A paleo-perspective for Assessing Climate Change in the Tropics

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Symposium:

Climate Change and The Tropics: Implications and Adaptation

Friday November 21, 2014

Rutgers University

Lamont-Doherty Earth Observatory
COLUMBIA UNIVERSITY | EARTH INSTITUTE

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

PALEOCLIMATOLOGY

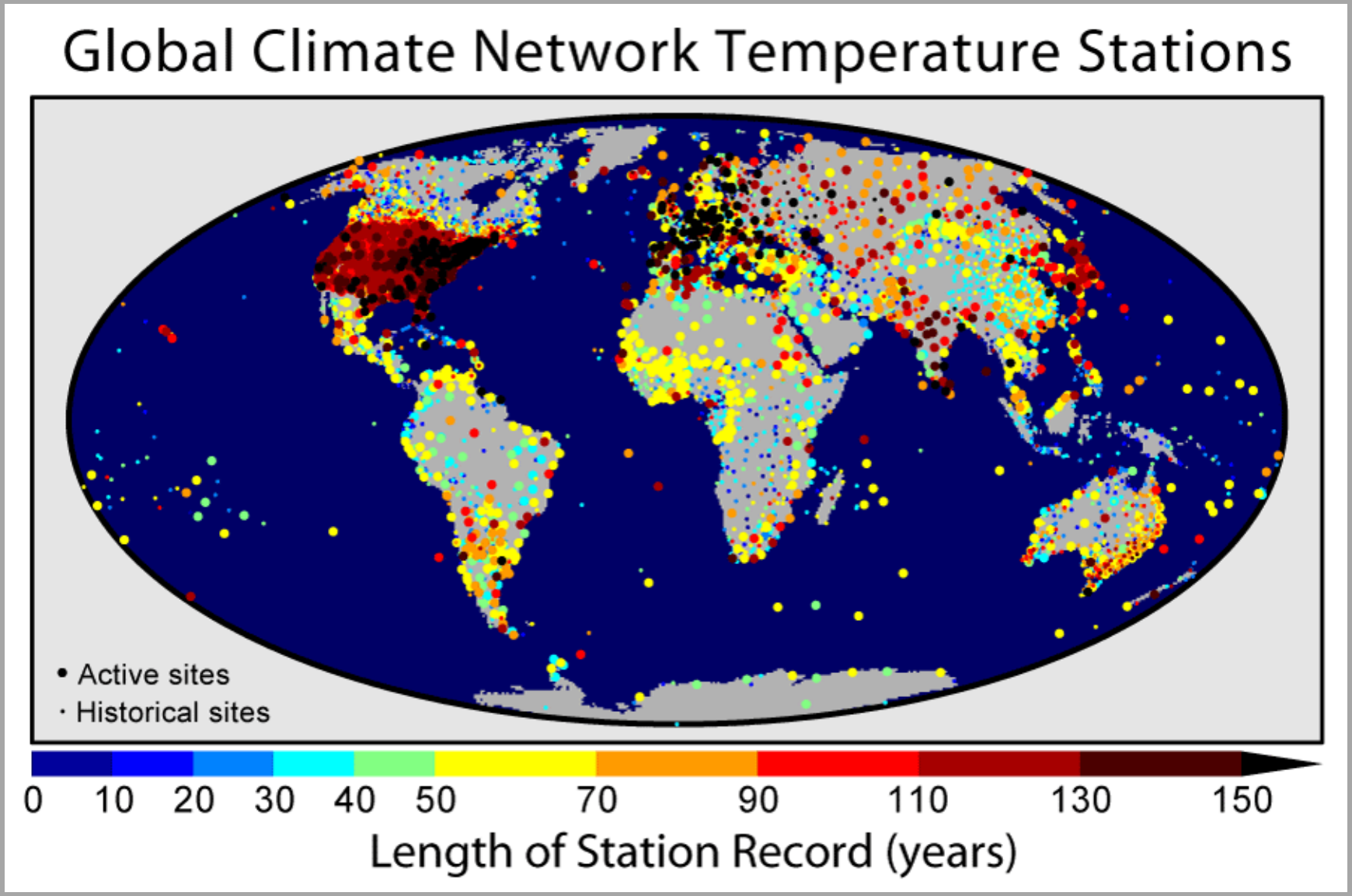
is the study of climate prior to the widespread availability of instrumental records such as temperature, precipitation among others (~ last 100-150 years)

WHY IS IT IMPORTANT TO KNOW ABOUT PAST CLIMATE?

A longer perspective allows us to study the full range of climate variability and change

Source: http://www.ncdc.noaa.gov/paleo

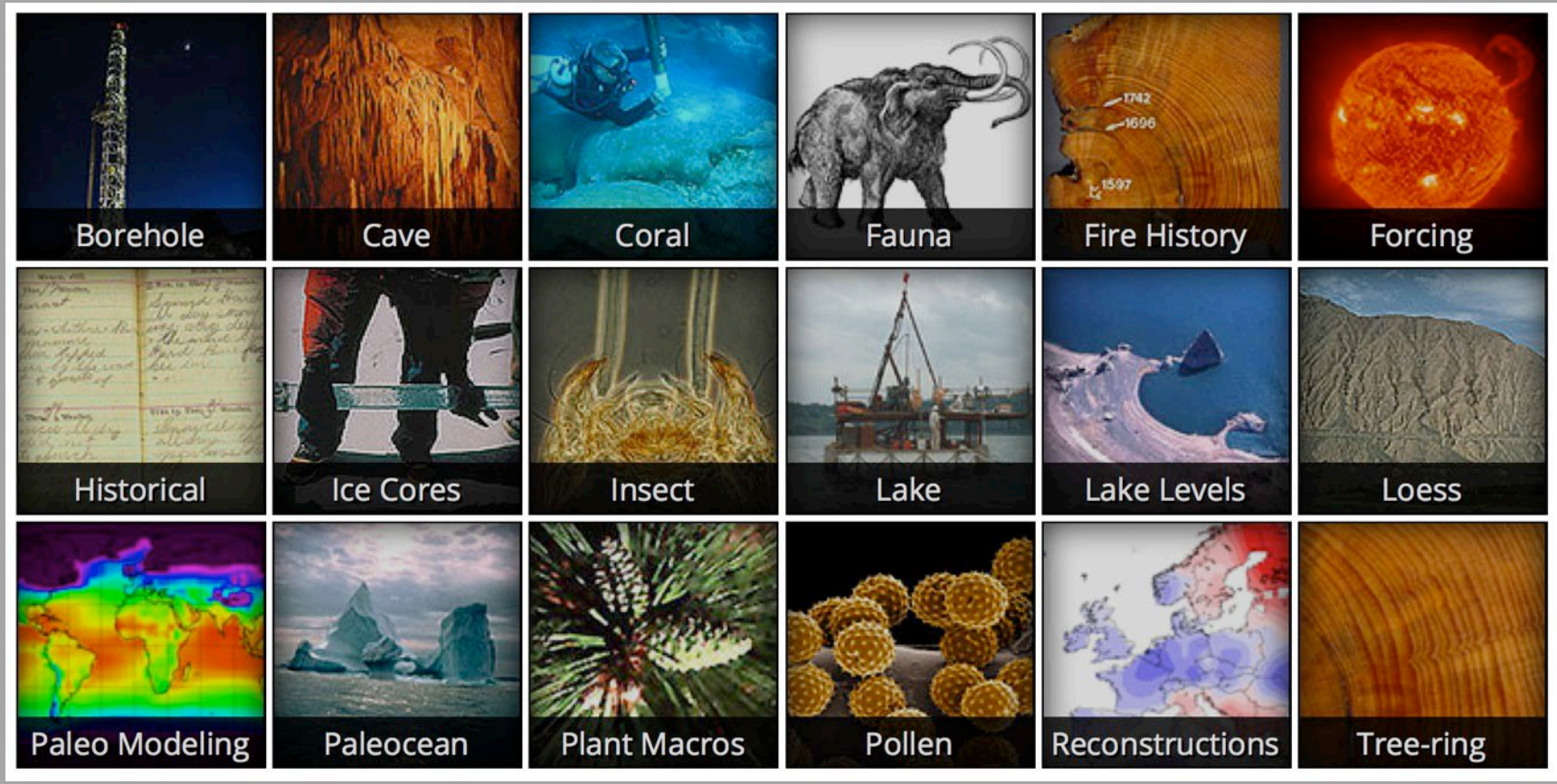
Long-term monitoring stations
Global Historical Climatology Network



Source: created for Global Warming Art by Robert A. Rohde
http://www.globalwarmingart.com/wiki/Image:GHCN_Temperature_Stations.png

HOW DO WE ESTIMATE PAST CLIMATE?

Using PALEOPROXIES that are biological or geological archives that respond directly or indirectly to climate



PALEOPROXIES can extend climate information from hundreds to millions of years.

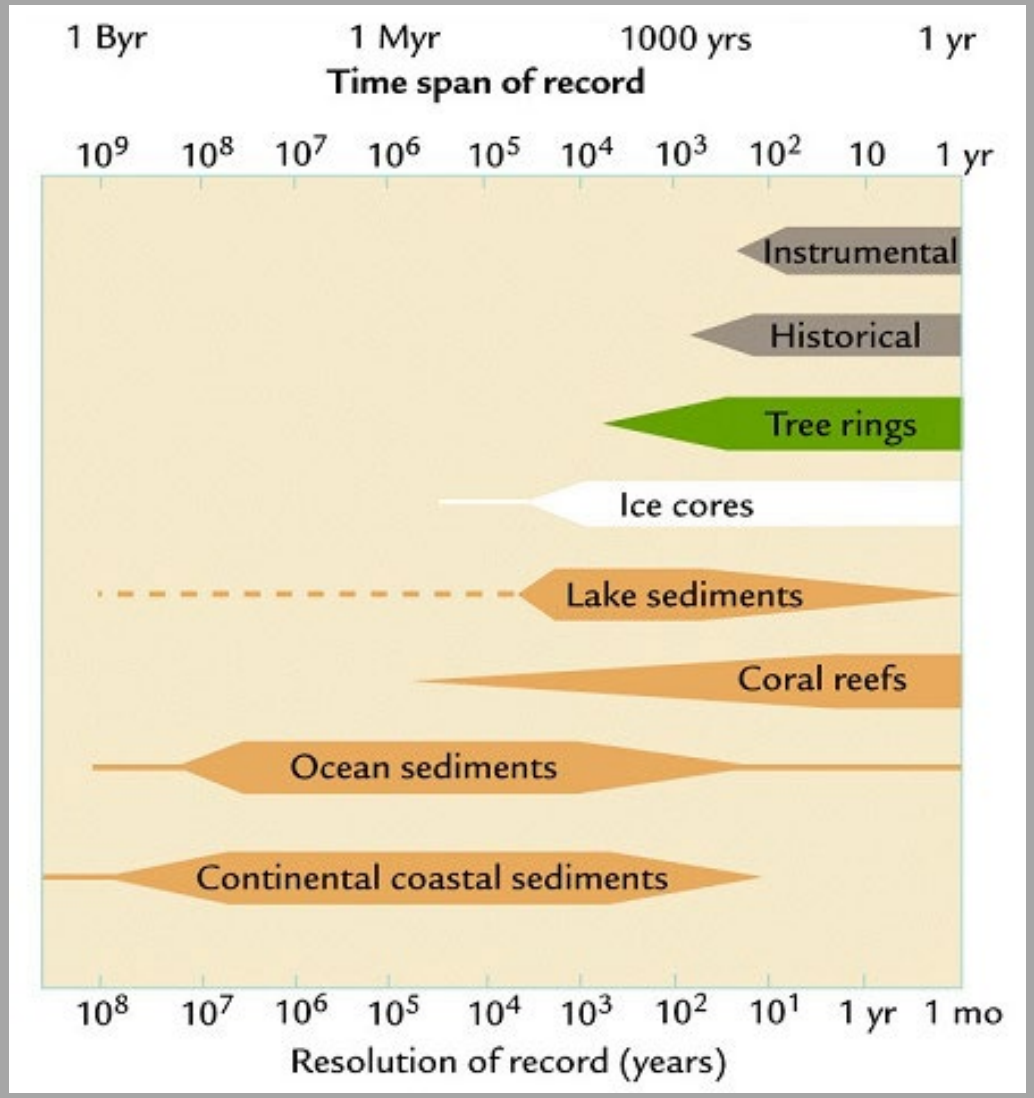
Source: http://www.ncdc.noaa.gov/data-access/paleoclimatology-data

PALEOCLIMATOLOGY is the study of changes in climate taken on the scale of the entire history of Earth.

