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

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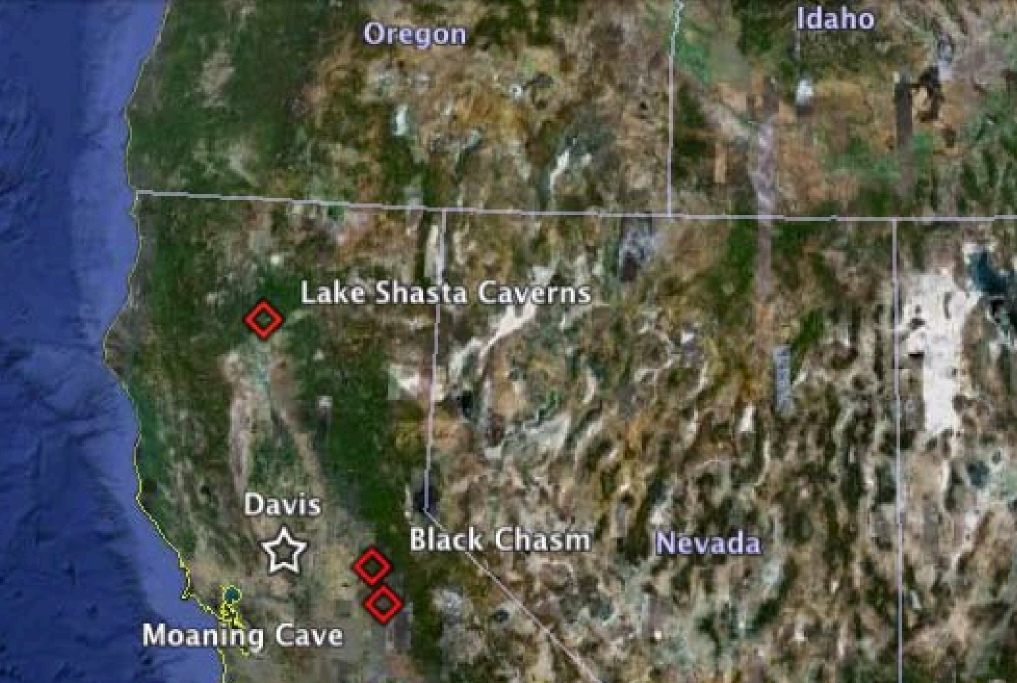
Paleoclimate Working Group, February 16, 2012

Outline

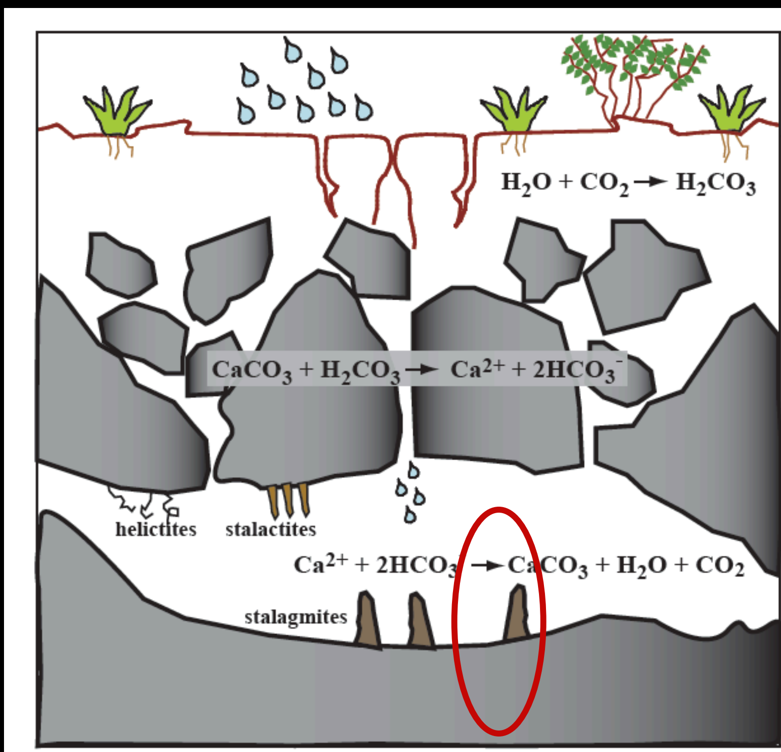
- Using speleothems as a proxy for climate change in the Pacific Northwest
- Comparing proxy data with the TRACE and other paleoclimate simulations
- The need for resolution
- Experimental design
- Using the TRACE restarts
- Bringing new tools to new users


