POS Teleconnections Breakout session

Paleoclimate insights in teleconnection dynamics

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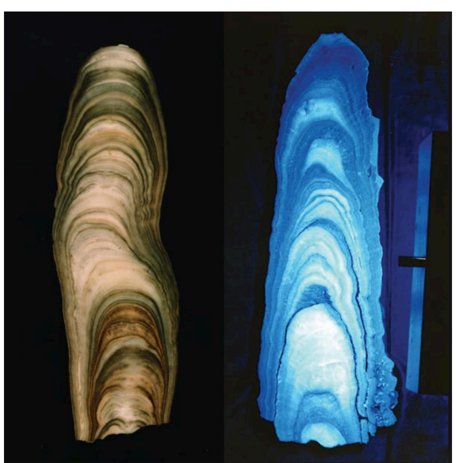

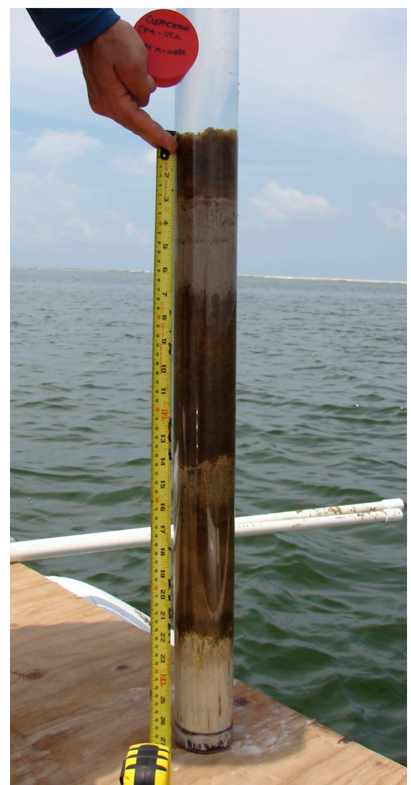
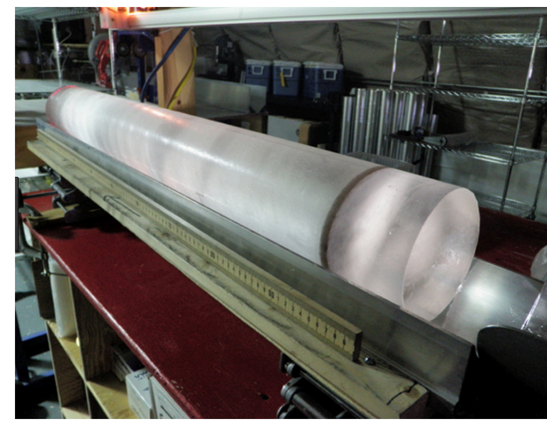
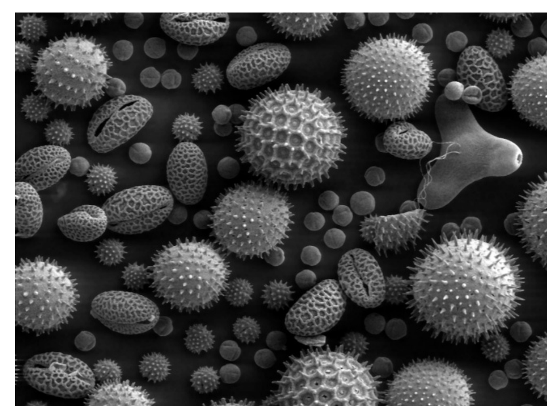

Key time periods for developing insight into teleconnections:

Common Era

- Capability to extend the observational period with high temporal and spatial resolution of precip, temp
- Key to constraining decadal-centennial climate variability

Abrupt climate change events

- No modern analogue but may hold relevance for the future

Paleoclimate reconstructions limited by:

- Paucity of long, continuous, high-resolution proxy records from dynamically-important regions
- Limited process-level understanding of many proxy systems
- Challenges in comparing proxy data with climate model output

Recent promising developments:

- Development and application of proxy system models
- Paleoclimate data assimilation and advanced climate field reconstruction techniques
- Increased number of isotope-enabled GCM simulations,

=> Enabling improved data/model comparisons

But still need more long, high-resolution proxy records from under-sampled and dynamically-important regions (e.g. tropical Pacific, Southern Hemisphere)!

