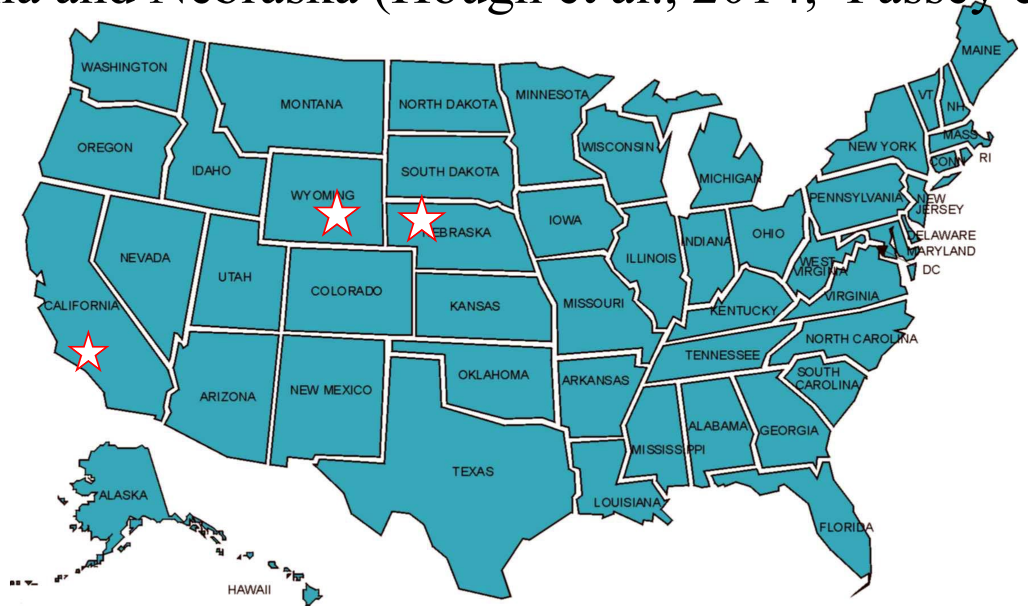
Determining the timing of soil carbonate formation: implications for paleoclimate reconstructions

Nicole Sarieddine[1] (nicolesa@uw.edu), Katharine Huntington[1], Julia Kelson[1]
[1]Department of Earth and Space Sciences, University of Washington, Seattle

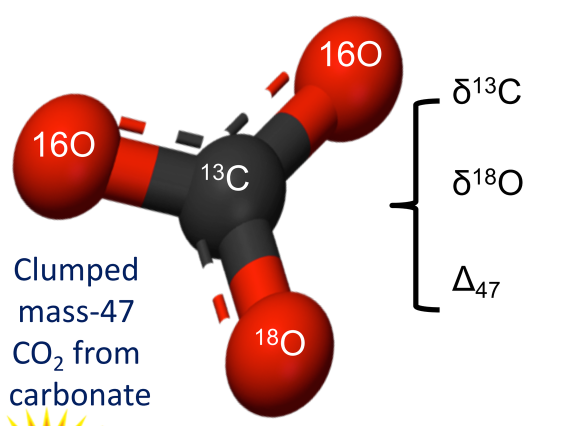
1. Introduction

- Learning about how earth surface temperature have responded to changes in carbon dioxide concentrations is important for understanding how our current climate will respond to atmospheric changes.
- In this study we:
  - Investigate the time of year soil carbonates form, which is important for interpreting the soil temperature recorded by clumped isotopes.
  - Test **whether soil carbonates form during soil drying events** using soil moisture and temperature data measured remotely by a satellite and published modern soil clumped isotope temperatures.
  - Compare the air temperature of the month with the greatest net negative soil moisture content (determined from the satellite data) to the measured growth temperature of soil carbonates (estimated through geochemistry) at three locations, Wyoming, California and Nebraska (Hough et al., 2014; Passey et al., (2017)).

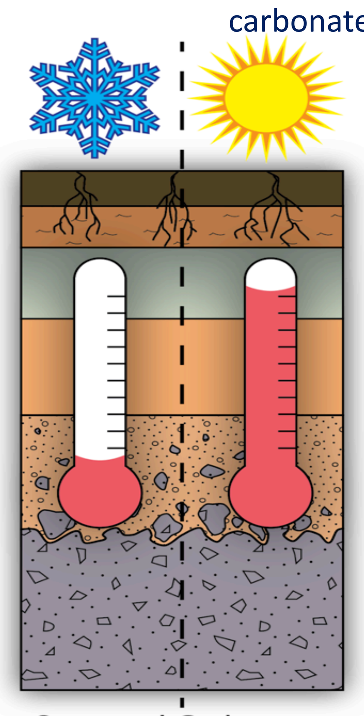


Soil carbonates record the temperature at the time of their formation in their stable isotopic composition (clumped isotopes).