Oregon
Idaho
Lake Shasta Caverns
Davis
Black Chasm
Nevada
Moaning Cave
500 k


Stalagmite Records


Cave Monitoring

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

Hiatus

56 ± 3 ka

61 ± 1 ka

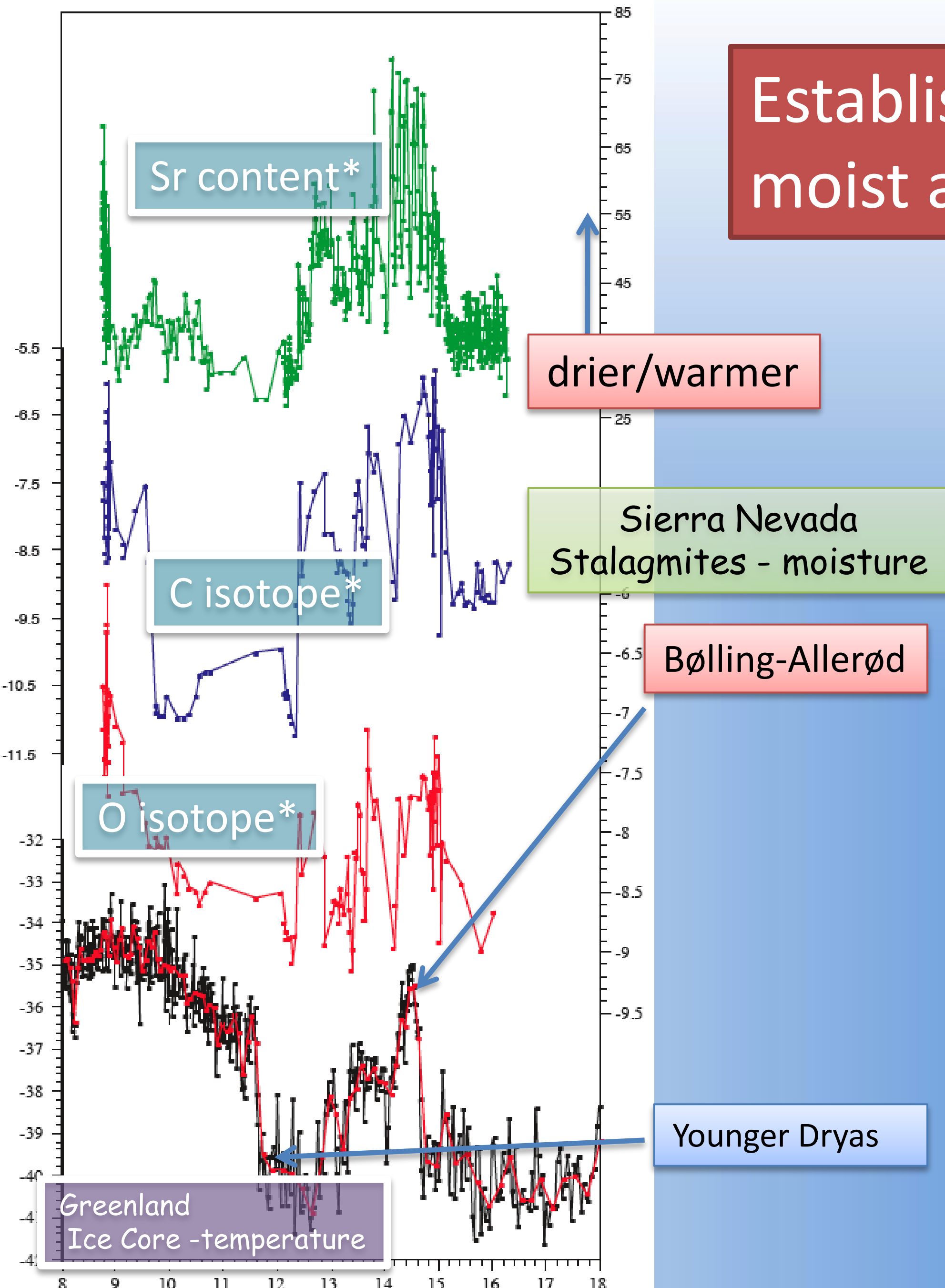
63.4 ± 0.8 ka

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

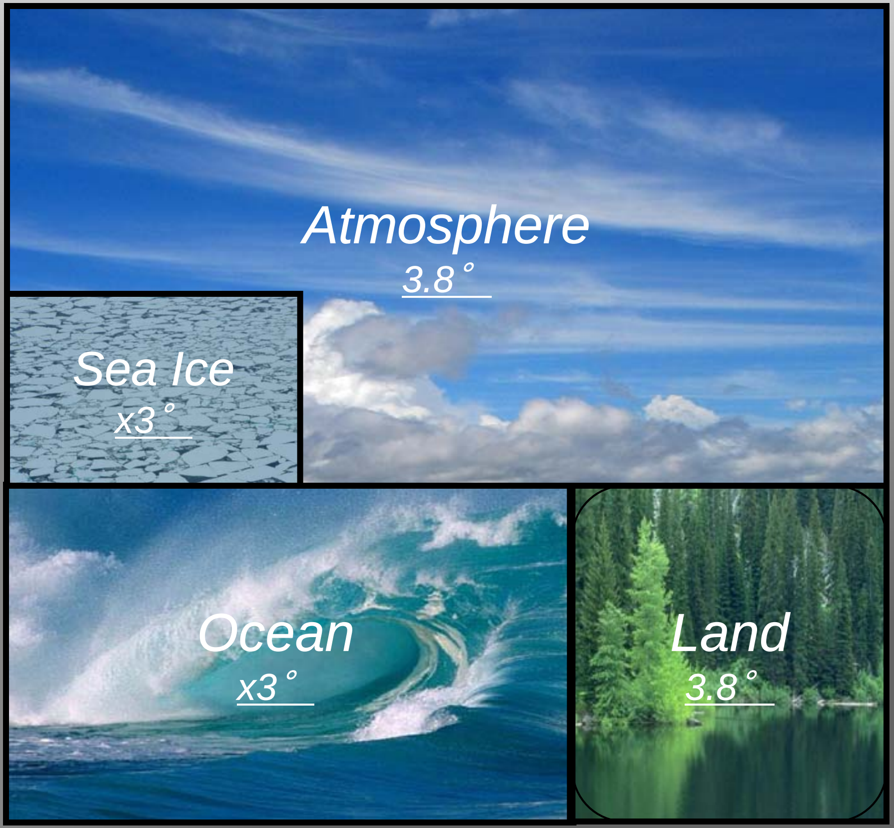
Community Climate System Model, version 3

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

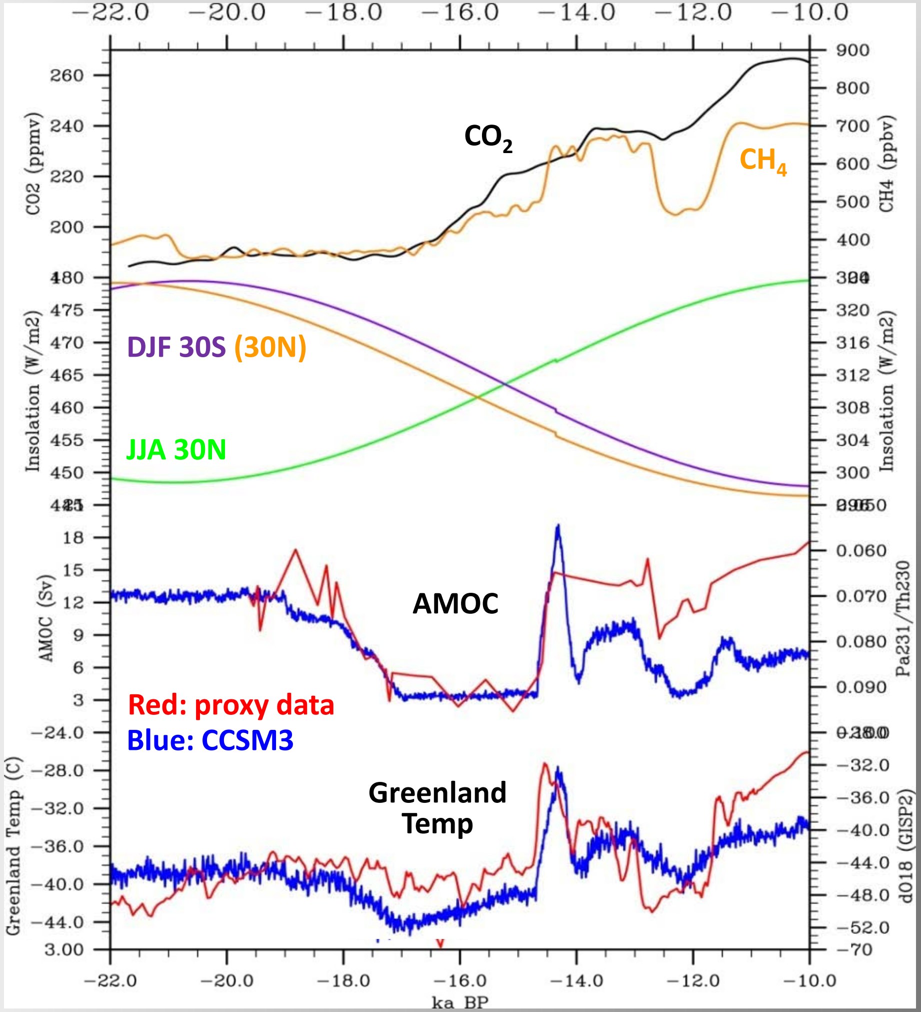
Sea ice model
dynamics-thermodynamics



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: CO_2, CH_4, N_2O
- Ice sheet extents and heights
- Meltwater fluxes