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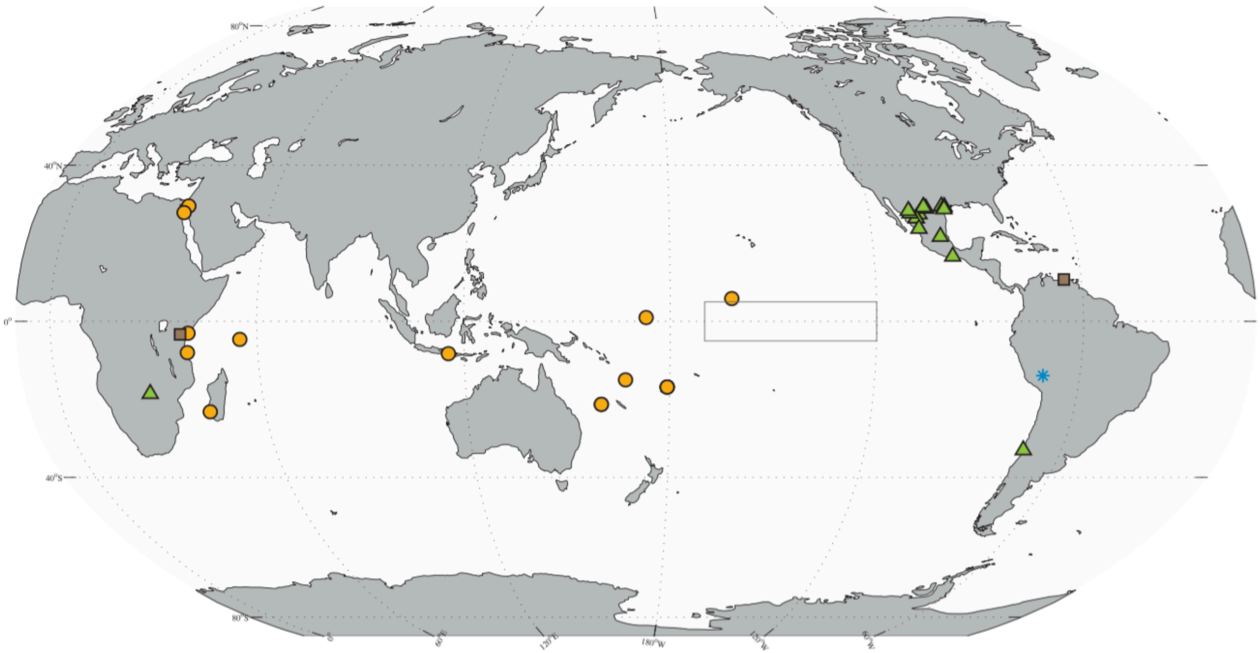
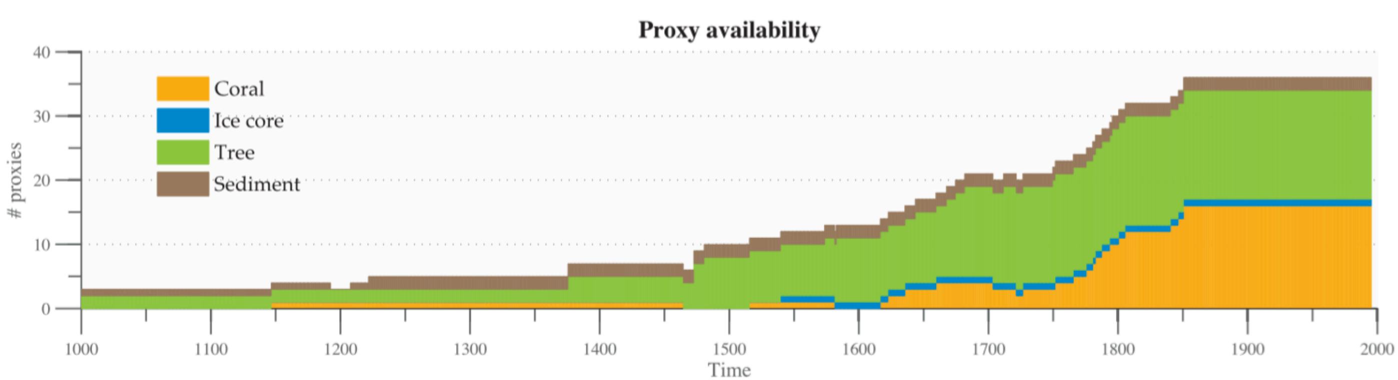
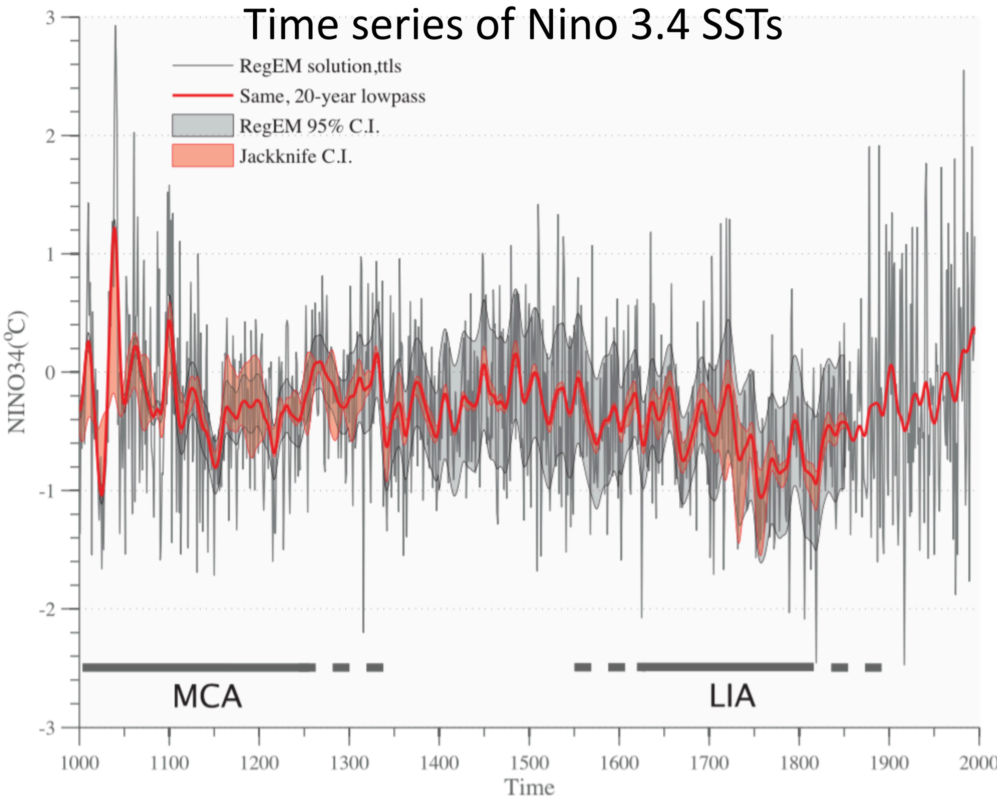
A millennial history of central Pacific SST variability

