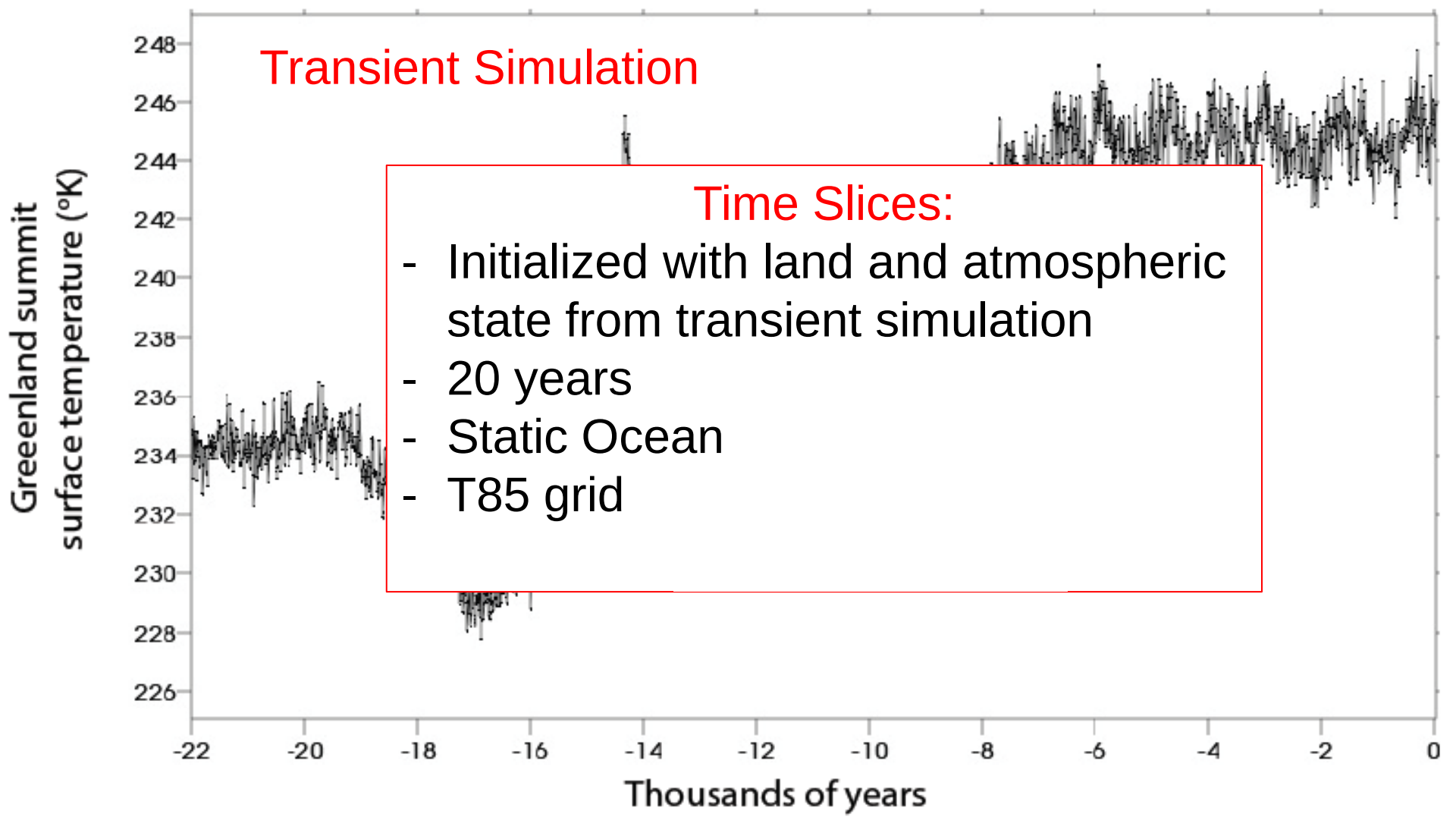
Transient Simulation



Time Slices:

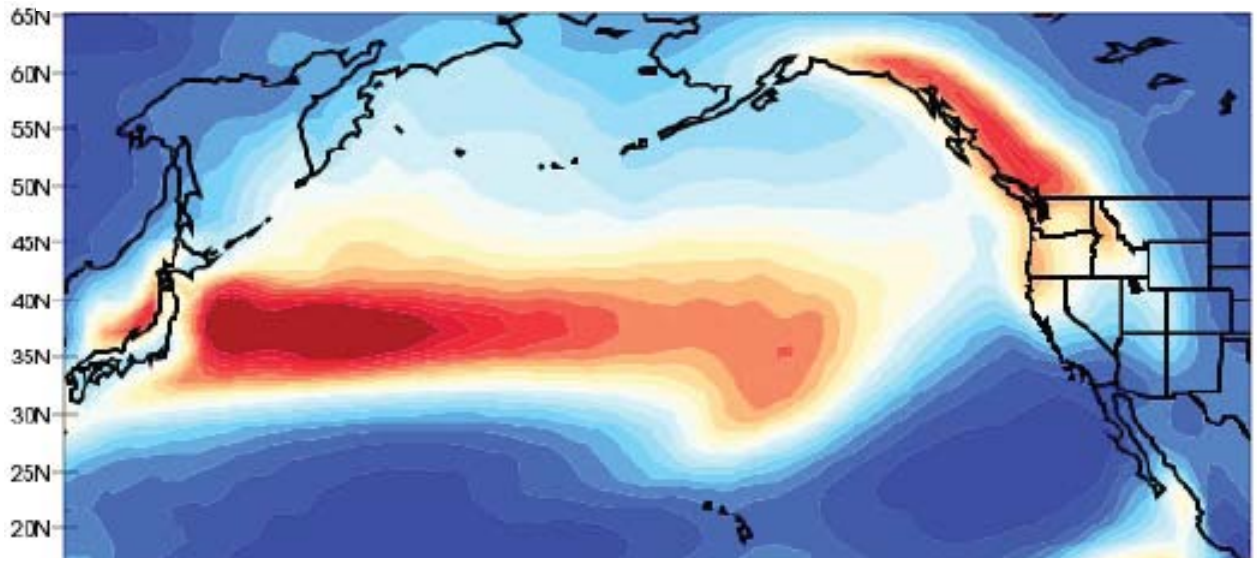
- Initialized with land and atmospheric state from transient simulation
- 20 years
- Static Ocean
- T85 grid

Evaluation of model performance

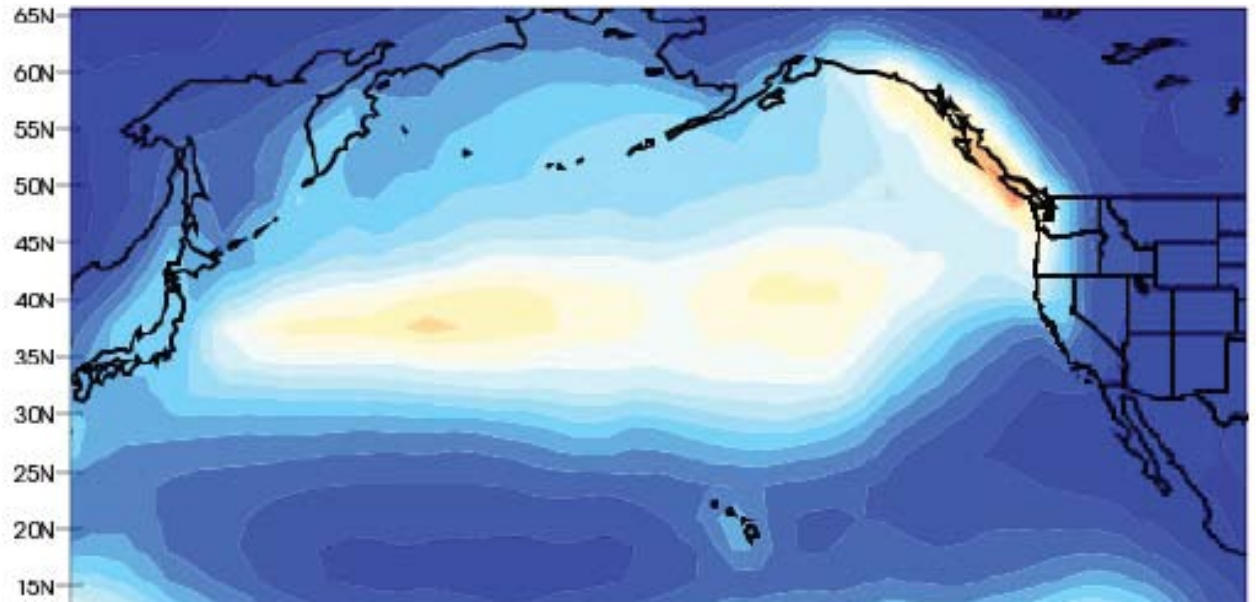
- Control simulation of modern conditions
- Comparison to:
  - Modern Era Retrospective Reanalysis (MERRA)
  - Global Precipitation Climatology Project (GPCP)