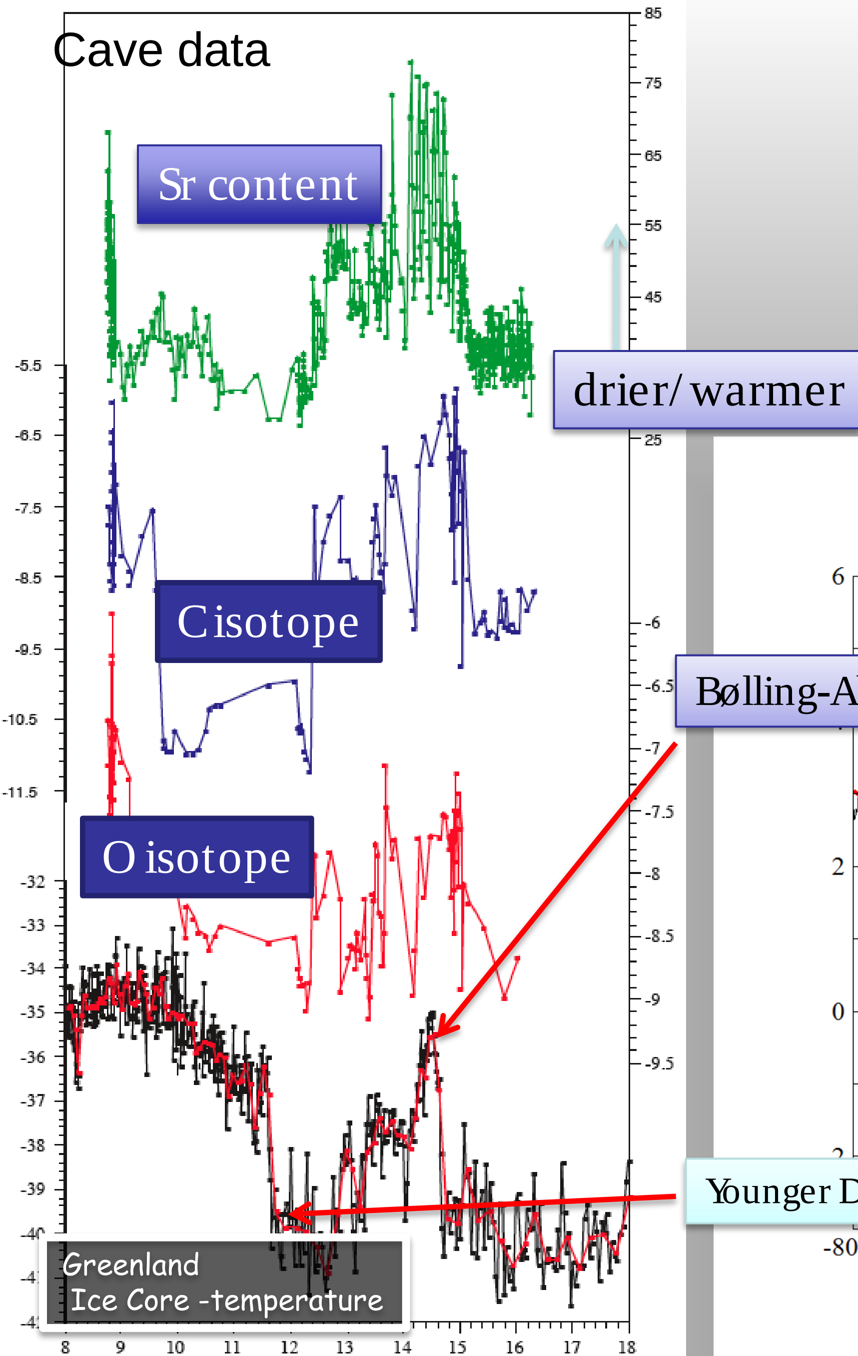
Three Simulations

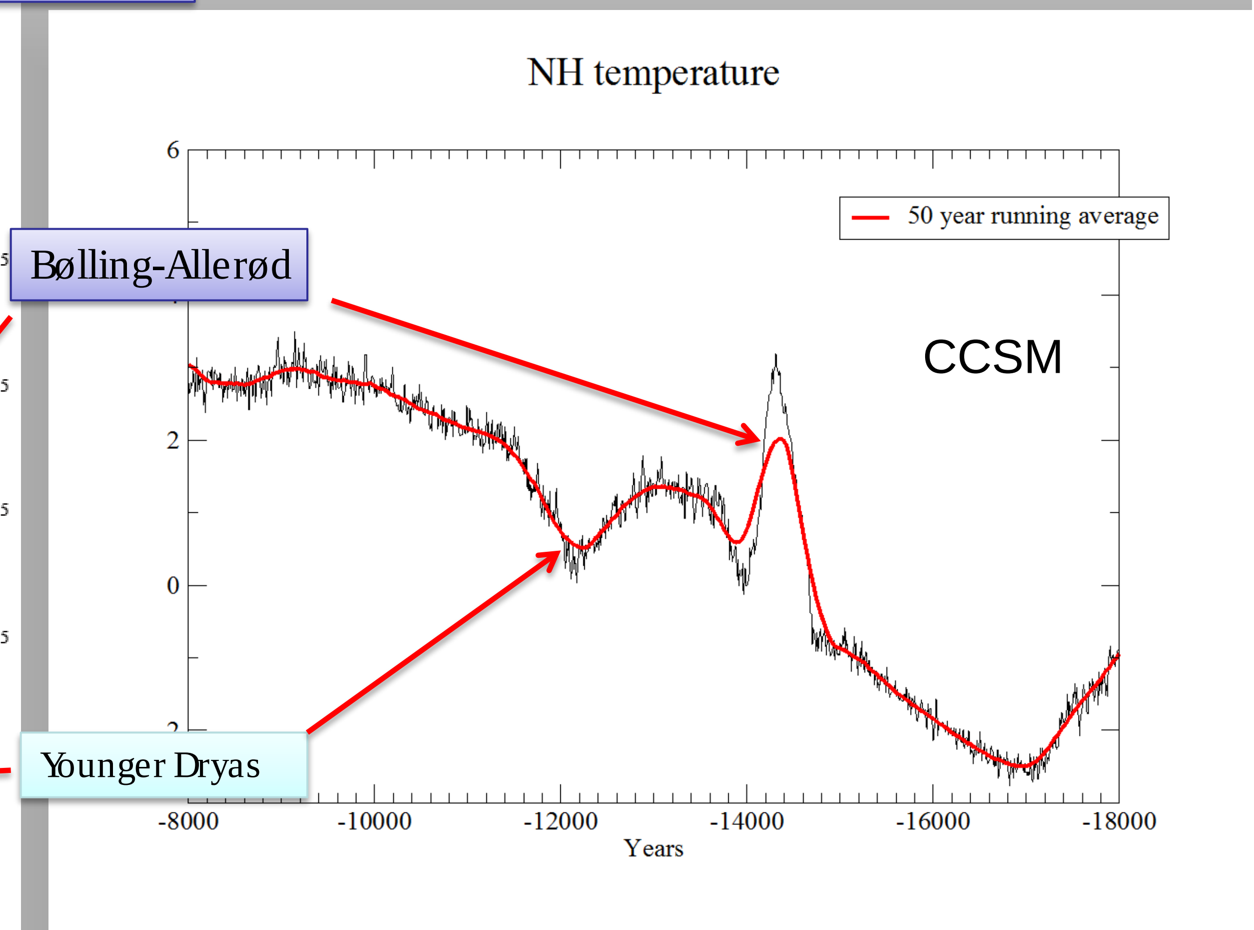
- Baseline: all transients forcings
- 2 sensitivity simulations: 17-11ka *
  - Only orbital forcing changes
  - Only CO_2 forcing changes

* All other forcings – ice sheets, meltwater, CO_2 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