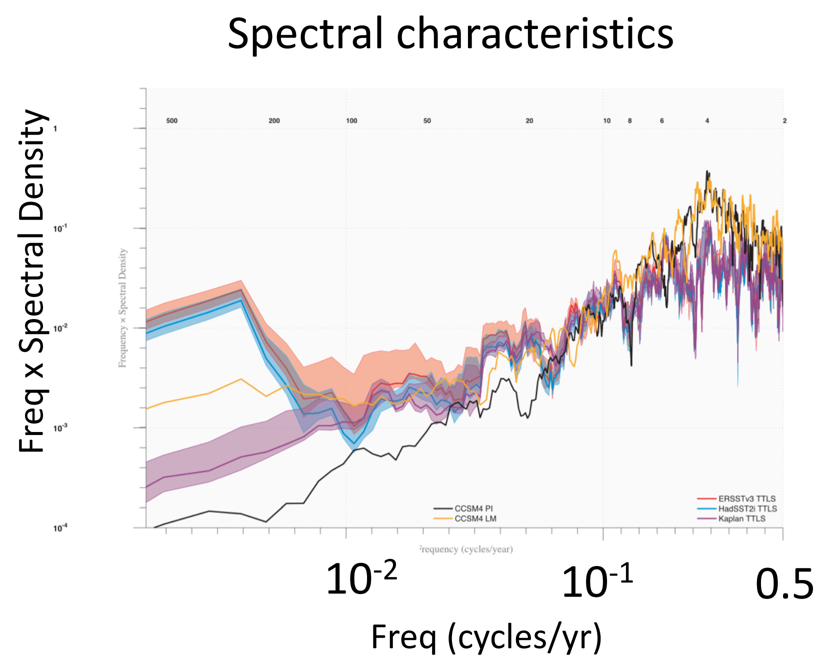




Emile-Geay et al., 2013

A millennial history of central Pacific SST variability

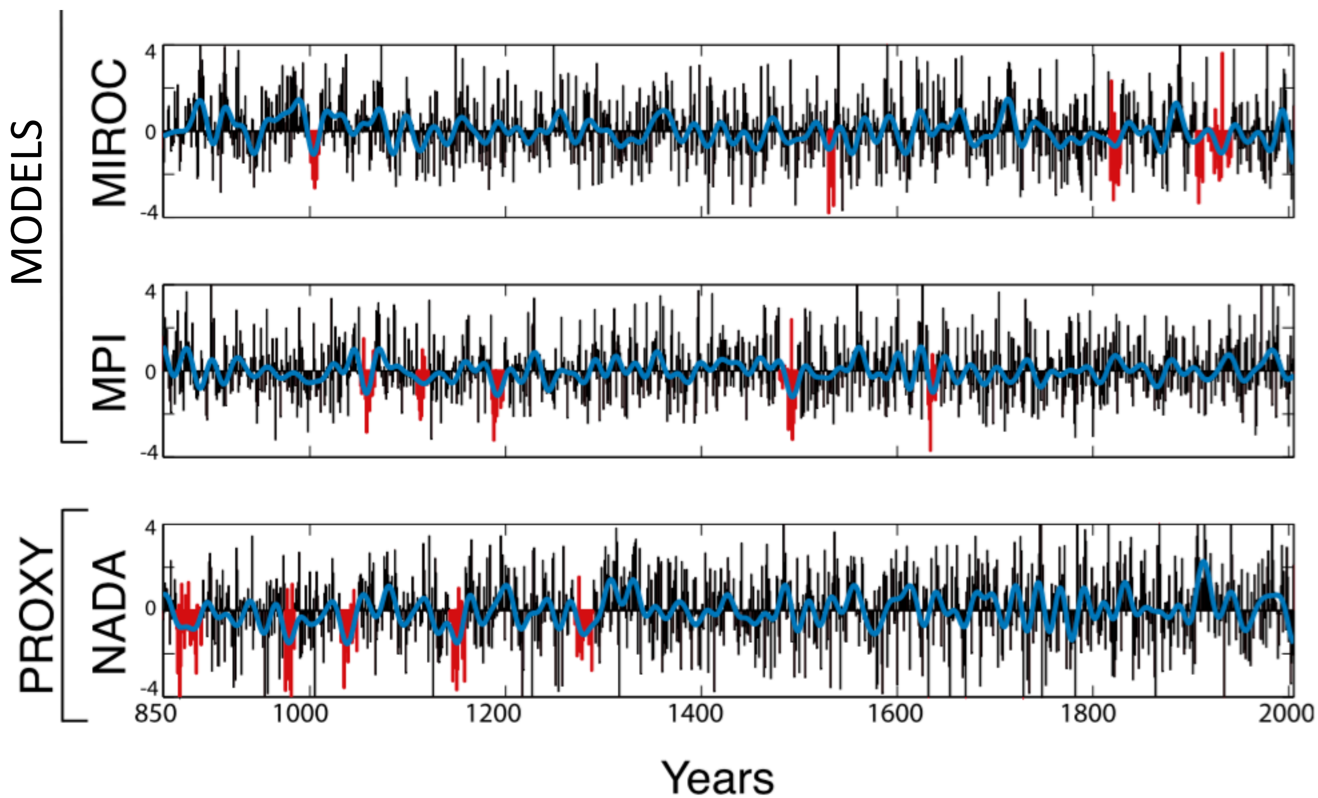




- Best estimates of Nino 3.4 SSTs suggest greater tropical Pacific decadal-to-multidecadal variability in the reconstructions, as compared to CGCM simulations.
- Centennial-scale variability poorly constrained due to uncertainties in tropical Pacific SSTs since A.D. 1850 and the paucity of long, high-resolution paleoclimate records from the central/eastern Pacific.

Investigating the causes of megadroughts in the Southwest US

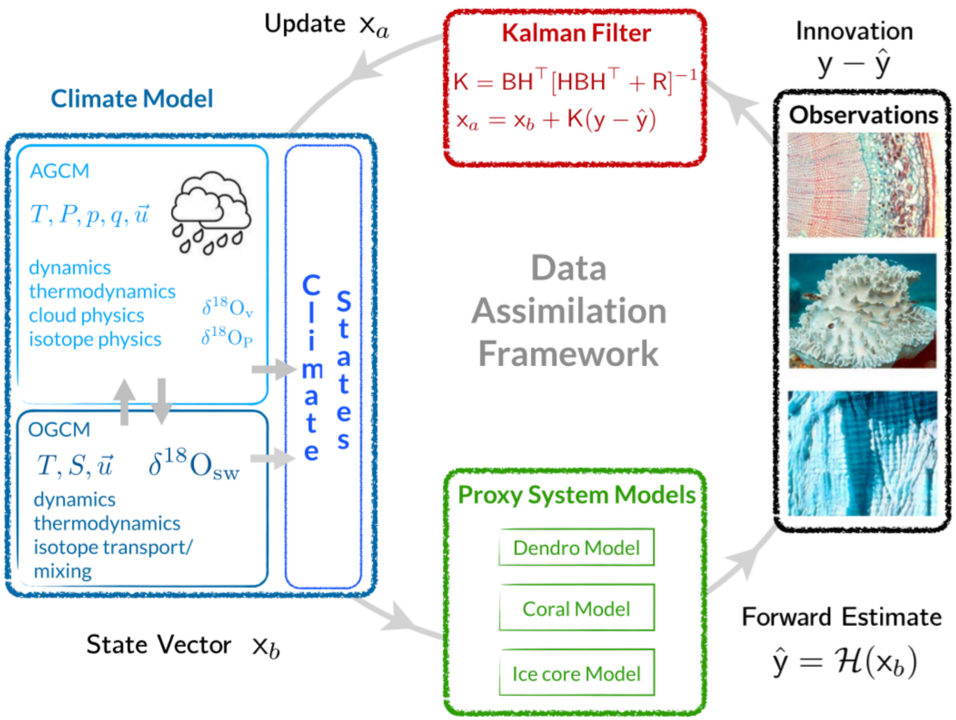
- Comparison btwn CMIP5/PMIP3 last millennium simulations & tree-ring derived North Atlantic drought atlas
  - Indicates pronounced differences in underlying teleconnection dynamics between paleoclimatic reconstructions and models

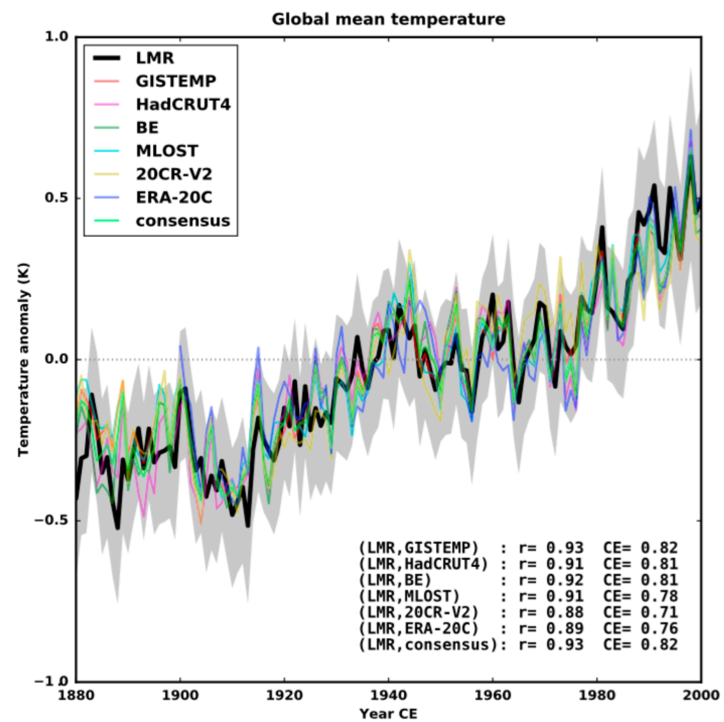


PDSI time series for Southwest region in models and proxy reconstructions

Coats et al., 2015

The Last Millennium Climate Reanalysis Project





Hakim et al., 2016

Paleoclimate Data Assimilation

(*Hakim et al., 2016; Steiger and Hakim, 2015*)