Evaluation of model performance: modern precipitation

CCSM3



Observed (GPCP)



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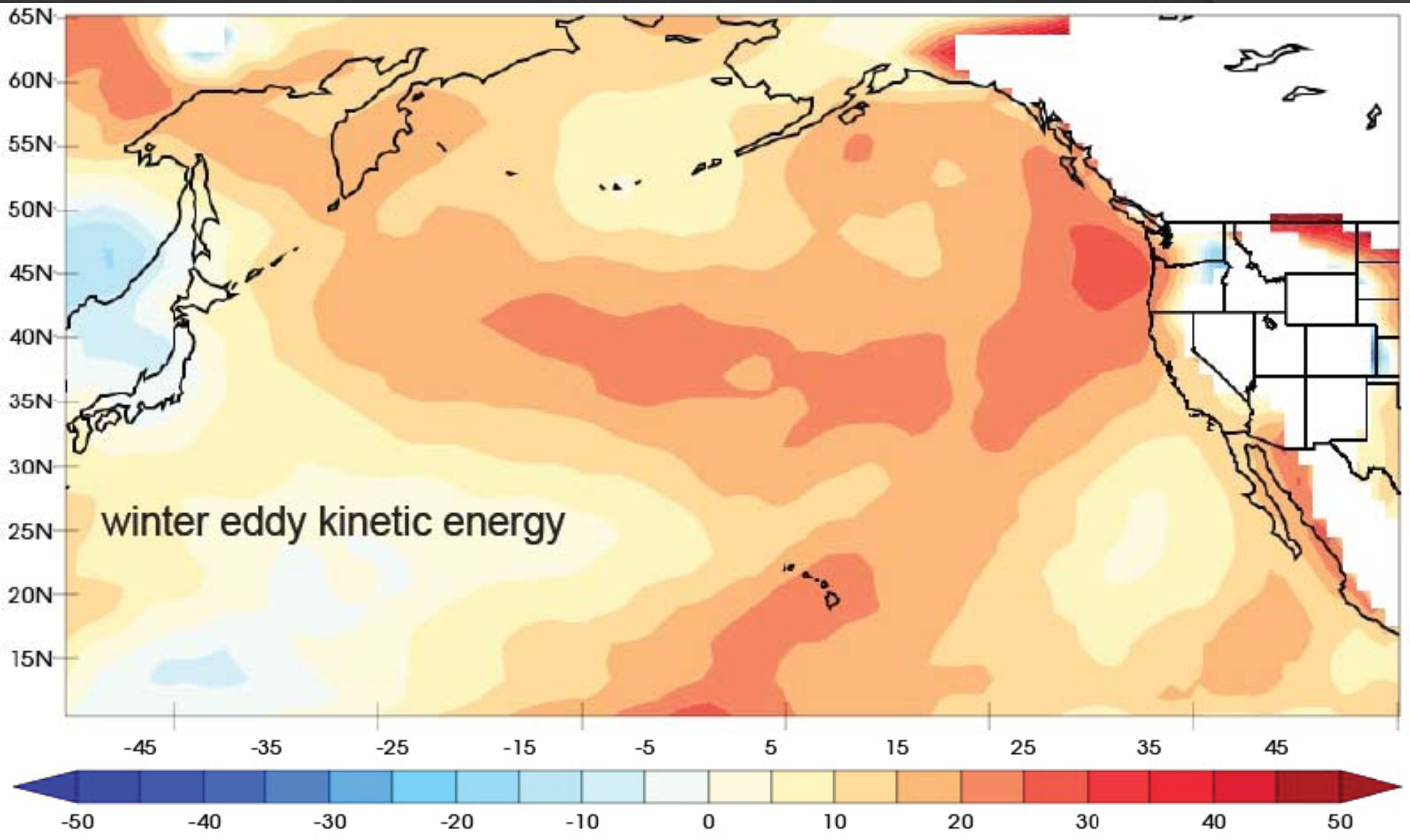
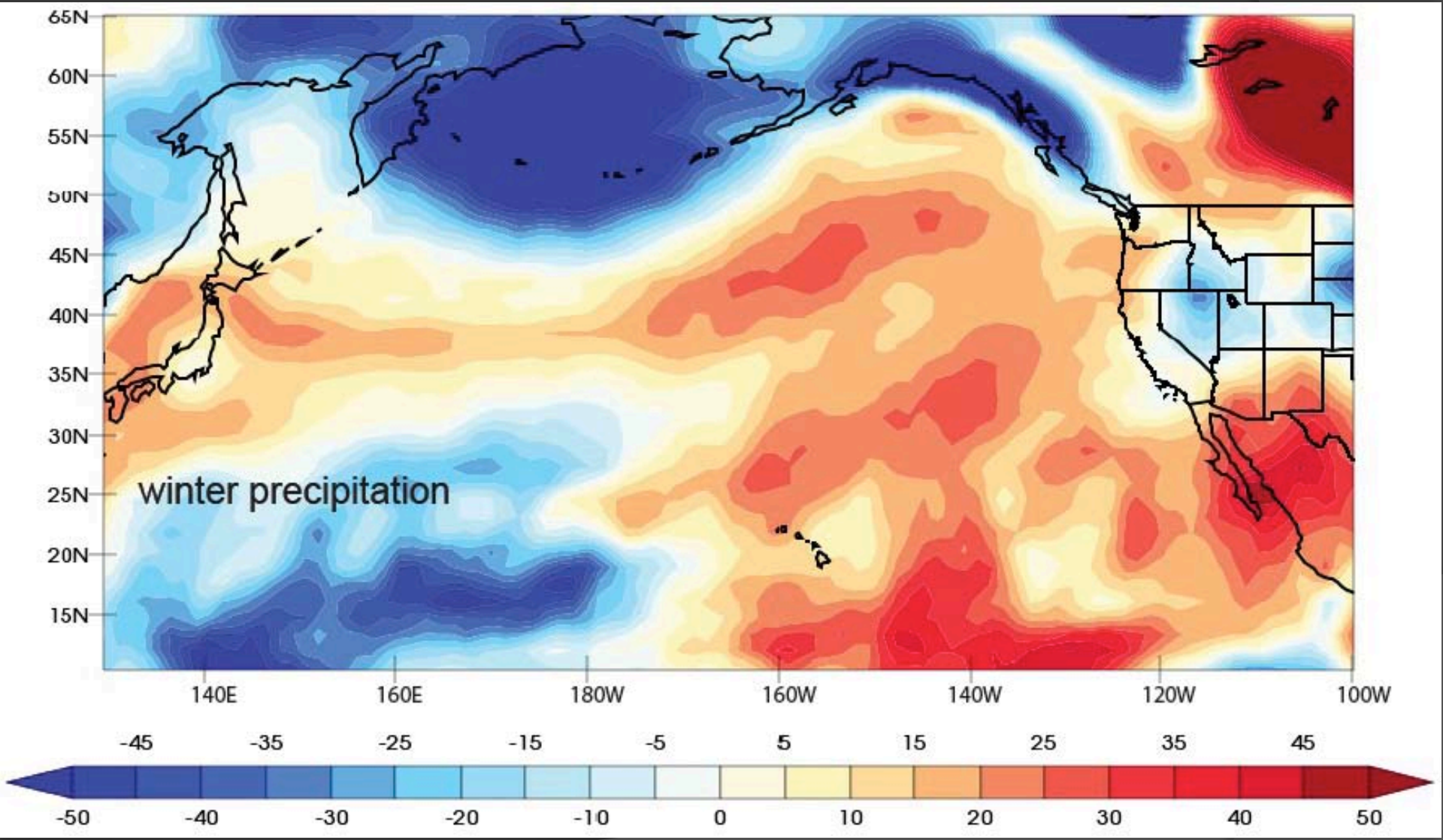
Intensified storm track during Younger Dryas



DJF 850 hPa Eddy Kinetic Energy (m^2/s^2)