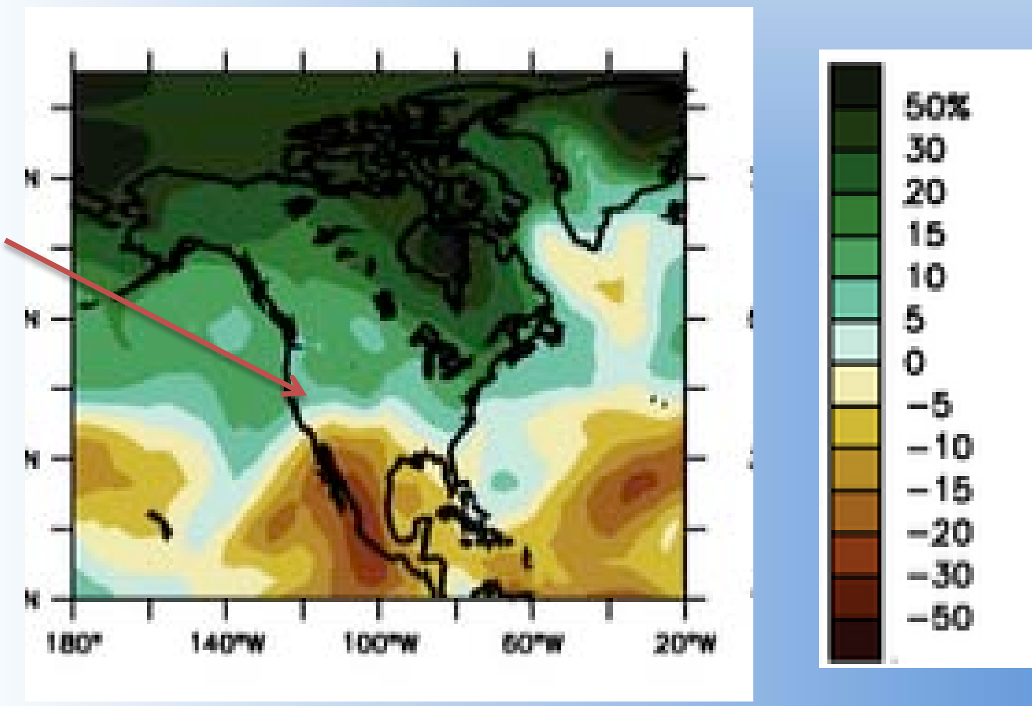




Using the TraCE runs to look in detail at events in the past

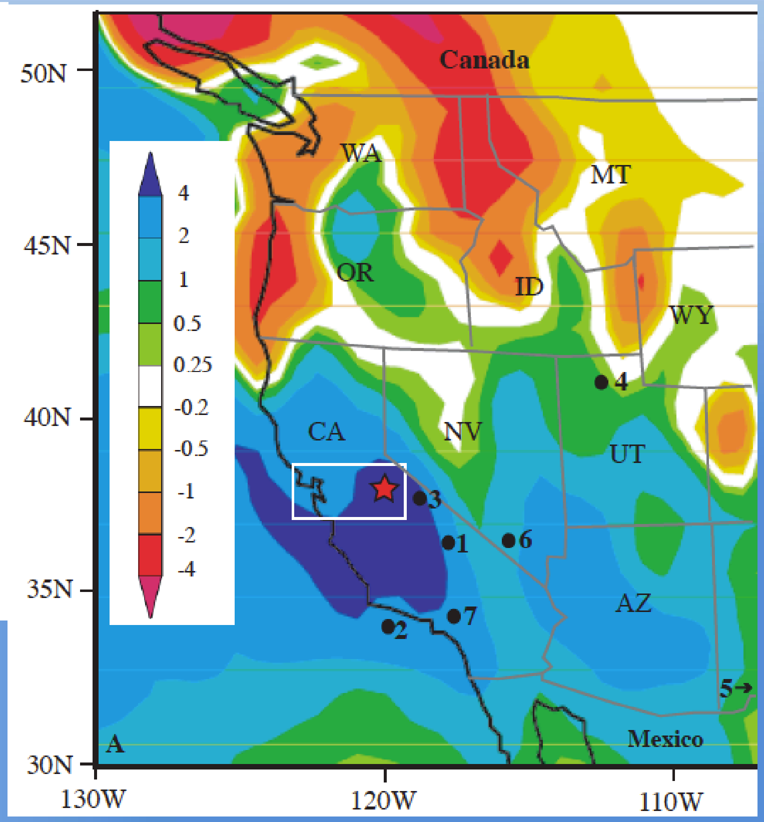
- Proxy data gives us the opportunity to look at large changes in the climate and compare with model output
- Help sort out issues where proxy data disagrees
- Determine if the TraCE run get essence of the state of the climate in the past

Oster et al. have established the cave data likely shows increased precipitation in the Western US during the Last Glacial Maximum



IPCC Ar4 (DJF precip)

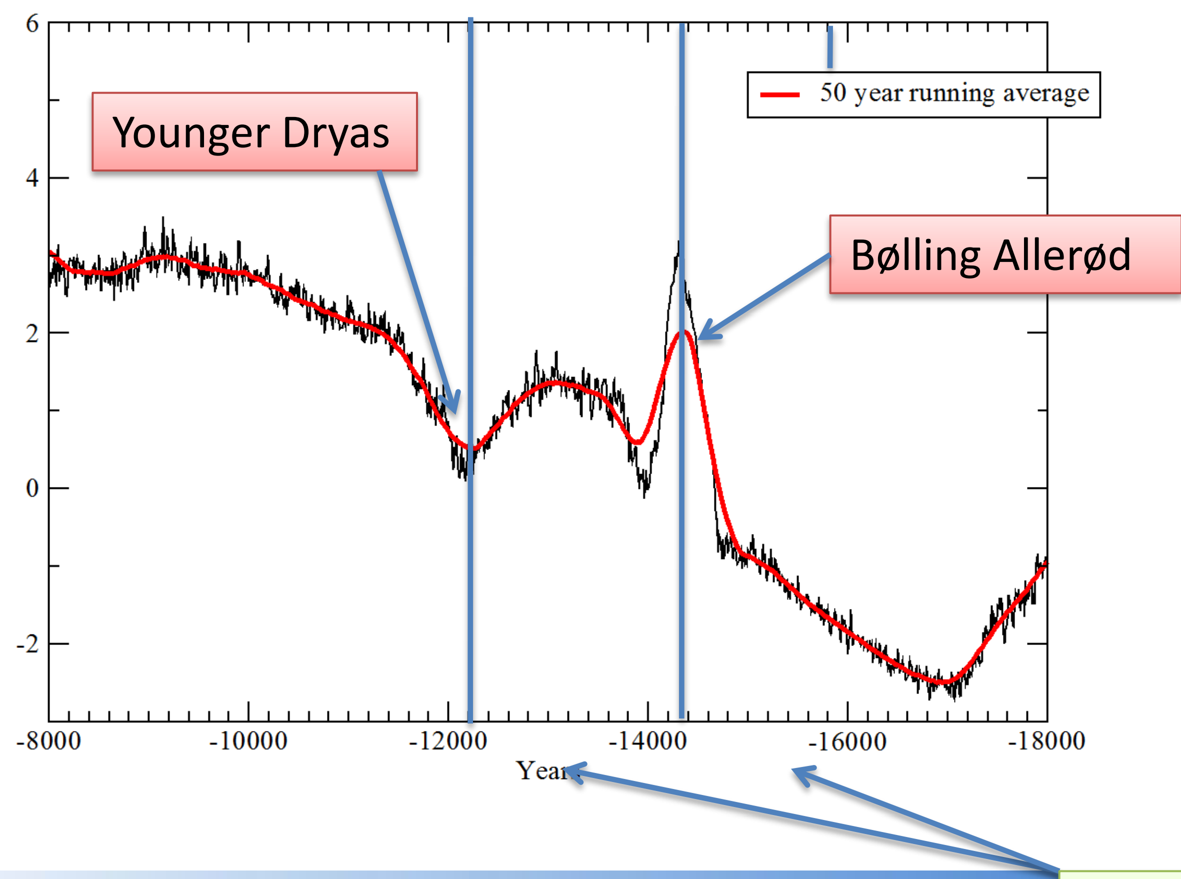
Last glacial Maximum



Kim et al. (DJF)

Using the TraCE simulations to look in detail at periods of interest

Surface temperature average over the Northern hemisphere from the TraCE simulation