Paleoclimate data assimilation (PDA) uses model-simulated climate states to measure the novel information in proxy data and to distribute that information to all climate variables subject to the dynamical constraints of the climate model.

Advantages:

1. Infers multiple climate fields simultaneously
2. Generally does not assume stationary teleconnections (unlike most purely statistical approaches)
3. Uses dynamical models to infer spatial relationships within and between climate fields. The fields are thus dynamically consistent.
4. Can include proxies with dependence on multiple state parameters (e.g., temperature and moisture controls on tree-ring width) and different timescales (e.g., annual and decadal resolution)

Proxy System Models

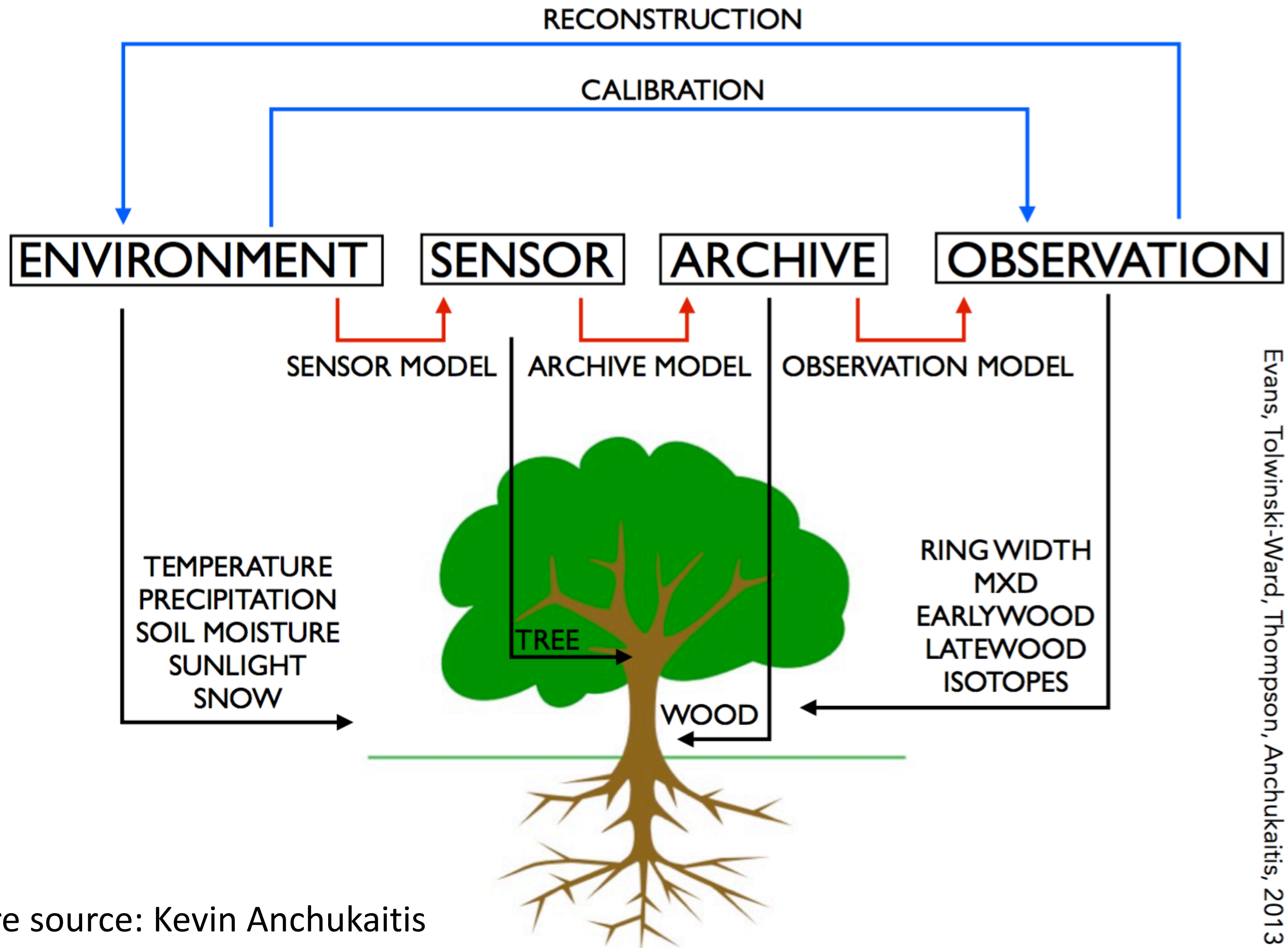
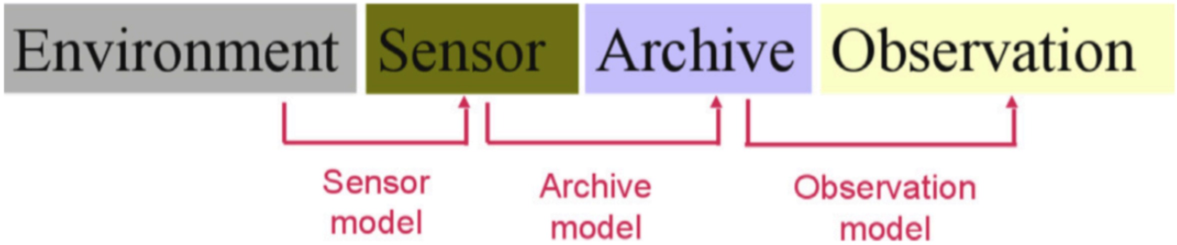


Figure source: Kevin Anchukaitis

Proxy System Models



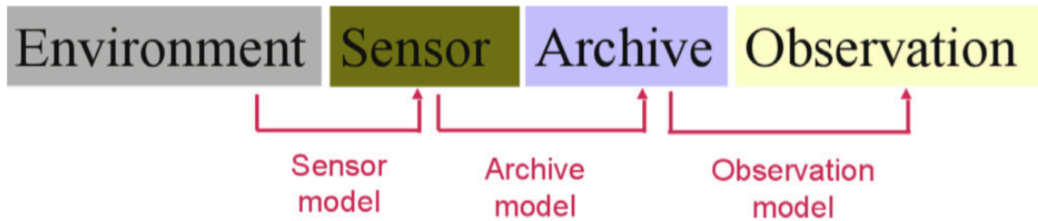
1. Design optimal sampling networks for paleoclimate reconstruction

