High Resolution Simulation of the Last Glacial Maximum

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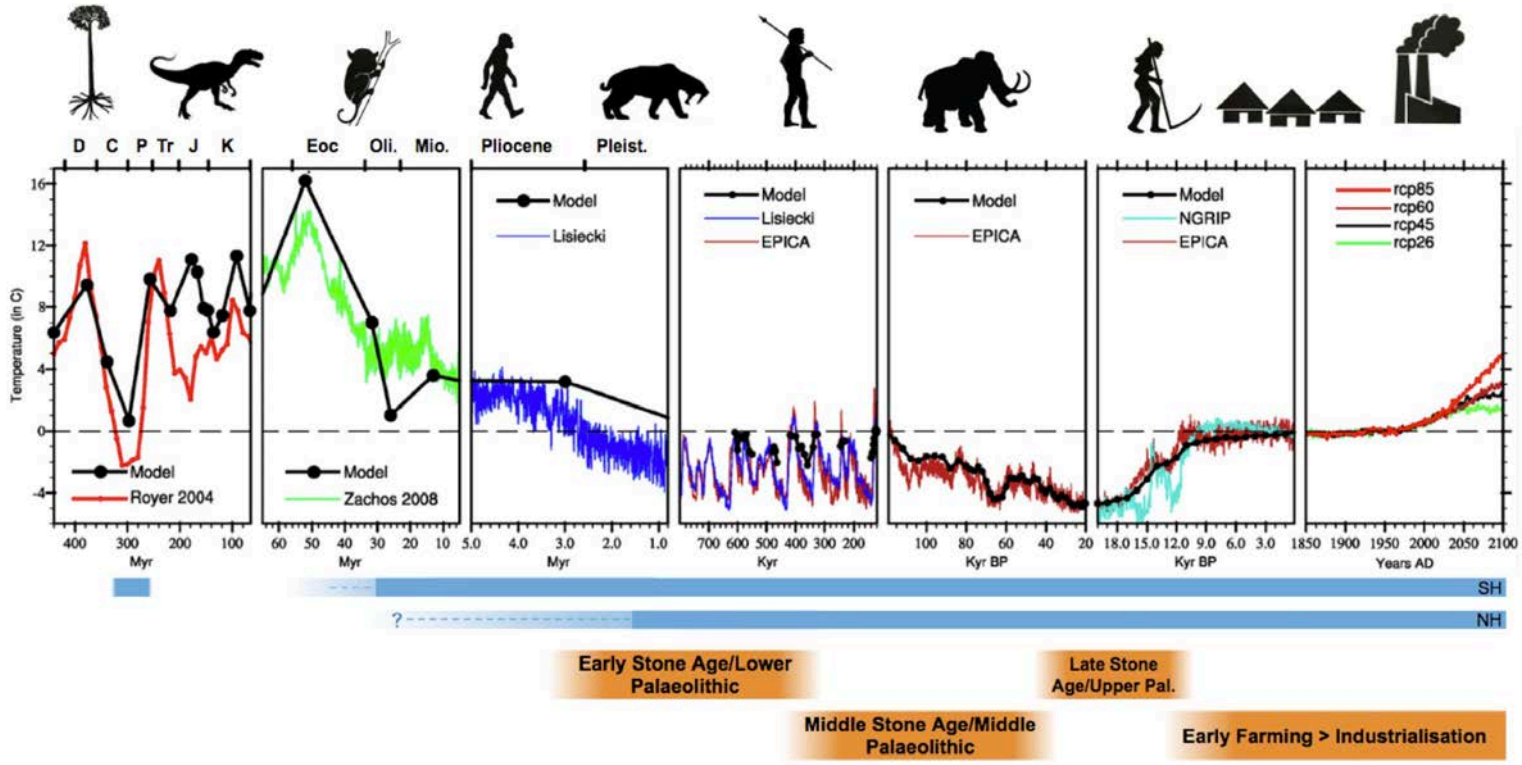
I use Blue Waters to…

…simulate past climates!



Haywood et al., 2019

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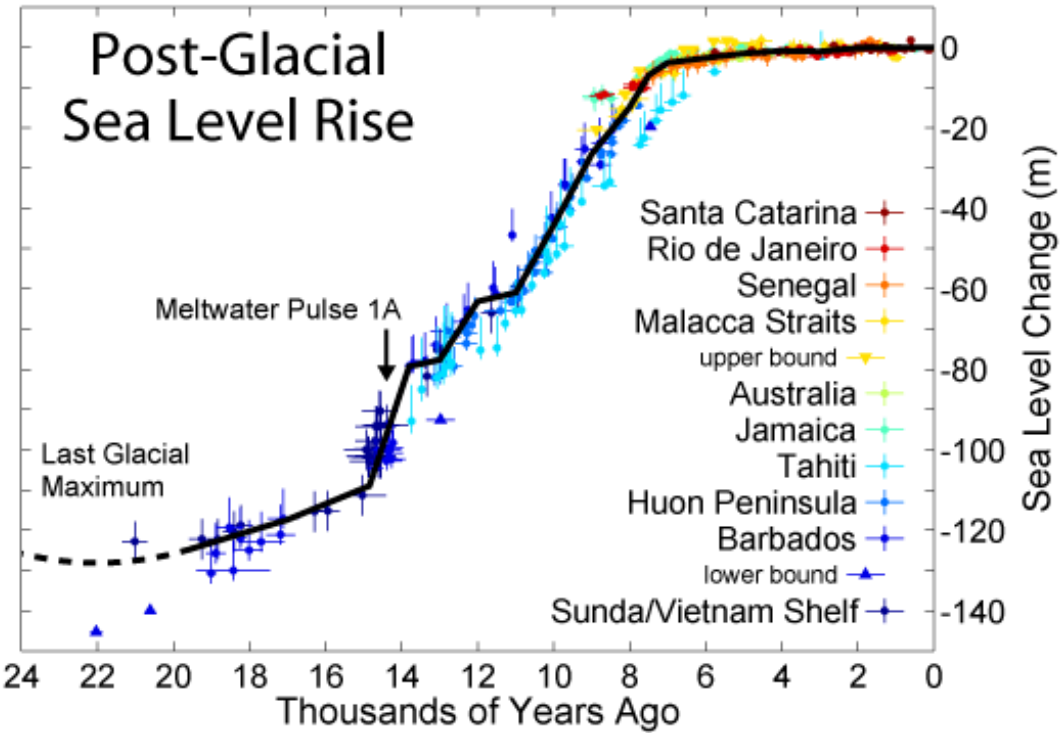
Specific, I use Blue Waters to…

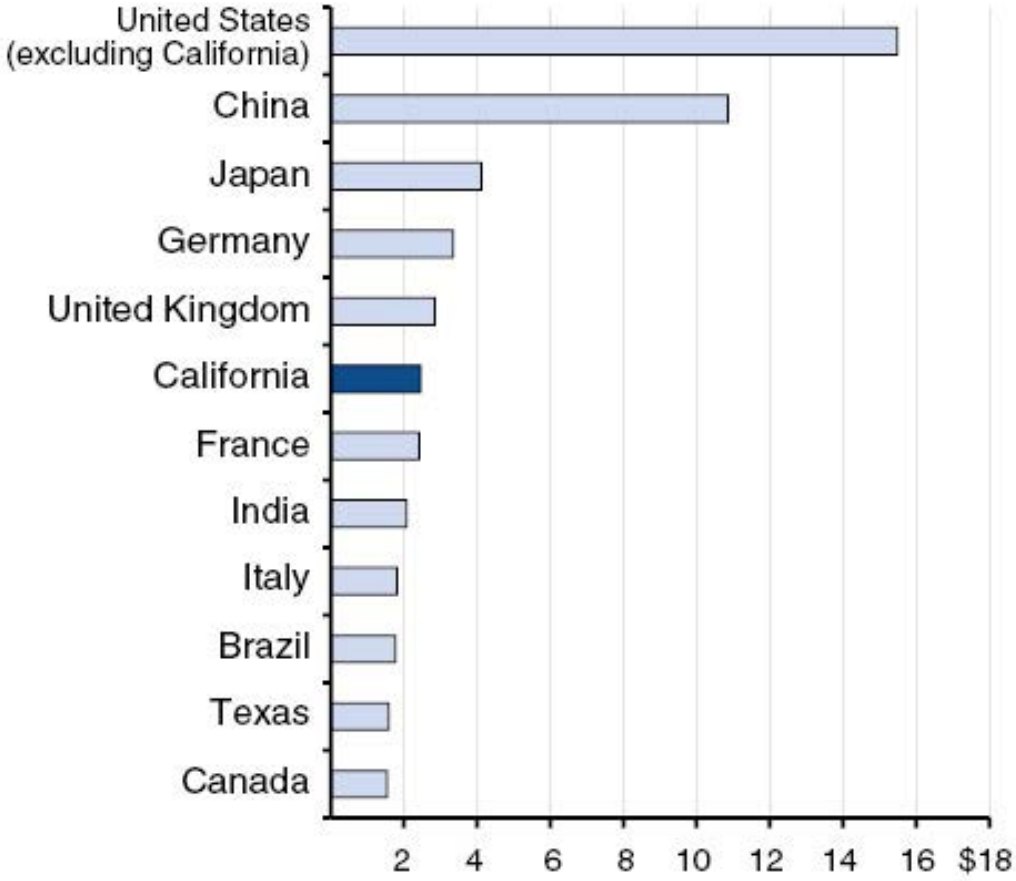
…simulate hydroclimate change in California since 21 thousand years ago.



