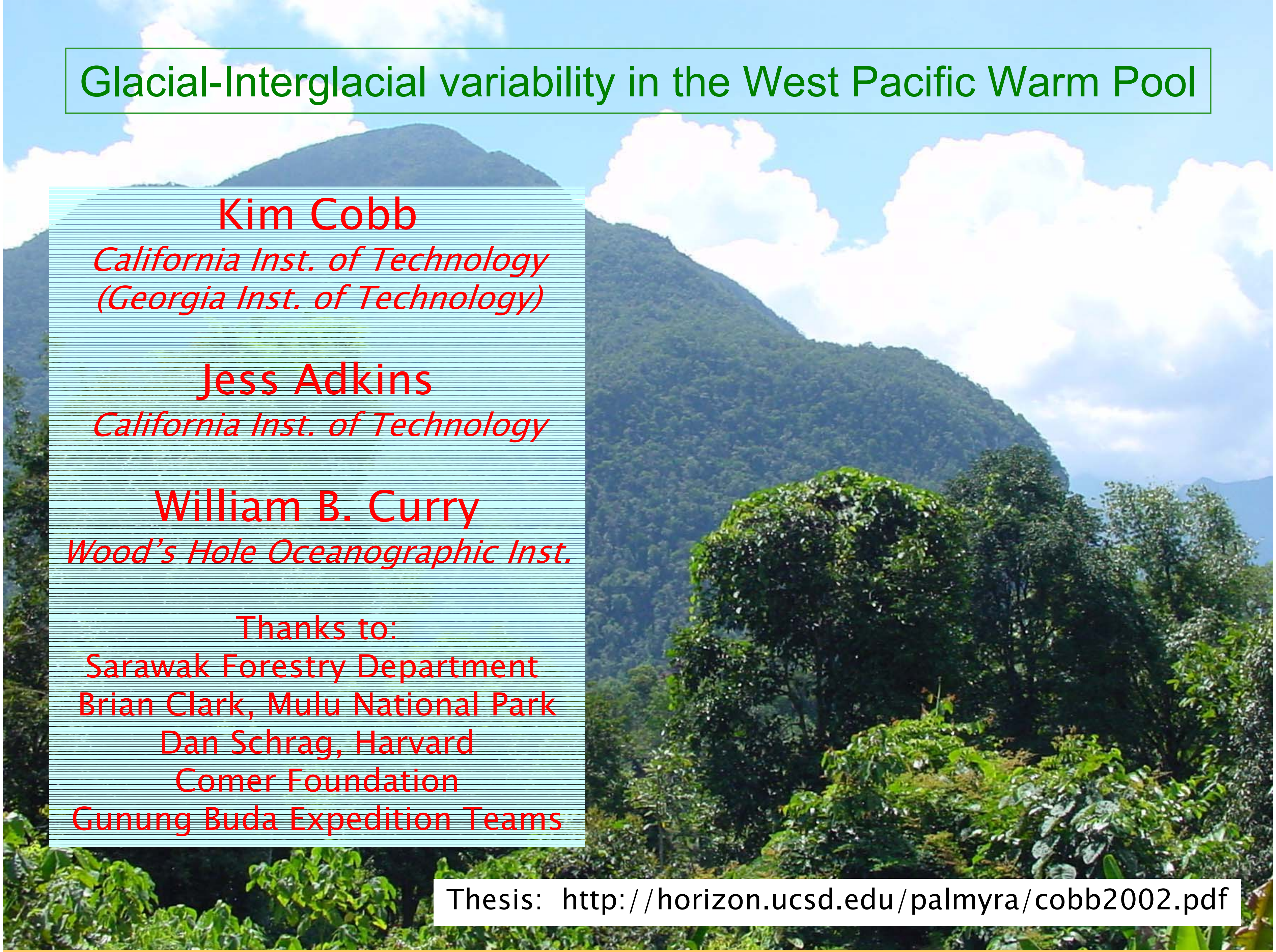
Glacial-Interglacial variability in the West Pacific Warm Pool



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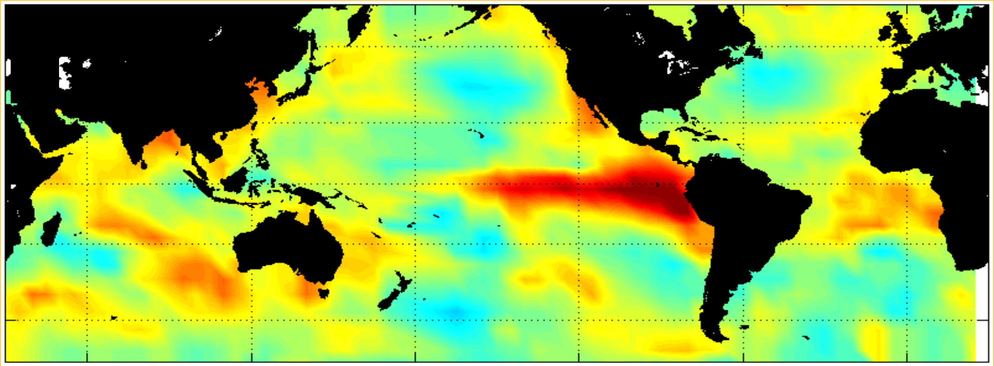
Gunung Buda Expedition Teams

Thesis: http://horizon.ucsd.edu/palmyra/cobb2002.pdf

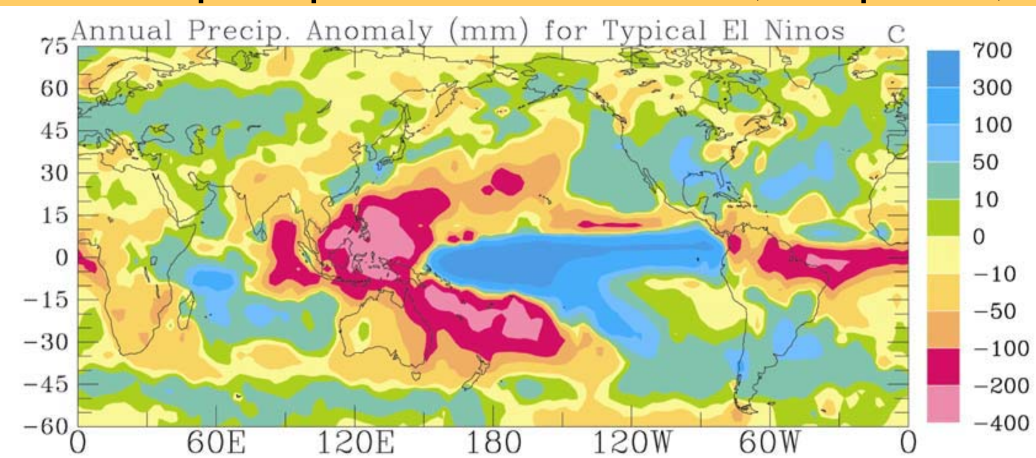
El Nino-Southern Oscillation (ENSO)
SST anomalies (Dec 1997)



How will tropical Pacific respond to greenhouse forcing?