"Clumped" carbonate ion



Soil carbonate nodule



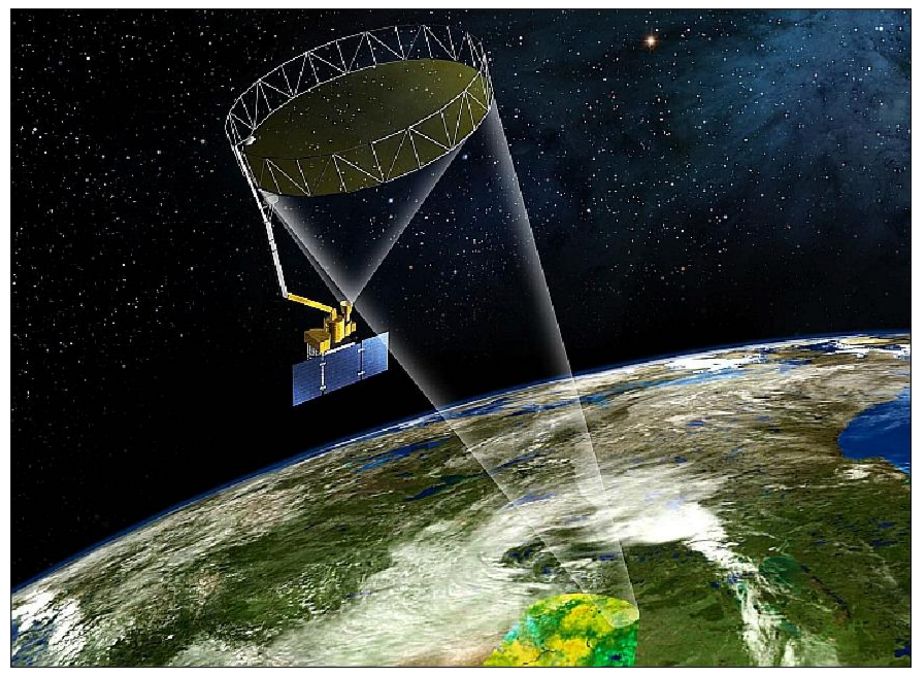
Seasonal Carbonate Formation Biases

We use the clumped isotope temperature to reconstruct climate.

However, the temperatures recorded by the soil carbonates are **seasonally dependent**, because carbonate formation depends on seasonal rainfall/soil drying. This is why our research aims to determine the season of carbonate formation. Season of formation will help make paleoclimate temperature estimates more accurate.

2. The Satellite: Soil Moisture Active Pass (SMAP)

- The soil moisture content is mapped through a combination of measurements made by two instruments carried by SMAP, a radar and radiometer.
- This satellite has been gathering near-surface soil moisture data globally since 2015 at 35-65 km resolution.
- Near-surface soil moisture data is then expanded to the root zone based on modelling and data assimilation.



SMAP Satellite

3. Mapping Soil Drying with SMAP data

Using satellite data and GIS, we mapped change in soil moisture at each satellite grid. We predict that soil carbonates form during the month with the most negative change in soil moisture (the month with the most soil-drying). We will test this hypothesis by comparing the SMAP-predicted temperature with the formation temperature from clumped isotopes.

