An integrated speleothem proxy and climate modeling study of the last deglacial climate in the Pacific Northwest

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Outline

• Using speleothems as a proxy for climate change in the Pacific Northwest
• Comparing proxy data with the TRACE and other paleoclimate simulations
• The need for resolution
• Experimental design
• Using the TRACE restarts
• Bringing new tools to new users
How do speleothems record climate change?

These deposits can be dated with U-series isotopes captured by the growing crystals – to a precision of 1 to 2% of their ages.

Build a ‘rock calendar’ of how cave conditions and the climate above changed through time.

56 ± 3 ka

Hiatus

61 ± 1 ka

63.4 ± 0.8 ka

66.6 ± 1 ka

66.8 ± 1 ka

67.3 ± 1 ka
Establishing the link between cool-moist and warm-dry conditions

It would be a useful test of paleoclimate models to compare with these and other proxy data.
Transient Simulations: 21,000 years ago to the present

Community Climate System Model, version 3

**Atmospheric model**
- T31 (~4° lat-lon), 26 levels

**Land model**
- sub-grid land types
- “dynamic vegetation”

**Ocean model**
- ~3° lat-lon, with resolution of
  - ~0.6° in tropics and North Atlantic, 25 levels

**Sea ice model**
- dynamics-thermodynamics

DOE INCITE grant:
- Jaguar supercomputer - 125 simulated years per wall clock day

Courtesy Bette Otto-Bliesner
Transient Forcings and Simulations

Forcings
- Orbital insolation
- Greenhouse gases: CO₂, CH₄, N₂O
- Ice sheet extents and heights
- Meltwater fluxes

Three Simulations
- Baseline: all transients forcings
- 2 sensitivity simulations: 17-11ka *
  - Only orbital forcing changes
  - Only CO₂ forcing changes

* All other forcings – ice sheets, meltwater, CO₂ or orbital, held at 17ka values

Courtesy Bette Otto-Bliesner
TraCE-21,000 (Transient Climate Evolution of the last 21 kyr) run compared to proxy data

Cave data

- Sr content
- drier/warmer
- C isotope
- O isotope
- Bølling-Allerød
- Younger Dryas

Greenland Ice Core temperature

NH temperature

CCSM

50 year running average
Using the TraCE runs to look in detail at events in the past

- Proxy data gives us the opportunity to look at large changes in the climate and compare with model output
- Help sort out issues where proxy data disagrees
- Determine if the TraCE run get essence of the state of the climate in the past
Oster et al. have established the cave data likely shows increased precipitation in the Western US during the Last Glacial Maximum.
Using the TraCE simulations to look in detail at periods of interest

Surface temperature average over the Northern hemisphere from the TraCE simulation

- Younger Dryas
- Bølling Allerød

Selected time slices
Need for higher resolution to study West Coast

January Precipitation, mm/day

TraCE run

TraCE T85 run

17Ka
Rerunning time slices at T85 may provide the detail needed.
Experimental design

• Extract the TRACE T31 (3.75 degree resolution) simulations for selected time periods, then regrid and rerun selected time slices at T85 (~ 1.4 degree resolution)
• Ocean temperature remain fixed to those calculated at T31
• Short 5-year runs – longer runs to follow
• Select daily DJF 500hPa geopotential height
• Smooth and calculate the variance
To help sort out the picture of paleoclimate we need an objective way to estimate storm tracks

• First attempt is to use an Eulerian measure the called dynamic storm track, which is defined as a region of enhanced standard deviation of the bandpass filtered 500-hPa geopotential height (Blackmon 1976; Wallace et al. 1988; Lau 1988).

• Limitations: Because of the time filtering of, the storm track is restricted to the characteristic time scale of synoptic cyclones; however, a considerable amount of synoptic-scale variability within this frequency band is not related to cyclones but to large-scale waves and high-pressure systems.
The Younger Dryas appears to have a stronger and expanded storm track.

Peak of the Bølling Allerød ~14.3 kya

Peak of the Younger Dryas~12.2 kya

Variance of the Filtered 500hPa geopotential heights x 1000 meters²
Map Climatology of Midlatitude Storms (MCMS)

- Identify every cyclone and delineate its extent (closed contours) then project to a common reference (preserving size and shape) and add to the stack to be averaged.
- Lagrangian versus the maps (Eulerian)
- Preserves mean cyclone structure.
- Recursive search seeded on center.

Courtesy Mike Bauer NASA GISS
Other factors that may influence precipitation in the proxy record

• Atmospheric rivers
• Increase occurrence as the climate warms?
Occurrence of Atmospheric Rivers: an additional complication (Dettinger, 2009)

<table>
<thead>
<tr>
<th></th>
<th>Average # per yr</th>
<th># yrs &lt; 5 ARs</th>
<th># yrs &gt; 15 ARs</th>
<th># yrs &gt; 20 ARs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reanalysis 1961-2000</td>
<td>5.8 days/yr</td>
<td>42 % of yrs</td>
<td>3 % of yrs</td>
<td>0 % of yrs</td>
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<tr>
<td><strong>Projections</strong></td>
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<tr>
<td>1961-1980</td>
<td>8.5</td>
<td>25</td>
<td>16</td>
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<td>1981-2000</td>
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<td>2046-2065</td>
<td>11.6</td>
<td>12</td>
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<tr>
<td>2081-2100</td>
<td>11.7</td>
<td>16</td>
<td>32</td>
<td>12</td>
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</tbody>
</table>

- Increased occurrence of ARs in future climate scenarios

- 30% increase
- 53% decrease
- 100% increase
- 85% increase
The case of cooler-wetter and warmer-drier isn’t settled

- Inconsistent picture of how the regional climate changes in western North America
- In some studies late Pleistocene cooling events in the North Atlantic region have been dry climates in the Sierra Nevada and western Great Basin regions (Oster at al.)
- Glacial (moraines) in California suggest drier during cool periods.. So do lakes
- Speleothem records suggest wetter during the cool periods
- Controversy not settled...
New tools to help with analysis

UV-CDAT
Skin temperature shows large effect of fresh water flux into North Atlantic

YD minus BA Surface Temperature mm/day
The noise here may indicate too short sample

YD minus BA Precipitation mm/day