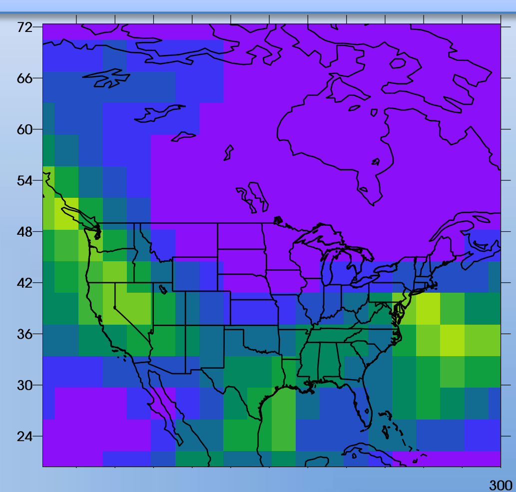


Need for higher resolution to study West Coast

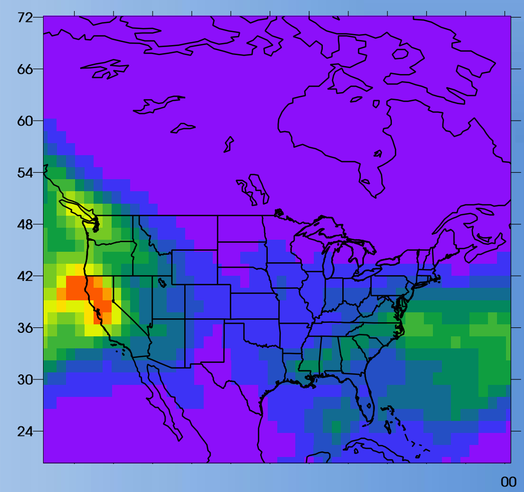
January Precipitation, mm/day

17Ka

TraCE run

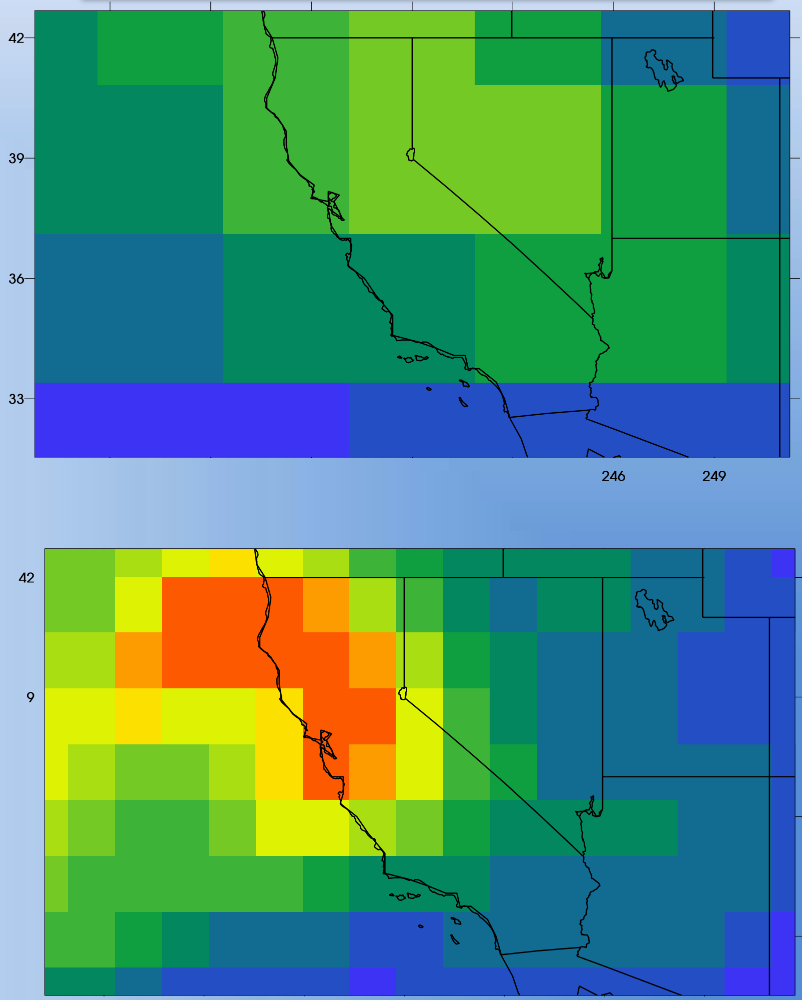


TraCE T85 run



Rerunning time slices at T85 may provide the detail needed

January Precipitation, mm/day



17Ka

Experimental design

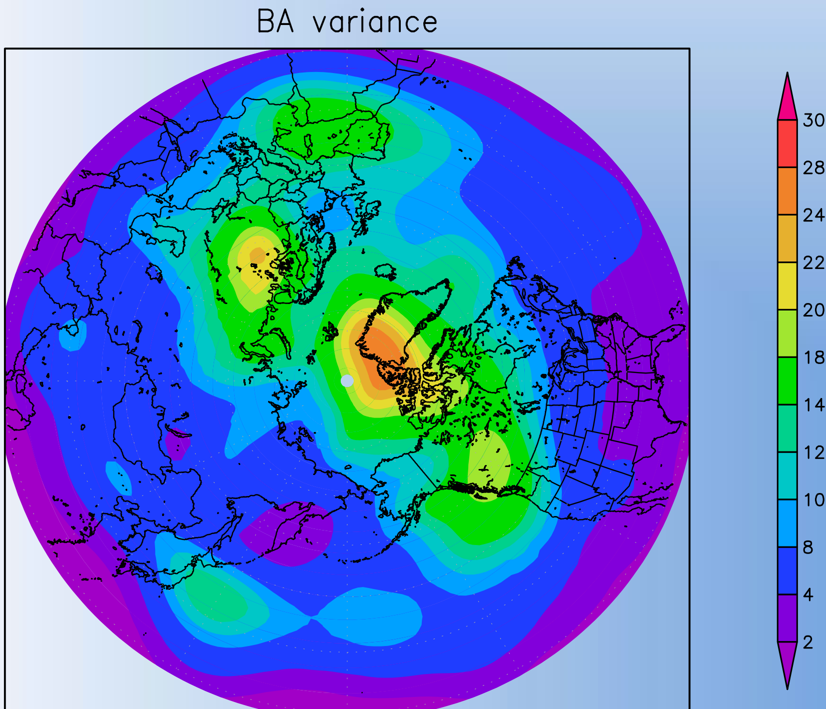
- Extract the TRACE T31 (3.75 degree resolution) simulations for selected time periods, then regrid and rerun selected time slices at T85 (~ 1.4 degree resolution)
- Ocean temperature remain fixed to those calculated at T31
- Short 5-year runs – longer runs to follow
- Select daily DJF 500hPa geopotential height
- Smooth and calculate the variance

To help sort out the picture of paleoclimate we need an objective way to estimate storm tracks

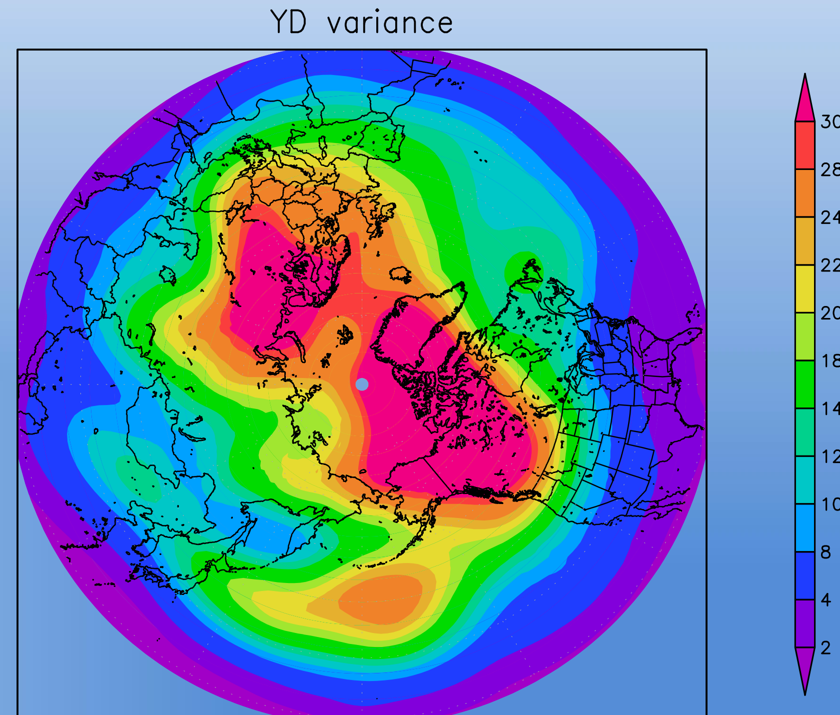
- First attempt is to use an Eulerian measure the called dynamic storm track, which is defined as a region of enhanced standard deviation of the bandpass filtered 500-hPa geopotential height (Blackmon 1976; Wallace et al. 1988; Lau 1988).