2. Apply proxy system models to climate system models to improve data/model comparisons
   - Identify deficiencies in (1) process-level understanding of the proxy sensors, (2) paleo-observing network, and/or (3) climate model simulations

3. Apply proxy system models to observations to test consistency of proxy interpretations

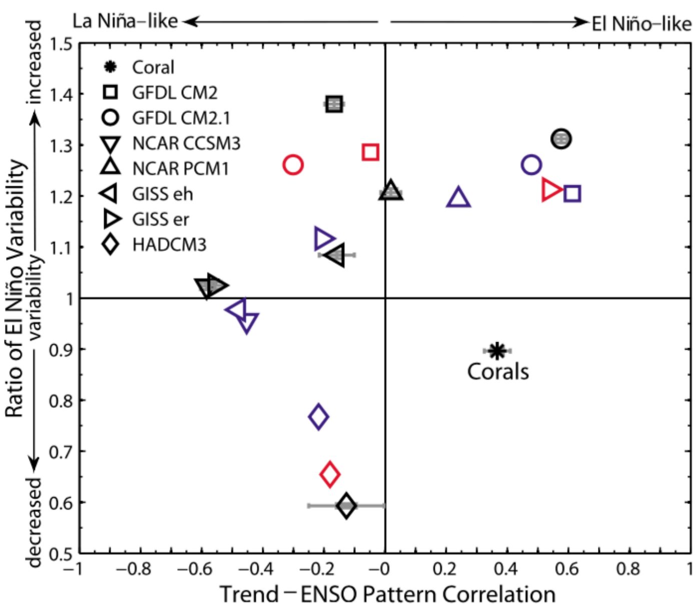
4. Model the total uncertainty in the response of proxy systems to environmental forcing and its expression in paleoclimatic reconstructions

Proxy System Models



Application: Model/data comparison

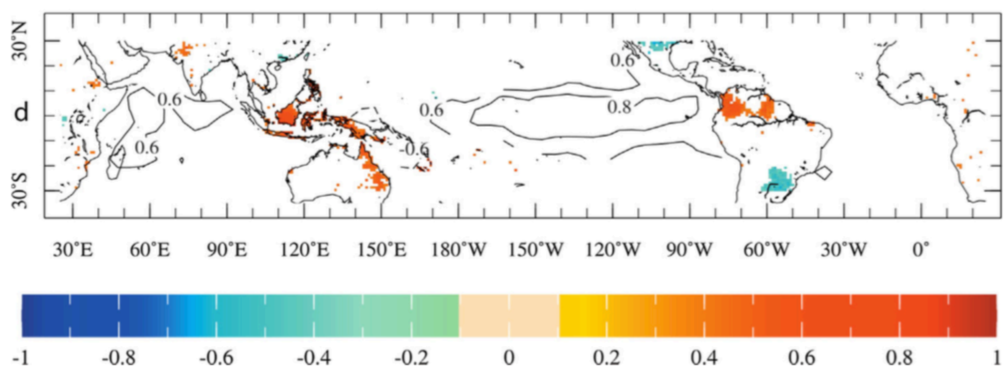
$$\delta^{18}O_{coral} = f(T, S)$$



Thompson et al., 2011

Application: Optimal sampling network

$$\delta^{18}O_{cellulose} = f(T, \delta^{18}O_{rain}, \delta^{18}O_{vapor}, \%RH)$$



Evans et al., 2016

Iso2k

A community-sourced global database
of paleo-water isotopes from the past two millennia

The Iso2k database v.0 as of 12/2015
(v.1 expected ~end of summer 2016)