Why California?

- 6th largest economy in the world

mercurynews.com



lao.ca.gov

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California Drought

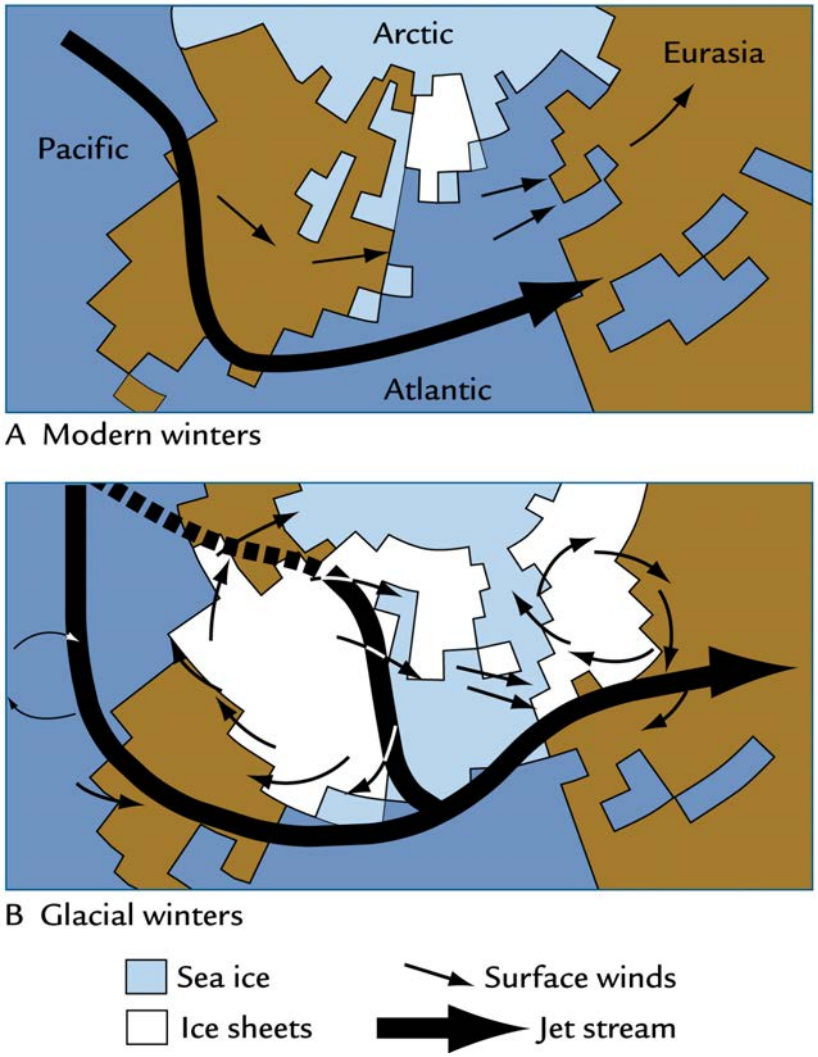
- Drought prone region
- Uncertain future climate changes

WattzOn Labs Digital Magazine

Justin Sullivan

LGM Climate

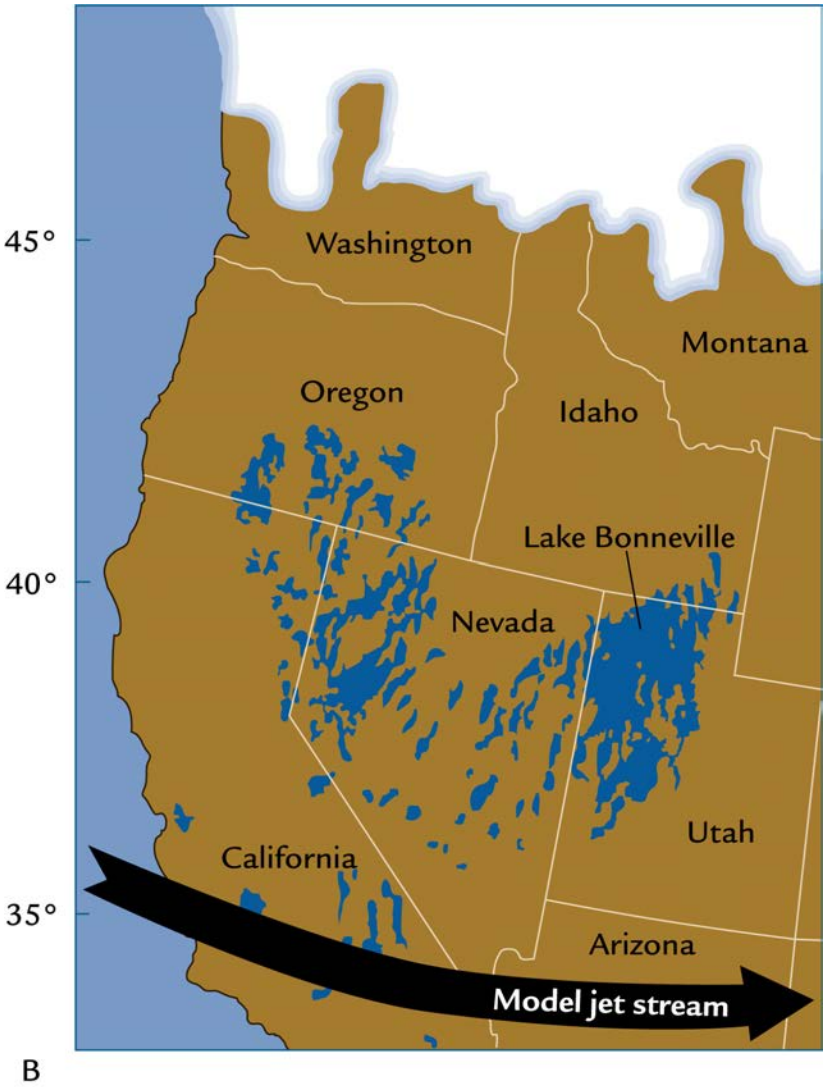
- Multiple lines of evidence for circulation changes at the Last Glacial Maximum (21 ka)



Ruddiman, 2000

LGM Hydrology

- Wetter Southwest US
  - Shift in storm tracks?



Ruddiman, 2000

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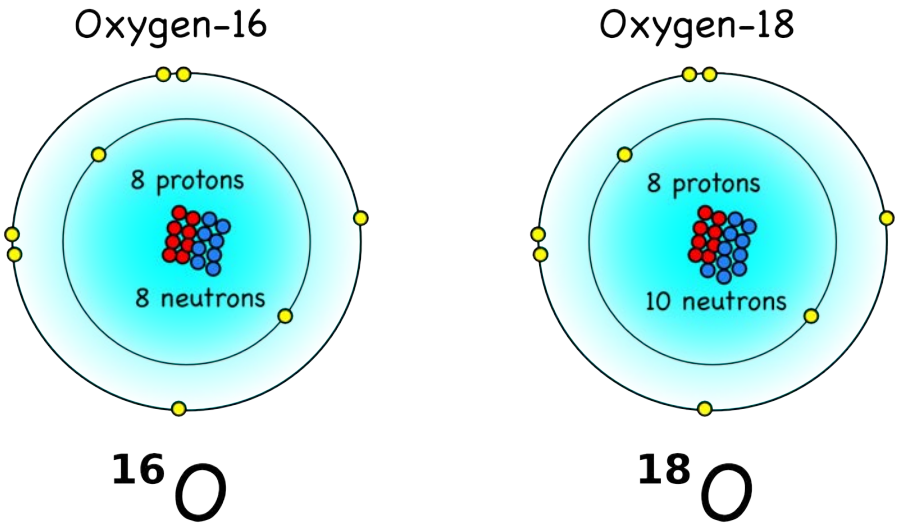
Oxygen Isotopes

- Lighter isotopes preferentially go to the higher energy state
- Fractionation is temperature dependent
- Allows tracking of water through the hydrological cycle



Urbano (2011)