Wong et al., in prep

Greater moisture associated with intensified Younger Dryas storm track

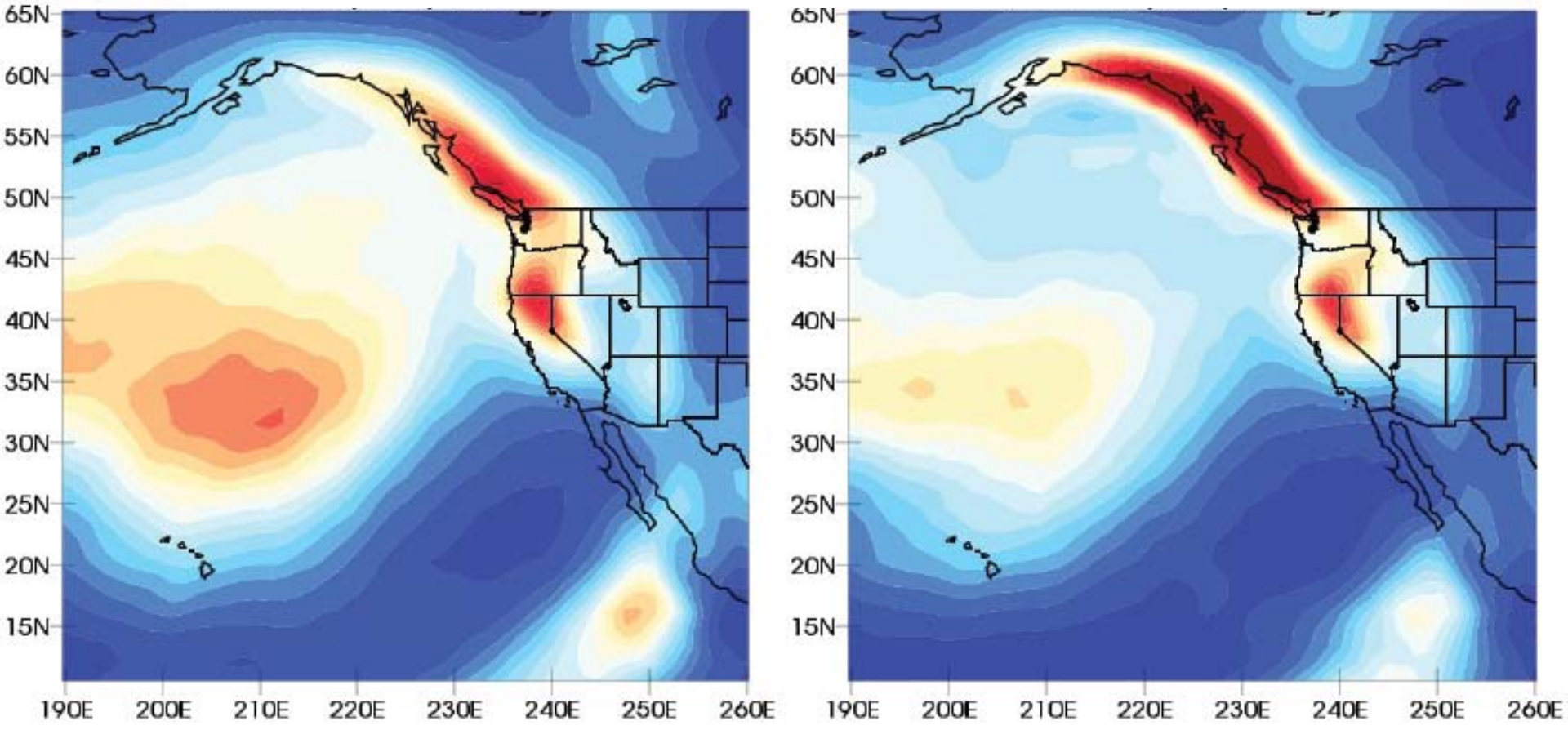


DJF precipitation (% difference)