~600 records

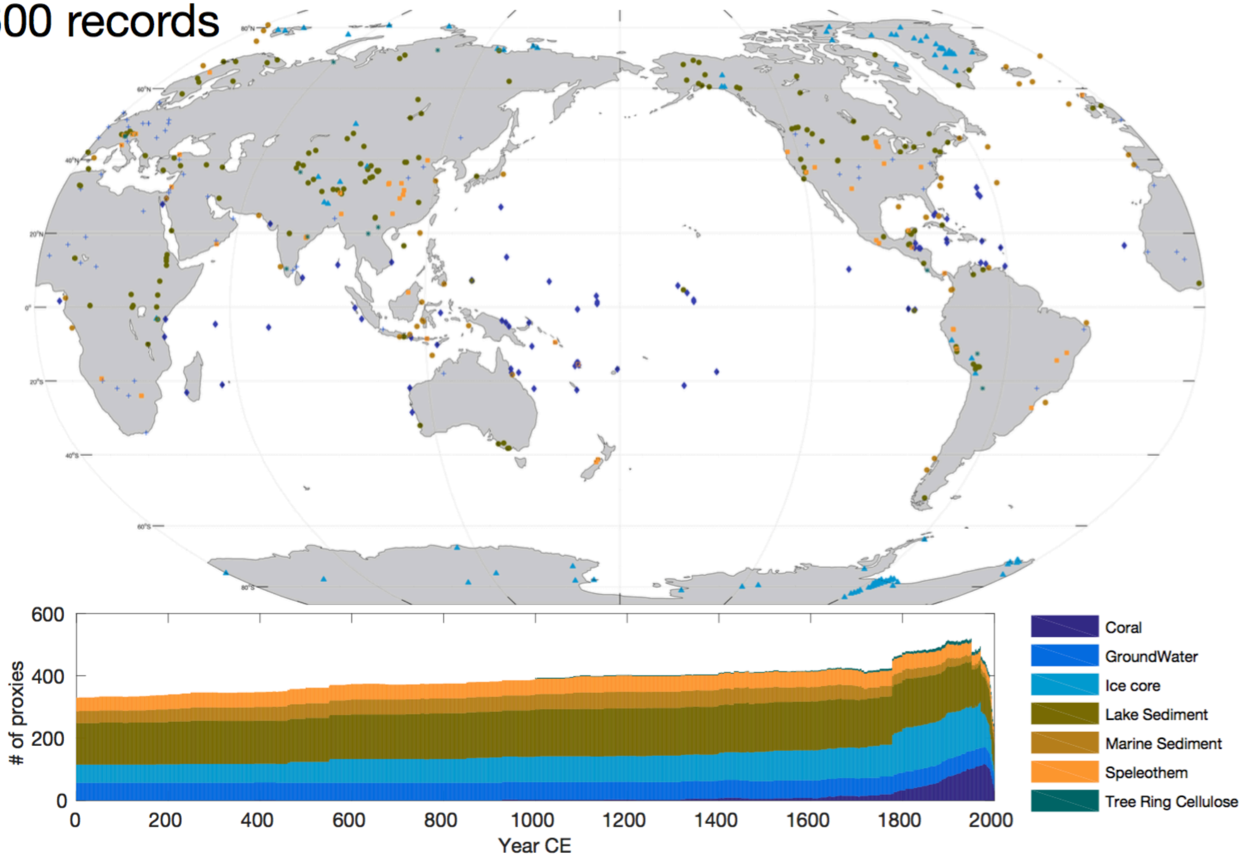


Figure source: Bronwen Konecky & Judd Partin

Best practices for proxy-model comparisons of hydroclimate during the Common Era

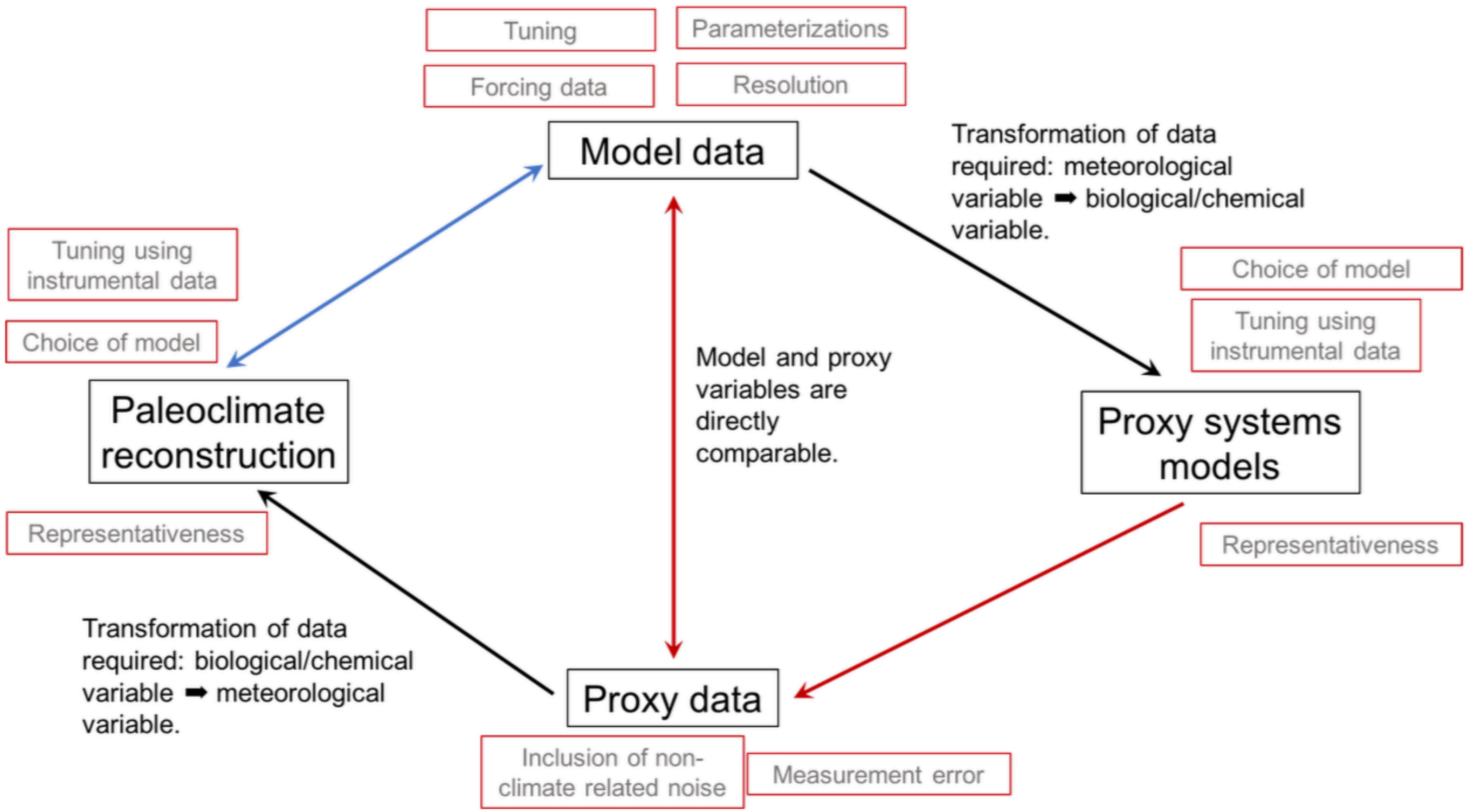
Clim. Past Discuss., doi:10.5194/cp-2017-37, 2017
Manuscript under review for journal Clim. Past
Discussion started: 7 April 2017

Climate of the Past Discussions
Open Access
EGU

Comparing proxy and model estimates of hydroclimate variability and change over the Common Era

Hydro2k Consortium: Jason E. Smerdon[1], Jürg Luterbacher[2,3], Steven J. Phipps[4], Kevin J. Anchukaitis[5], Toby Ault[6], Sloan Coats[7,8], Kim M. Cobb[9], Benjamin I. Cook[1,10], Chris Colose[10], Thomas Felis[11], Ailie Gallant[12], Johann H. Jungclaus[13], Bronwen Konecky[8], Allegra LeGrande[10], Sophie Lewis[14], Alex S. Lopatka[15], Wenmin Man[16], Justin S. Mankin[1,10], Justin T. Maxwell[17], Bette L. Otto-Bliesner[7], Judson W. Partin[18], Deepti Singh[1], Nathan J. Steiger[1], Samantha Stevenson[7], Jessica E. Tierney[19], Davide Zanchettin[20], Huan Zhang[2], Alyssa R. Atwood[9,21], Laia Andreu-Hayles[1], Seung H. Baek[1], Brendan Buckley[1], Edward R. Cook[1], Rosanne D'Arrigo[1], Sylvia G. Dee[22], Michael Griffiths[23], Charuta Kulkarni[24], Yochanan Kushnir[1], Flavio Lehner[7], Caroline Leland[1], Hans W. Linderholm[25], Atsushi Okazaki[26], Jonathan Palmer[27], Eduardo Piovano[28], Christoph C. Raible[29], Mukund P. Rao[1], Jacob Scheff[1], Gavin A. Schmidt[10], Richard Seager[1], Martin Widmann[31], A. Park Williams[1], Elena Xoplaki[2]