Geological timescales

Source: USGS (United States Geological Survey) – Graham J., Newman W. & Stacy, John (2008)

PROXY SPAN AND RESOLUTION



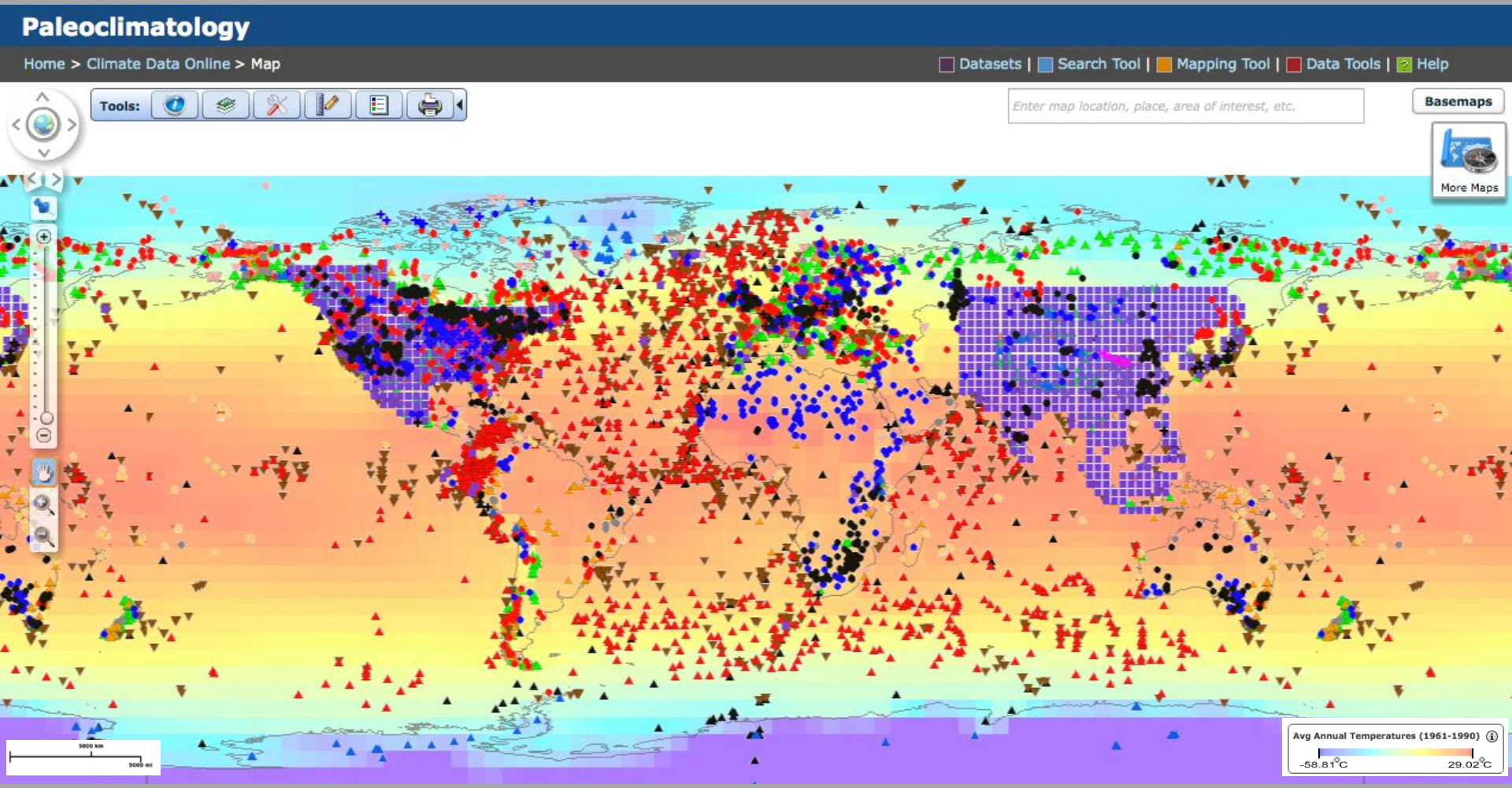
- **Time span** range of time for which data from a given type of proxy exists.

- **Resolution** detail in a given type of proxy data (e.g. annual, decadal, centennial).

Resolution of paleoclimate proxy data tends to decrease as the **time span** covered gets longer.

Source: http://eo.ucar.edu
Credit: National Oceanic and Atmospheric Administration Paleoclimatology Program/Department of Commerce

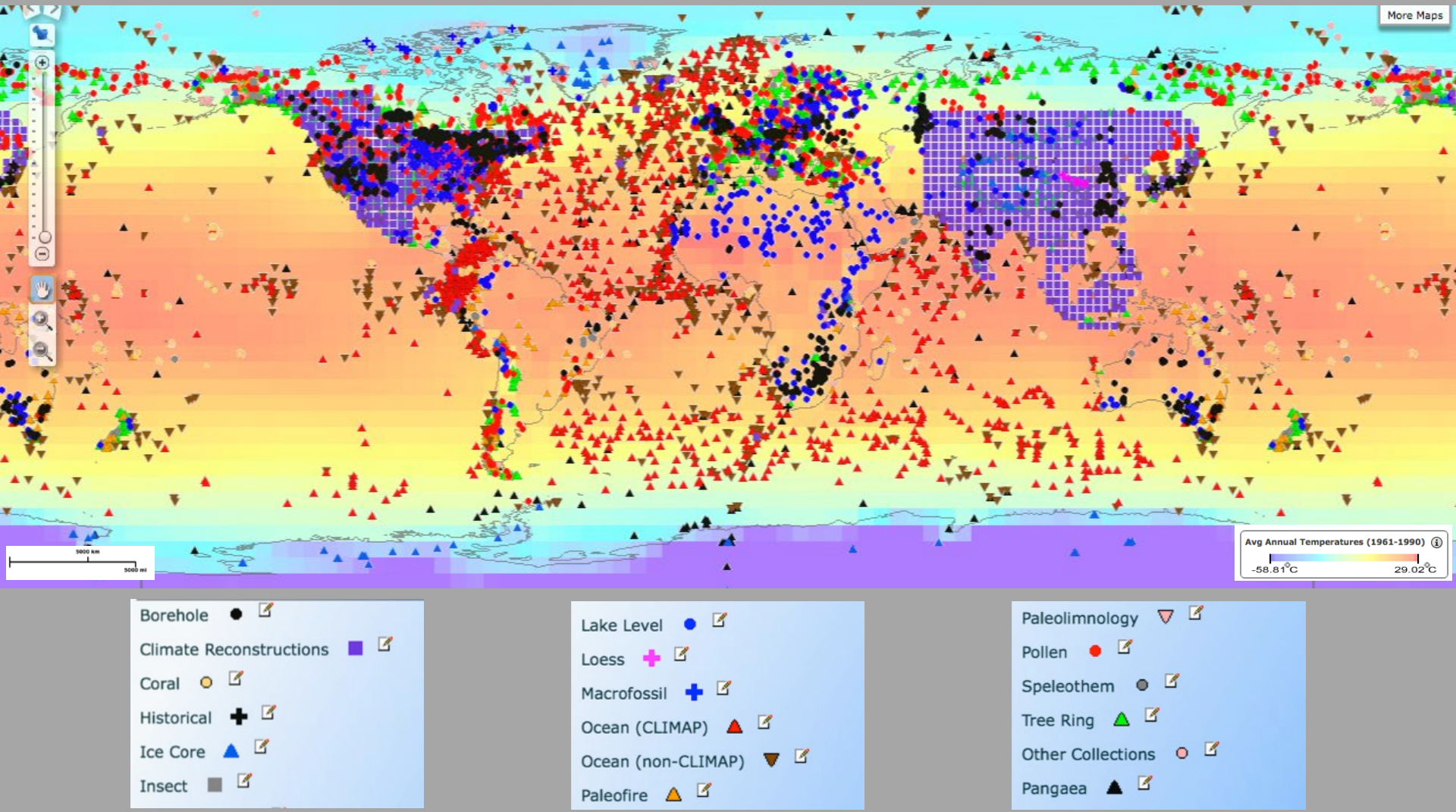
PALEOCLIMATOLOGY DATASETS



Source: http://gis.ncdc.noaa.gov/map/viewer/#app=cdo&cfg=paleo&theme=paleo

PALEOCLIMATOLOGY DATASETS

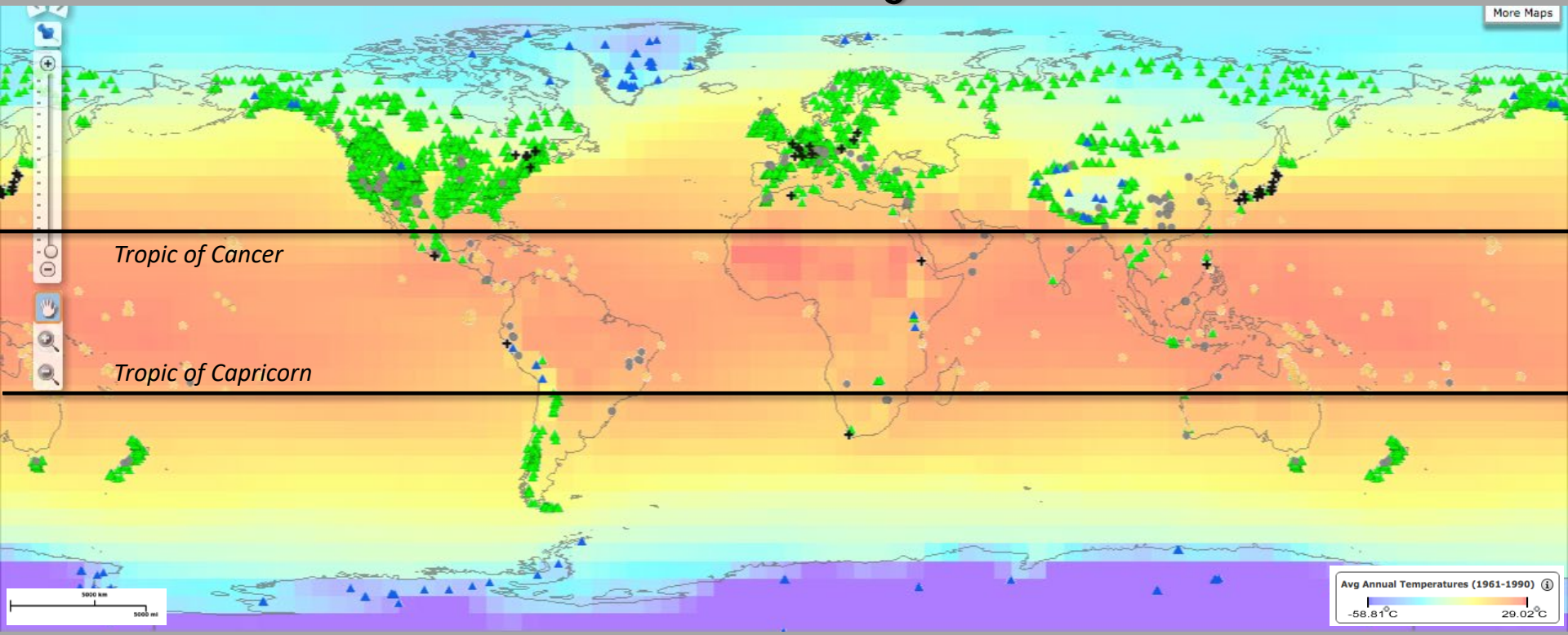
Paleoclimate proxy records are NOT evenly distributed in space across the planet

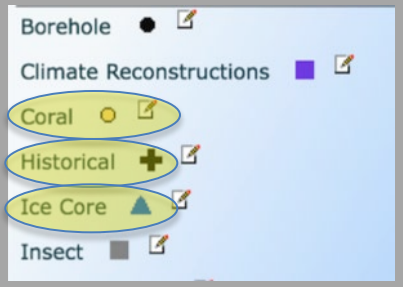


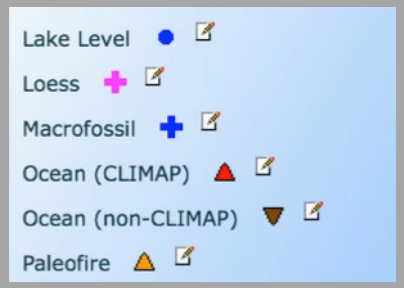
Source: http://gis.ncdc.noaa.gov/map/viewer/#app=cdo&cfg=paleo&theme=paleo

PALEOCLIMATOLOGY DATASETS

Most common high-resolution (annual) paleoproxies: coral, historical, ice cores, speleotherm and tree rings.