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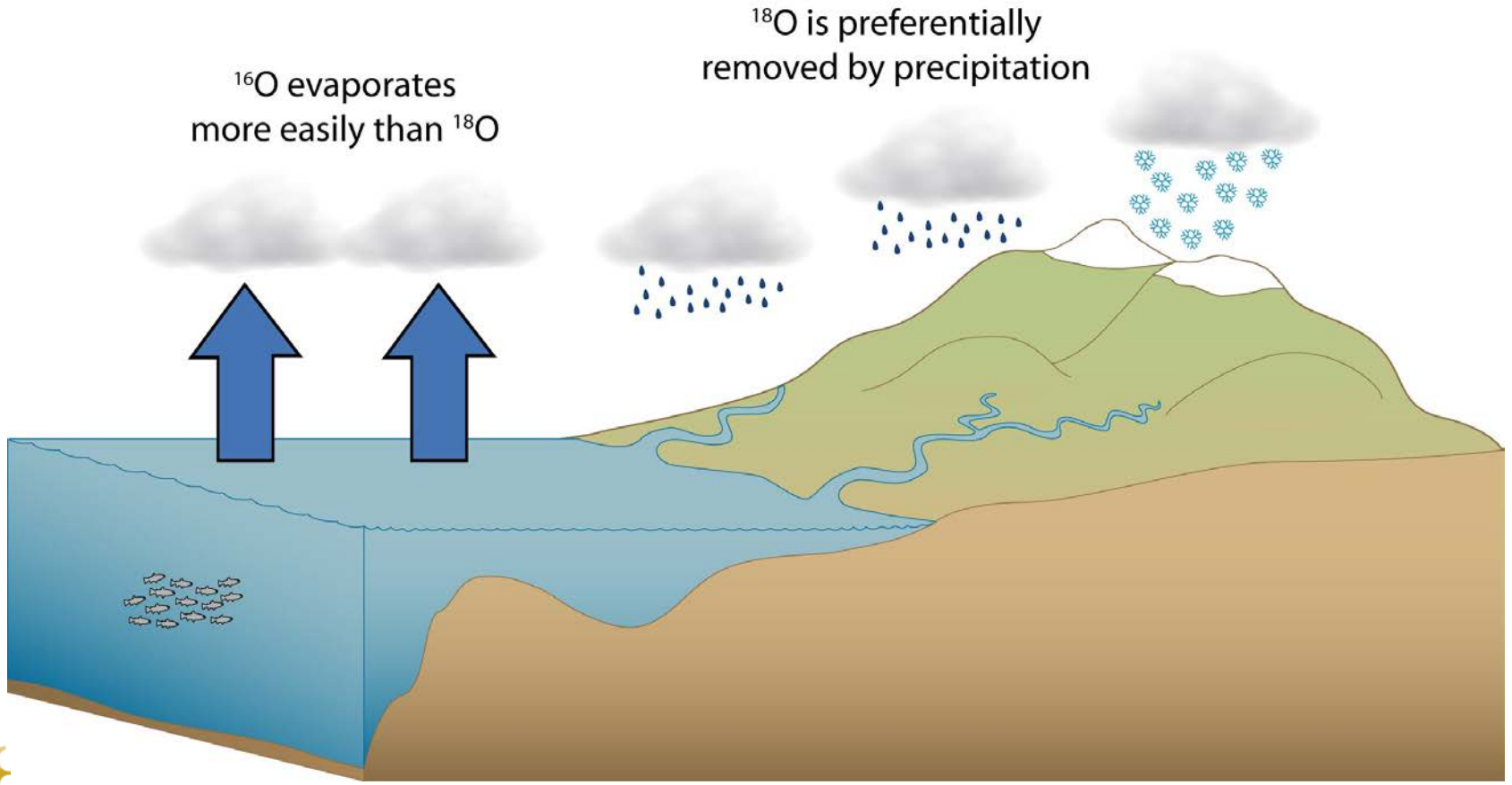
$\delta^{18}O$ Meaning

$$\delta^{18}O\ (\text{in } ‰) = \frac{(^{18}O/^{16}O)_{\text{sample}} - (^{18}O/^{16}O)_{\text{standard}}}{(^{18}O/^{16}O)_{\text{standard}}} \times 1000$$

- Low value = depleted, lighter
- High value = enriched, heavier

Oxygen Isotopes Signals

- At its most basic…



Versteegh (2012)

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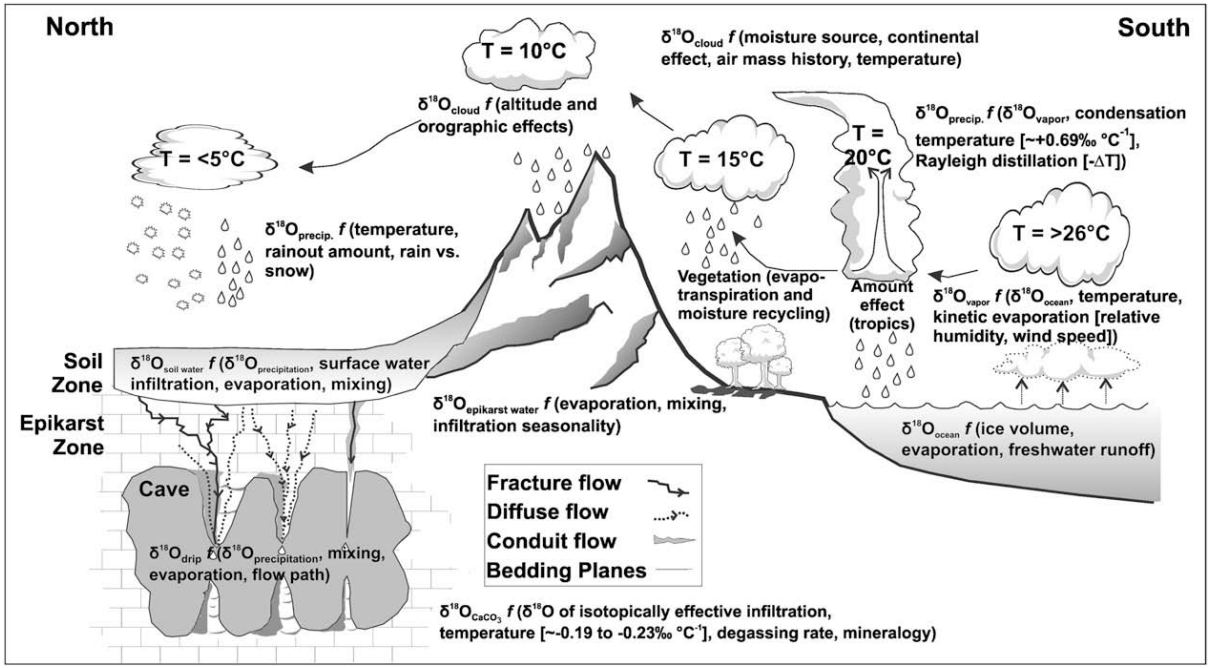
Oxygen Isotopes Complications

- Source
- Circulation
- Amount effect
- Temperature
- Changes through time



Lachniet (2009)

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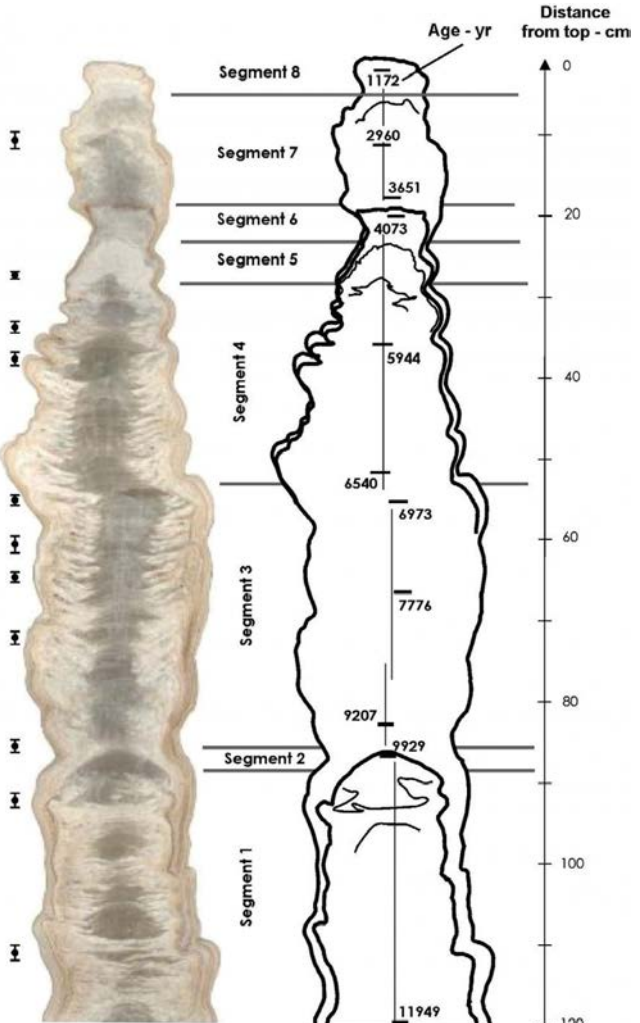
Speleothems

- Chemical reaction as water flows through the surface
- Calcium carbonate formations via carbonate dissolution
  - Allows $\delta^{18}O$ to be determined
- Absolute dating (U/Th)



Verheyden et al. (2008)