- 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

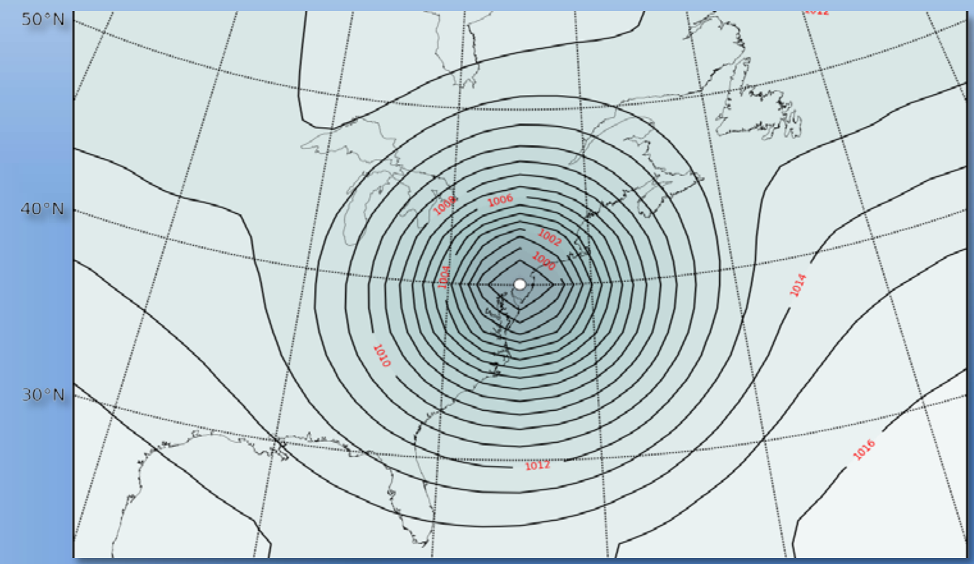


Peak of the Younger Dryas~12.2 kya

Variance of the Filtered 500hPa geopotential heights x 1000 meters ^{2}

Map Climatology of Midlatitude Storms (MCMS)

- Identify every cyclone and delineate it’s 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)

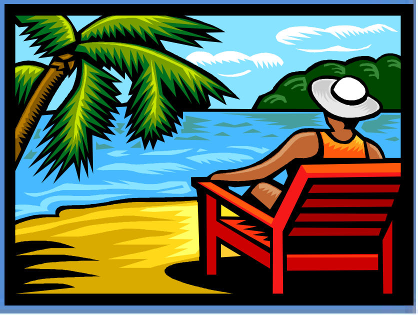
Numbers of AR storms on Central California coast in 7 climate-change projections & historical record

	Average # per yr	# yrs < 5 ARs	# yrs > 15 ARs	# yrs > 20 ARs
Reanalysis 1961-2000	5.8 days/yr	42 % of yrs	3 % of yrs	0 % of yrs
Projections				
1961-1980	**8.5**	**25**	**16**	**5**
1981-2000	**9.0**	**27**	**16**	**8**
2046-2065	**11.6**	**12**	**28**	**10**
2081-2100	**11.7**	**16**	**32**	**12**
	30% increase	**53% decrease**	**100% increase**	**85% increase**

Increased occurrence of ARs in future climate scenarios

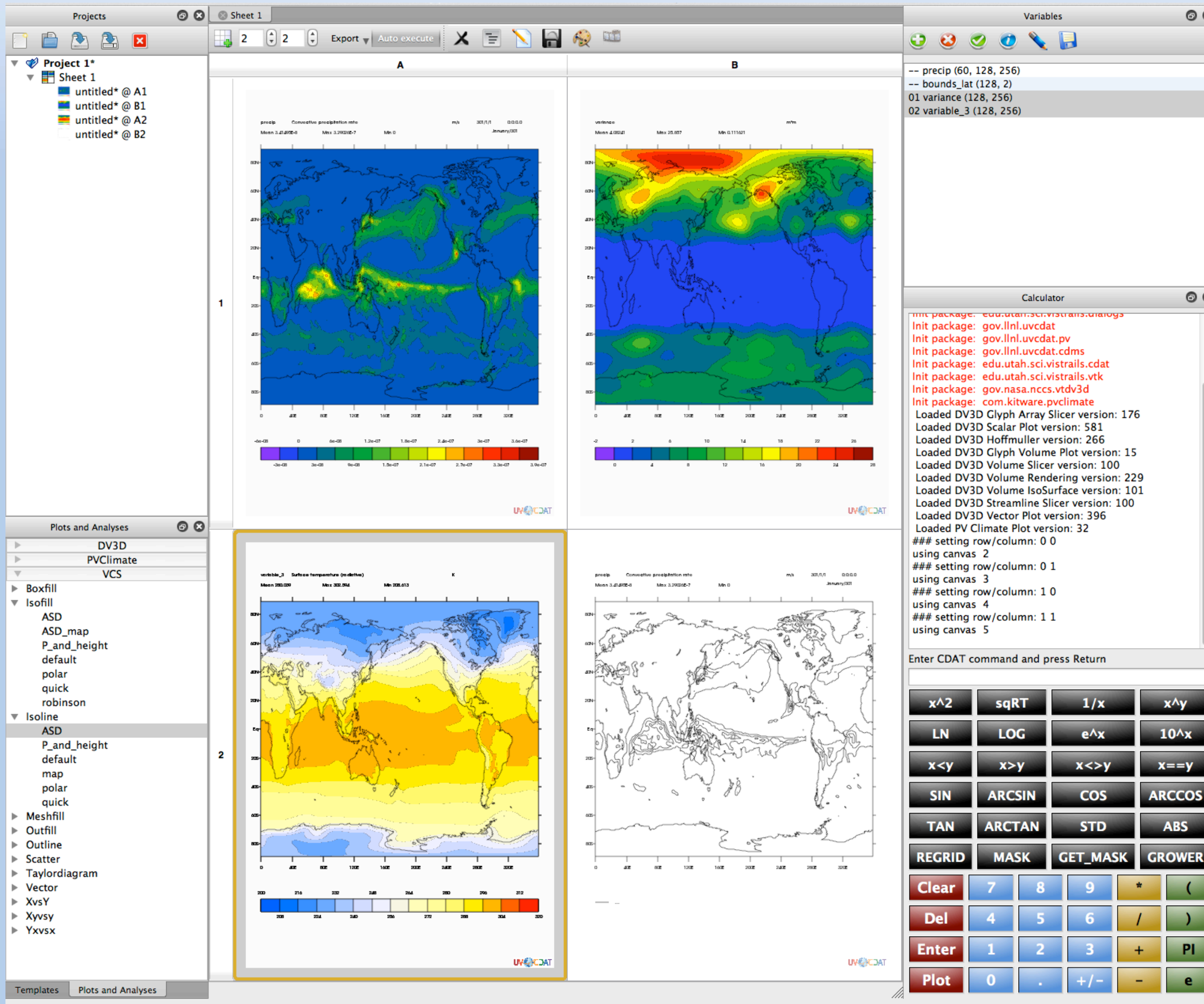
The case of cooler-wetter and warmer-drier isn't settled