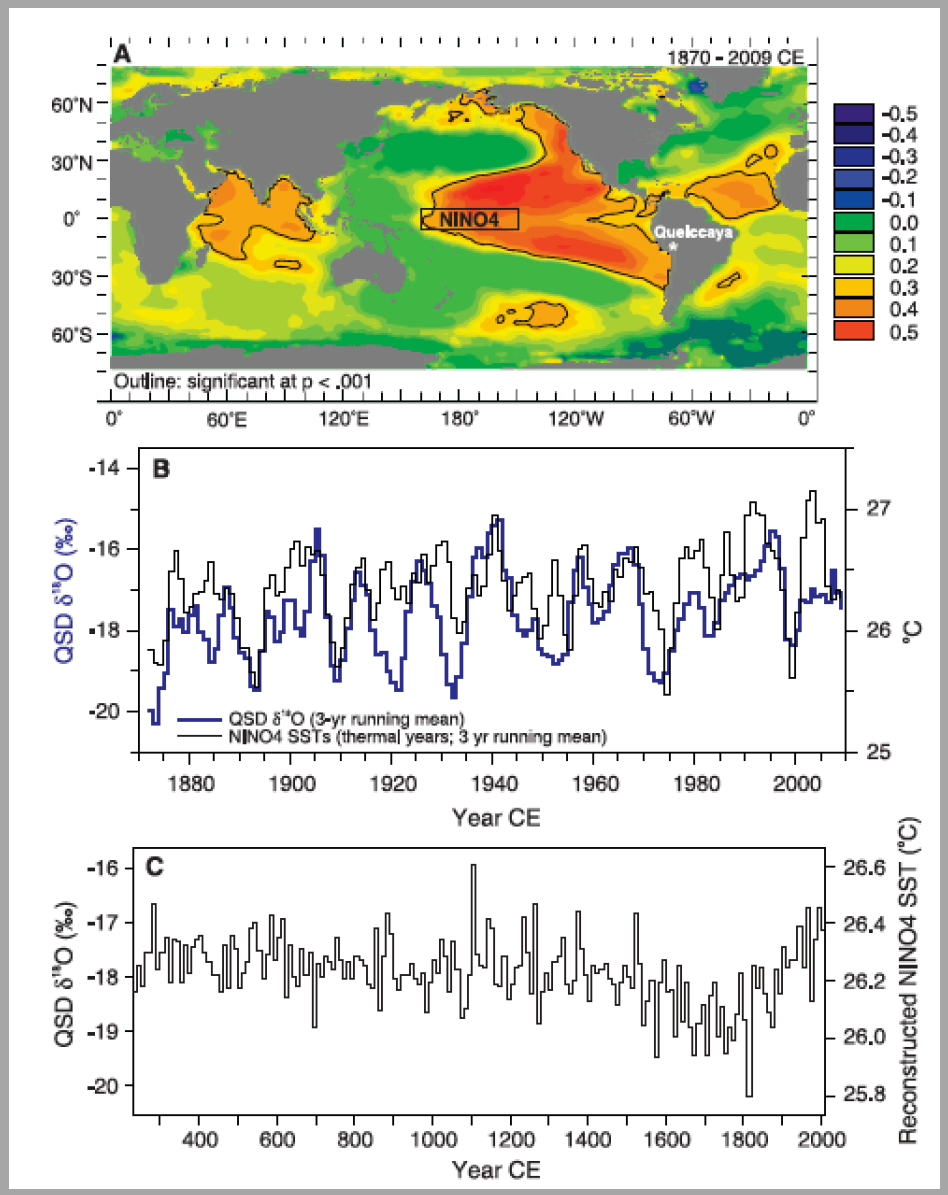




Source: http://gis.ncdc.noaa.gov/map/viewer/#app=cdo&cfg=paleo&theme=paleo

Sea SurfaceTemperatures (SST) and ENSO reconstruction based on ice records

- Quelccaya ice cap, Peru (5670 m a.s.l.)
- Annually-resolved



$\delta^{18}O$ record - SST: Highest correlations SST Tropical Pacific

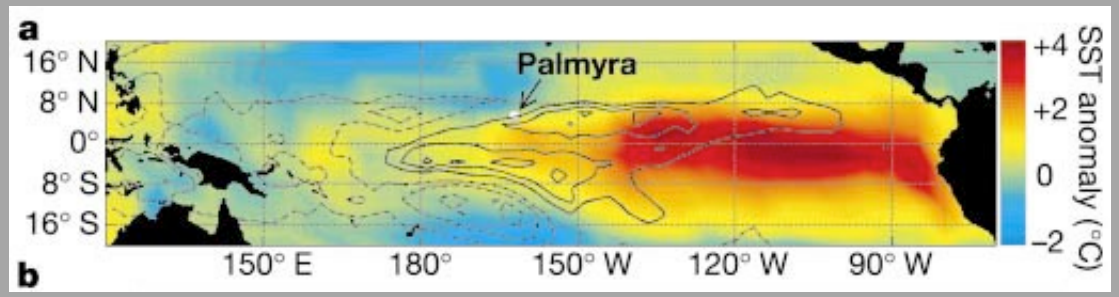
$\delta^{18}O$ record vs. NIÑO SST: calibration period 1870-2010

Reconstruction NIÑO4 SST 200-2000 CE

Thompson, et al. 2013 Science

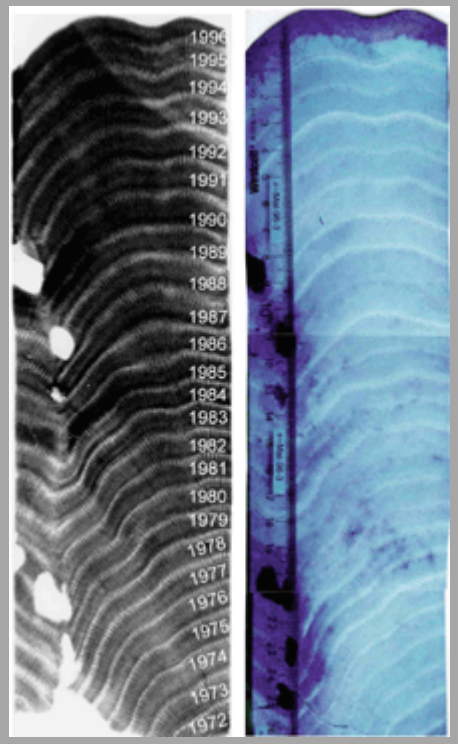
Variability of SST and ENSO based corals (Tropical Pacific)

Cobb, et al. 2003 Science

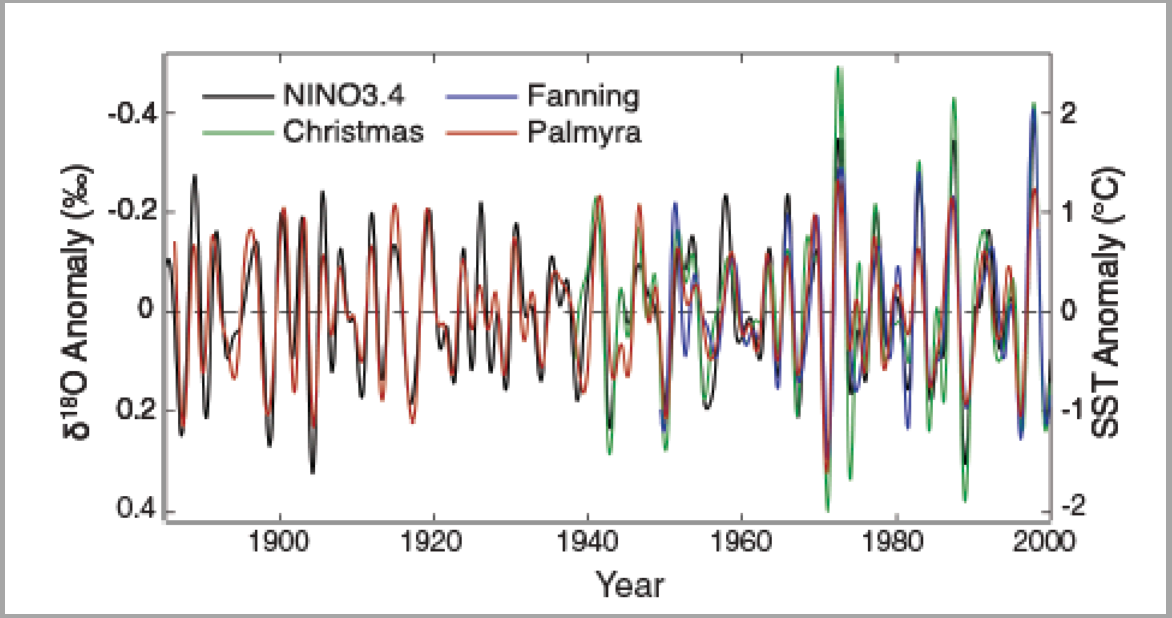


Living Porites corals (last 200 years)

Annual resolution

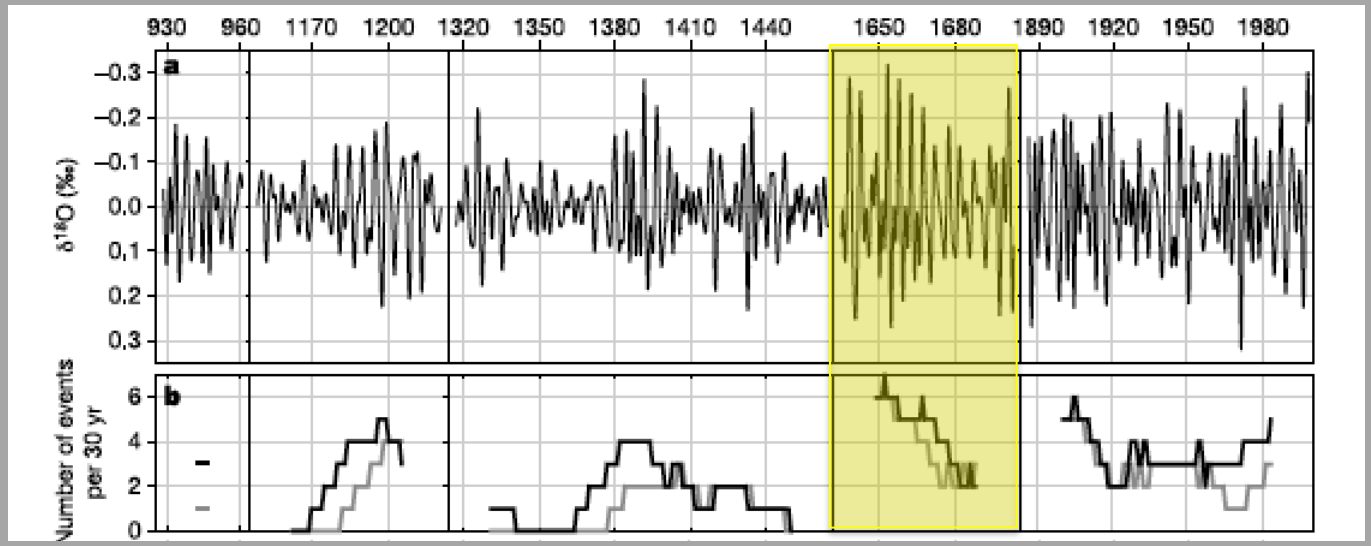


Cobb, et al. 2013 Science



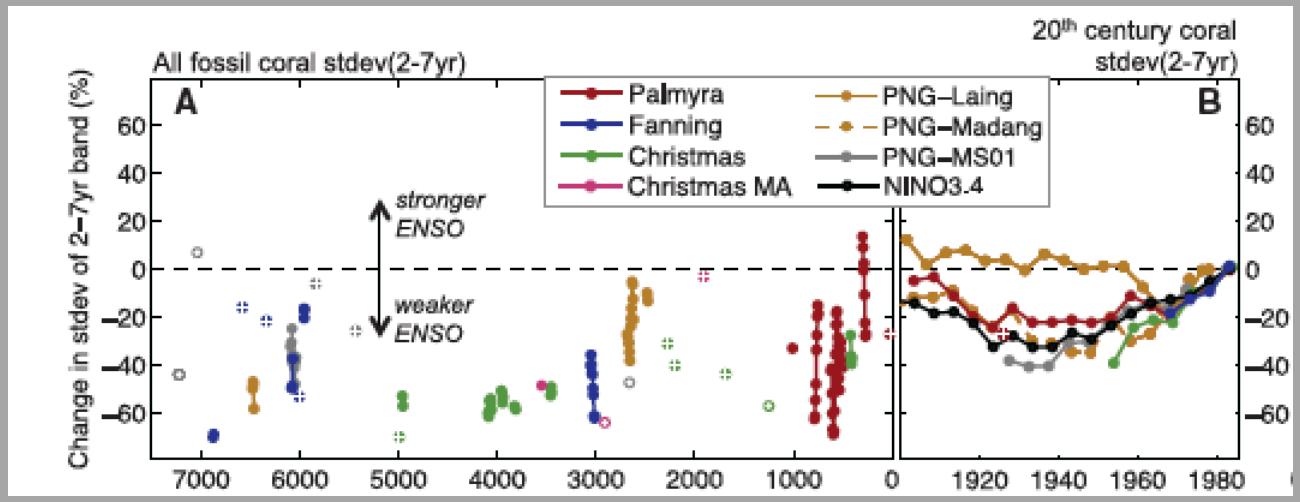
Pictures: http://shadow.eas.gatech.edu/~kcobb/publications/pubs.html#Presentations

Variability of SST and ENSO based corals (Tropical Pacific)



Cobb, et al. 2003 Science

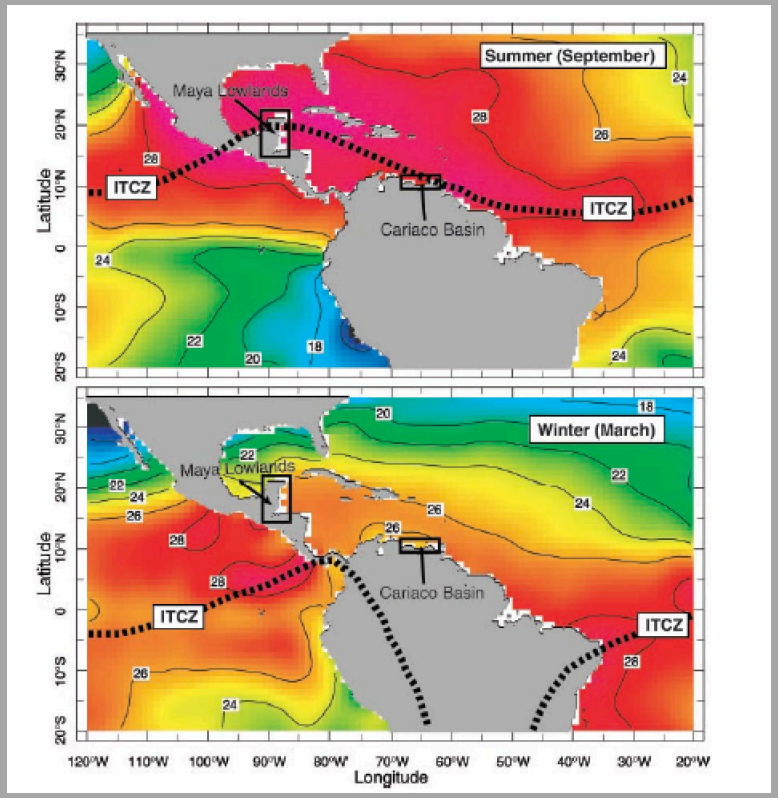
- Time span: last 1000 years
- High ENSO activity 17th century