- -internal variability large
- -global impacts (esp. precip)
- -societal relevance

ENSO precipitation anomalies (composite)



Dai and Wigley, 2000

What is the role of the tropical Pacific in low-frequency climate changes of the past?

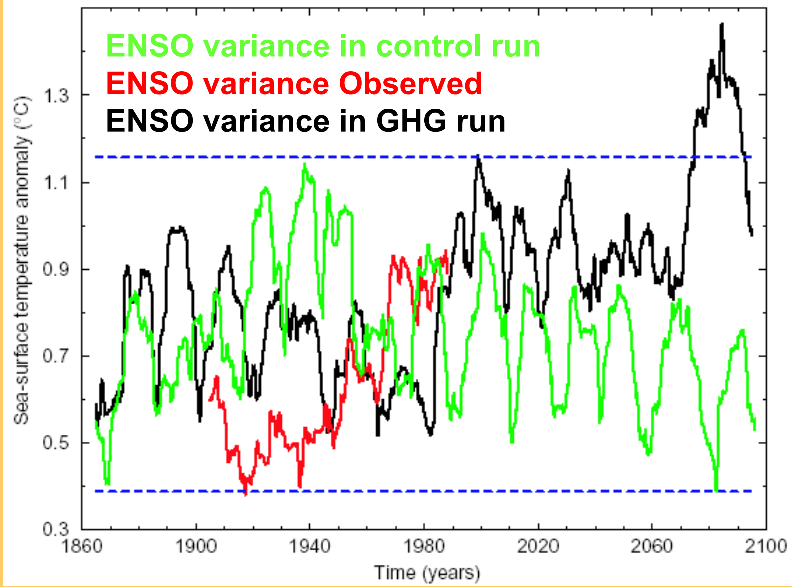
Through an ENSO-centric looking glass

<u>Timmermann et al, Nature 1999</u>

→forced ENSO model with greenhouse forcing

→ENSO variance increases under greenhouse forcing

→trend towards El Nino-like mean state in tropical Pacific

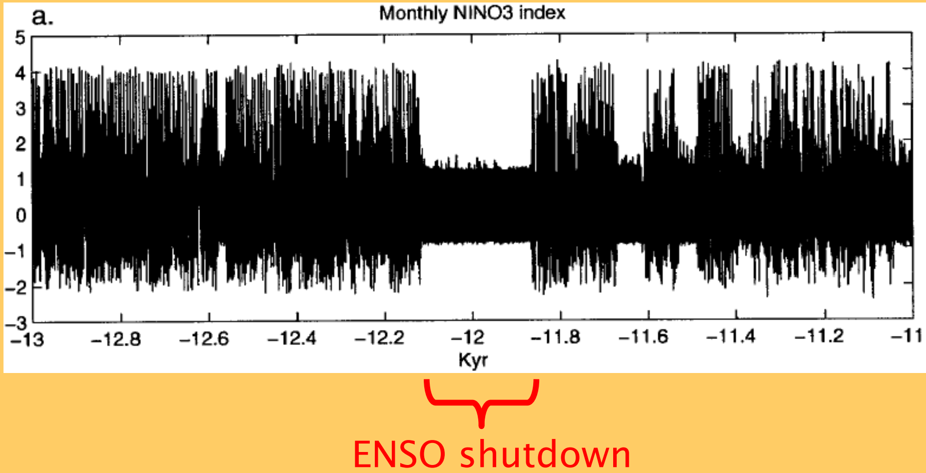


<u>Clement et al, Paleoceanography 1999</u>

→forced Cane-Zebiak model with orbital insolation changes

→ENSO response to smooth forcing could be abrupt

→changes in ENSO could trigger abrupt climate changes observed in Greenland (and many other NH sites)

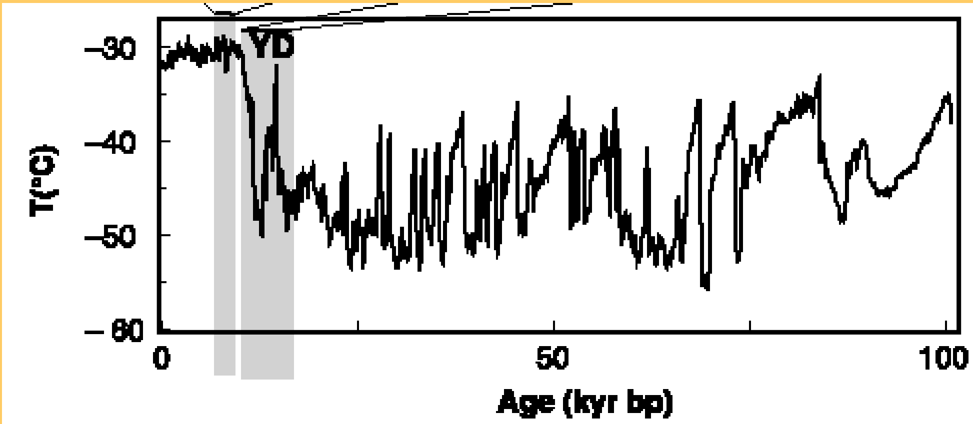


Example: abrupt climate change

What impact do changes in variability have on background state?

How do background state changes impact variability?

What sequence of mechanisms generate near-simultaneous, near-global climate changes?



Grootes et al., 1993

Review in Alley et al, Science 2003

<u>Four ingredients needed</u>

1) history of forcing (CO_2, solar irradiation, sea level, etc)
2) background state evolution
3) variability around background state (ENSO stats, etc)
4) dynamical understanding (models that reproduce paleoclimate variability)

What we know about tropical Pacific glacial climate from proxies

Types of archives:

deep-sea sediments – low-resolution in tropical Pacific, poorly dated, long, common

corals – high-resolution, short, rare

Tropical Pacific glacial mean state

→ West Pacific 2 to 4°C colder (Tudhope et al, 2001; Visser et al., 2003; Stott et al, 2002; CLIMAP; Kienast et al, 2001)

→ East Pacific 0 to 4° colder (Koutavas et al., 2002; CLIMAP; Lea et al, 2000)

→ zonal SST gradient greater (Andreasen & Ravelo, 1997; Lea et al, 2000)

→ zonal SST gradient smaller (Stott et al, 2002)

Tropical Pacific glacial variability

→ENSO damped (Tudhope et al, 2001) (?)