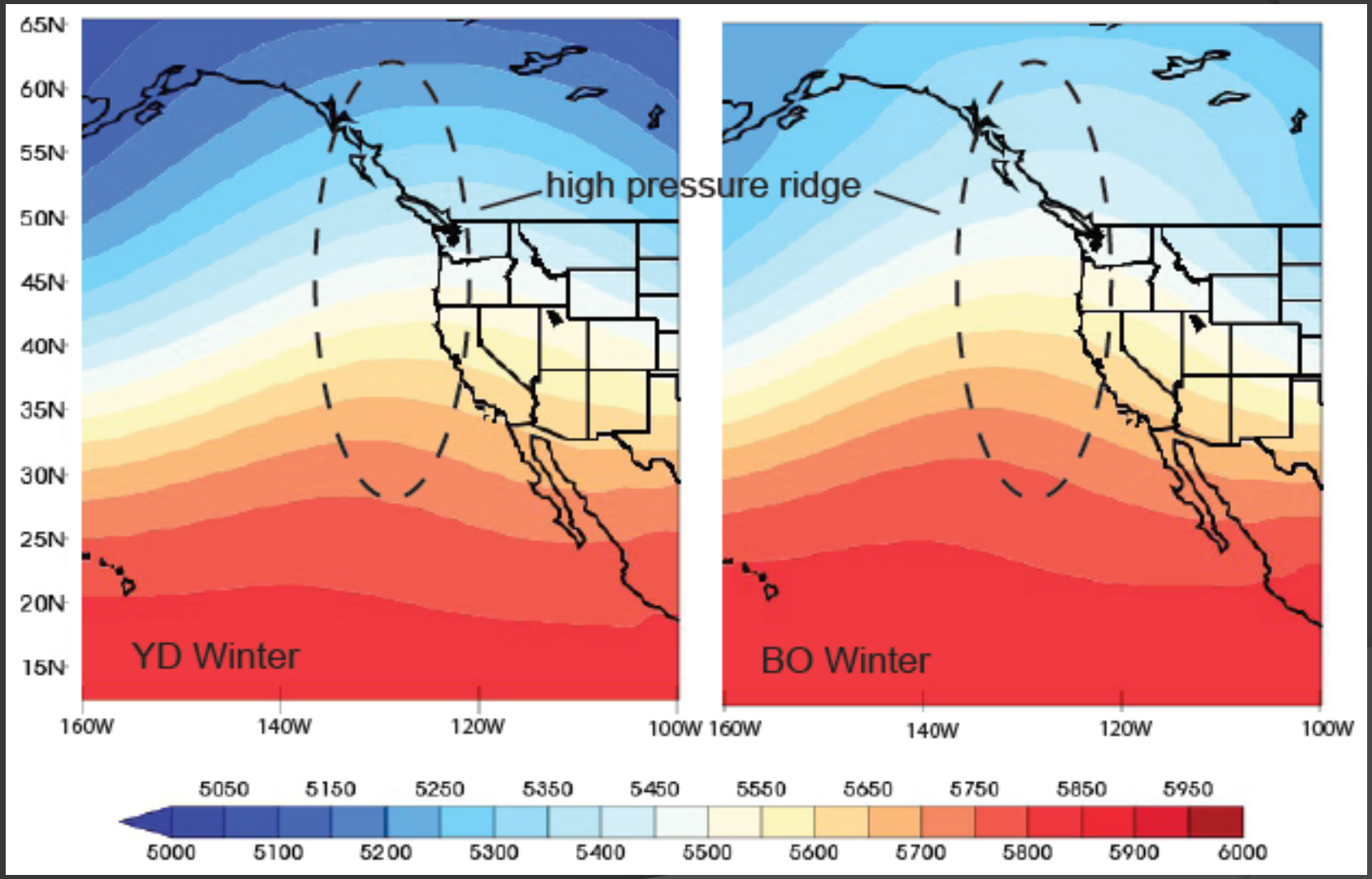
Model winter precipitation

Younger Dryas

Bølling



Stronger high pressure ridge diverts storm track during Bølling

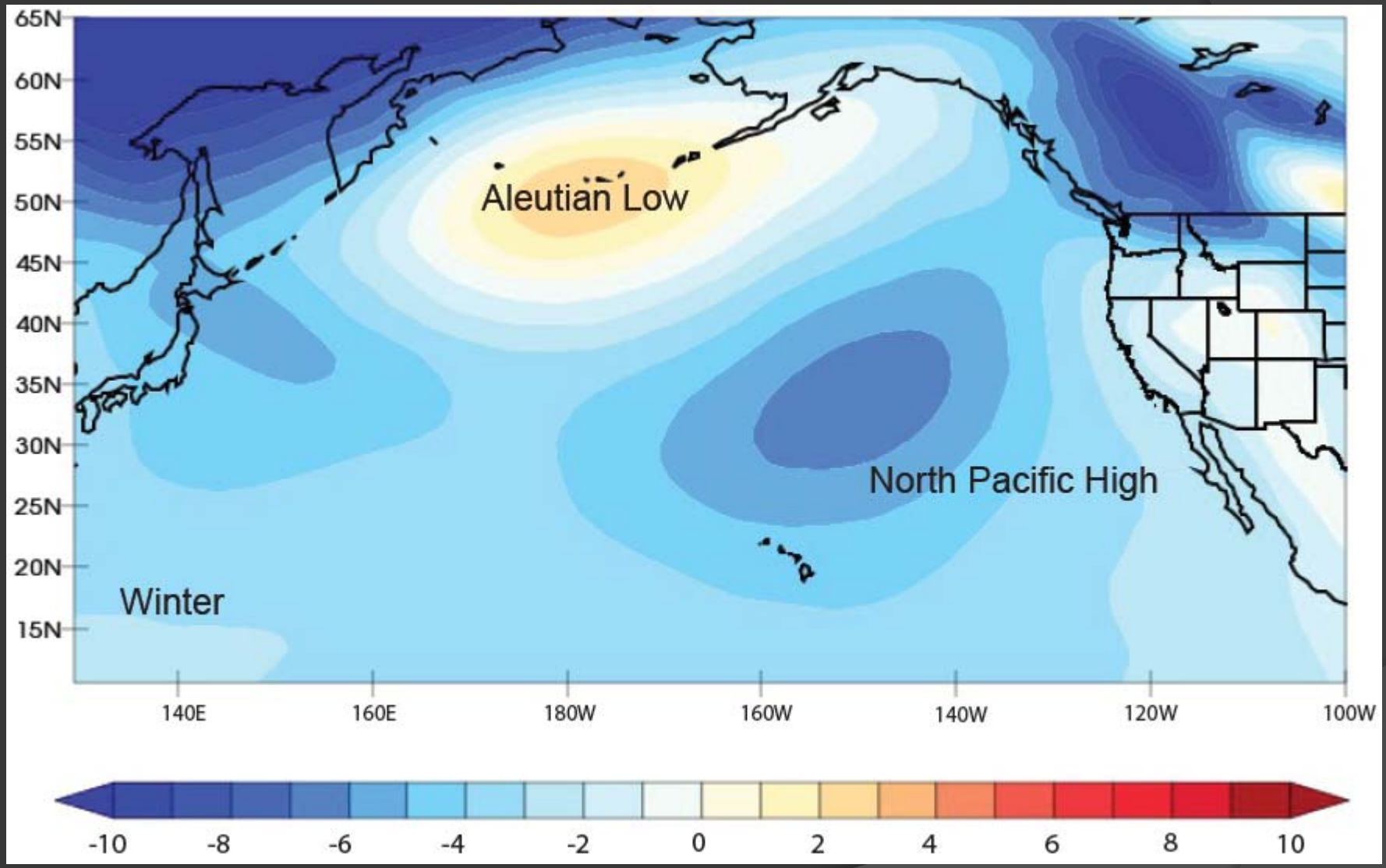


500 hPa geopotential heights (m)

Wong et al., in prep

What about tropical moisture source?

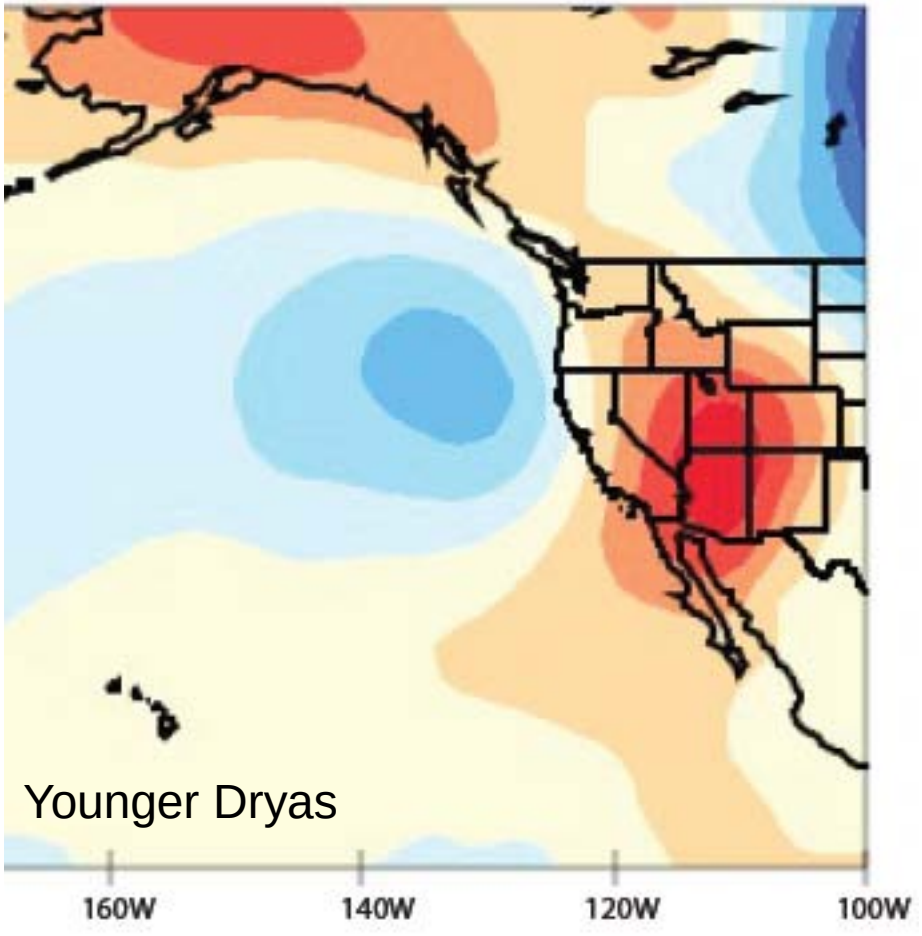
Weaker pressure anomalies during Younger Dryas

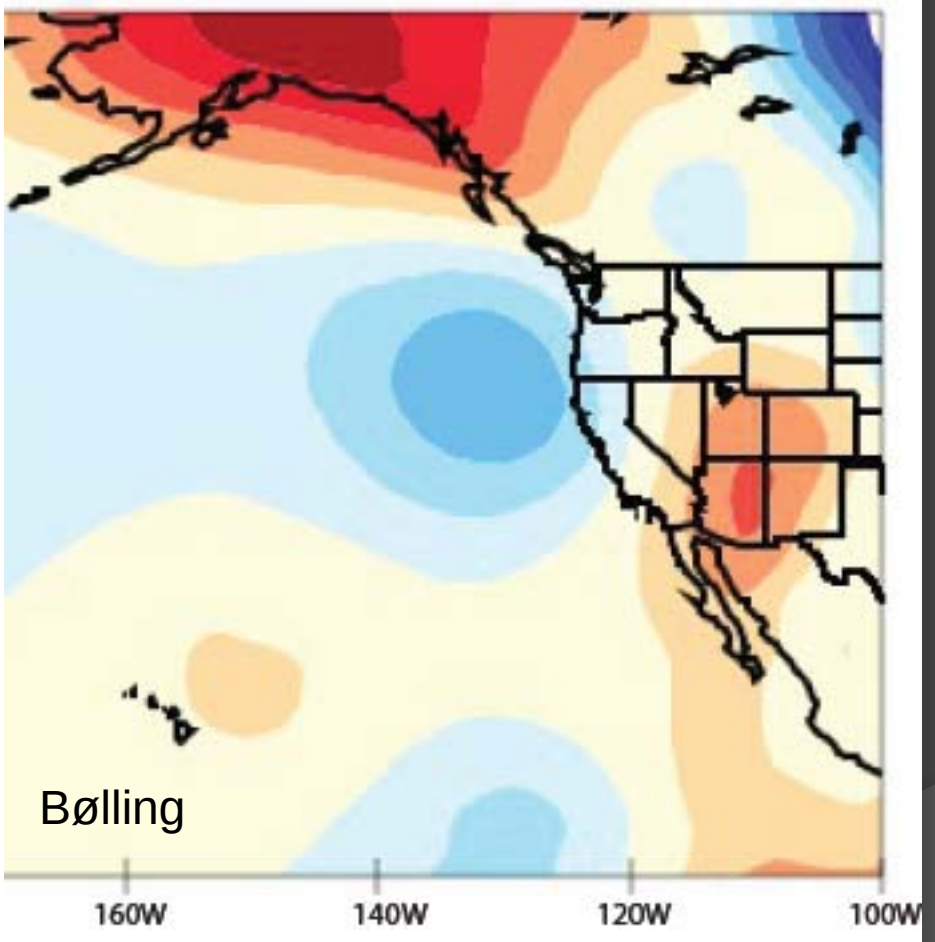


DJF Sea Level Pressure (hPa)