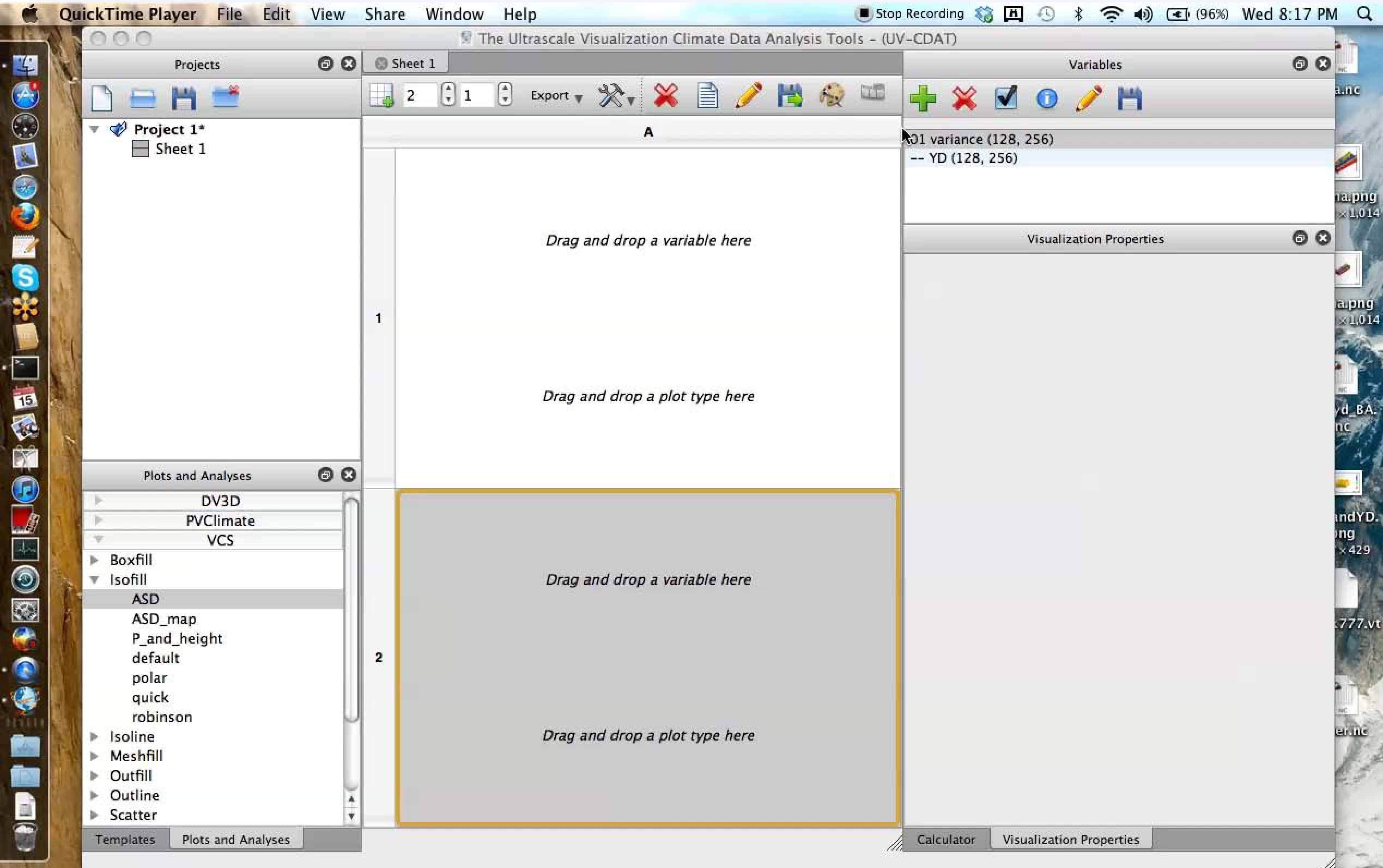
- Inconsistent picture of how the regional climate changes in western North America
- In some studies late Pleistocene cooling events in the North Atlantic region have been dry climates in the Sierra Nevada and western Great Basin regions (Oster at al.)
- Glacial (moraines) in California suggest drier 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

