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

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Palmer Drought Severity Index
January, 2014

National Climatic Data Center, NOAA

- extreme drought: -4.00 and below
- severe drought: -3.00 to -3.99
- moderate drought: -2.00 to -2.99
- mid-range: -1.99 to +1.99
- moderately moist: +2.00 to +2.99
- very moist: +3.00 to +3.99
- extremely moist: +4.00 and above
The drought in California as seen from space. The lack of snow at Lake Tahoe and in the Sierras is pronounced.
Ridiculously Resilient Ridge

California Weather Blog
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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
Outline

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Paleomoiosture reconstructions suggest wetter Younger Dryas
Shift of the westerlies hypothesis
Split jet stream during Last Glacial Maximum
Northward storm track shift simulated in scenarios of future warming

Sewall, 2005

DJF Eddy Kinetic Energy (m²/s²)
Alternative hypothesis
Tropical Pacific moisture source
Alternative hypothesis – tropical Pacific moisture source variability driven by North Pacific High

[Lyle et al., 2012]
Alternative hypothesis – tropical Pacific moisture source variability driven by North Pacific High

- Weak North Pacific High
- Cool SST
- Southerlies enabled
- Strong Gradient
- Warm SST

Modified from Doose et al., 1995
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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 (m²/s²)
Greater moisture associated with intensified Younger Dryas storm track
Model winter precipitation

Younger Dryas

Bølling
Stronger high pressure ridge diverts storm track during Bølling
What about tropical moisture source?
Weaker pressure anomalies during Younger Dryas
Stronger summer southerlies during Younger Dryas

JJA 500 hPa meridional wind velocity (m/s)

Younger Dryas

Bølling
Greater summer precipitation......
.... But low precipitation amount

Younger Dryas

Bølling

JJA precipitation (mm/d)
Additional finding - evapotranspiration

Annual evapotranspiration difference (% difference)

Wong et al., in prep
Additional finding - evapotranspiration

Ground evaporation differences

Canopy evapotranspiration differences
Additional finding - evapotranspiration

Leaf Area Index

Canopy evapotranspiration
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