Wong et al., in prep

Stronger summer southerlies during Younger Dryas

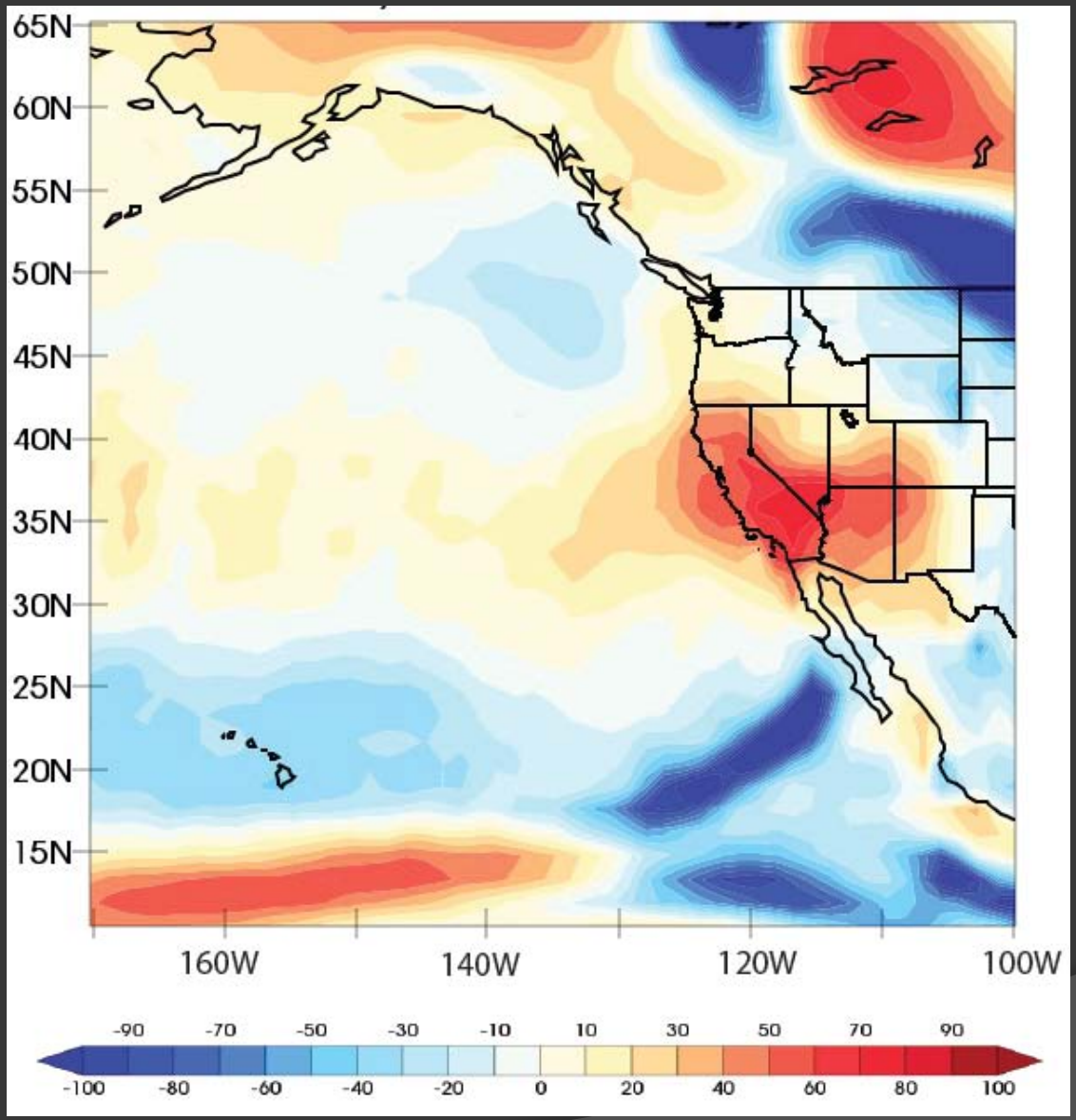




JJA 500 hPa meridional wind velocity (m/s)

Wong et al., in prep

Greater summer precipitation……

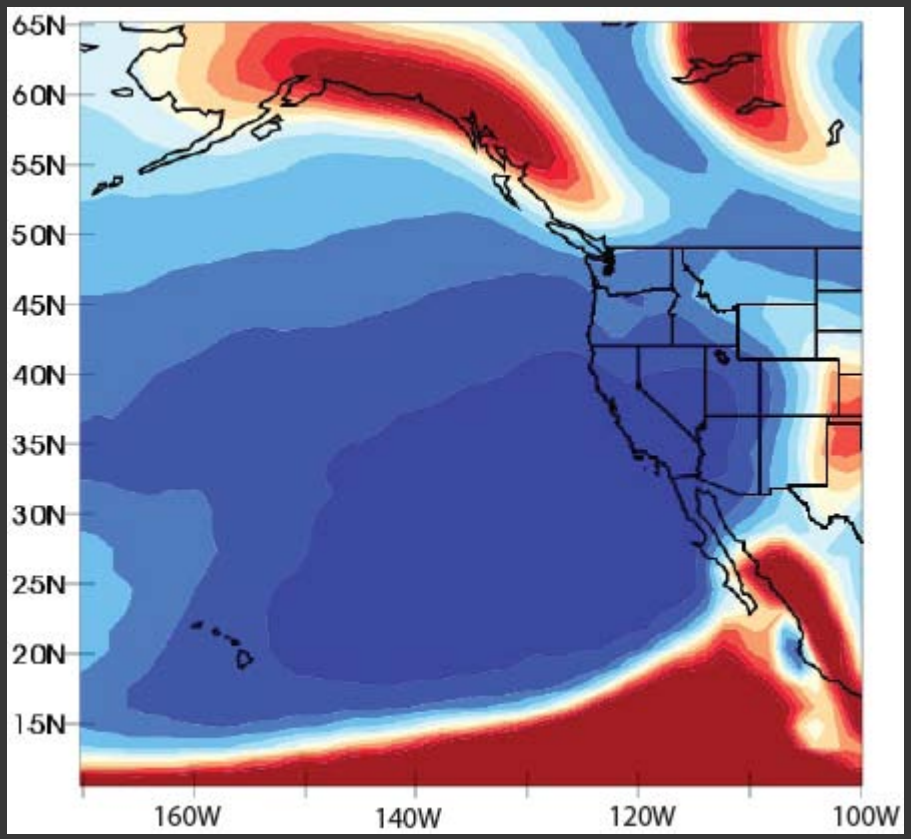


JJA precipitation (percent difference)