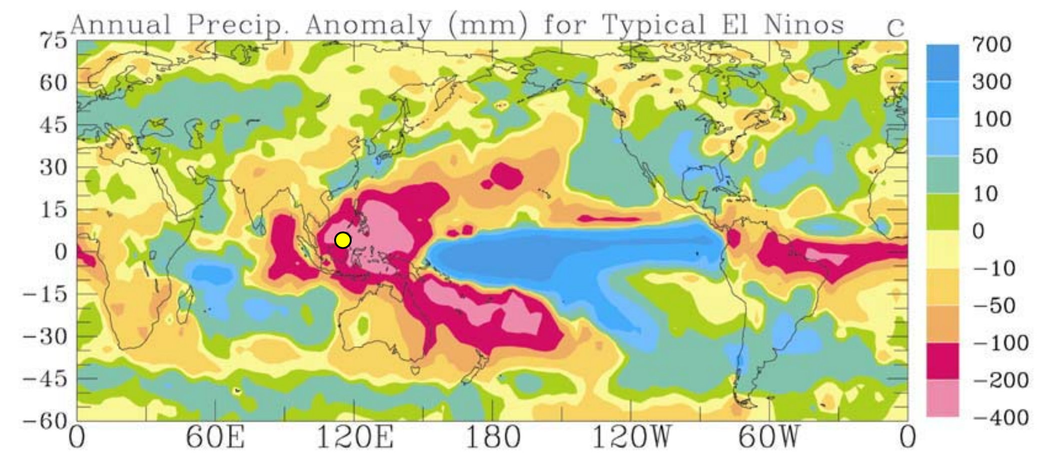
→signature of Greenland-like abrupt climate change in sediments (?) (Kienast et al., 2001; Stott et al., 2002)

NOT MUCH

The uber-proxy

Requirements:
→ultra-high-resolution (subseasonal or better)
→can be independently, absolutely dated to high precision
→long (tens of thousands of years)
→no biological overprinting
→made of carbonate (can use geochemical proxies)
→common (can check reproducibility)
→ENSO-sensitive (located in center of action)
→quantitative reconstructions (ie degrees C, psu, mm rain/day, etc)

Our candidate: speleothems from N. Borneo



Dai and Wigley, 2000

Goal: track precipitation variability in Warm Pool at ENSO to glacial-interglacial timescales

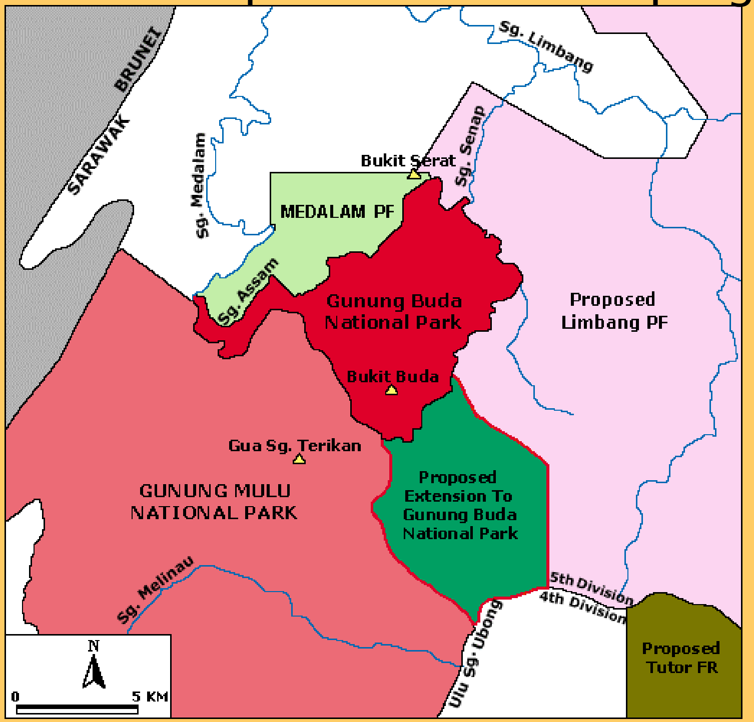
September 2003 field trip to Gunung Buda National Park

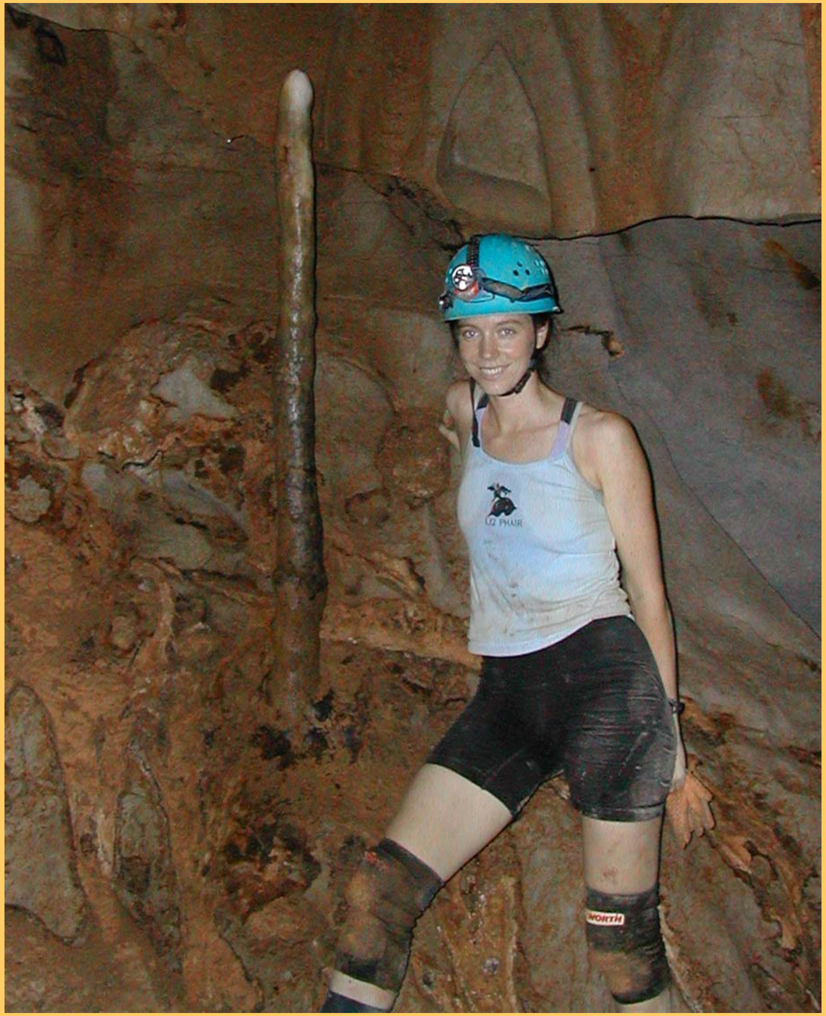
Results:

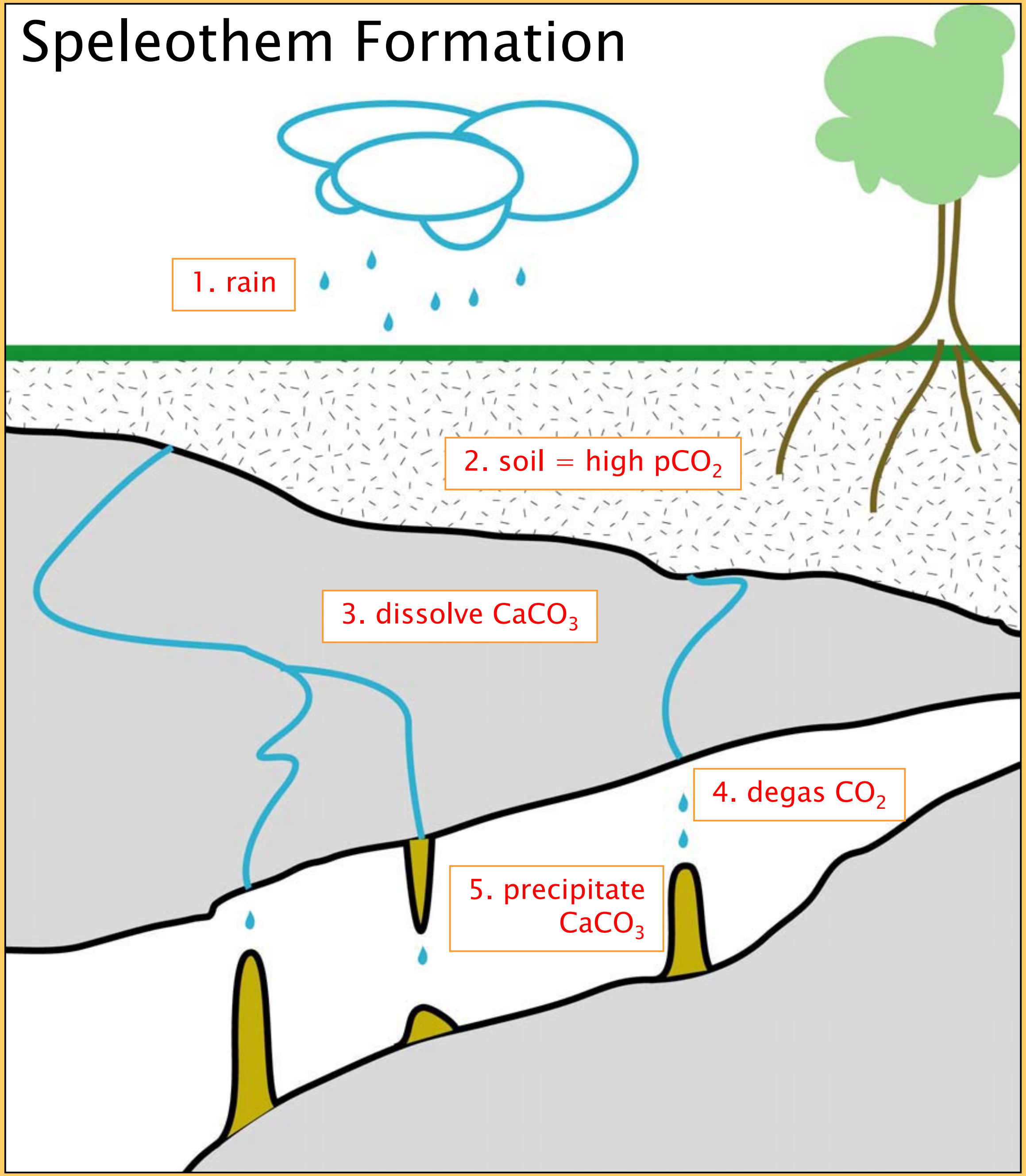
-collected 50 speleothems
(20 pristine) ranging in size
from .01 to 1.8m