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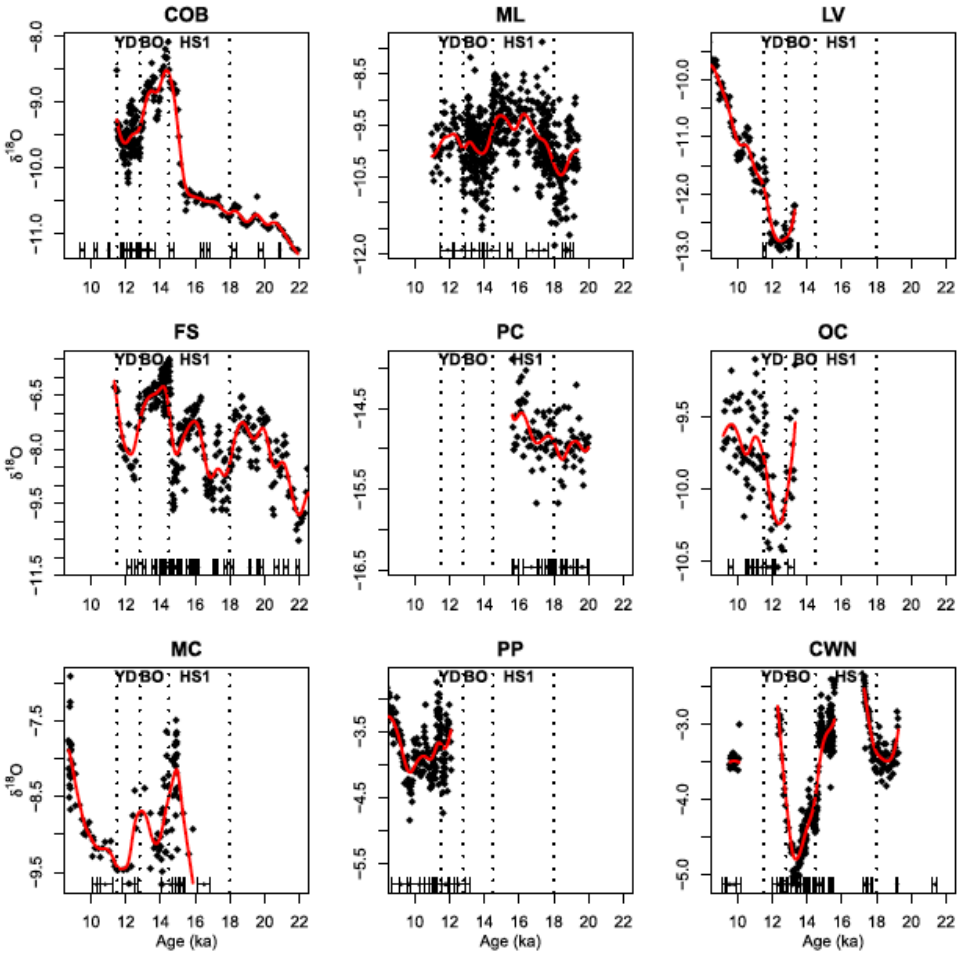
Southwest US Climate Since 21 ka

- Lots of regional climate variability during the deglaciation
- Mechanisms debated



Oster et al. (2016)

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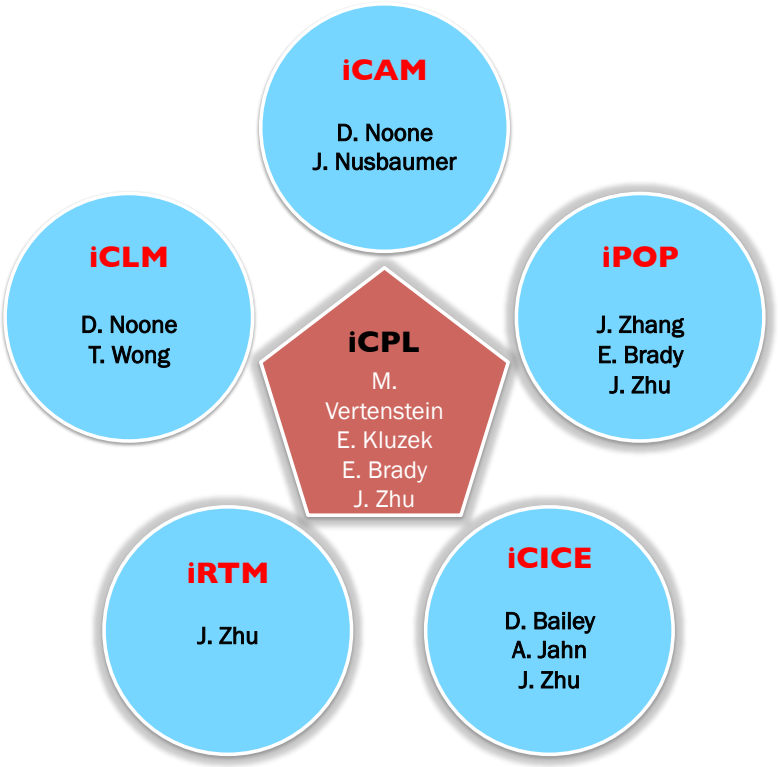
Community Earth System Model

- State-of-the-art Earth System Model
- iCESM1.2
  - Brady et al., in review; JAMES
- Fully coupled with water isotope tracers



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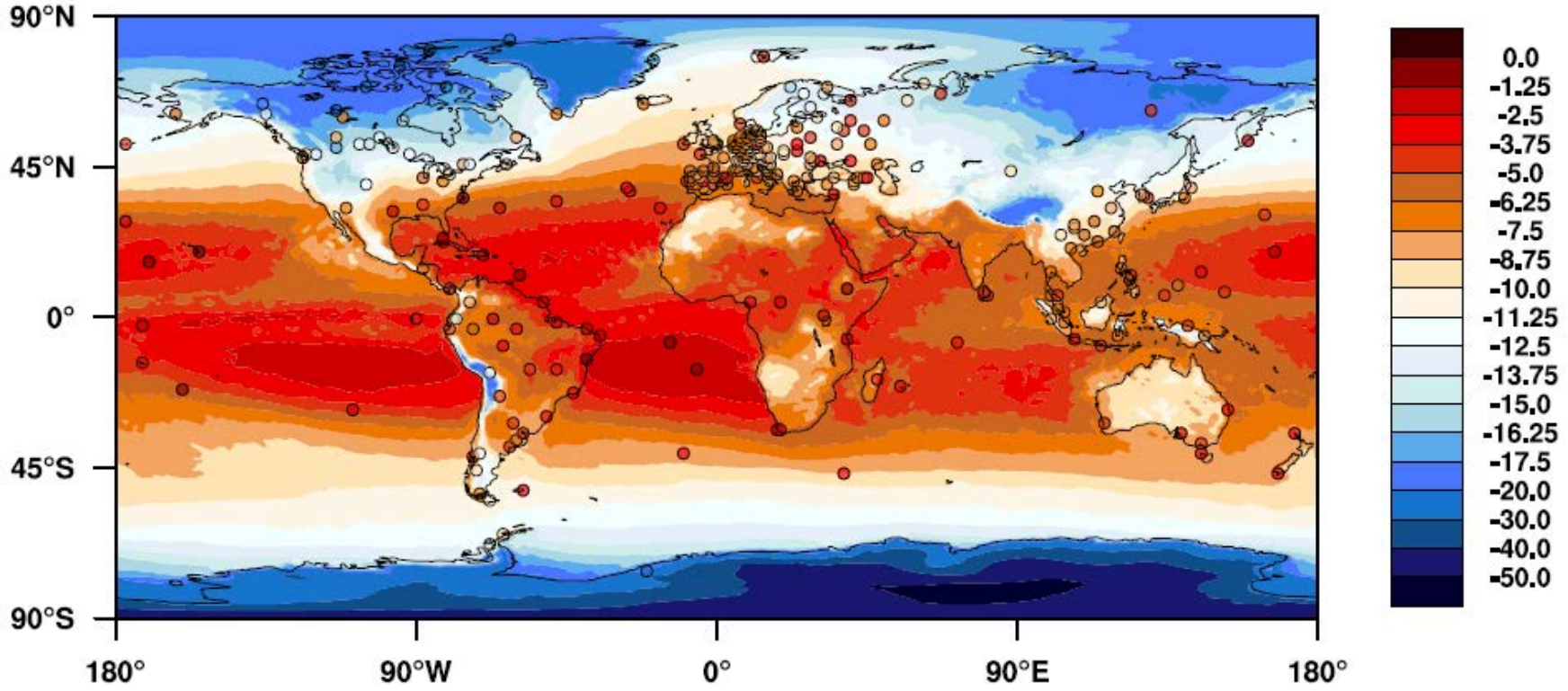
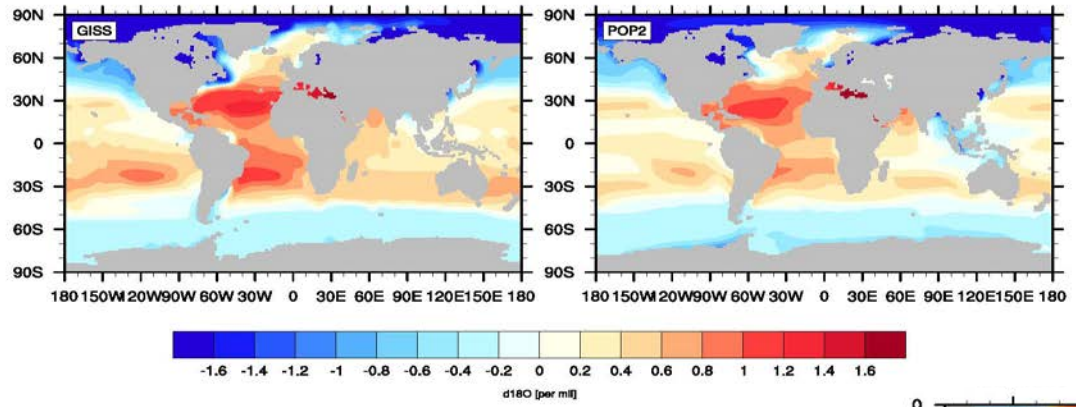
Oxygen Isotopes in CAM5