Cobb, et al. 2013 Science

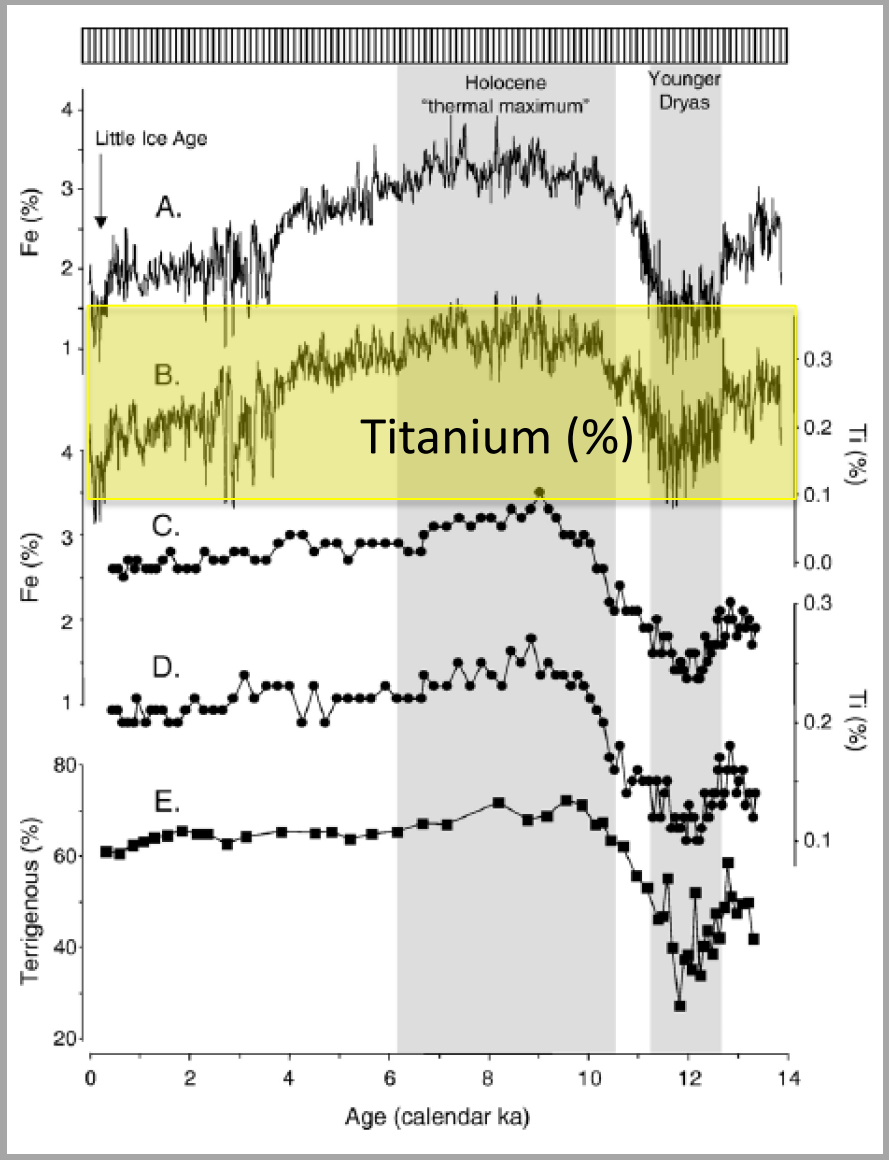
- Time span: last 7000 years
- 20th century ENSO's variance higher than average fossil coral, but not unprecedented.

Intertropical Convergence Zone (ITCZ) migration based on marine sediments (Caribbean)

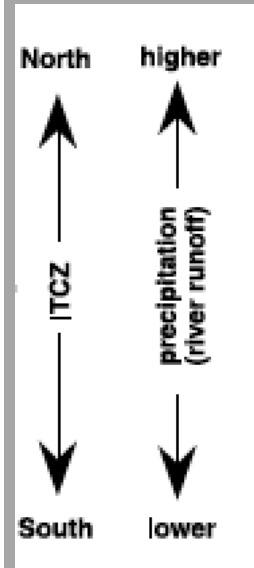


Haug, et al. 2003 Science.

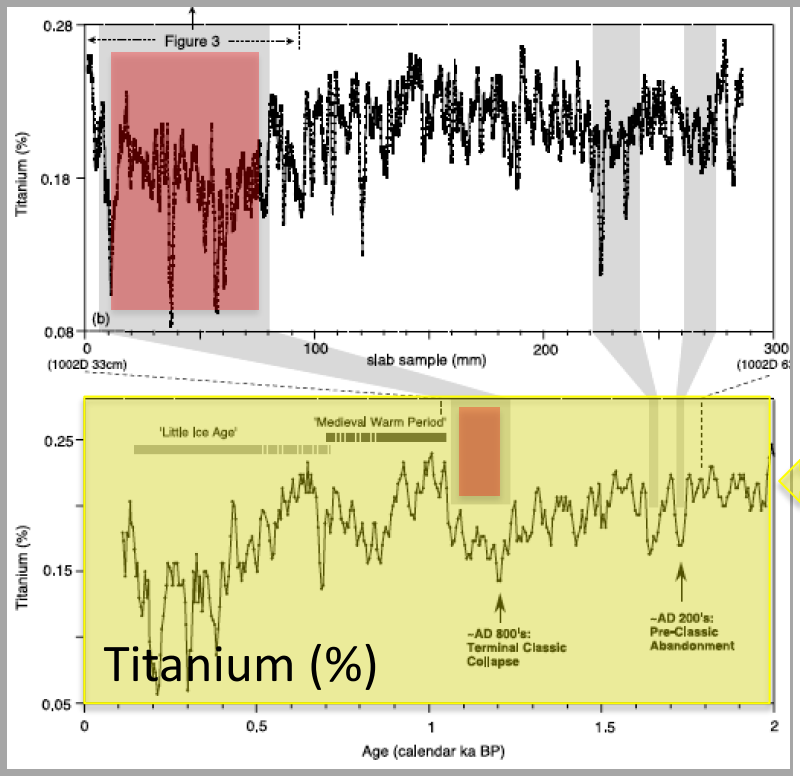
- Cariaco basin, Venezuela
- Shallow basin (annual and sub-annual records in some parts of the core)
- Total time span: last 14000 yrs



Peterson & Haug, 2006 Palaeogeography, Palaeoclimatology, Palaeocology

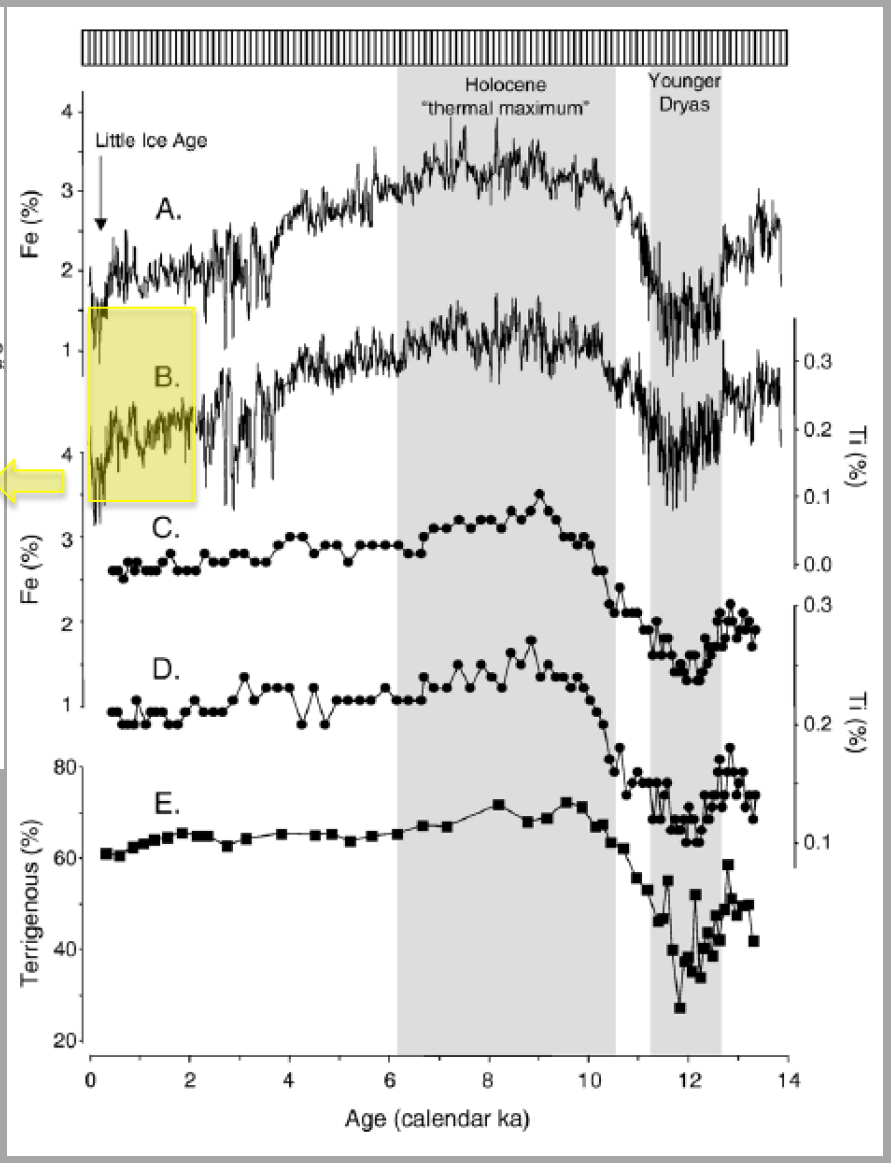


Intertropical Convergence Zone (ITCZ) migration based on marine sediments (Caribbean)

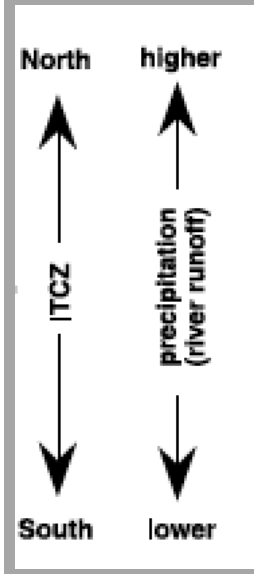


Haug, et al. 2003 Science.

- Last 2000 yrs
- Sub-annual resolution (400 yrs)
- Maya classical collapse (~800 AD), agriculture-dependent.

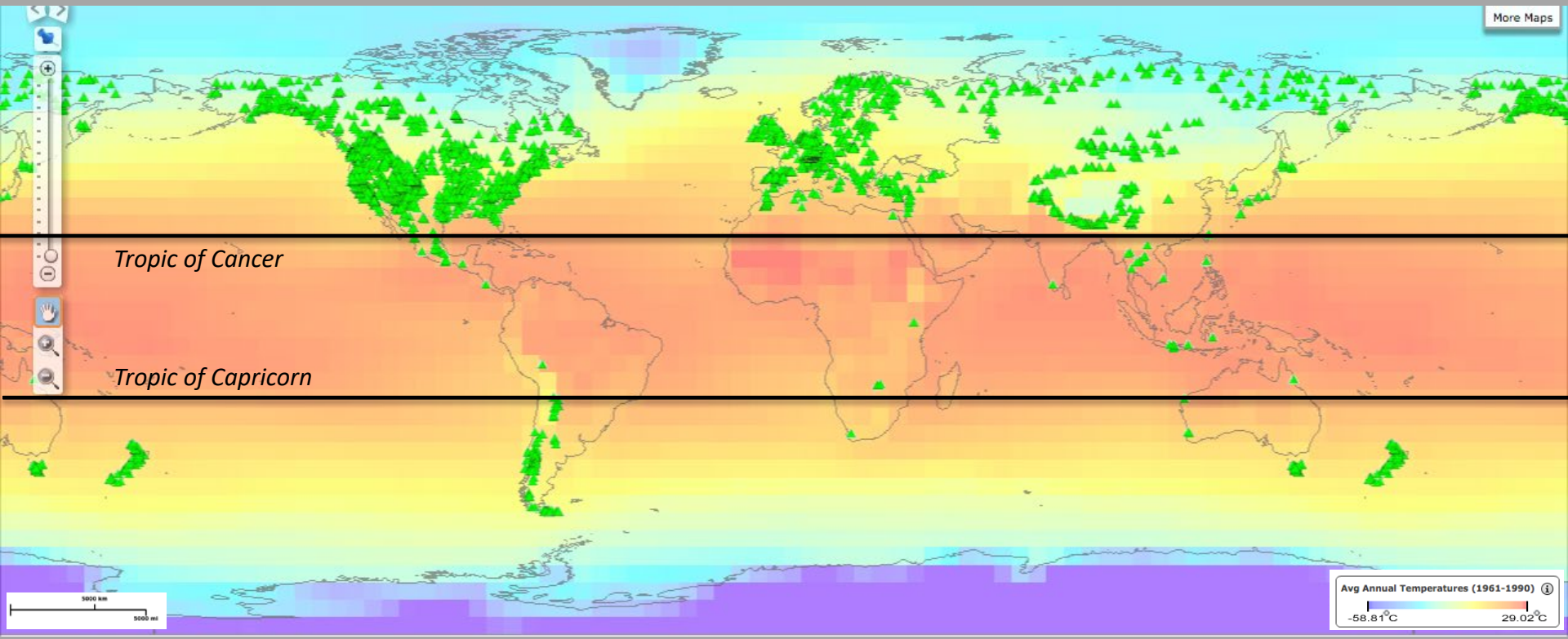


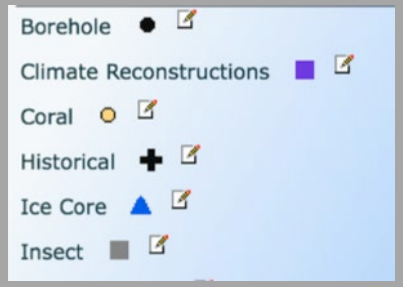
Peterson & Haug, 2006 Palaeogeography, Palaeoclimatology, Palaecology