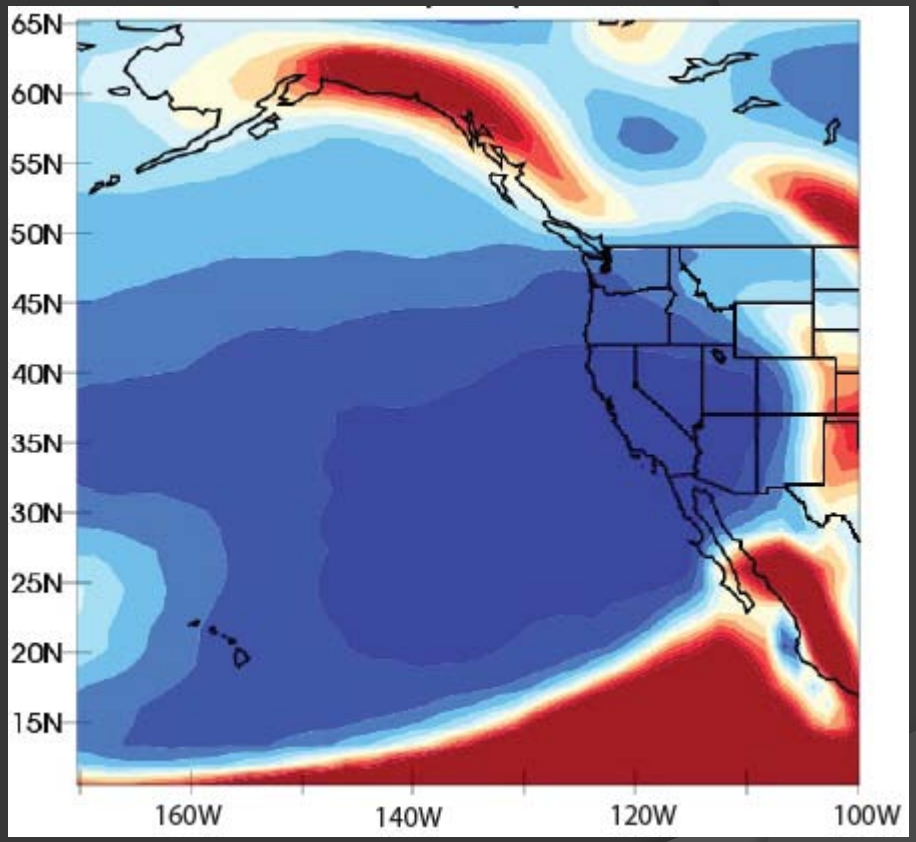
Wong et al., in prep

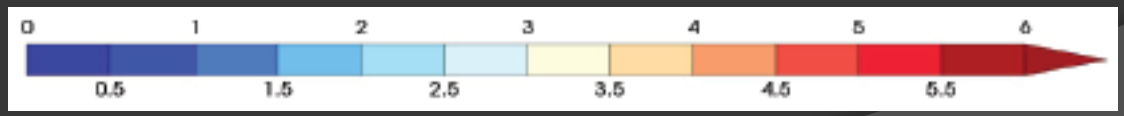
.... But low precipitation amount

Younger Dryas



Bølling

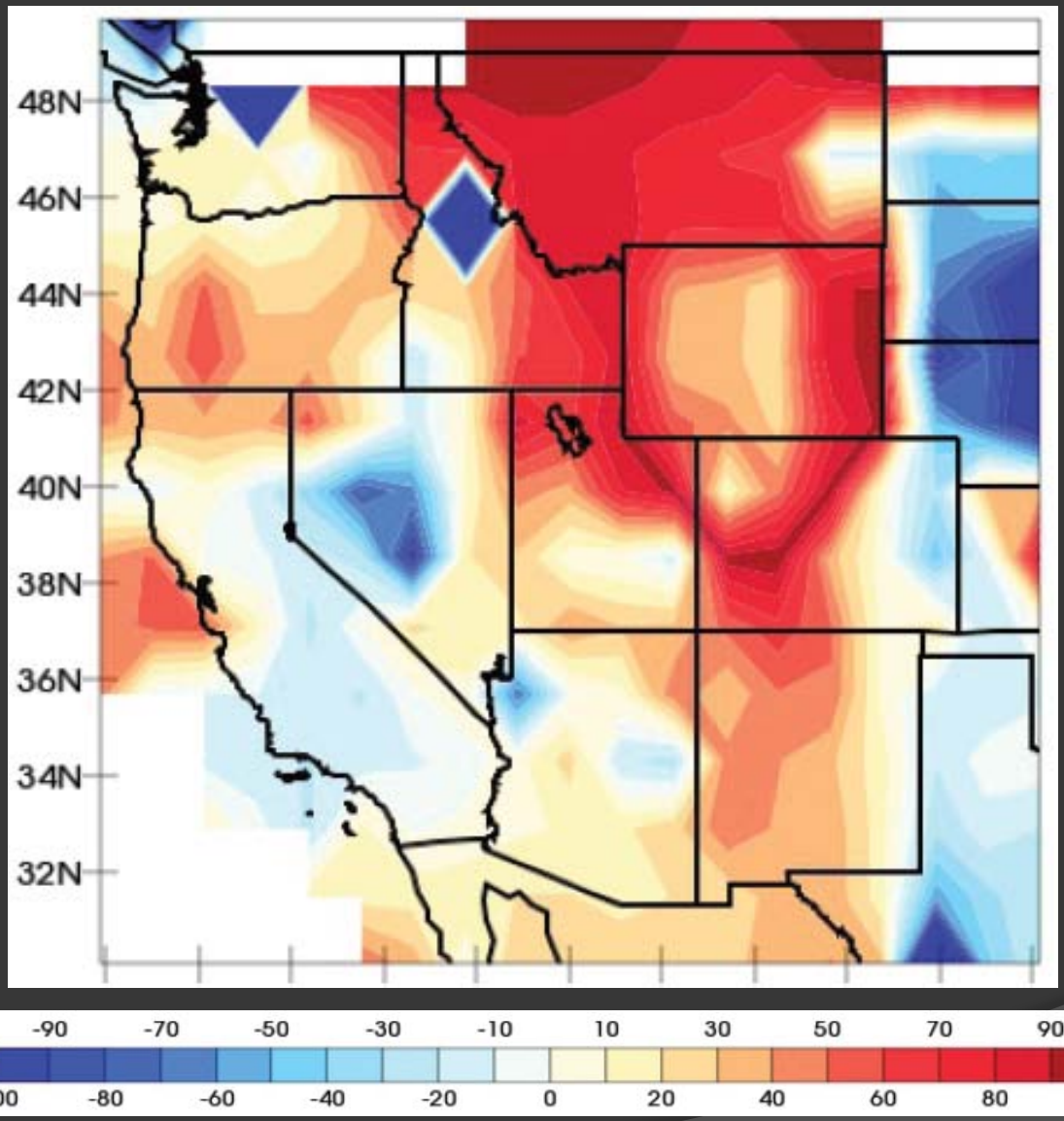




JJA precipitation (mm/d)

Wong et al., in prep

Additional finding - evapotranspiration

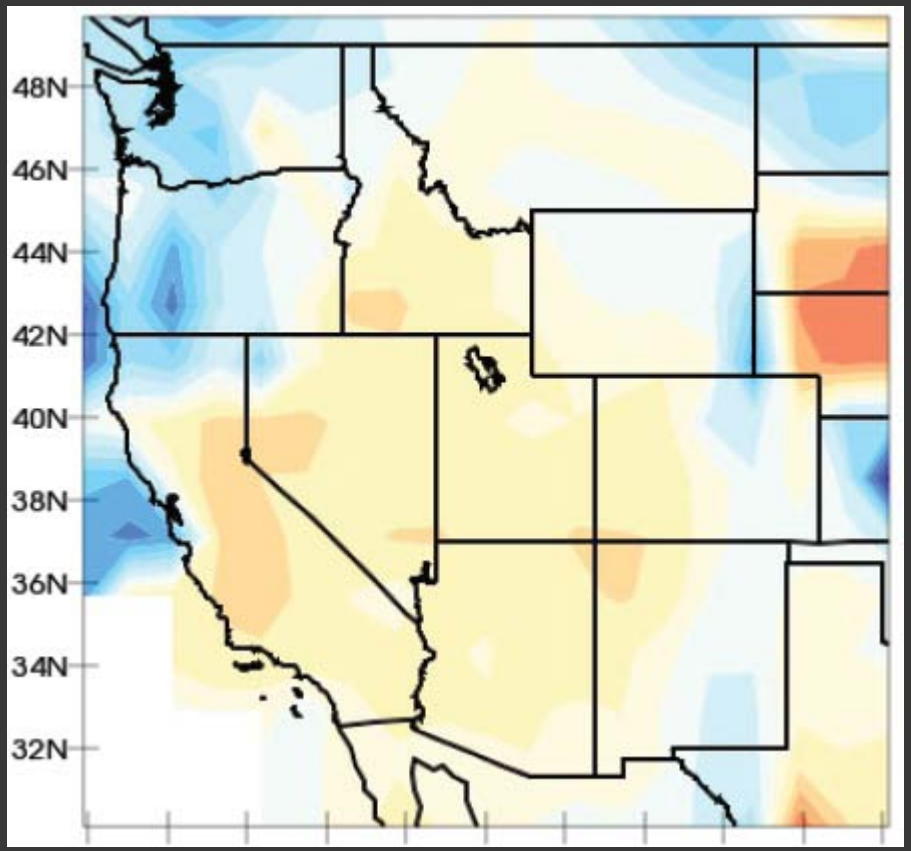


Annual evapotranspiration difference (% difference)