- Well simulates present day isotopic distribution



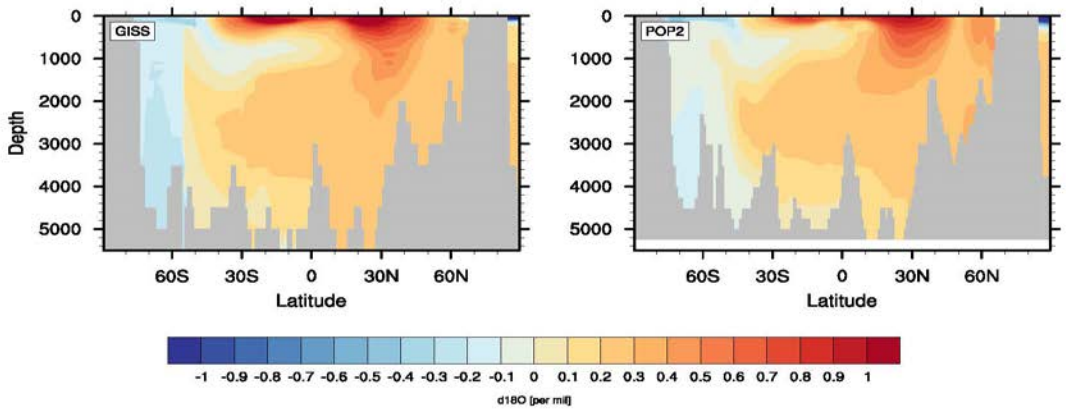
Nusbaumer et al. (2017)

Oxygen Isotopes in POP2



Ocean Surface

Atlantic Ocean



LeGrande and Schmidt (2006)

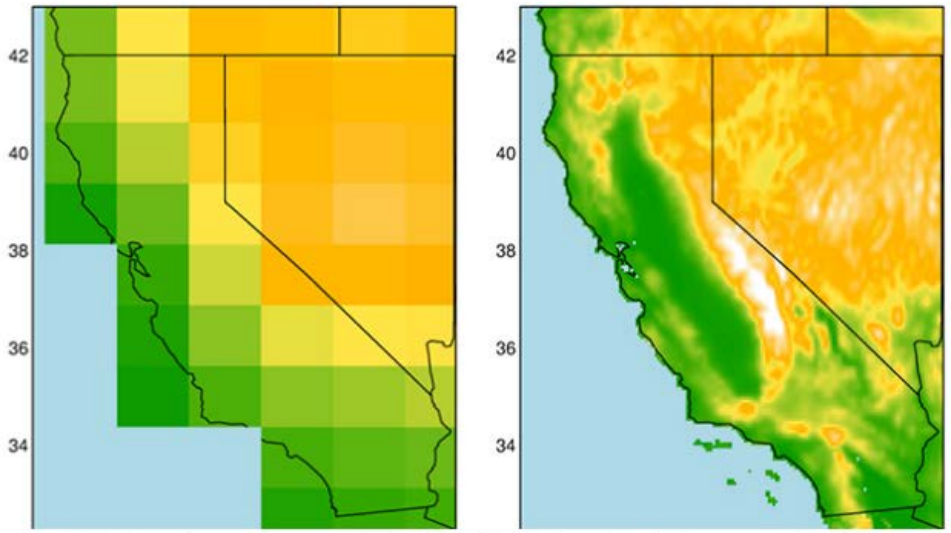
Experiment Design

- 7 experiments spanning the deglaciation (PMIP protocol; ICE-6G)

Run	Obliquity	Precession	Eccentricity	CO_2 (ppm)	Ice Sheets
Preindustrial	23.459	0.01690	0.016767	284.3	0 ka
LGM	22.949	0.01772	0.018994	190	21 ka
HS1	23.756	-0.00544	0.019560	224	16 ka
BO	23.886	-0.01069	0.019635	234	15.0 ka
OD	23.997	-0.01508	0.019679	239	14.0 ka
YD	24.159	0.01989	0.019613	260	12.5 ka
MH	24.105	0.00	0.018682	264.4	6 ka

Experiment Setup

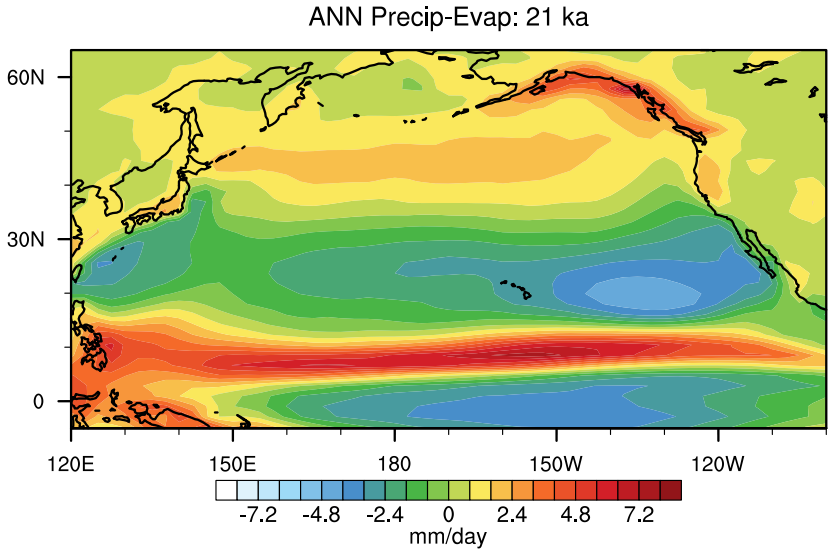
- Need to equilibrate the ocean
  - Run with lower resolution configuration
- Need to resolve key topographic features
  - Sierra Nevada requires at least 0.25° resolution

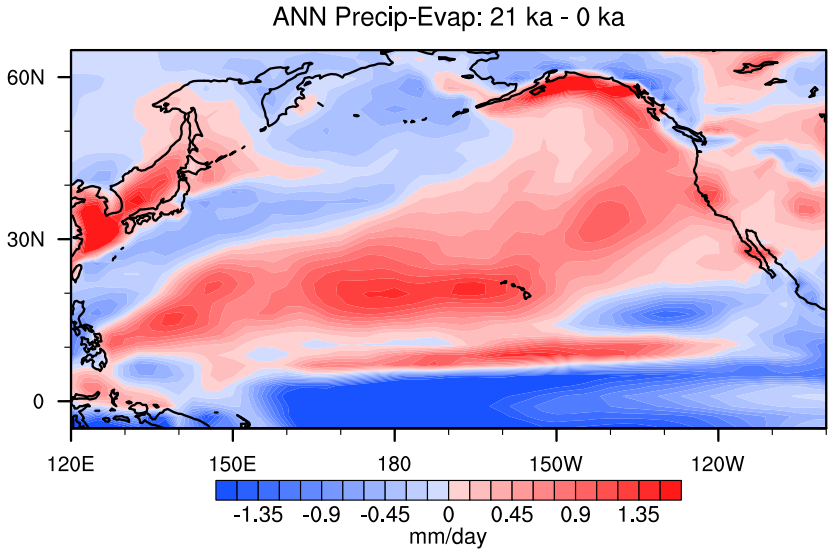


Global climate model representation of California elevations (left) compared to LOCA

Precip – Evap Response

- The western US gets wetter at the LGM
- Both increased precipitation and dampened evaporation