-collected 64 dripwater samples
for geochemical analyses

-started weekly rainwater and
dripwater collection program





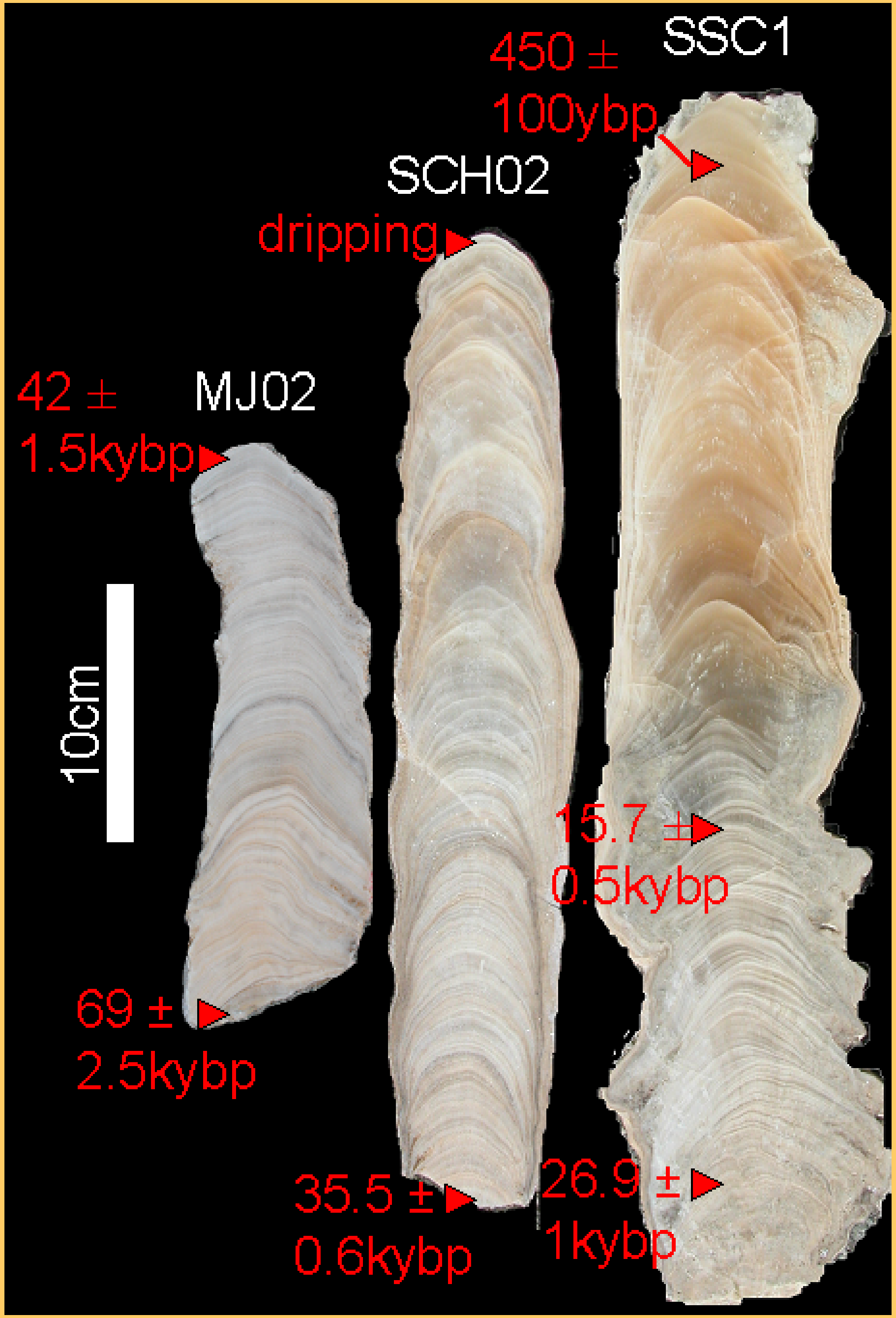


Carbonate dissolution/precipitation

$CO_2 + CaCO_3 + H_2O$

bedrock dissolution ⇩ ⇧ *speleothem precipitation*

$2HCO_3^- + Ca^{2+}$



Constructing Paleoclimate Records from Speleothems

DATING

$^{238}U \rightarrow {}^{234}U \rightarrow {}^{230}Th$

-theoretical precision = <1‰
(10yrs in 10,000yrs)
-realistic precision = <1%
(100yrs in 10,000yrs)

CLIMATE PROXIES

$\delta^{18}O$, $\delta^{13}C$, growth rate, $\Delta^{14}C$, Mg/Ca, optical properties, ? ? ?

STRATEGY

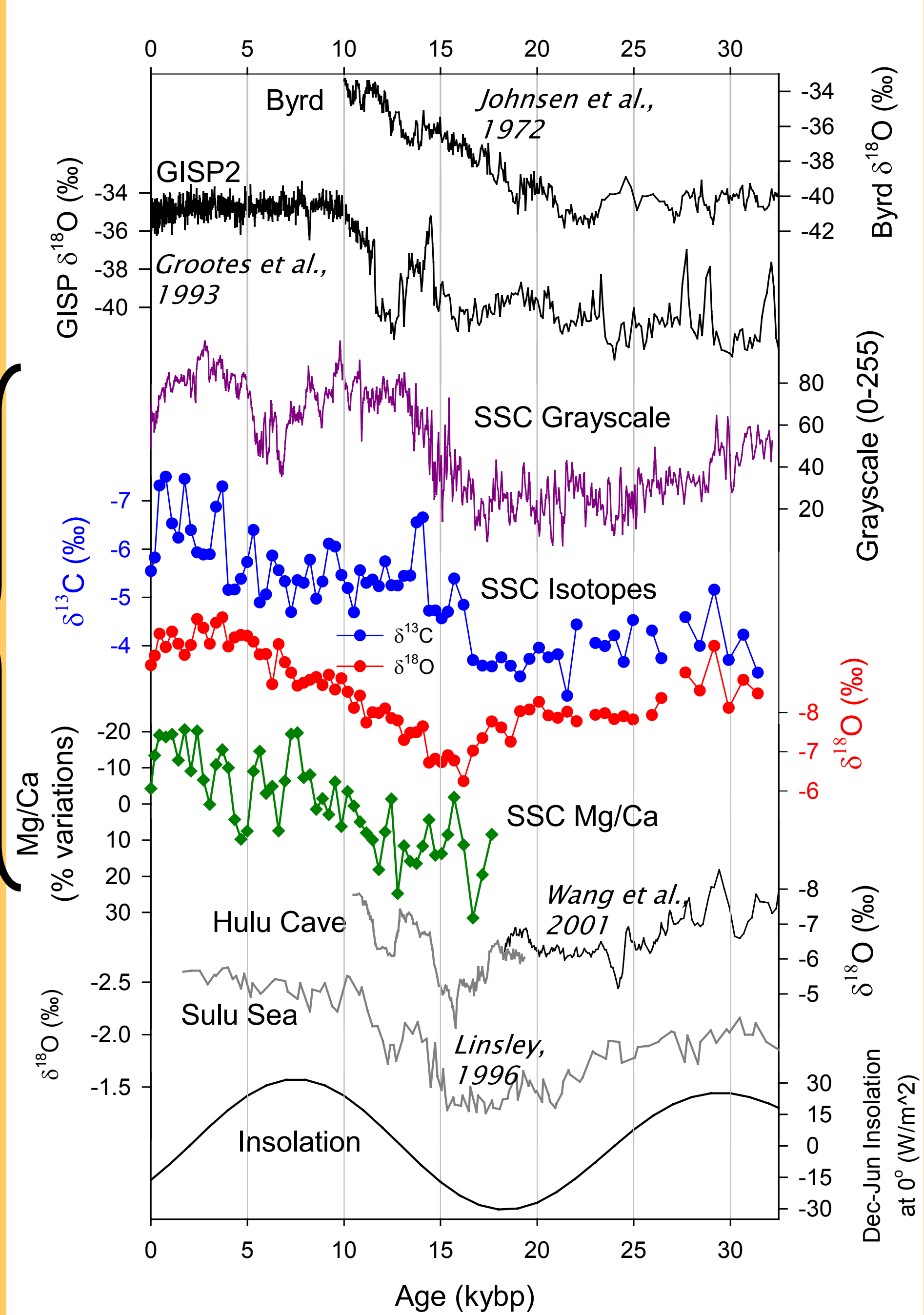
1. look for signals
2. calibrate signals
   a. on-site collections
   b. comparisons w/ instrumental data
3. pursue long, high-resolution reconstruction
4. <u>reproduce proxy records</u>
5. build large-scale climatic context

Phase I: Hunting for signals

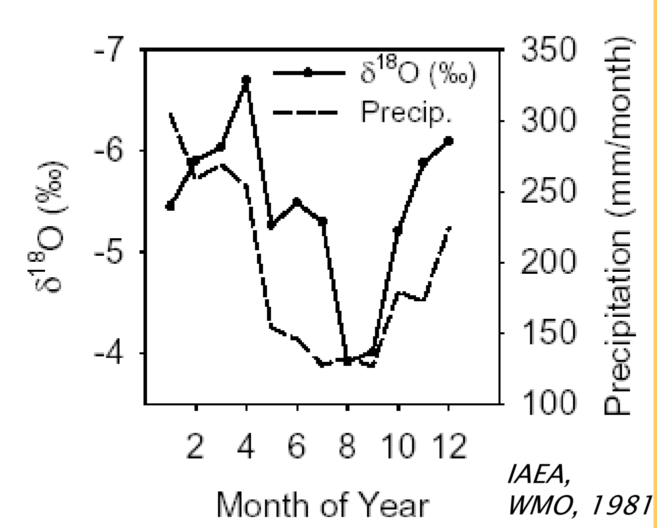
Preliminary observations:

- –glacial–interglacial signal in optical properties and geochemistry
- –consistent with wetter glacial
- –Younger Dryas missing?
- –Holocene variability
- –significant ecosystem response to glacial conditions implied