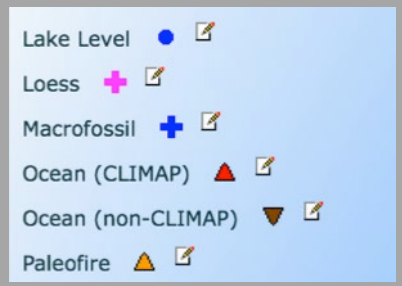


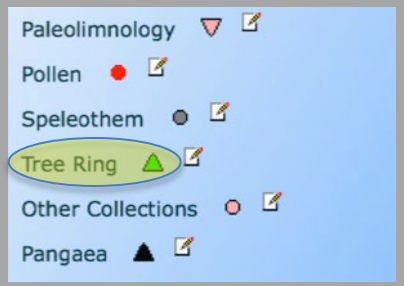
PALEOCLIMATOLOGY DATASETS

International Tree-Ring Data Bank (ITRDB)
~ 4300 tree-ring records



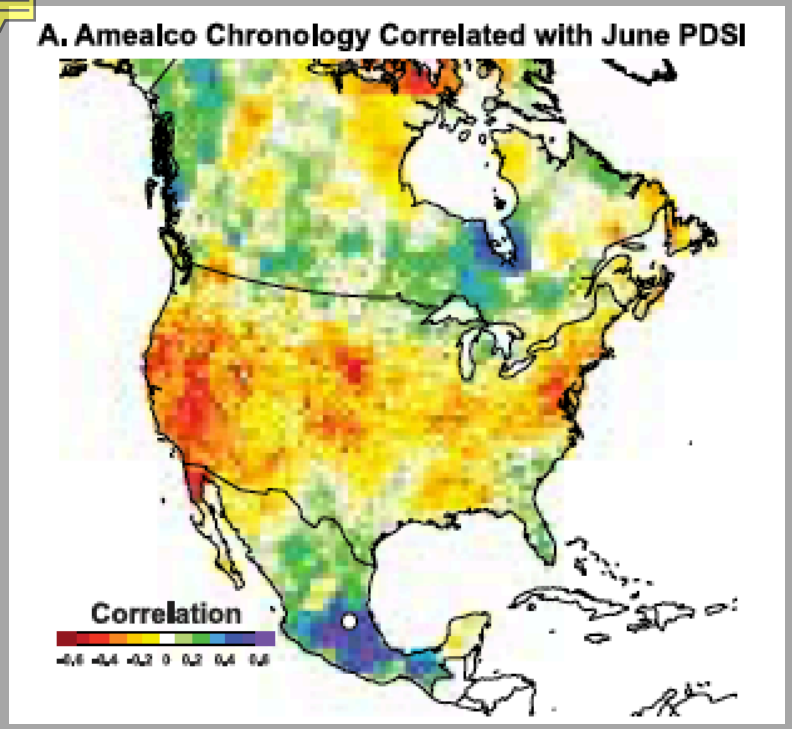




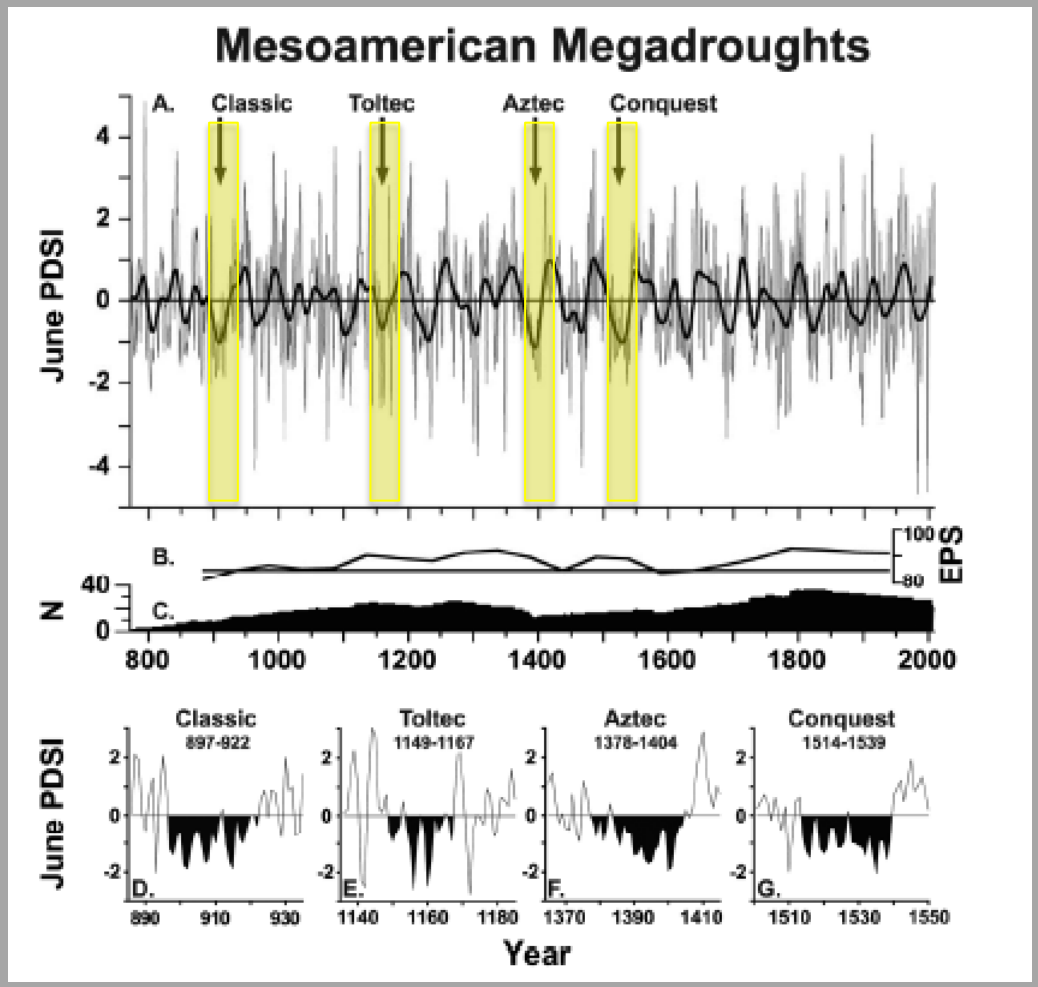


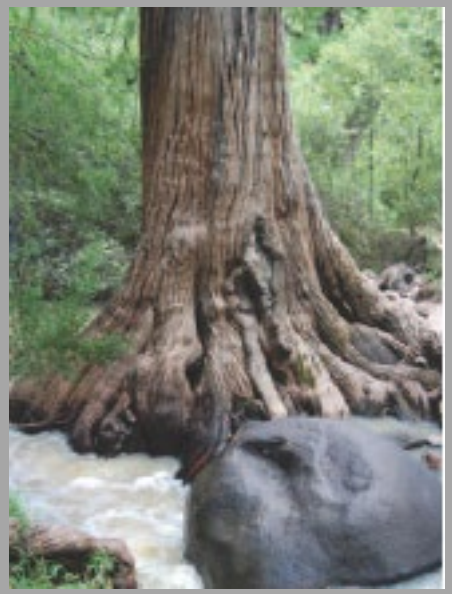
Source: http://gis.ncdc.noaa.gov/map/viewer/#app=cdo&cfg=paleo&theme=paleo

1200-yr tree-ring records in Mesoamerica: Mexico



- Time span: 771-2008 C.E.
- Reconstruction June PDSI



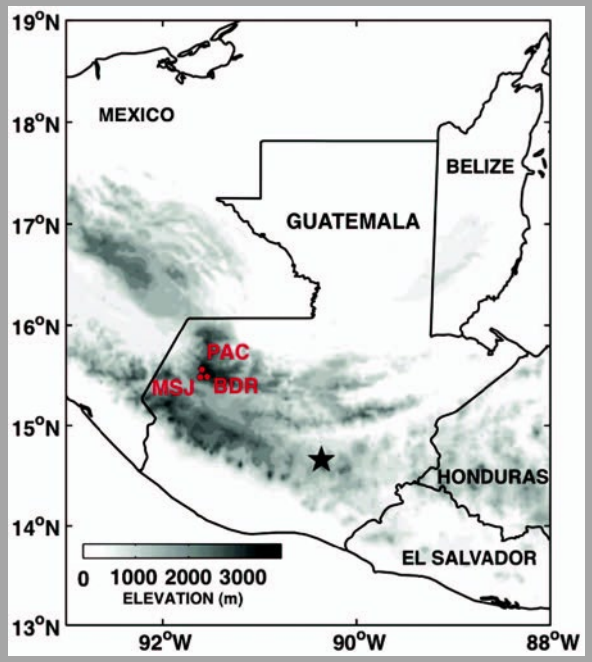


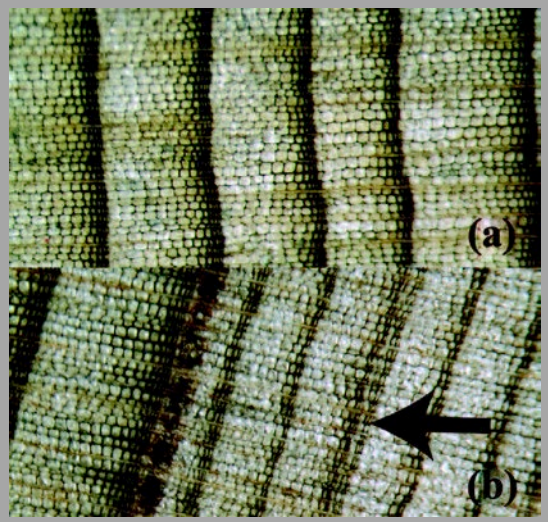
- Montezuma baldcypres (*Taxodium mucronatum*
- Gorge of Amealco, Tula, Mexico
- Latitude: ~ 20°N

D. STAHLE

Stahle, et al. 2011 Geophysical Research Letters

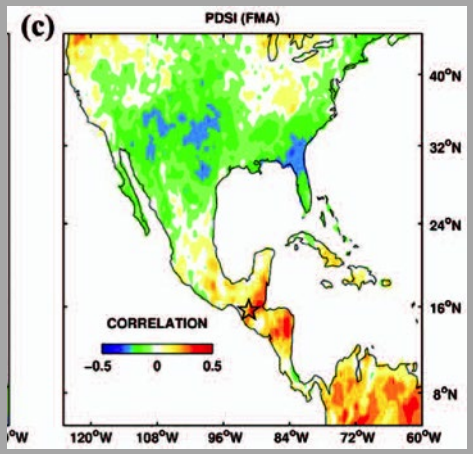
300-yr tree-ring records in Mesoamerica: Guatemala



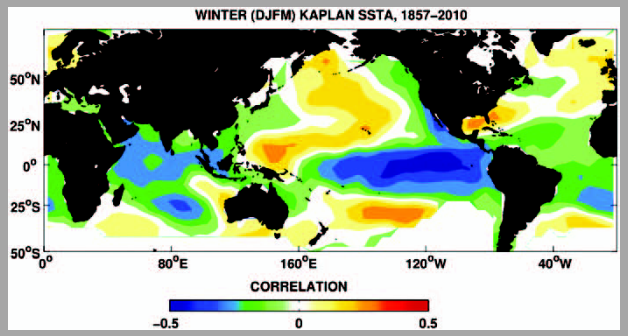


- *Abies guatemalensis*, Guatemala
- Time span: 1699-2010 C.E.
- Latitude: ~ 15°N

PDSI

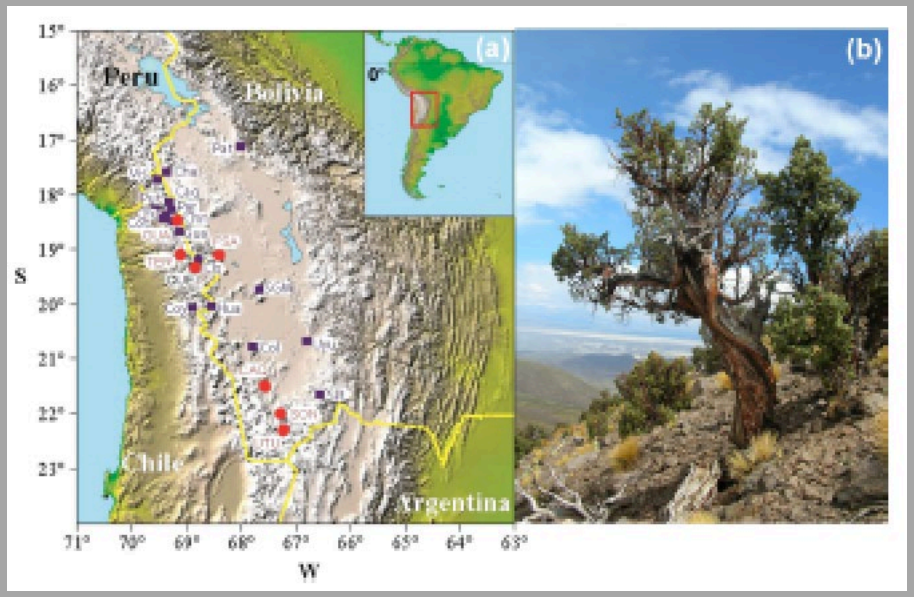


Winter (December–March) sea surface temperature anomalies (SSTA)