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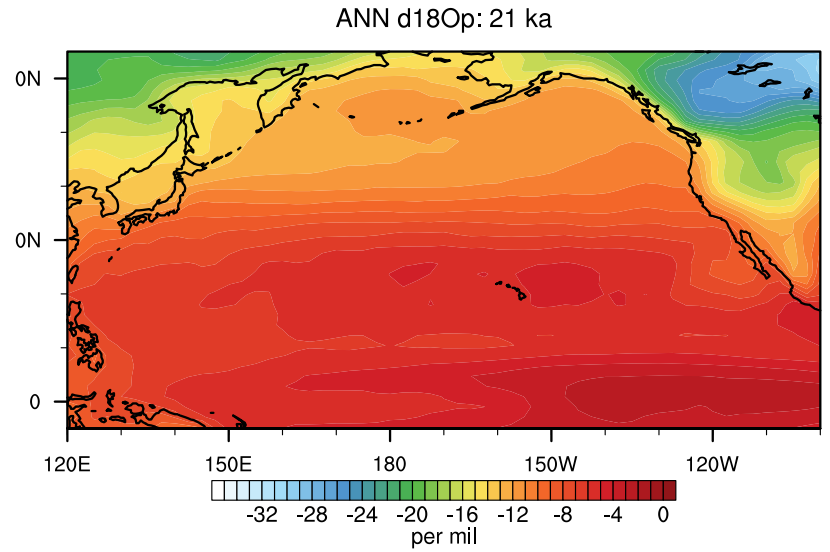
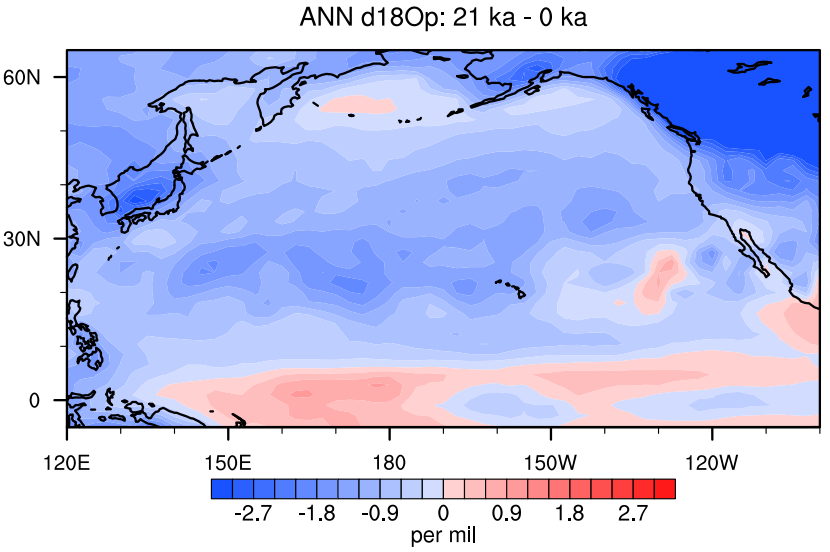
$\delta^{18}O$ of Precipitation Response

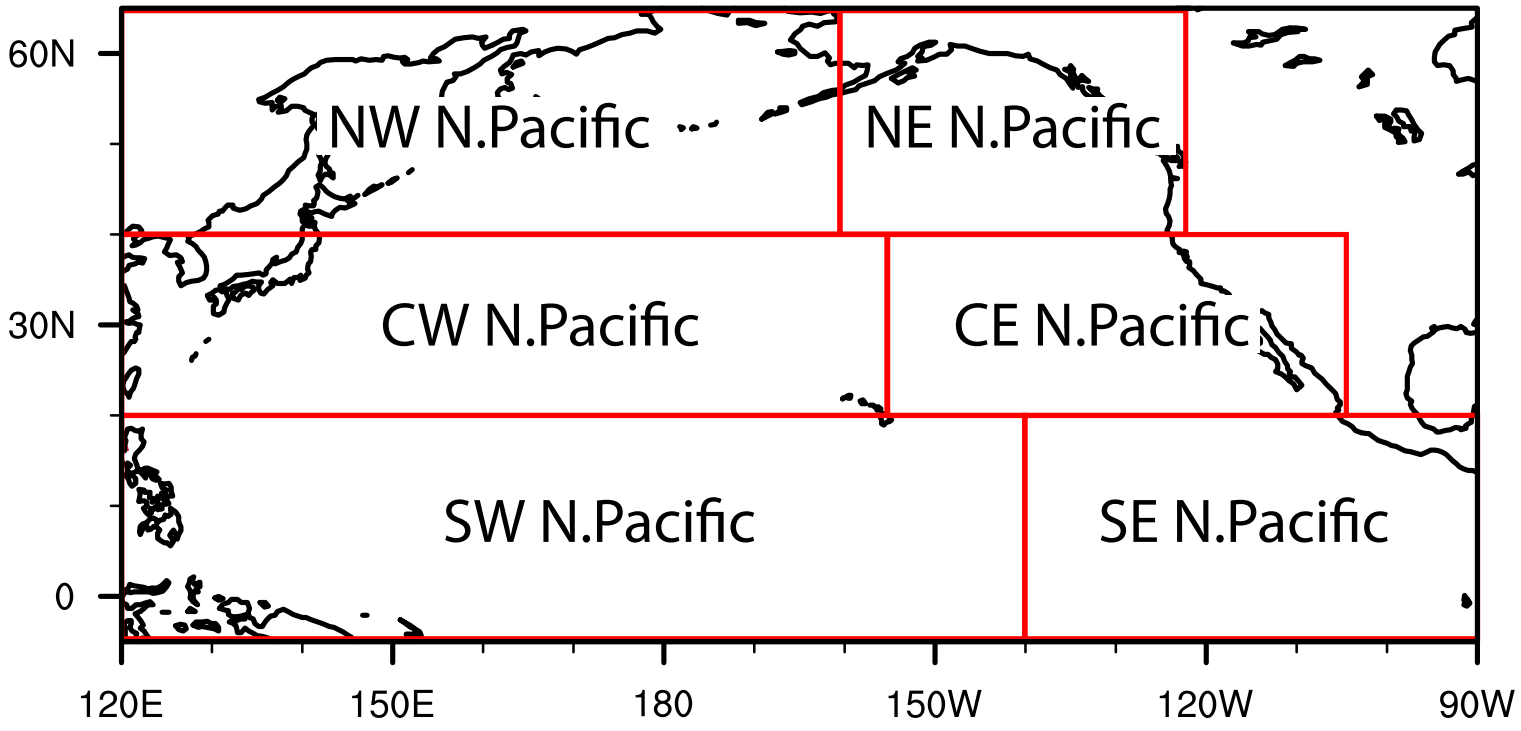
- Western US depletion of ~1.5 per mil





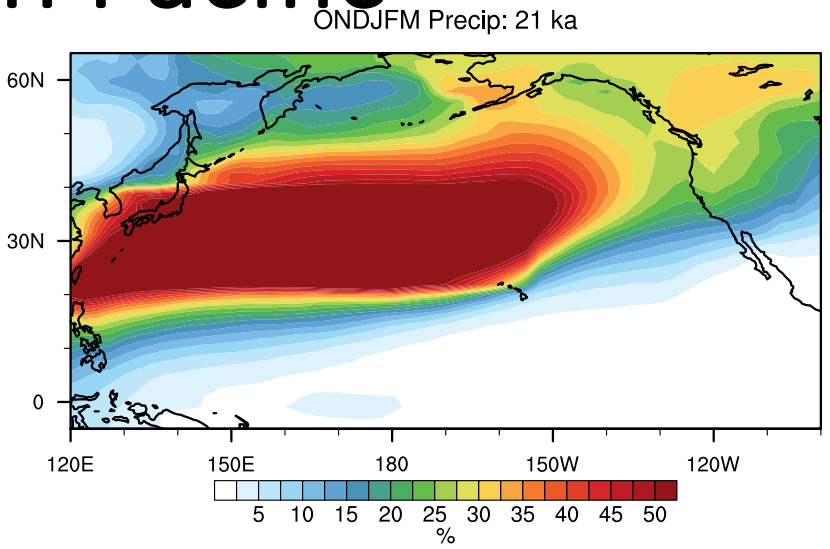
Water Tags

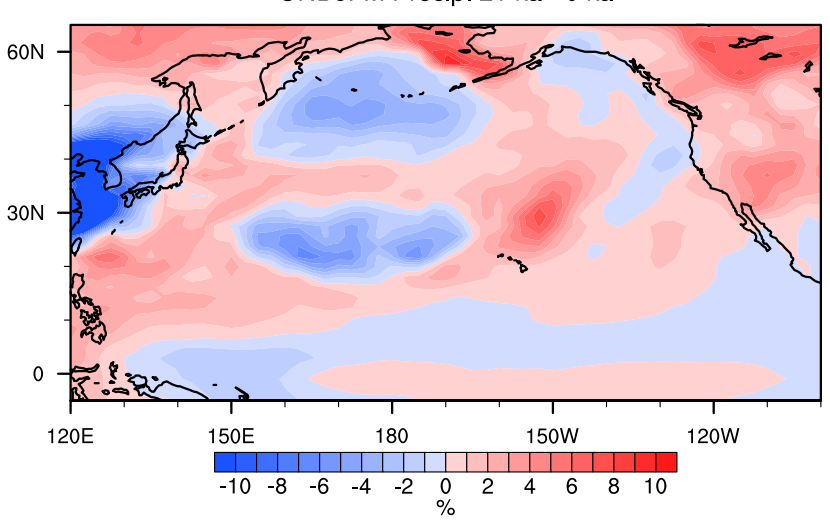
- Track the amount and isotopic composition of water originating from different regions