Best practices for proxy-model comparisons of hydroclimate during the Common Era



Hydro2k Consortium, *Clim. Past Disc*, 2017

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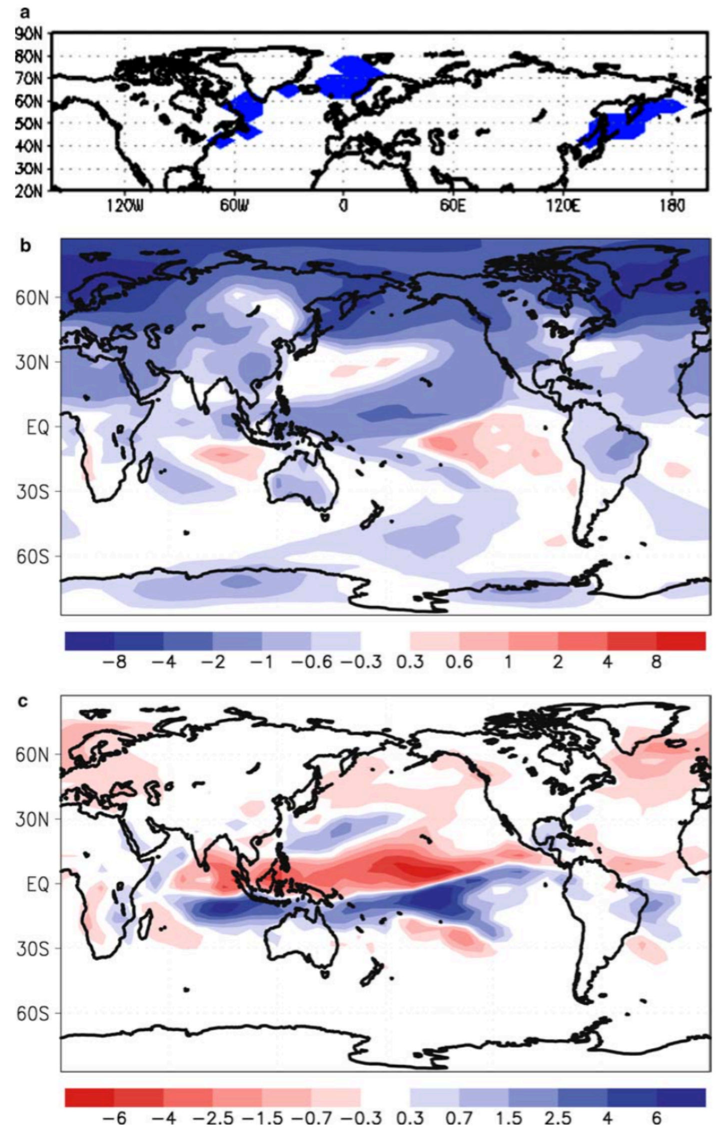
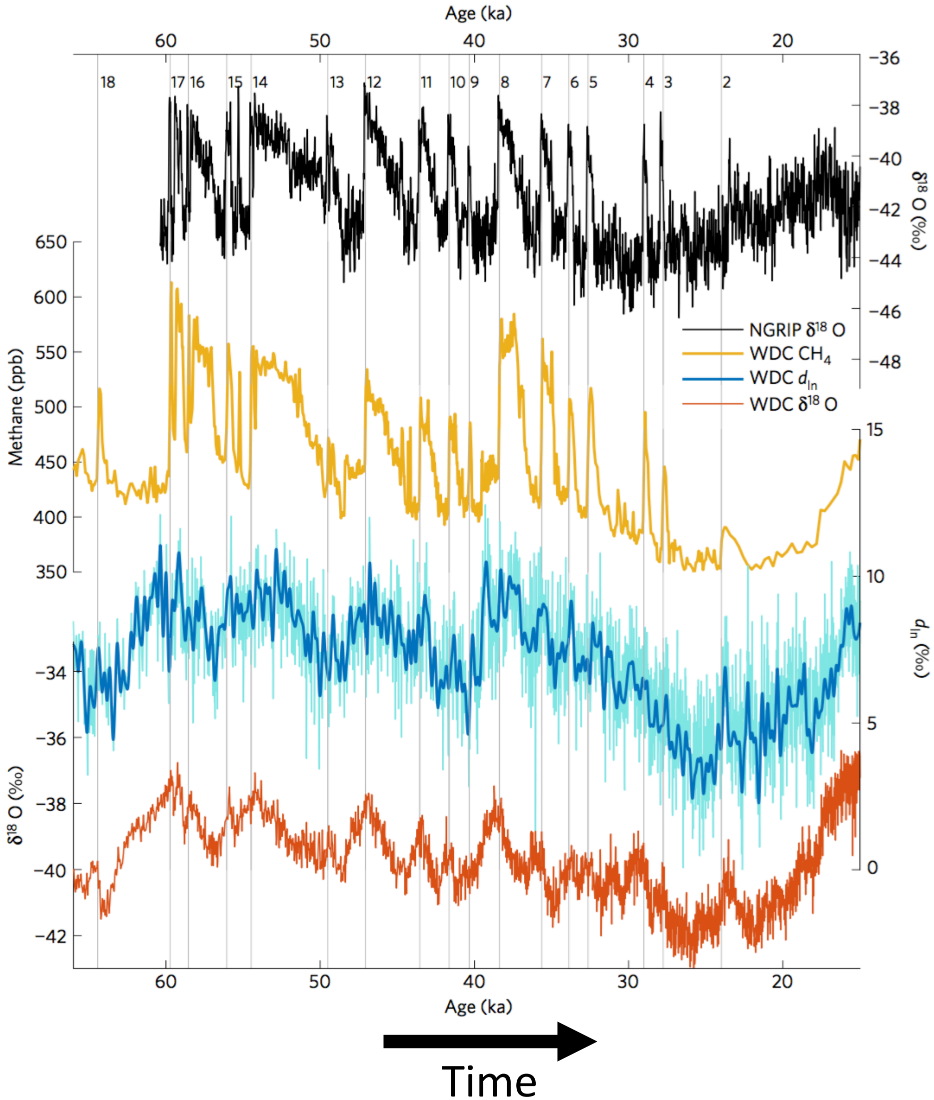
High latitude teleconnections to tropical climate

Early dynamics & modeling studies of high latitude teleconnections were **motivated by paleoclimate data** (e.g. Chiang and Bitz, 2005)