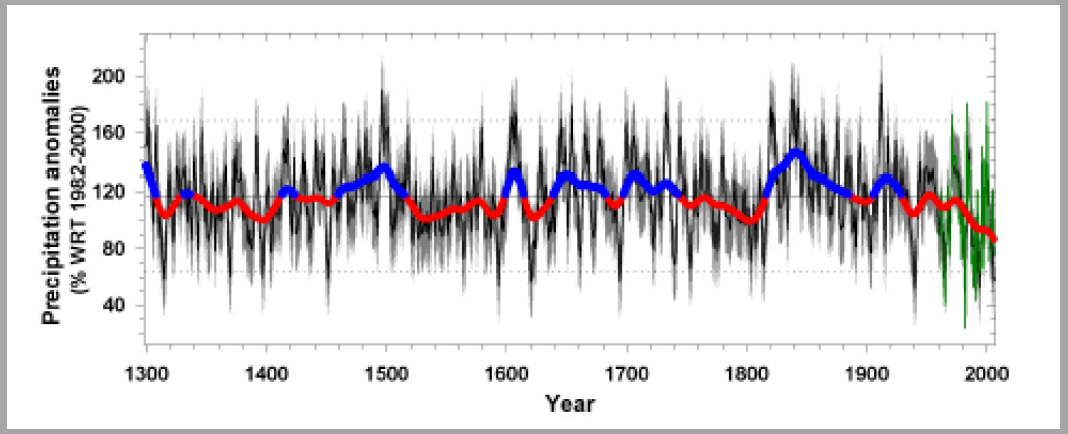


Anchukaitis, et al. 2013 Holocene

700-yr tree ring records in South America: Bolivia and Chile

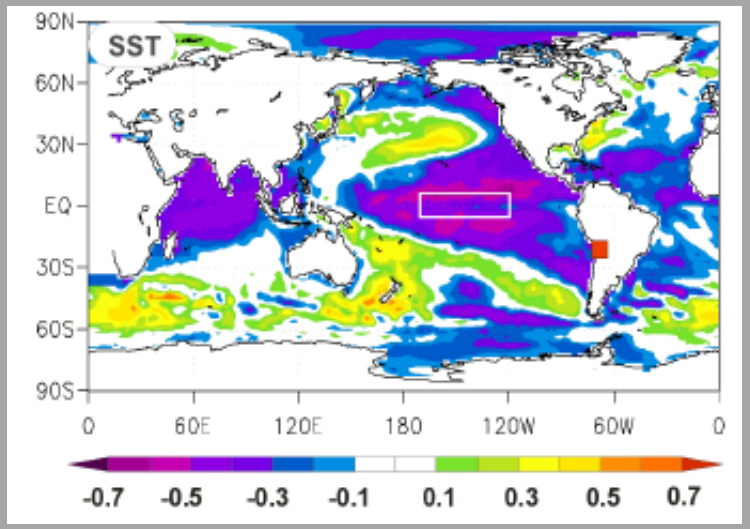


- *Polylepis tarapcana*, Altiplano region, Central Andes, Bolivia and Chile
- Latitude: ~ 17-23°S

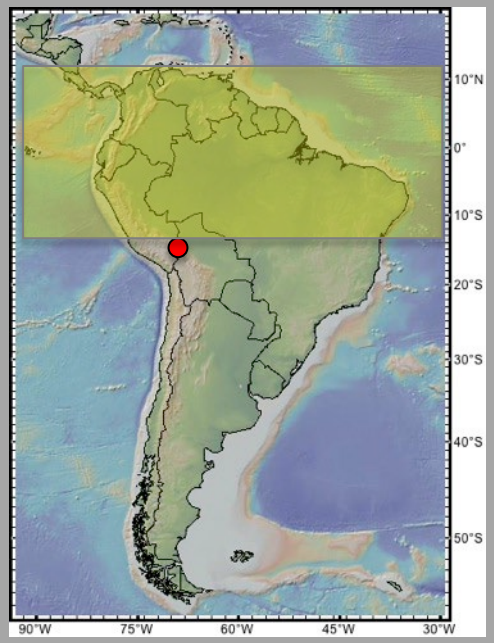


- Reconstruction Nov-Oct precipitation
- Time span: 1300-2006 C.E.

Precip. Recons. correlations vs. Nov-Oct SST (1948-2006)



Morales, et al. 2012 Climate of the Past

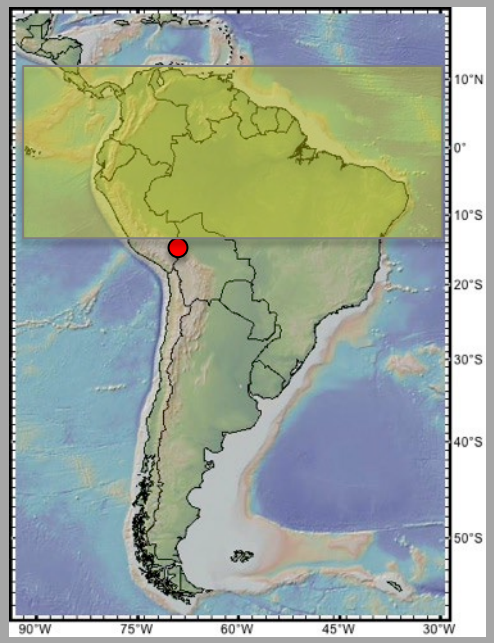


WHY THERE ARE FEW TREE-RING RECORDS IN THE INNER TROPICS?

- Lack of well-defined tree rings, sometimes.
- Absence of winter dormancy due to low temperatures in winter (e.g. extratropics).
- Seasonality in the tropics is mainly driven by changes in the hydrological cycle.

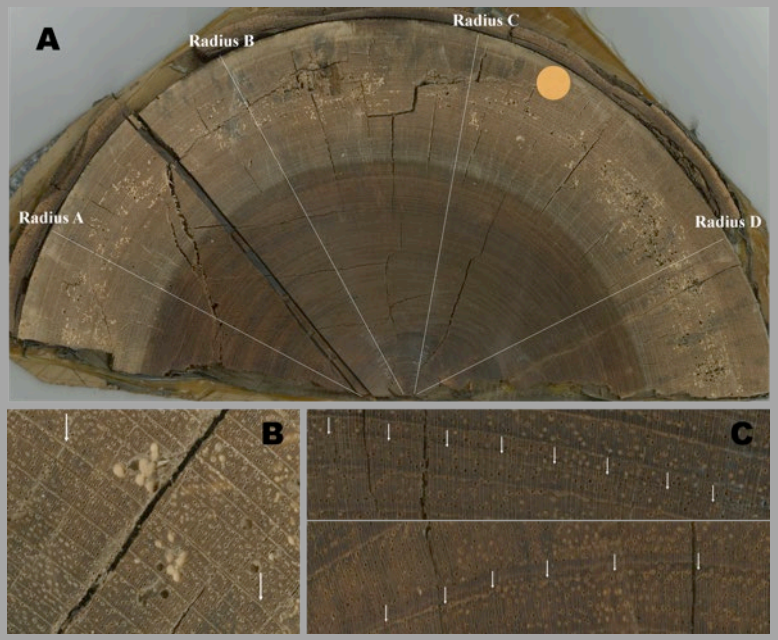
Andreu-Hayles & Dos Santos, et al. 2014 Radiocarbon (in press)

Annual periodicity in tropical tree rings



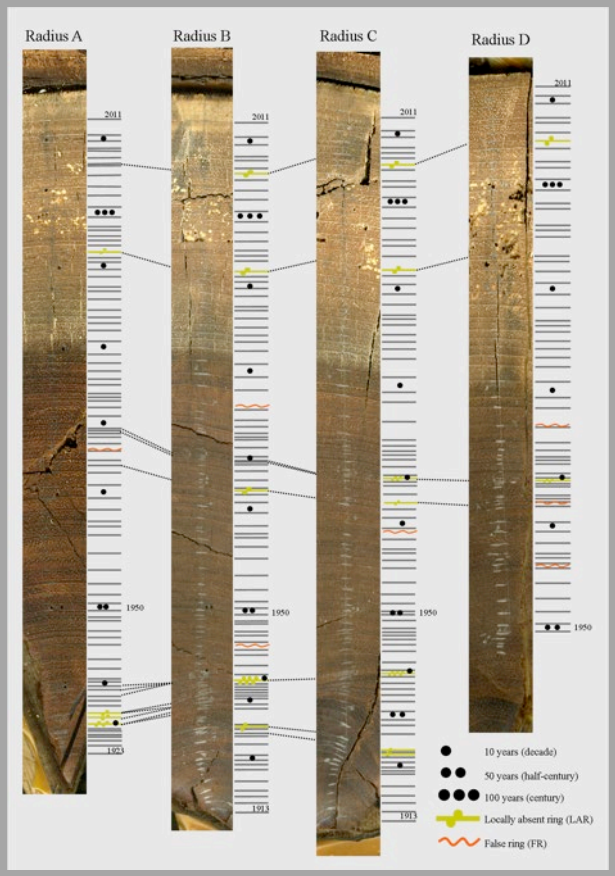
● *Pseudolmedia rigida*,

- Madidi National Park, Bolivia
- Latitude: ~ 14°S



Locally Absent Ring (LAR)

False Ring (FR)



Andreu-Hayles & Dos Santos, et al. 2014 Radiocarbon (in press)

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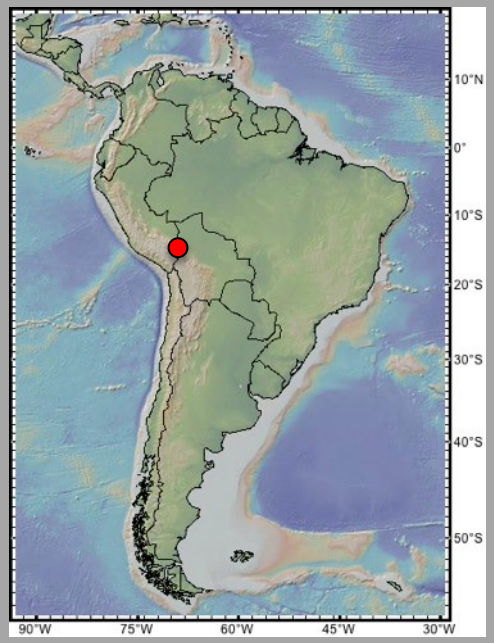
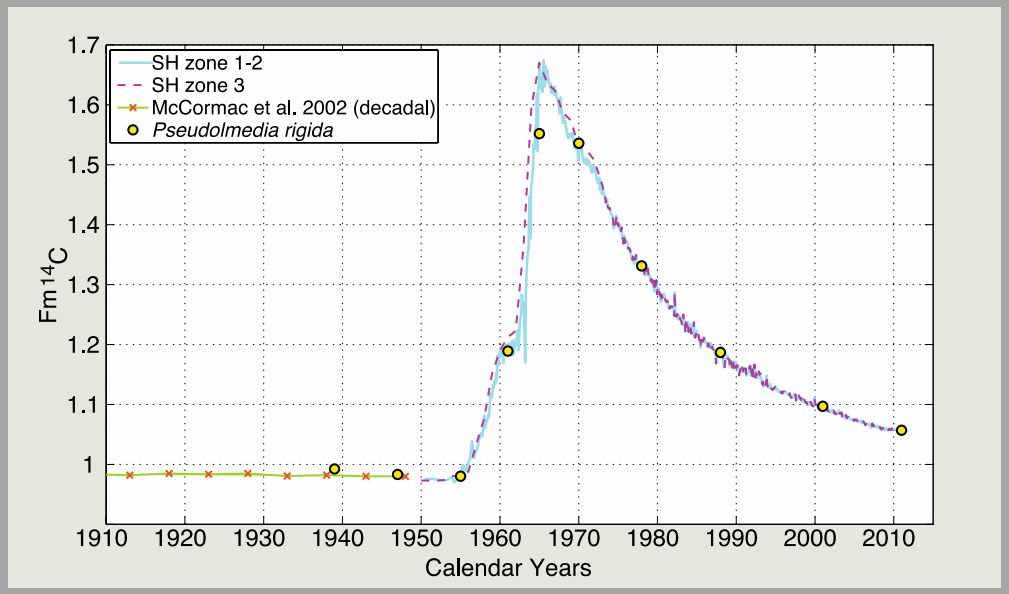
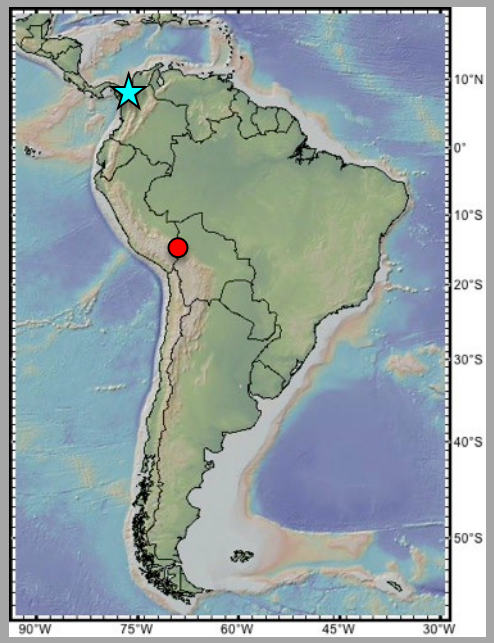