Winter Precipitation Amount: Central West North Pacific

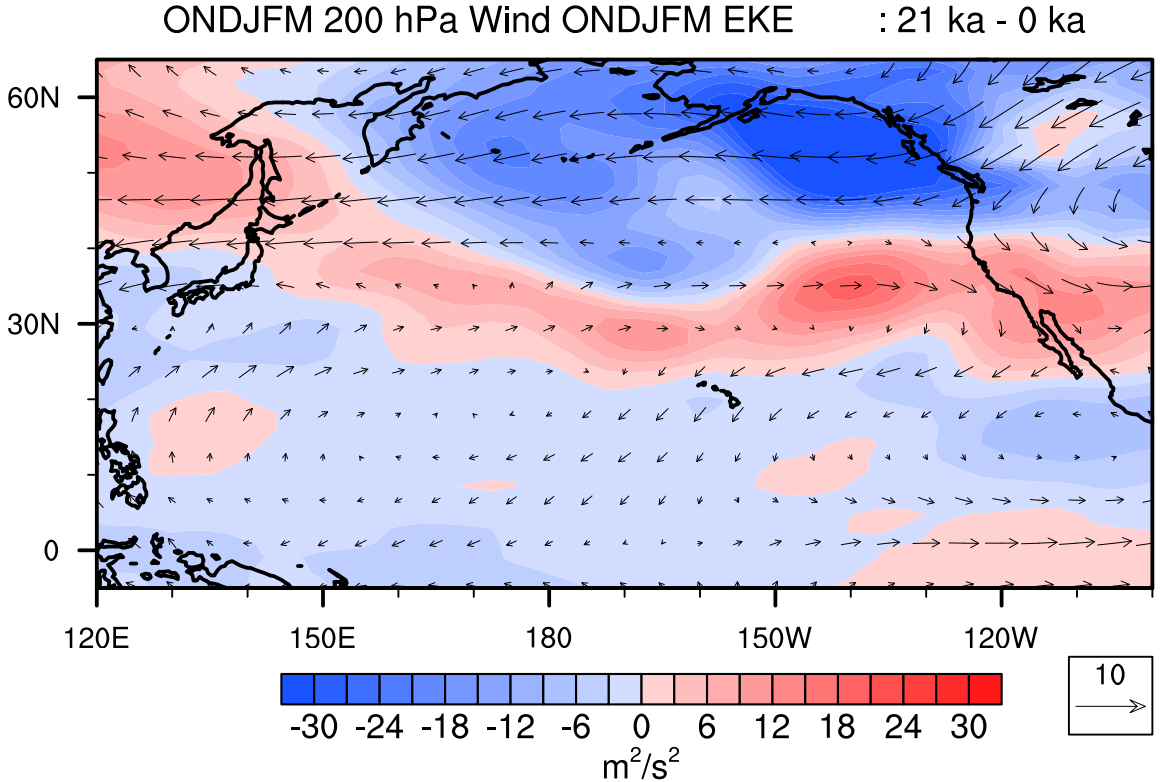
- Contributes **~7% more** to the total precipitation at the LGM
- Likely related to shift in storm track
  - Manabe and Broccoli, 1985





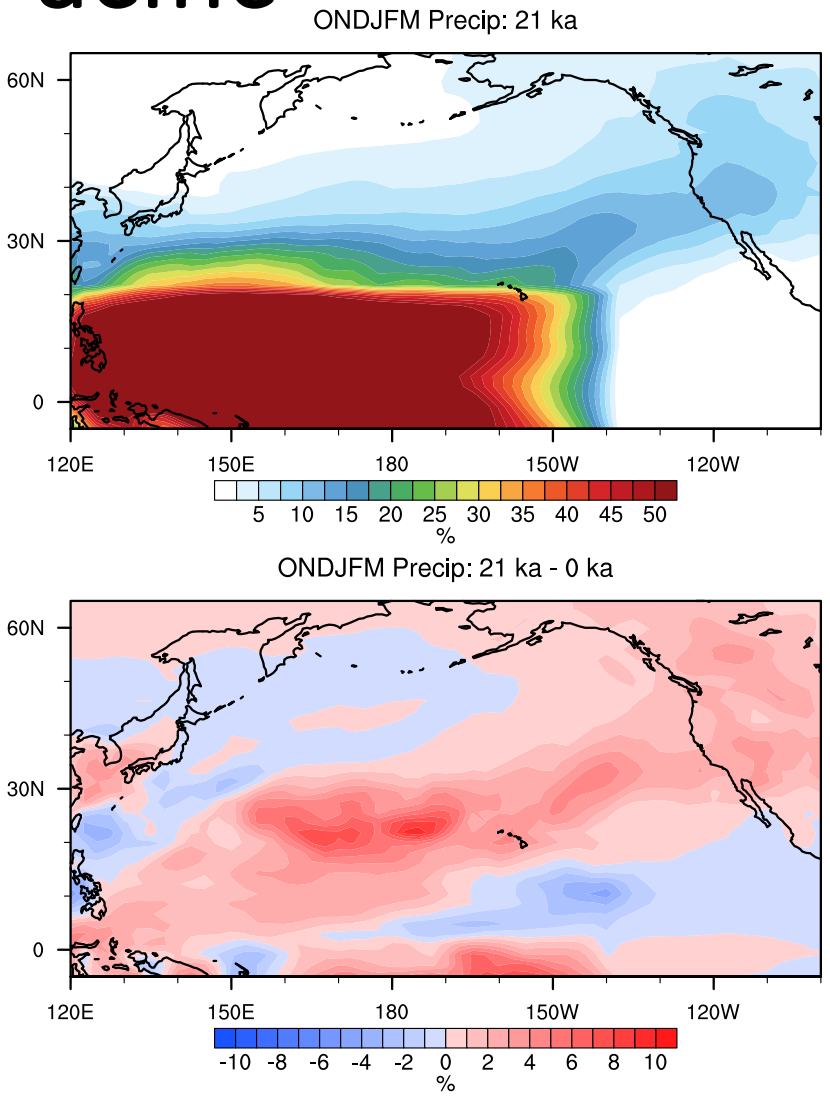
Eddy Kinetic Energy

- Southward shift of the storm tracks at the LGM
- Potentially explains the central Pacific moisture increase at the LGM



Winter Precipitation Amount: Southwest North Pacific

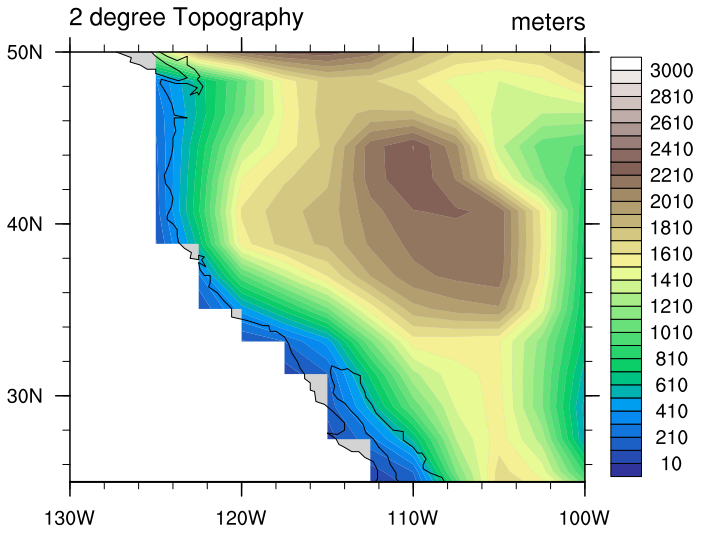
- Contributes **~4% more** to the total precipitation at the LGM
- Atmospheric river contribution?
  - Lora et al. 2017