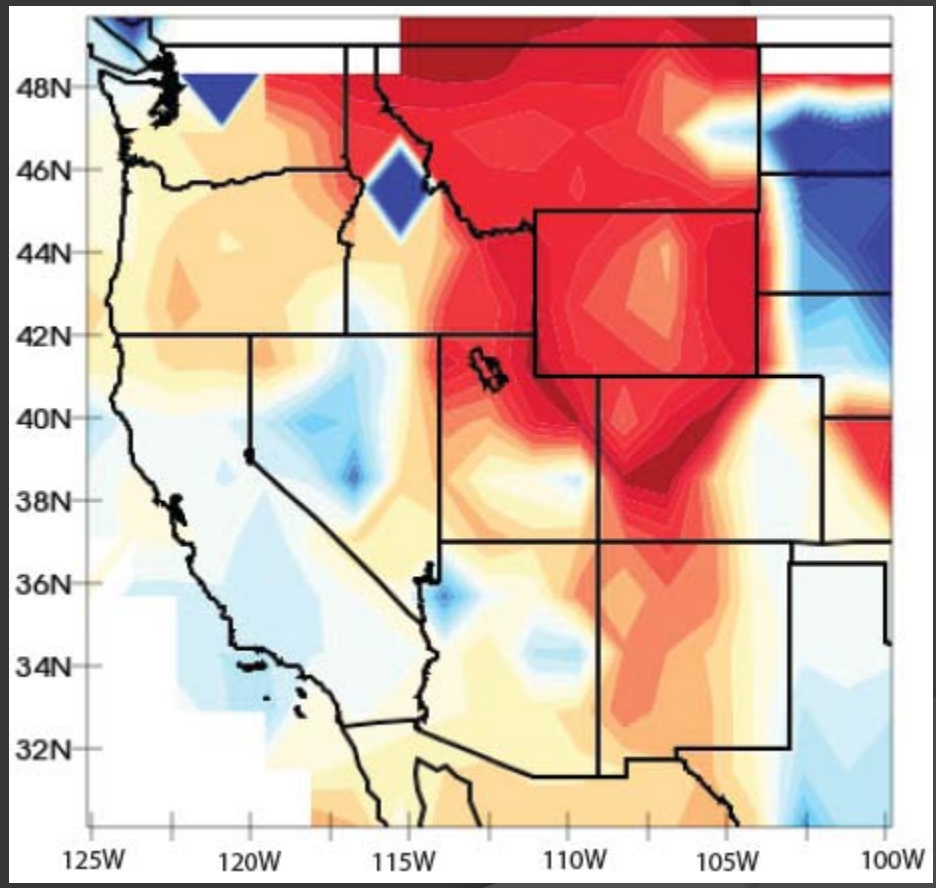
Wong et al., in prep

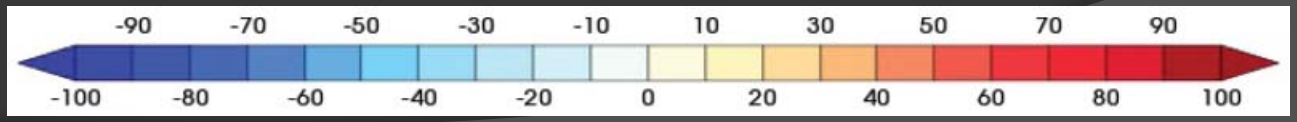
Additional finding - evapotranspiration

Ground evaporation differences



Canopy evapotranspiration differences



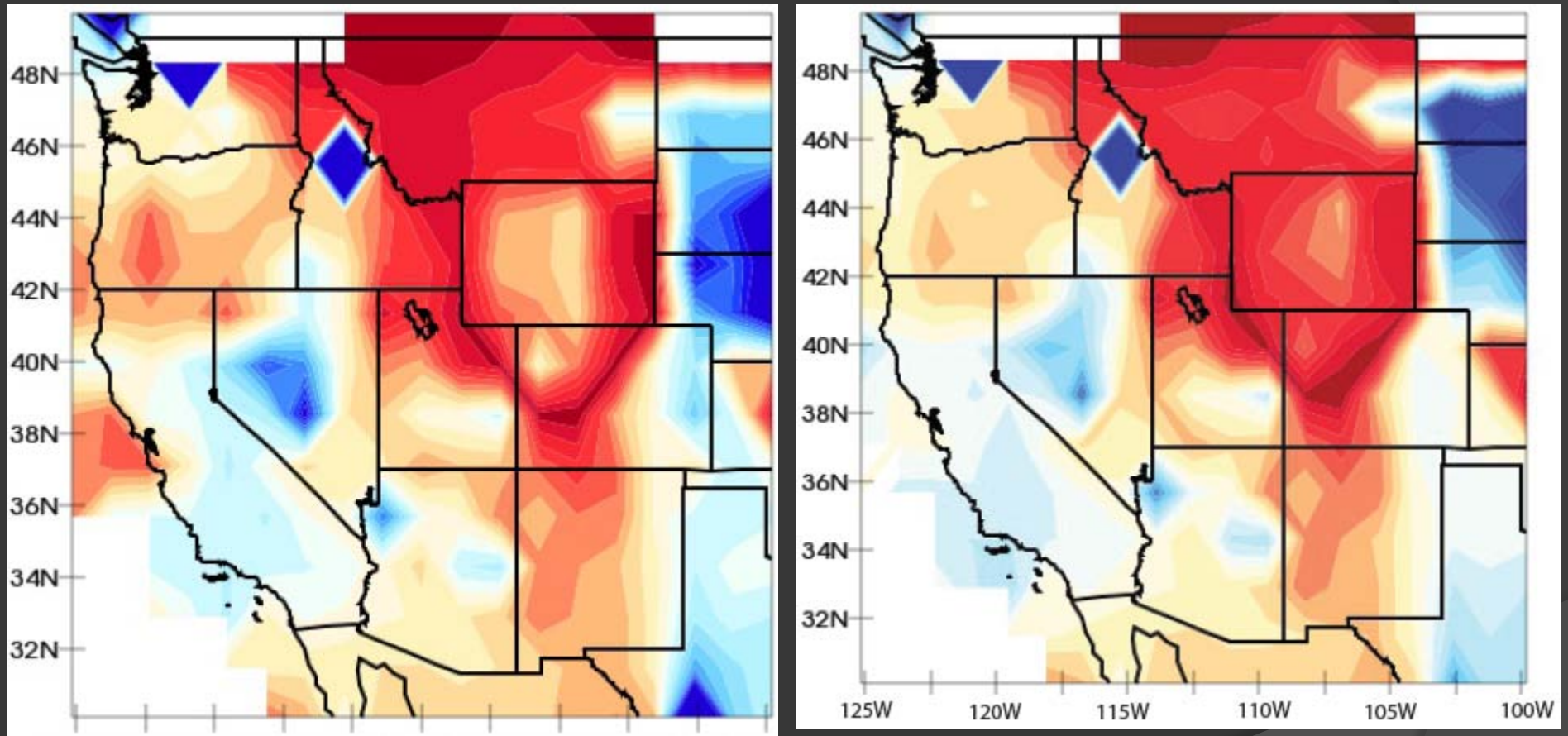


Wong et al., in prep

Additional finding - evapotranspiration

Leaf Area Index

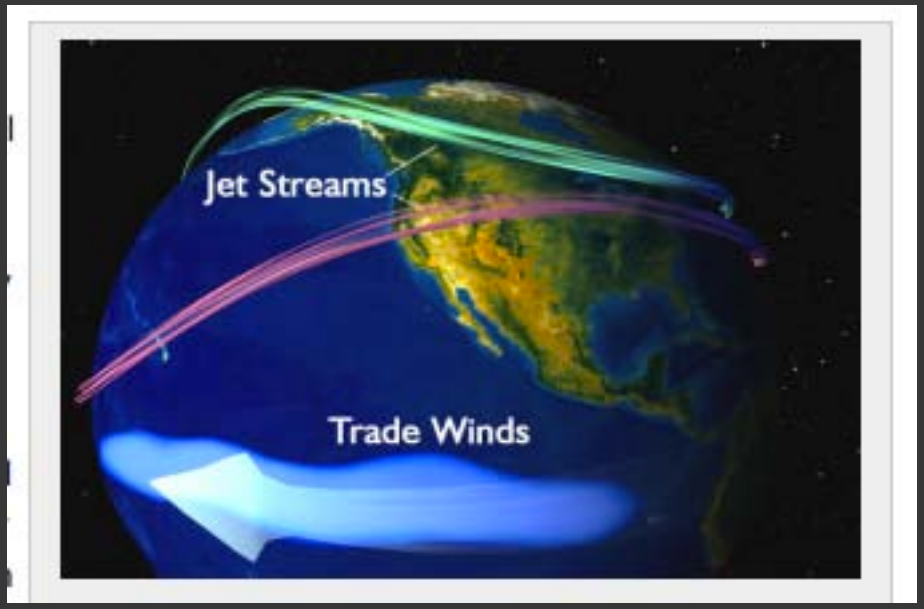
Canopy evapotranspiration

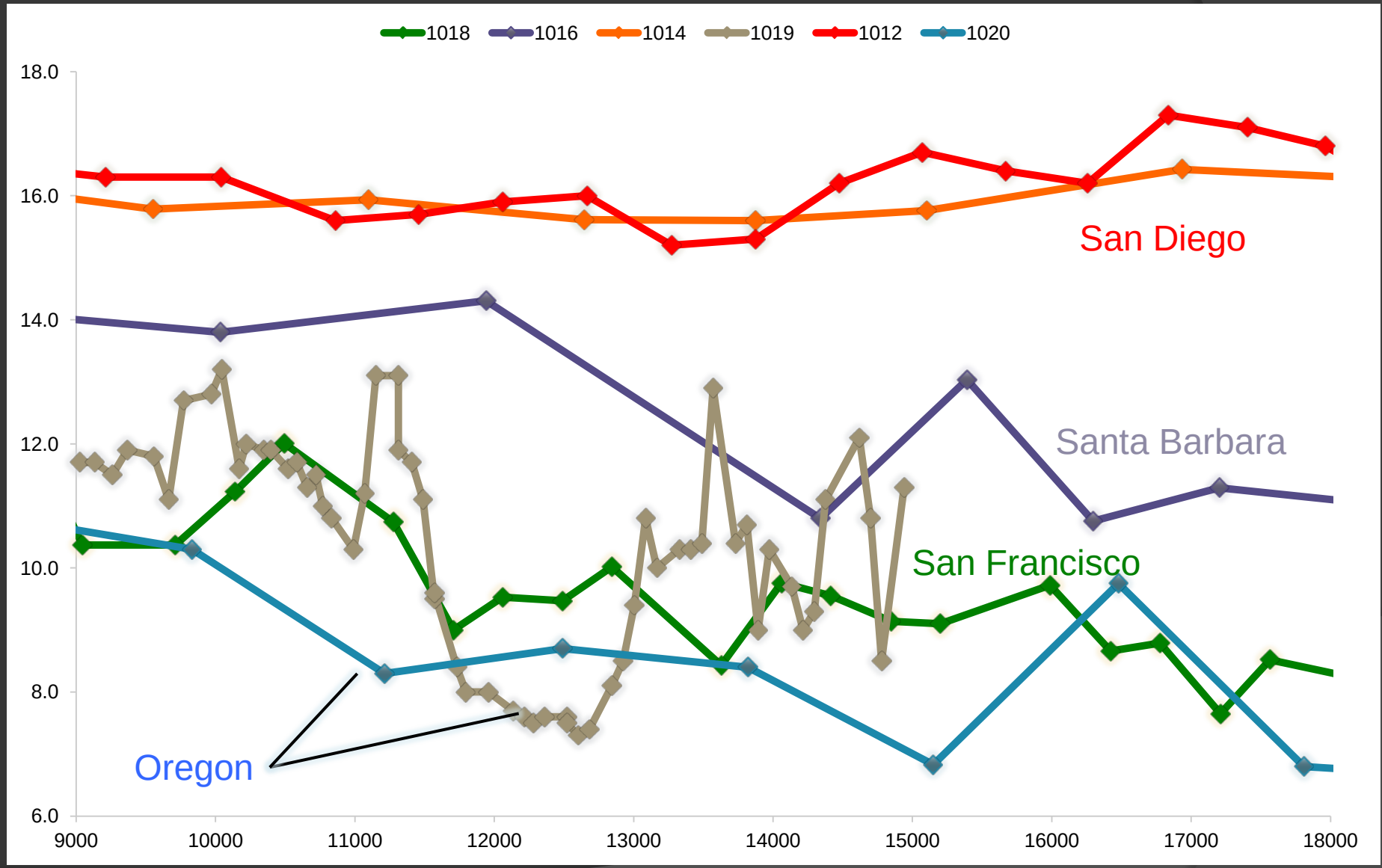


Wong et al., in prep

Conclusions

- Intensification of storm track can account for wetter YD
- No evidence for storm track migration
- Variability in North Pacific High, but small role of tropical moisture
- Increased evapotranspiration during YD despite cooler temperatures