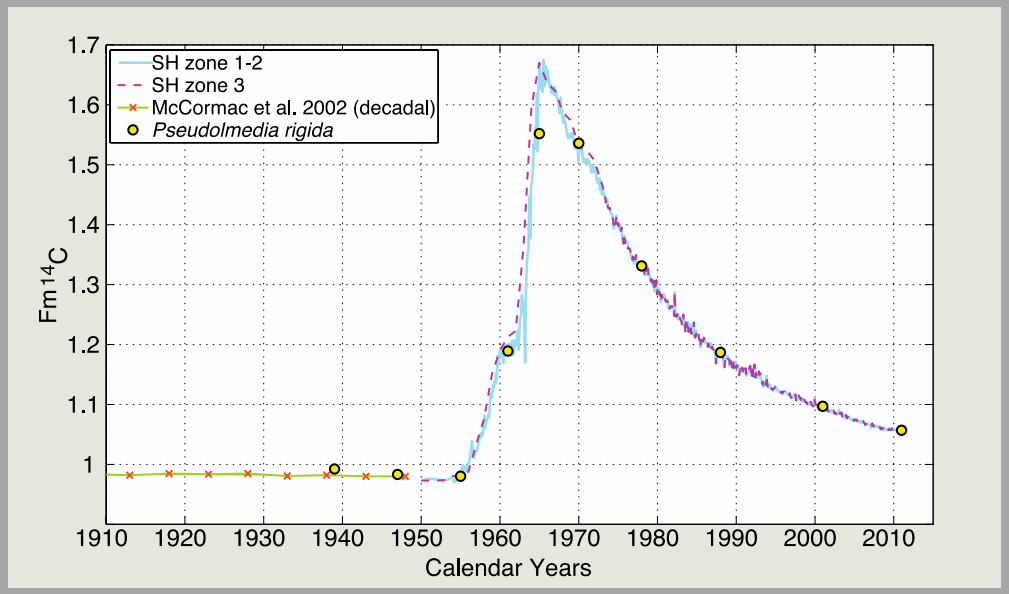


Andreu-Hayles & Dos Santos, et al. 2014 Radiocarbon (in press)

Pseudolmedia rigida, Madidi National Park, Bolivia

Annual periodicity in tropical tree rings



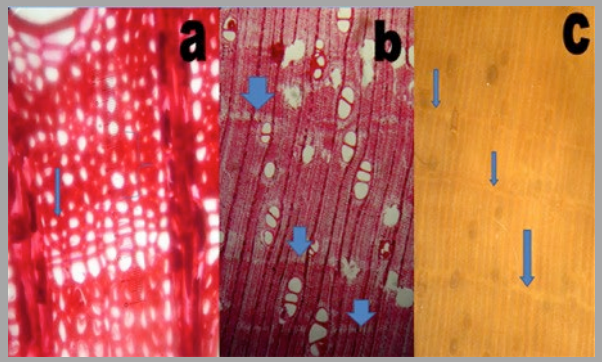


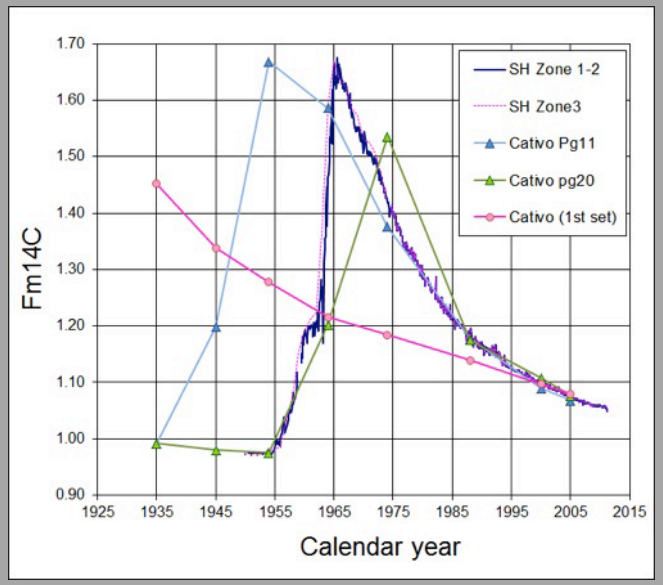
Andreu-Hayles & Dos Santos, et al. 2014 Radiocarbon (in press)

● *Pseudolmedia rigida*, Madidi National Park, Bolivia

★ *Prioria copaifera* (cativo)

- Atrato river, Colombian Pacific region
- Latitude: ~ 7°N

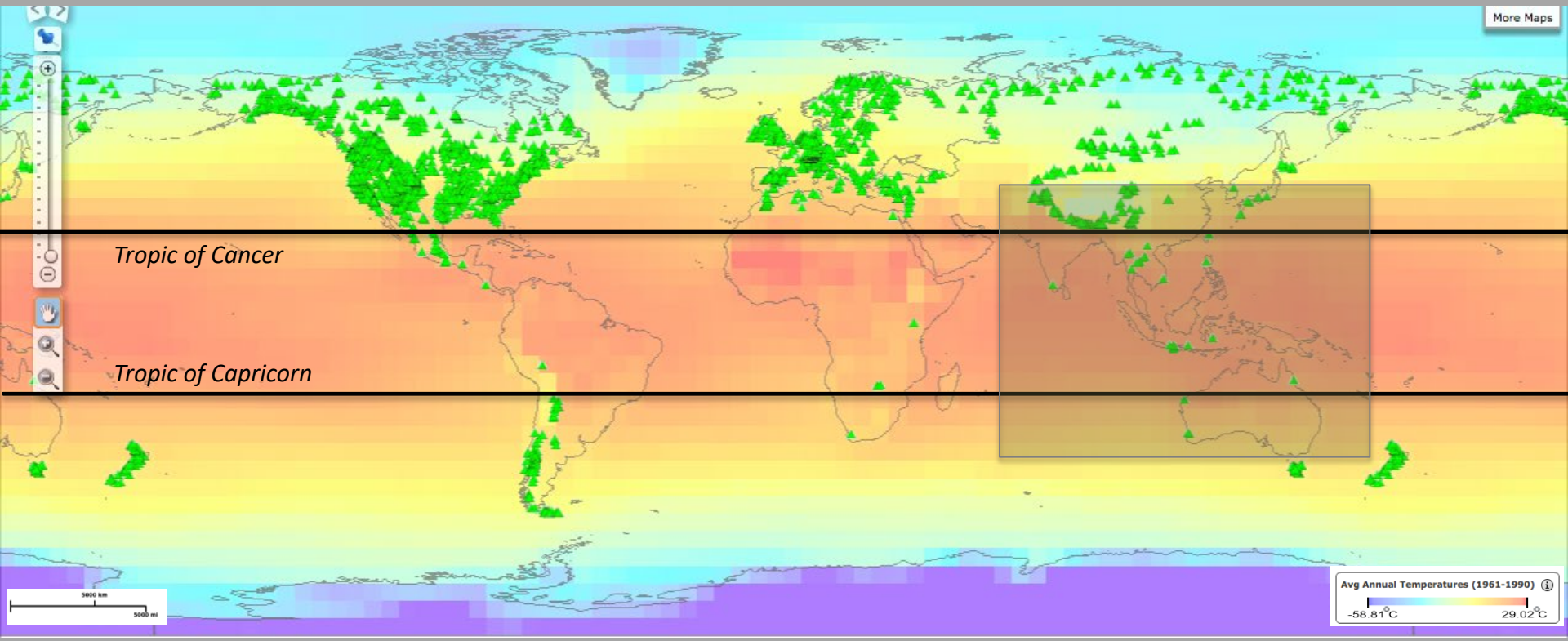




David Herrera-Ramírez, Andreu-Hayles et al. (unpublished)

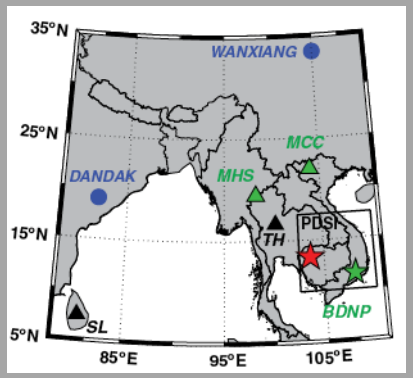
PALEOCLIMATOLOGY DATASETS

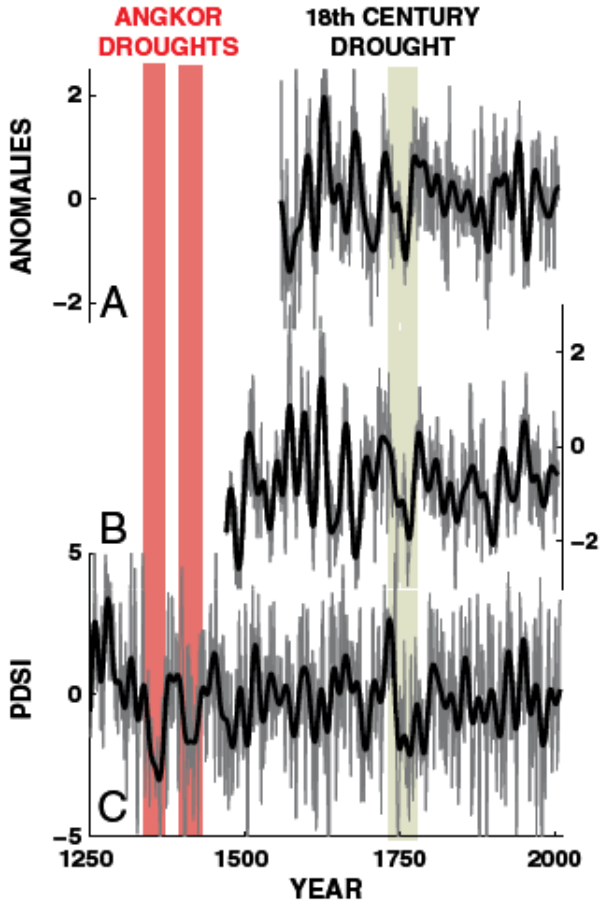
Some relevant tree-ring studies in Asia…



Source: http://gis.ncdc.noaa.gov/map/viewer/#app=cdo&cfg=paleo&theme=paleo

Monsoon variability in Asia based on tree-ring records validated with speleothem and coral records

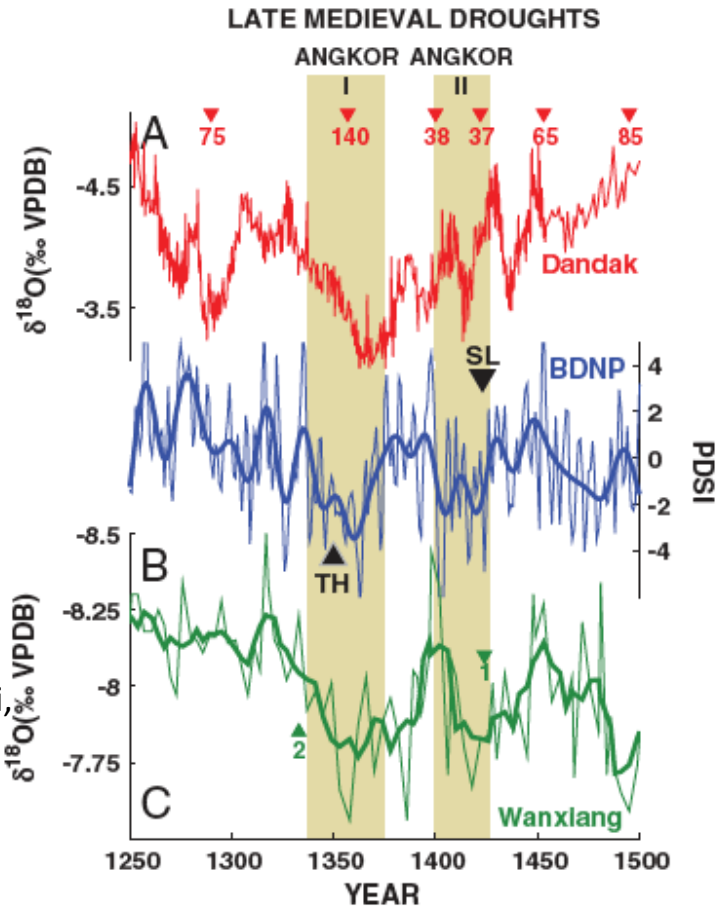




MHS: teak, Thailand

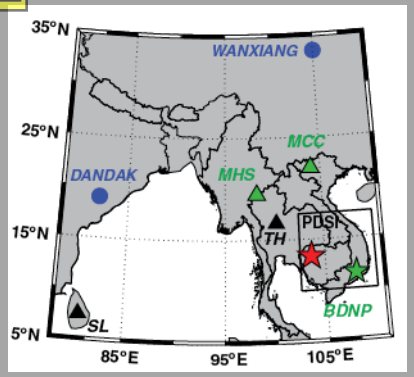
MCC: Fokienia hodginsii, Northern Vietnam

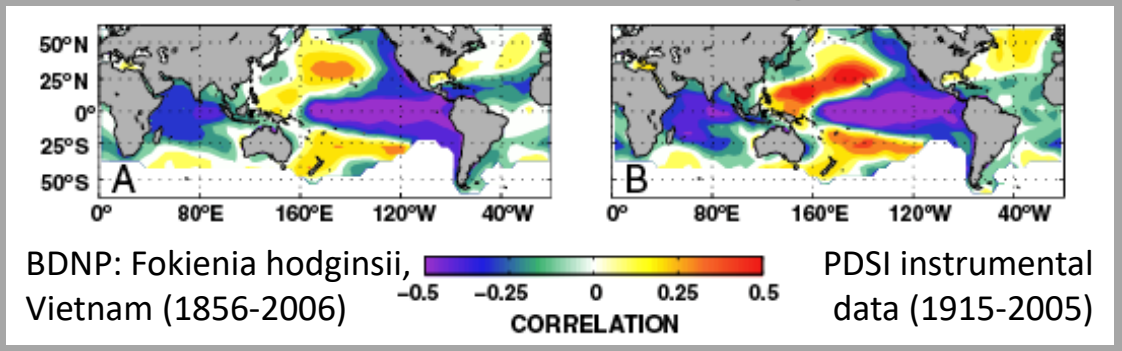
BDNP: Fokienia hodginsii, Central Vietnam