Preliminary analyses of SSC1



Phase 2: Calibrating Geochemical Signals



IAEA, WMO, 1981

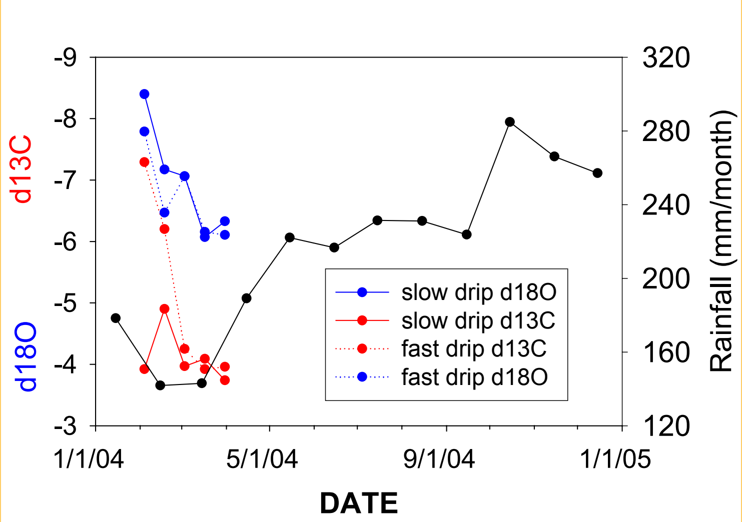
Ex: $\delta^{18}O$ of rainfall

-empirical relationship b/t rainfall amount and $\delta^{18}O$ of rainfall (Rozanski et al, 1993), dubbed the "amount effect"

Two-pronged approach

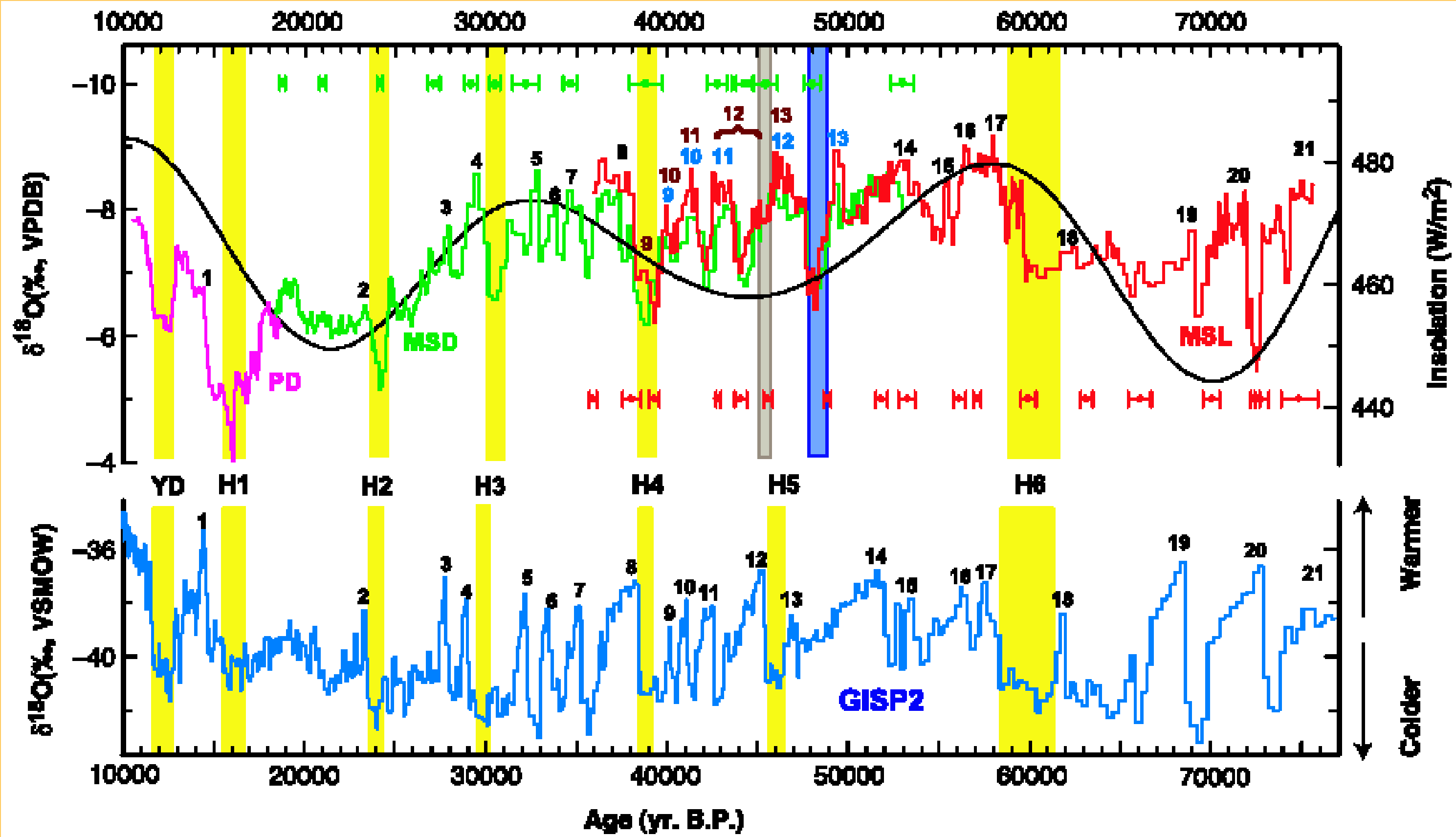
-measure timeseries of $\delta^{18}O$ and amount of rainwater and cave dripwater geochemistry over several ENSO cycles, compare to local and regional-scale precip. (or other climate parameter)

-track response of speleothem $\delta^{18}O$ to changes in climate over last 50 yrs



Examples of speleothem climate records

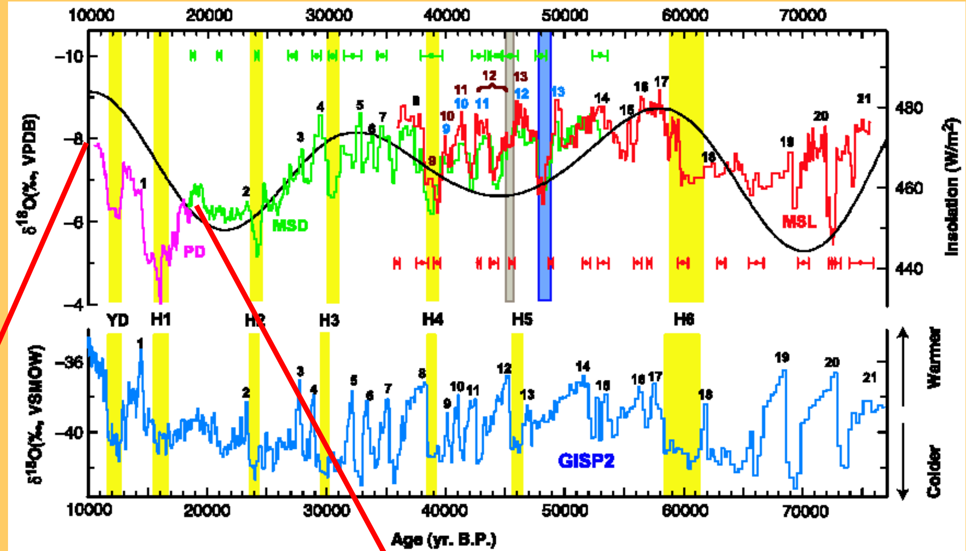
1. $\delta^{18}O$ in Chinese speleothem
   - abrupt climate change events of Greenland recorded adjacent to the tropical Pacific
   - improves ice core chronologies