Jet Streams
Trade Winds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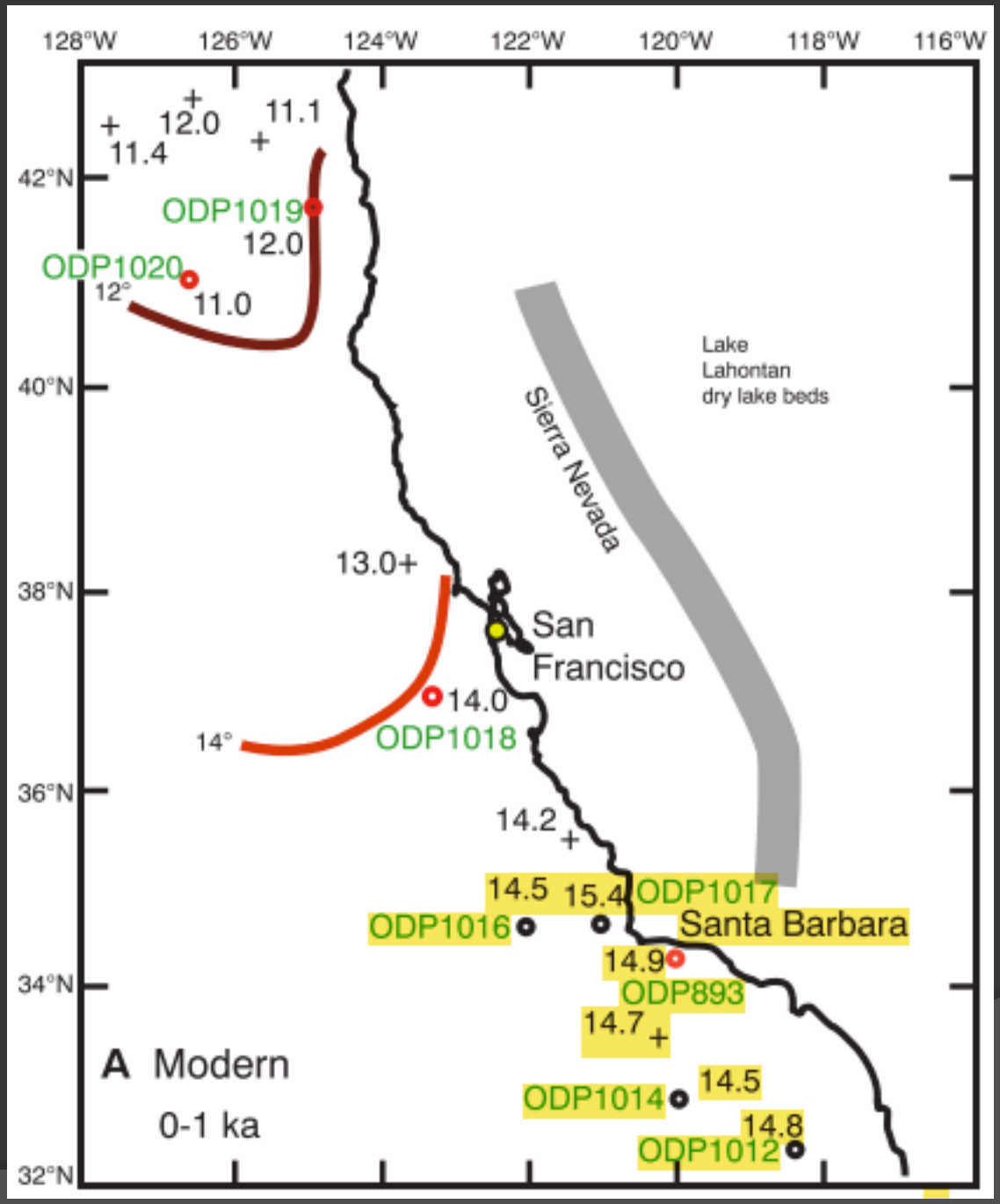
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122°W
120°W
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40°N
38°N
36°N
34°N
32°N
11.4
12.0
11.1
ODP1019
12.0
ODP1020
12°
11.0
Lake
Lahontan
dry lake beds
Sierra Nevada
13.0+
San
Francisco
14.0
ODP1018
14°
14.2
14.5
15.4
ODP1017
ODP1016
Santa Barbara
14.9
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A Modern
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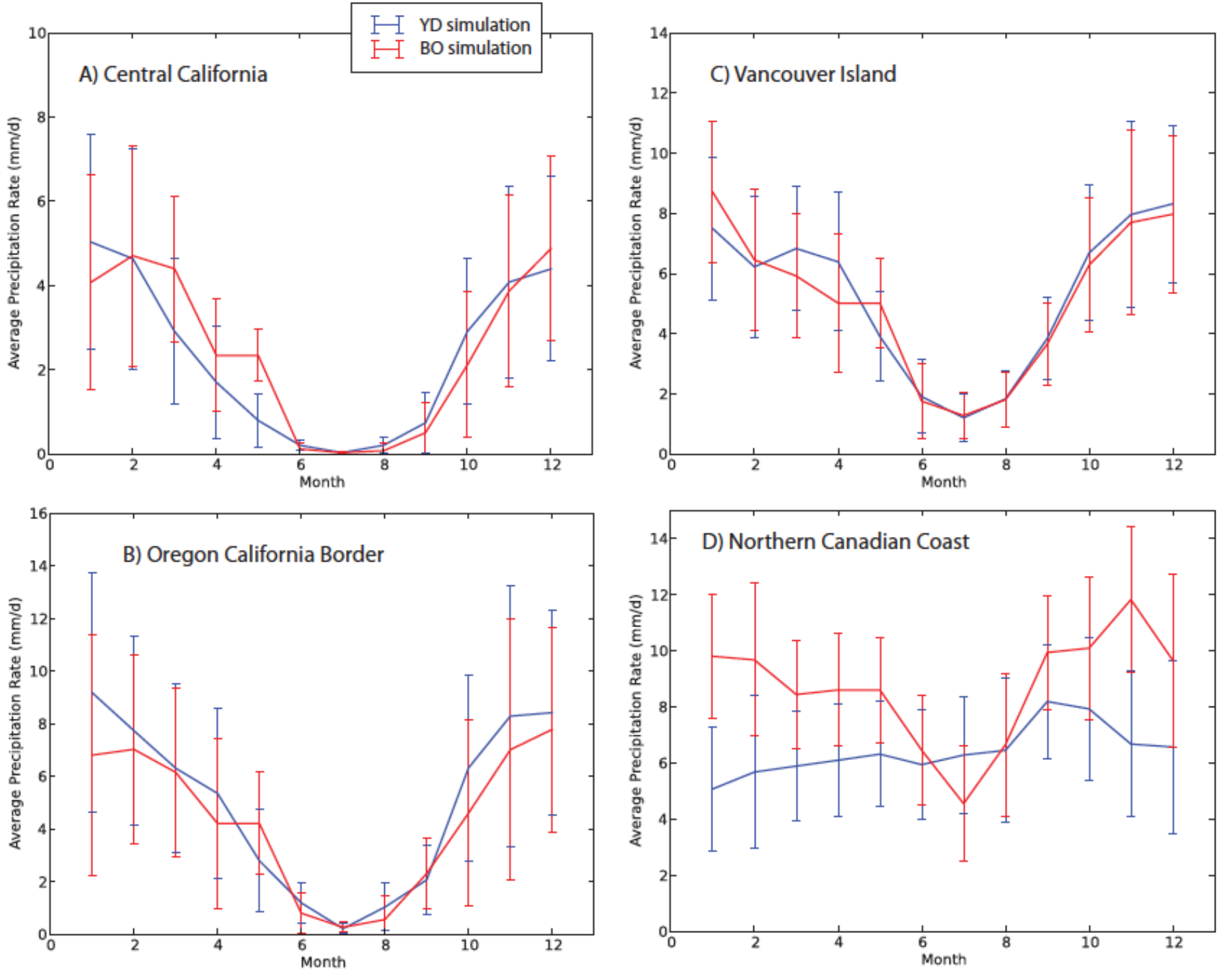
14.5
14.8
ODP1012


YD simulation
BO simulation
A) Central California
B) Oregon California Border
C) Vancouver Island
D) Northern Canadian Coast
Average Precipitation Rate (mm/d)
Month