Buckely, et al. 2010 PNAS

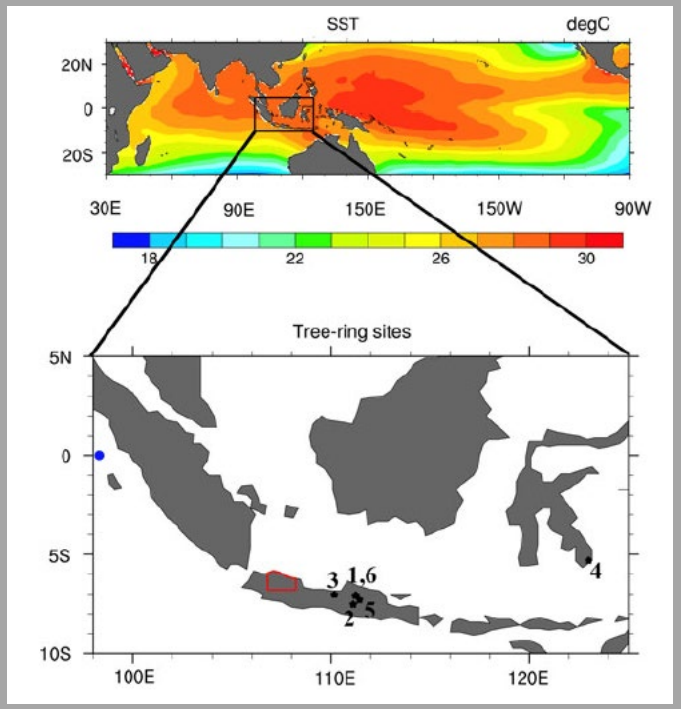
Vietnamese records of drought vs. SST





Buckely, et al. 2010 PNAS

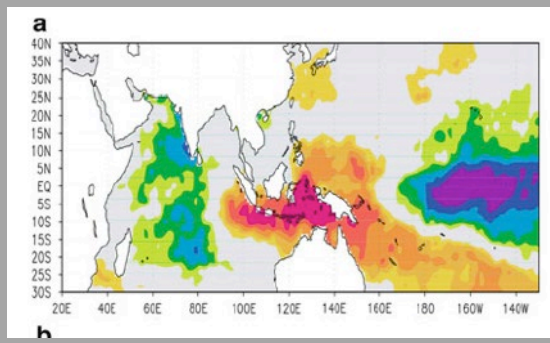
Java teak records last 200 yr and Mentawai coral series



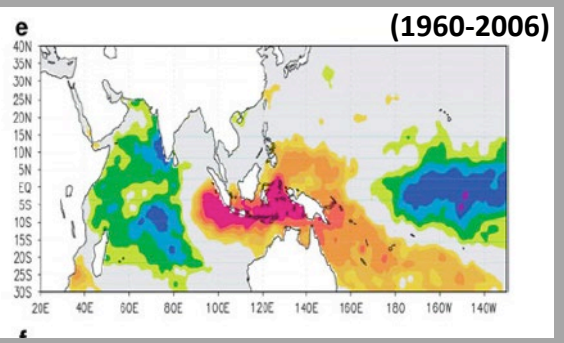
D'Arrigo, et al. 2011 Climate Dynamics

Teak streamflow recons.

Sep-Oct SST

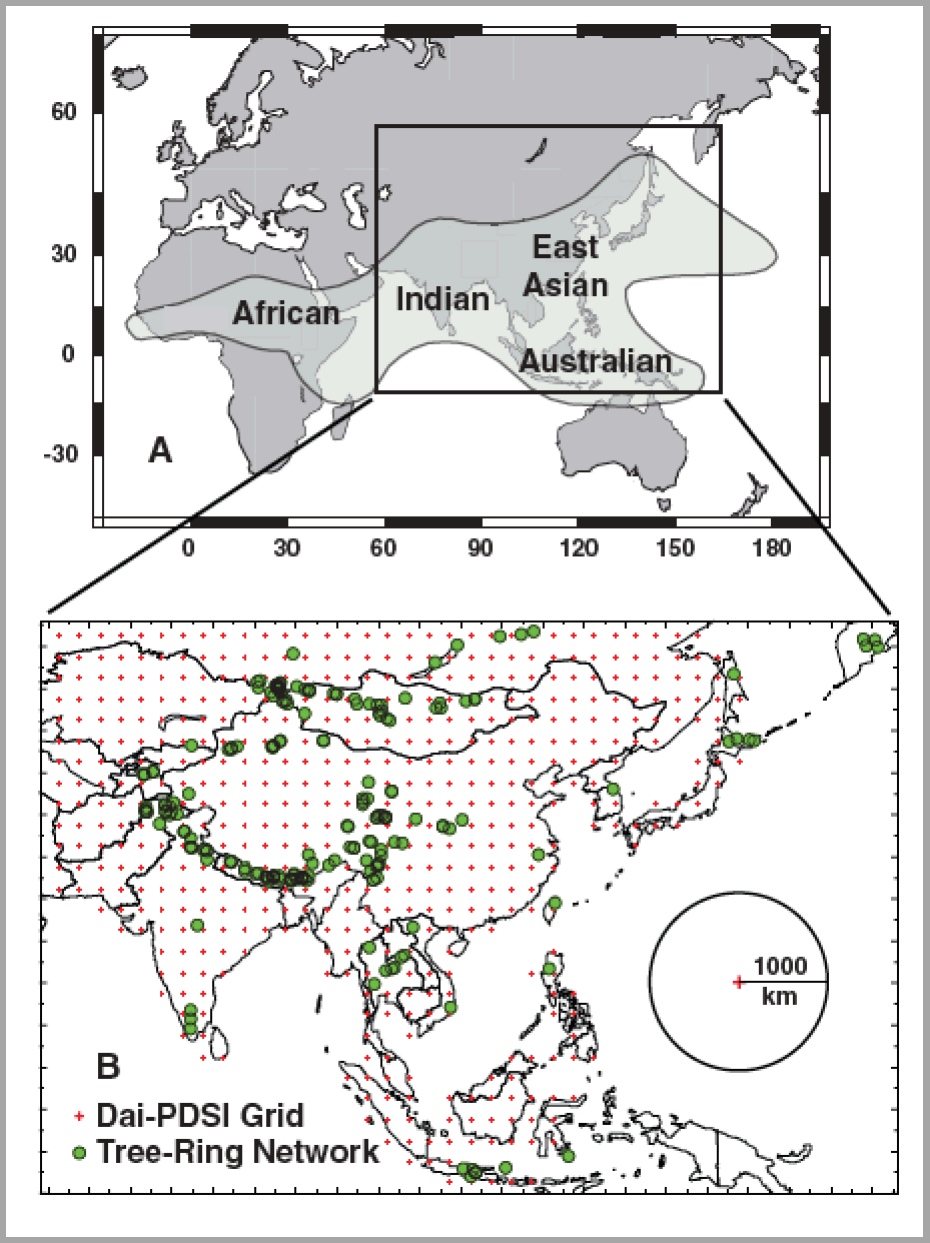


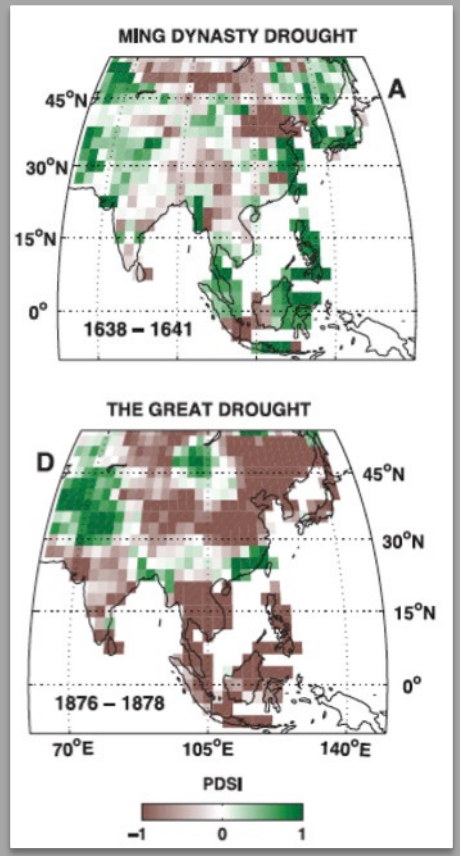
Coral Dipole Mode Index recons.

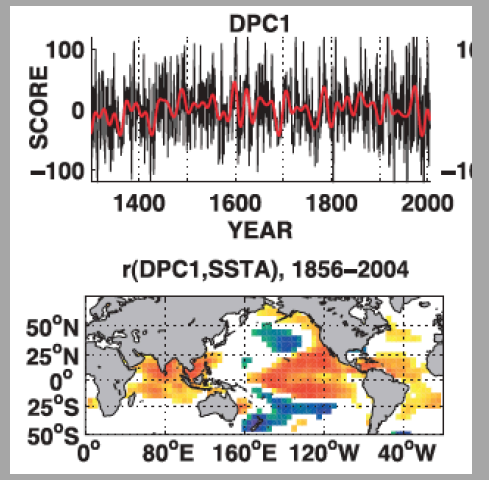


D'Arrigo, et al. 2011 Climate Dynamics

Monsoon Asia Drought Atlas (MADA)





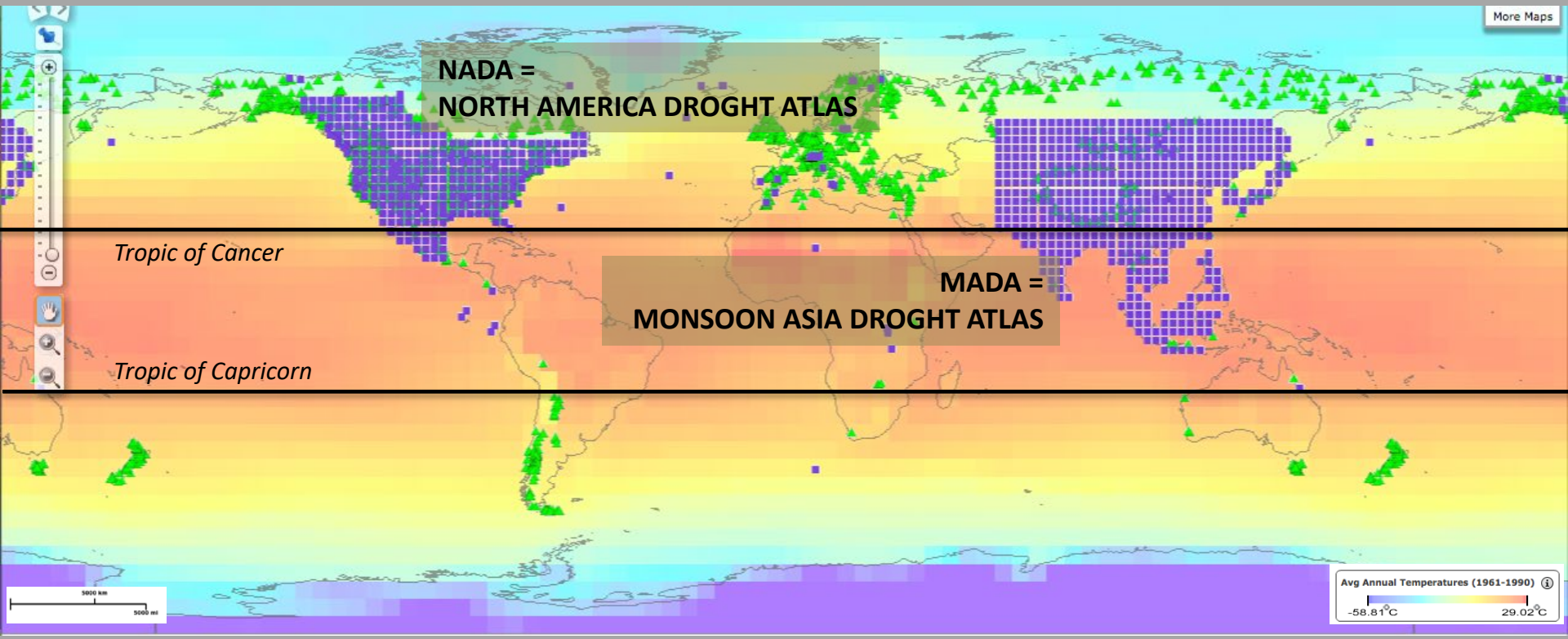


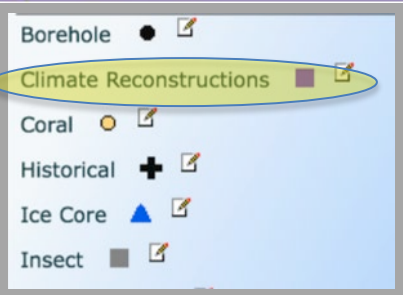
- Nº chronologies: 327
- Nº grid points PDSI recons: 534
- Time-span: 1300-2004 C.E.

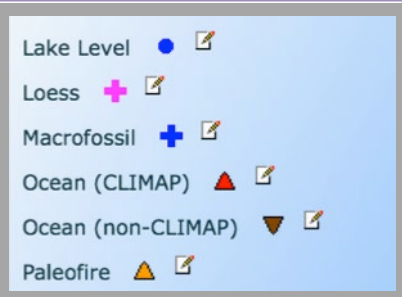
Cook, et al. 2010 Science

PALEOCLIMATOLOGY DATASETS

Drought Atlas in North America (NADA) and Asia (MADA) based on tree rings







Source: http://gis.ncdc.noaa.gov/map/viewer/#app=cdo&cfg=paleo&theme=paleo

TAKE-HOME MESSAGES

1. ***A paleo-perspective is needed to assess the full range of climate variability and change since instrumental records only cover (at maximum) the last 150 years.***

2. ***High-resolution (annual) paleo-proxies exist in the Tropics, however, tree-ring studies are challenging in this region.***

1. ***More data collection is needed to provide better estimates of ENSO variability, the monsoon systems and/or ITCZ migration (affecting the large-scale climate dynamics), as well as to generate or refine reconstructions of regional climate.***