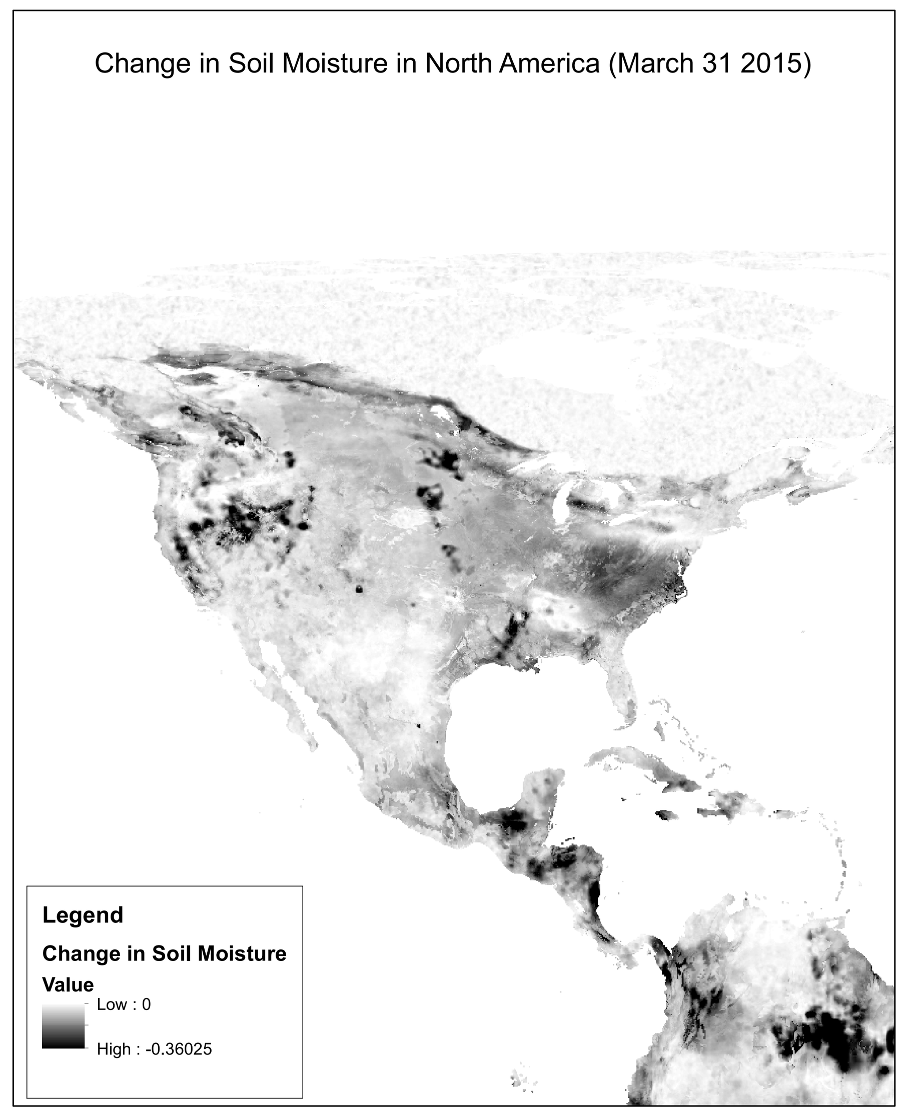


Figure 1: Change in soil moisture throughout one day (March 15, 2015) for all of North America.

4. Discussion – Comparing Measured Temperatures to Clumped Isotope Temperatures

Changes in Monthly Soil Moisture – Ex. from Wyoming

At specific locations, I calculated the net change in soil moisture on a monthly basis. I predict that soil carbonates form primarily during the month with the largest negative net change in soil moisture (drying). The formation temperature of carbonate is predicted from the satellite-measured temperature from that month.

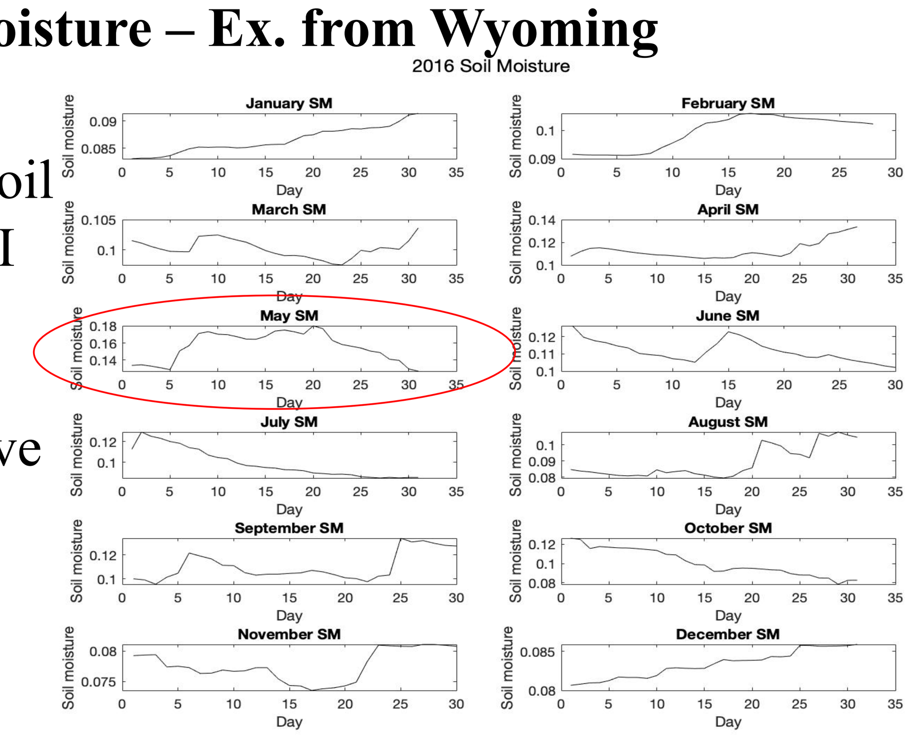


Figure 2: Soil moisture over the course of each month for 2016 at the Wyoming location.