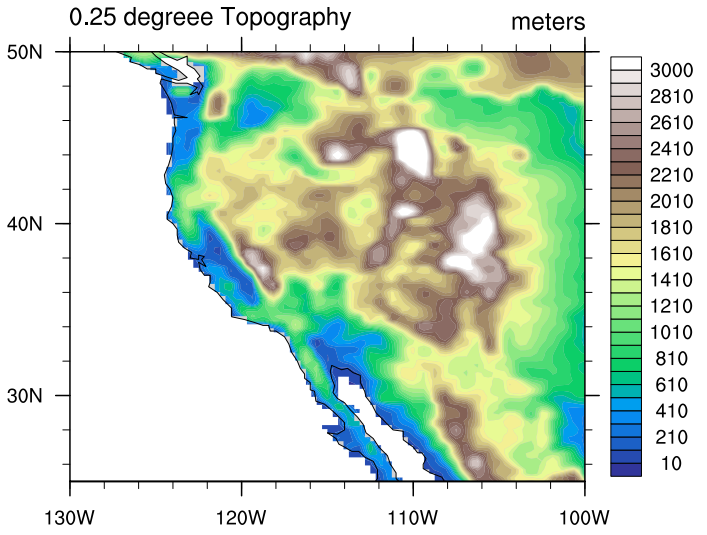


Next Step: High Resolution

- Low resolution limited
- Significant local variability

Wikipedia





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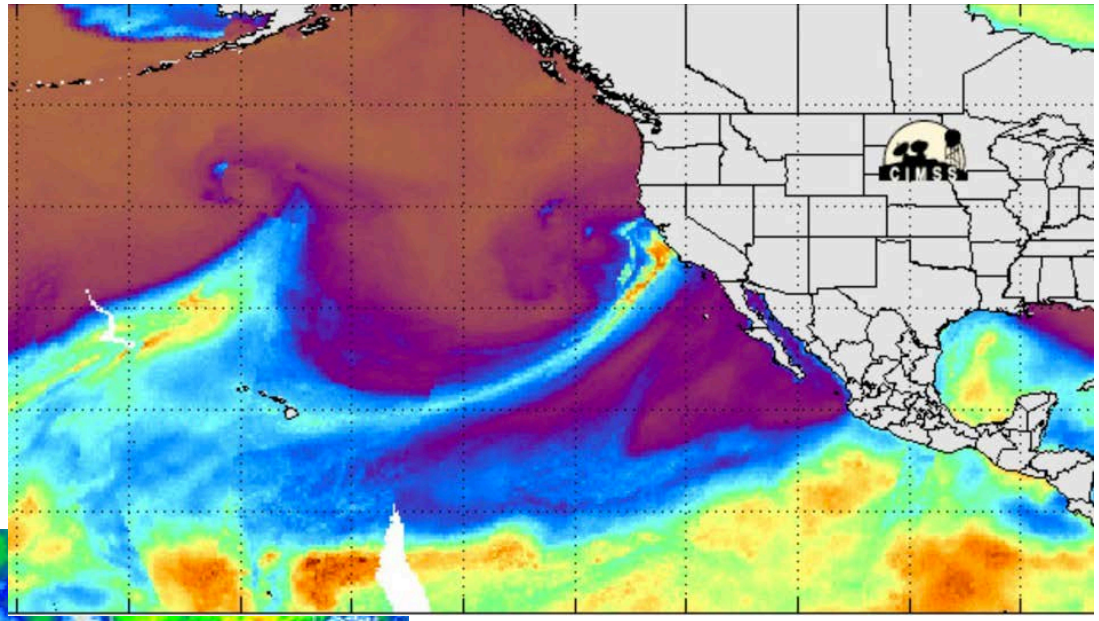
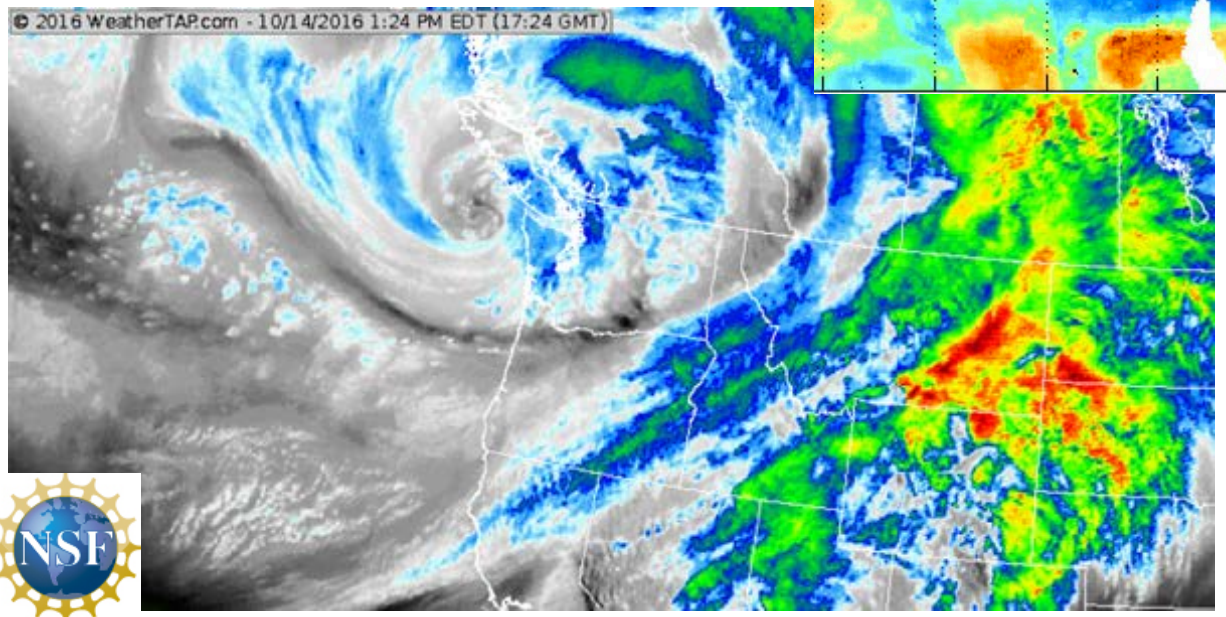
Next Step: High Frequency

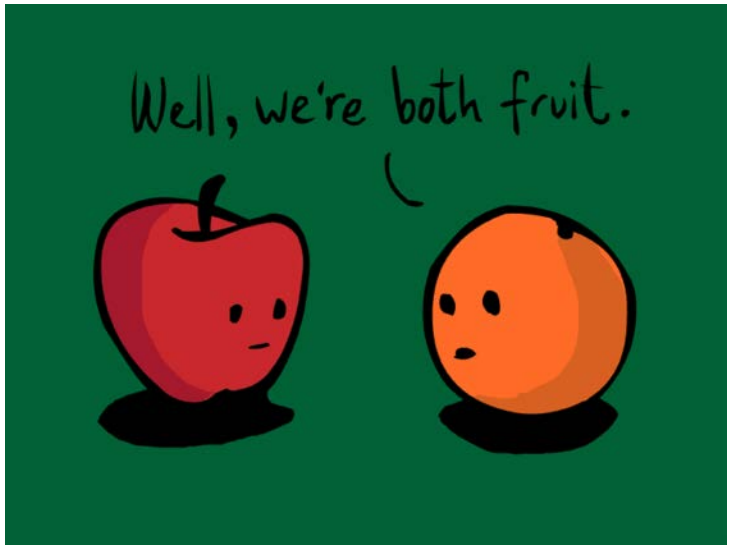
- Data is lost when averaging over months or years
- Need identification tools





Key Challenges

- Understanding hydroclimate change in Western US since 21 ka!
- Requires high resolution with water isotope tracers and high frequency outputs to perform an “apples to apples” comparison with speleothem records



woot.com

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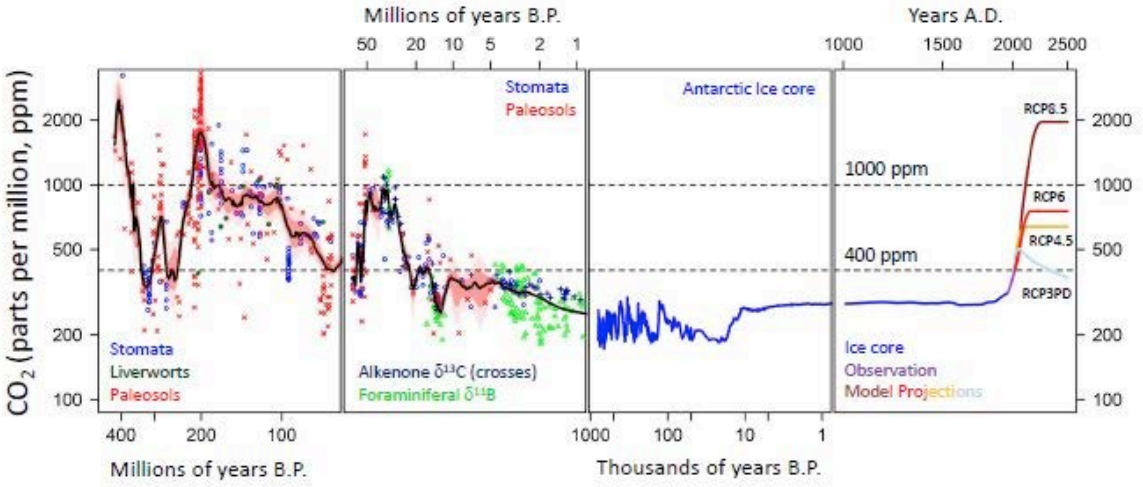
Why it Matters?

- Help inform proxies and models
- Improve understanding of Western US hydroclimate and abrupt climate change

Those who do not learn history are doomed to ~~repeat it~~ incorrectly forecast the future!



Foster et al. (2014)

Why Blue Waters?

- Paleoclimate simulations require a long time to equilibrate
- The addition of water isotopes adds ~50% cost
- To resolve Western US topography, you need 0.25° resolution

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Questions?