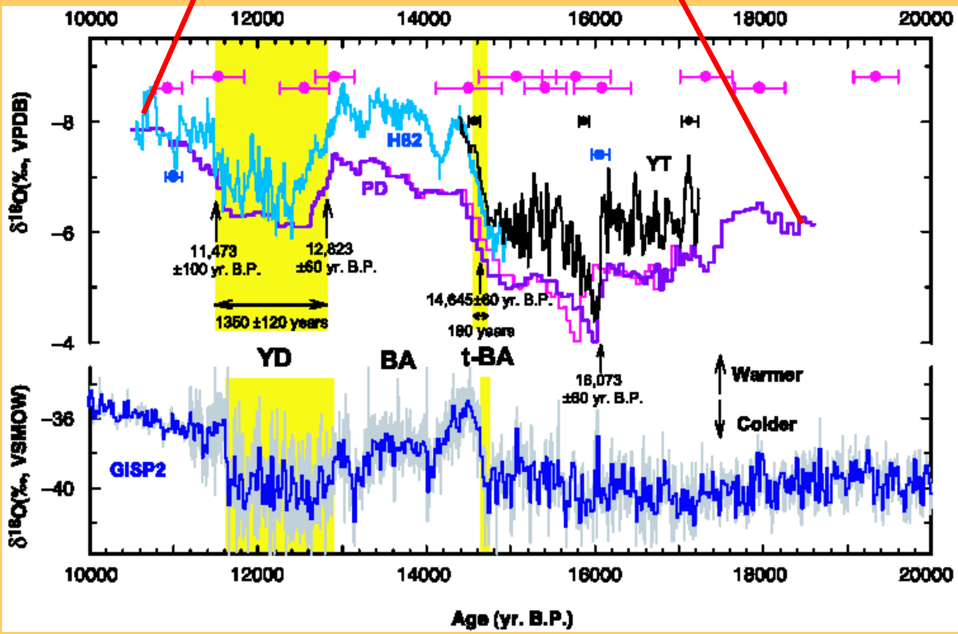


Wang et al., Science 2001

1. $\delta^{18}O$ in Chinese speleothem cont.