Predicted Carbonate Growth Temperature vs. Measured Carbonate Clumped Isotope Temperature

Location 1: Wyoming

Year	Month of Soil Drying	Soil Temperature of Month of Drying (°C)	Clumped Isotope Temperature (°C)
2015	June	22.33	**15 ± 3.7**
2016	May	10.87	
2017	October	3.86	
Average		**12.35**	

Location 2: Nebraska

Year	Soil Drying	Soil Temperature of Month of Drying (°C)	Clumped Isotope Temperature (°C)
2015	July	22.91	**19 ± 3.0**
2016	July	22.95	
2017	August	20.29	
Average		**22.05**	

Location 3: California

Year	Soil Drying	Soil Temperature of Month of Drying (°C)	Clumped Isotope Temperature (°C)
2015	July	32.12	**26 ± 1.76**
2016	July	22.36	
2017	August	9.41	
Average		**21.3**	

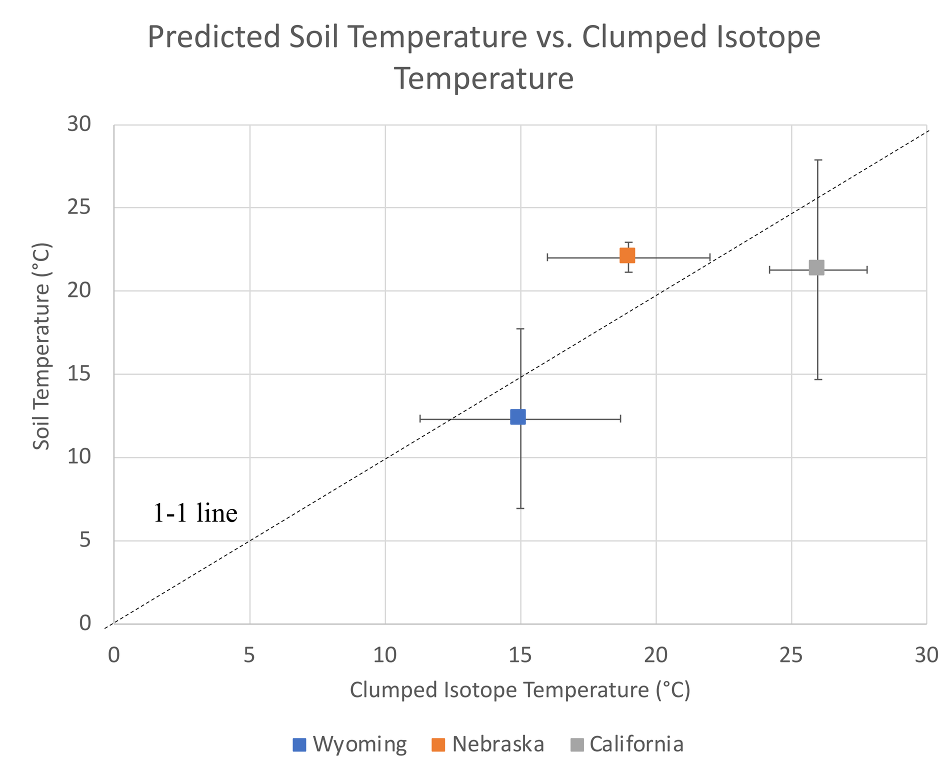


Figure 3: Average soil temperature of the month of greatest drying of each year (2015-2017) vs. clumped isotope temperature.

5. Conclusion and Implications for Paleoclimate Temperature Estimates

- Preliminary results suggest that the temperature of the month with the most drying agrees with formation temperature we estimated from clumped isotope geochemistry.
  - Within measurement error for Wyoming and Nebraska and California locations.
- The large standard errors of predicted temperature show that this method requires further refinement and data with longer time series.

References

Mohanty, B. P., Cosh, M. H., Lakshmi, V., & Montzka, C. (n.d.). Soil Moisture Remote Sensing: State-of-the-Science. https://doi.org/10.2136/vzj2016.10.0105; Hough, B. G., Fan, M., & Passey, B. H. (2014). Calibration of the clumped isotope geothermometer in soil carbonate in Wyoming and Nebraska, USA: Implications for paleoelevation and paleoclimate reconstruction. *Earth and Planetary Science Letters*, *391*, 110–120. https://doi.org/10.1016/j.epsl.2014.01.008; Map: USA Maps | Printable Maps of USA for Download. (n.d.). Retrieved April 2, 2019, from http://www.orangesmile.com/travelguide/usa/country-maps.htm; Satellite: NASA. (n.d.). SMAP mission preview : SMAP. Retrieved April 1, 2019, from https://smap.jpl.nasa.gov/resources/32/smap-mission-preview/; Passey, B. H., Levin, N. E., Cerling, T. E., Brown, F. H., & Eiler, J. M. (2010). High-temperature environments of human evolution in East Africa based on bond ordering in paleosol carbonates. *Proceedings of the National Academy of Sciences*, *107*(25), 11245-11249.