Chiang et al., 2005

Global atm teleconnections during D/O events

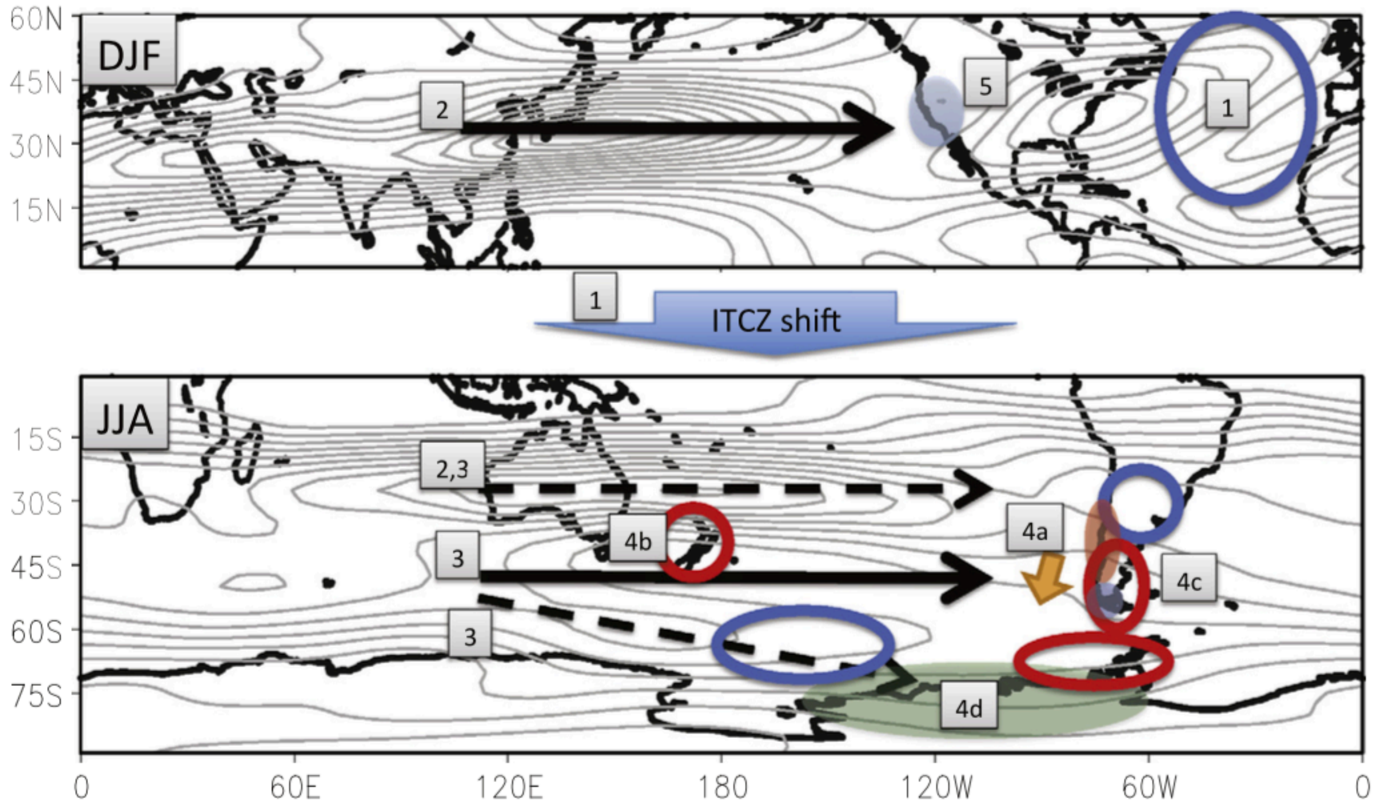


d18O

SH mid-latitude storm tracks shifted in tandem with meridional migrations of the ITCZ

Markle et al., *Nat. Geo.,* 2016

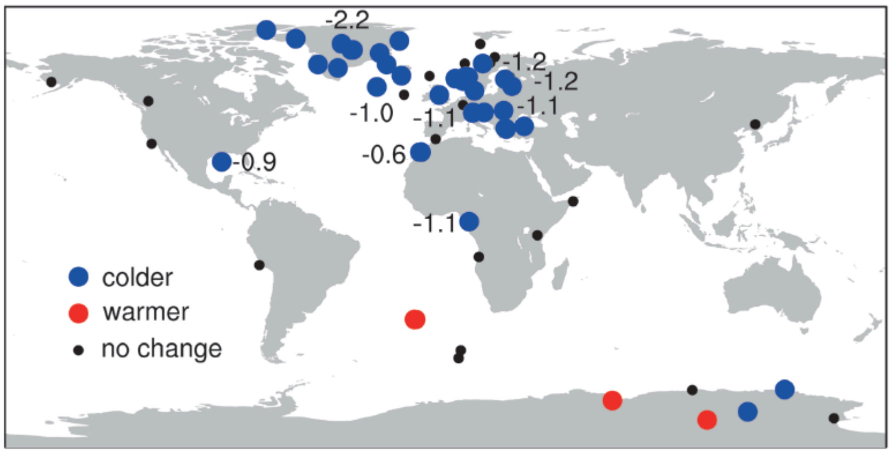
ITCZ shifts and South Pacific Split Jet during abrupt climate changes of the last glacial period



Chiang et al., 2014

Proxy reconstructions of the 8200 BP event

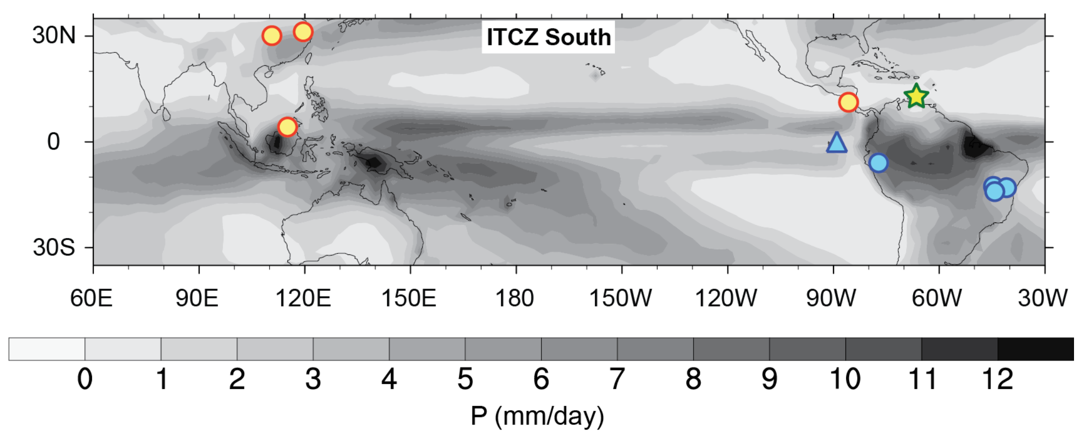
Temp records



Morrill et al., *Clim. Past*, 2013

More high-resolution proxy records needed from the tropical Pacific to better understand the global response to this event

Hydroclimate records



Atwood et al., *Nat. Geo*, in rev.

Conclusions

- Key periods for which proxies can provide novel insight into climate teleconnection patterns include the Common Era and abrupt climate changes of the last glacial
  - **More long, high-resolution proxy records are needed from under-sampled regions** to better constrain teleconnection patterns during these periods
- Emerging methods for improved proxy development and data/model comparisons may offer a wealth of new information on climate teleconnections:
  - **Proxy System Models** & **CGCMs with water isotopes** are enabling improved understanding of proxy records + direct comparison between proxy data, obs, models
  - **Paleoclimate data assimilation** can account for novel information in proxy data subject to the dynamical constraints of climate models
- Such approaches have led to improved understanding of hydroclimate variability during the CE and improved constraints on tropical Pacific climate variability during the last millennium