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The Ultrascale Visualization Climate Data Analysis Tools – (UV-CDAT)
Projects
Project 1*
Sheet 1
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Variables
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Visualization Properties
Plots and Analyses
DV3D
PVClimate
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Boxfill
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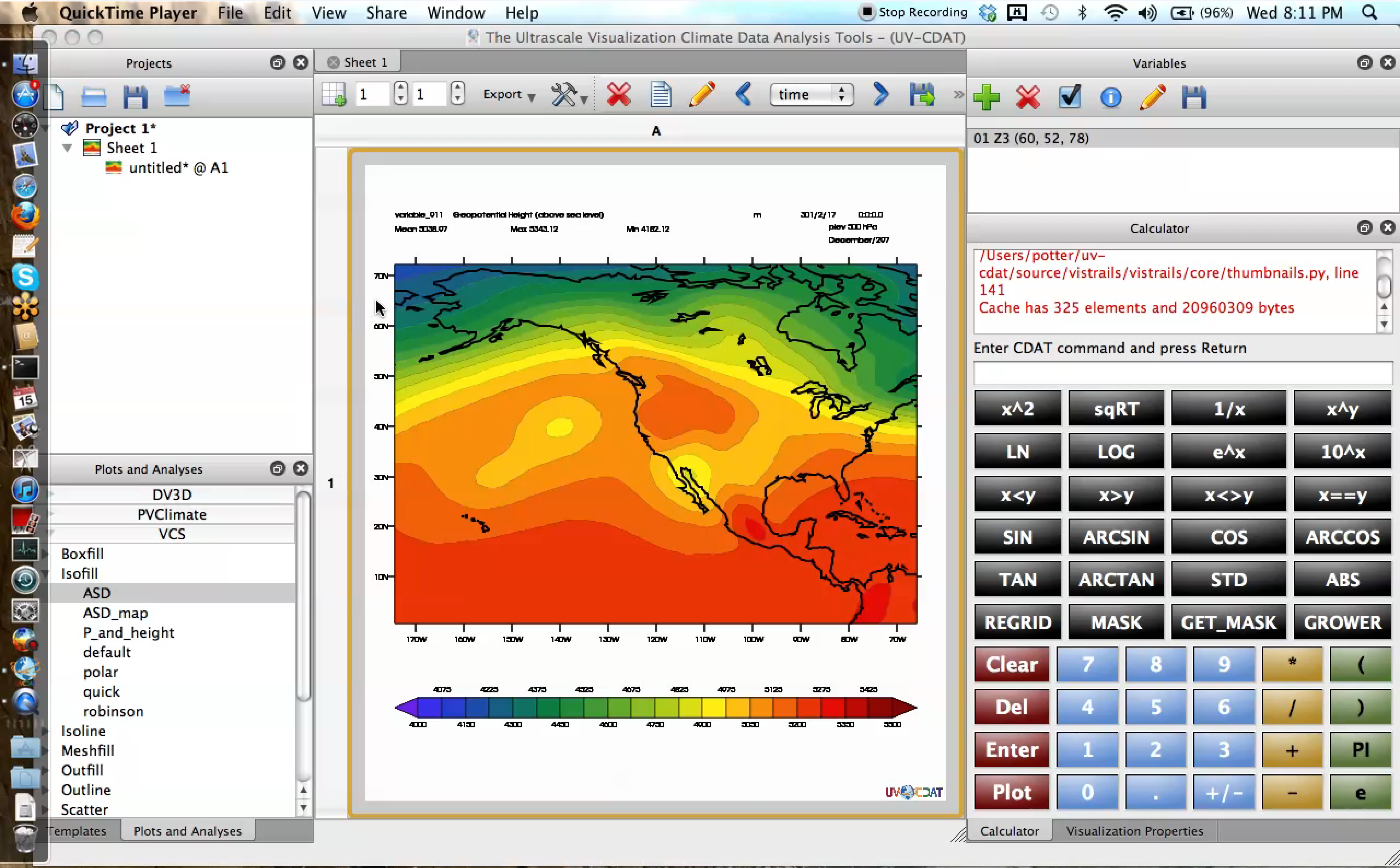
Plots and Analyses
Calculator
Visualization Properties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The Ultrascale Visualization Climate Data Analysis Tools – (UV-CDAT)
Projects
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Sheet 1
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01 Z3 (60, 52, 78)
Calculator
/Users/potter/uv-cdat/source/vistrails/vistrails/core/thumbnails.py, line 141
Cache has 325 elements and 20960309 bytes
Enter CDAT command and press Return
x^2
sqRT
1/x
x^y
LN
LOG
e^x
10^x
x<y
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x<>y
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DV3D
PVClimate
VCS
Boxfill
Isofill
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Meshfill
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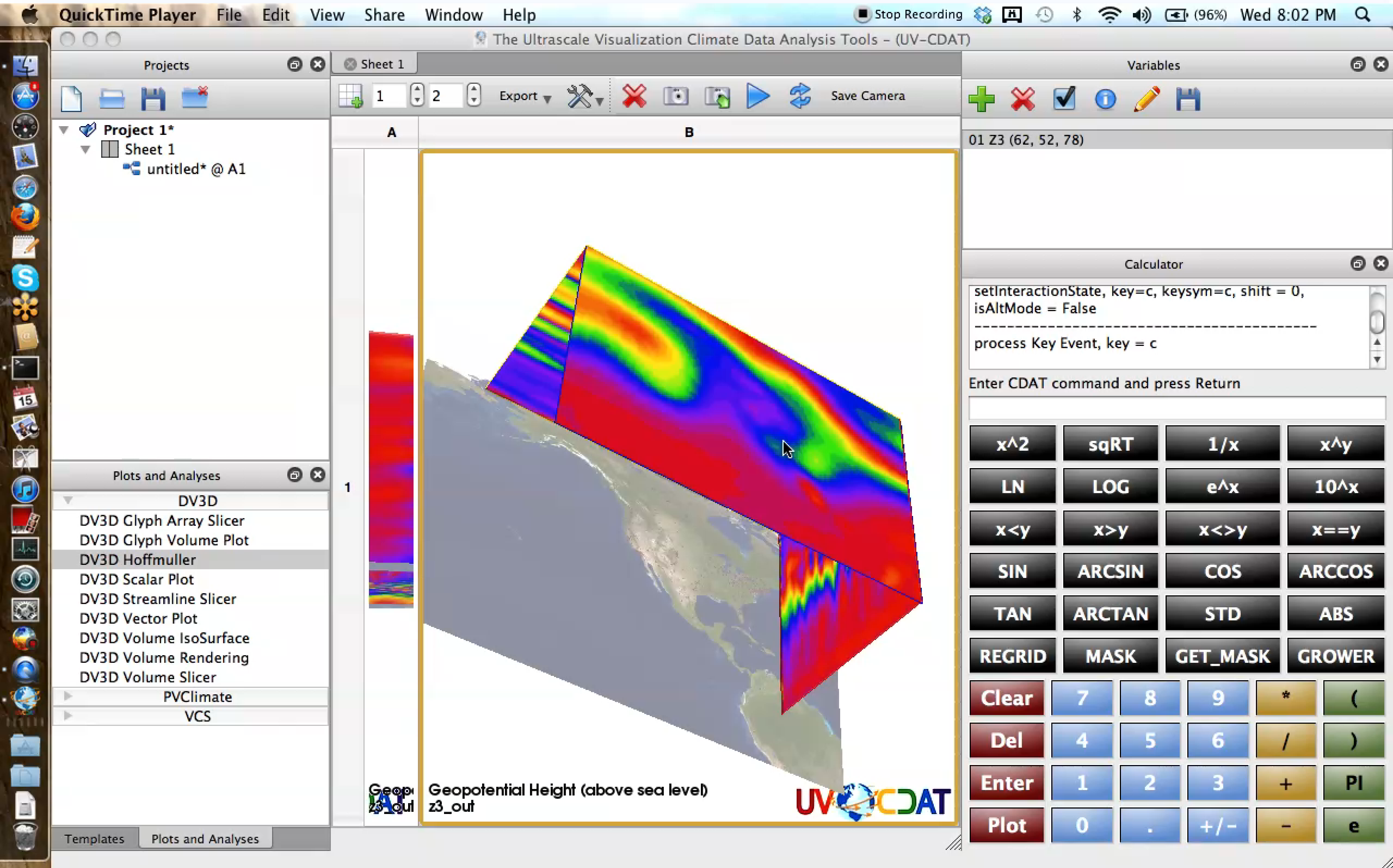
Calculator
Visualization Properties
UV-CDAT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Stop Recording
(96%) Wed 8:02 PM
The Ultrascale Visualization Climate Data Analysis Tools – (UV-CDAT)
Projects
Project 1*
Sheet 1
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Sheet 1
Export
Save Camera
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B
1
Variables
01 Z3 (62, 52, 78)
Calculator
setInteractionState, key=c, keysym=c, shift = 0, isAltMode = False
process Key Event, key = c
Enter CDAT command and press Return
x^2 sqRT 1/x x^y
LN LOG e^x 10^x
x<y x>y x<>y x==y
SIN ARCSIN COS ARCCOS
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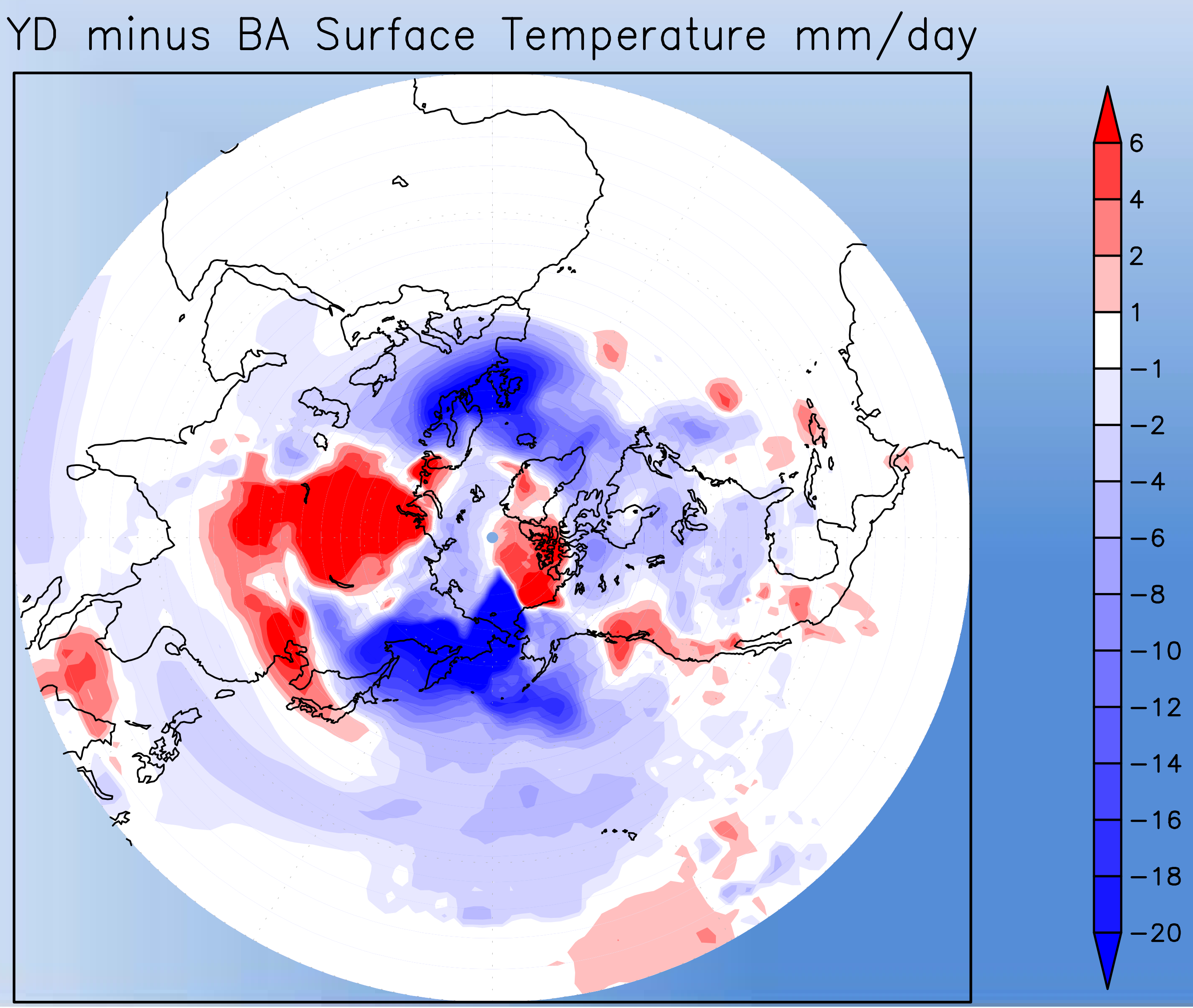
Plots and Analyses
DV3D
DV3D Glyph Array Slicer
DV3D Glyph Volume Plot
DV3D Hoffmuller
DV3D Scalar Plot
DV3D Streamline Slicer
DV3D Vector Plot
DV3D Volume IsoSurface
DV3D Volume Rendering
DV3D Volume Slicer
PVClimate
VCS
Templates
Plots and Analyses
Geopotential Height (above sea level)
z3_out
UV-CDAT

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



The noise here may indicate too short sample