- band-counting records capture timing, duration of climatic events

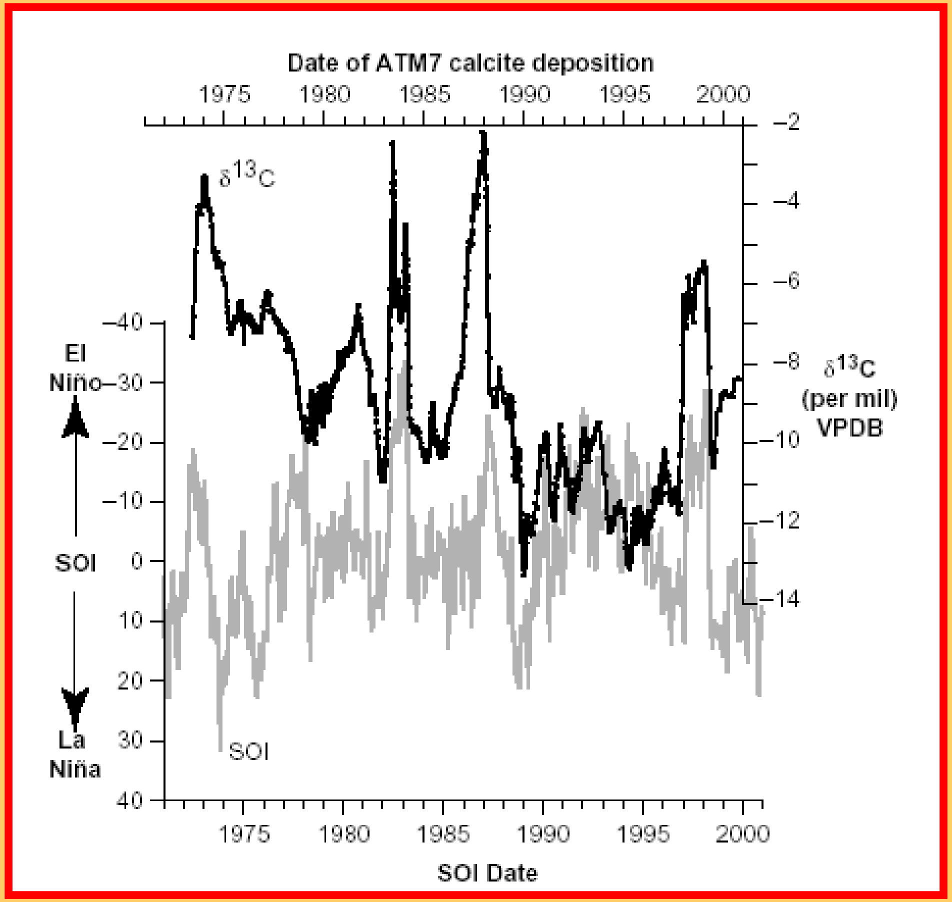




Wang et al., Science 2001

2. $\delta^{13}C$ in Belize speleothem

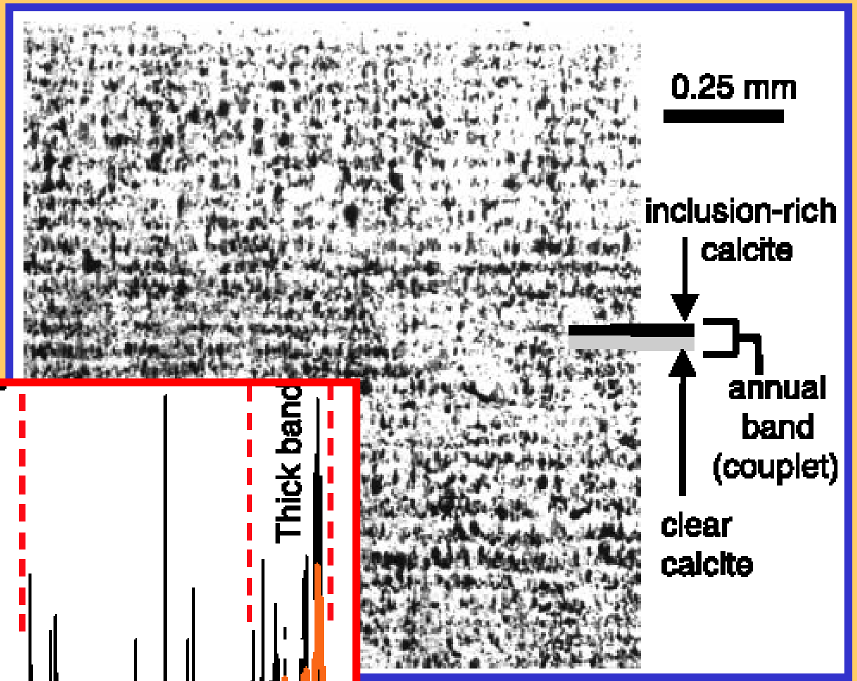
-records ENSO-related ecological change in absence of obvious ENSO response in temperature or precipitation

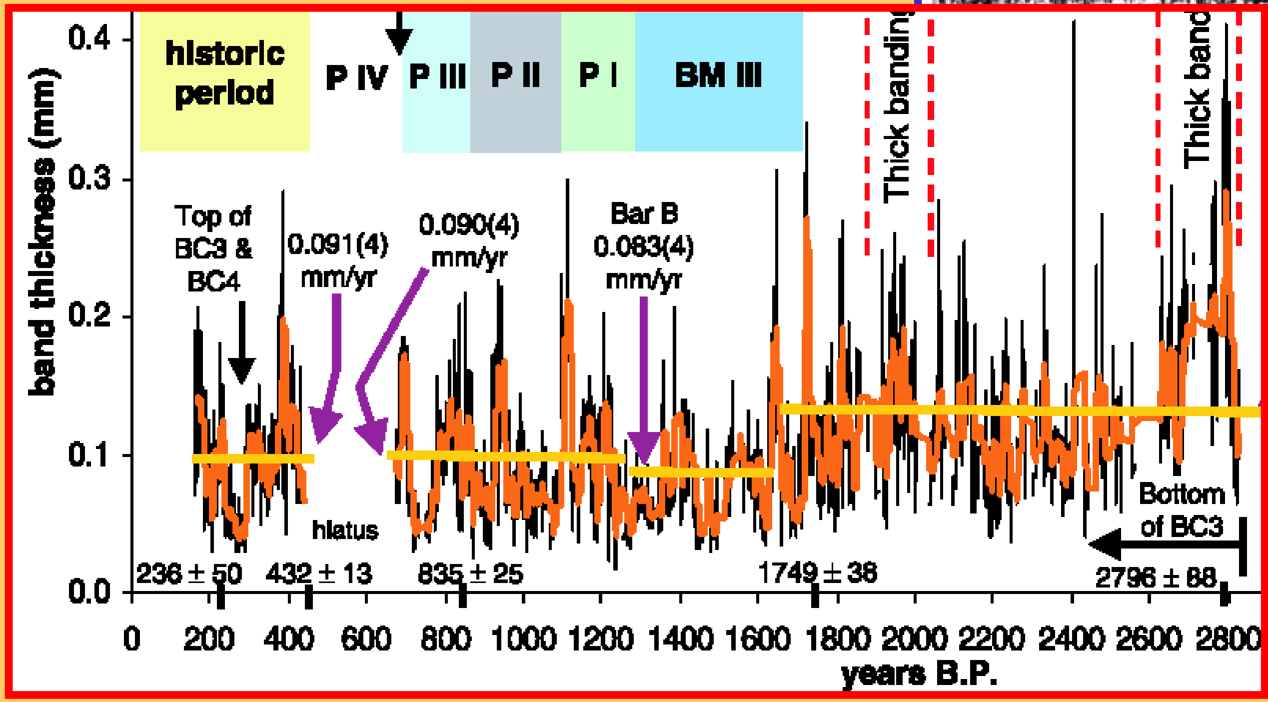


Frappier et al., Science 2002

3. Band-thickness in SW U.S. speleothem

-thickness of annual bands attributed to rainfall variability





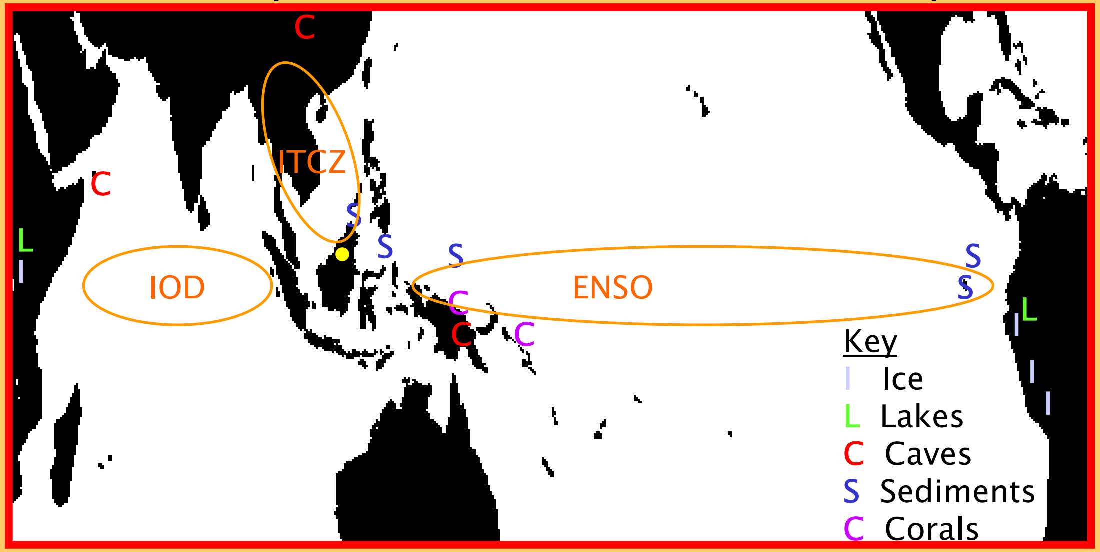
Polyak & Asmerom, Science 2001

Interpretation of N. Borneo precipitation records

Influences on N. Borneo precipitation:

- ENSO (Pacific zonal SST)
- ITCZ shifts (meridional temp.,monsoon)
- Indian Ocean Dipole (Indian zonal SST)

Answer: comparisons to other high-res., well-dated paleoclimate records, where possible



Summary

Much work to be done!

Speleothems . . .

can potentially provide sub-seasonal records of tropical climate variability, across a broad range of timescales.

will likely be key to determining lead/lag relationships for globally-coherent, low-frequency climate variability.

hopefully will improve long-range forecasts of tropical precipitation in a greenhouse world.