High latitude teleconnections to tropical mean climate: *paleoclimate data and models*

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Collaborators:
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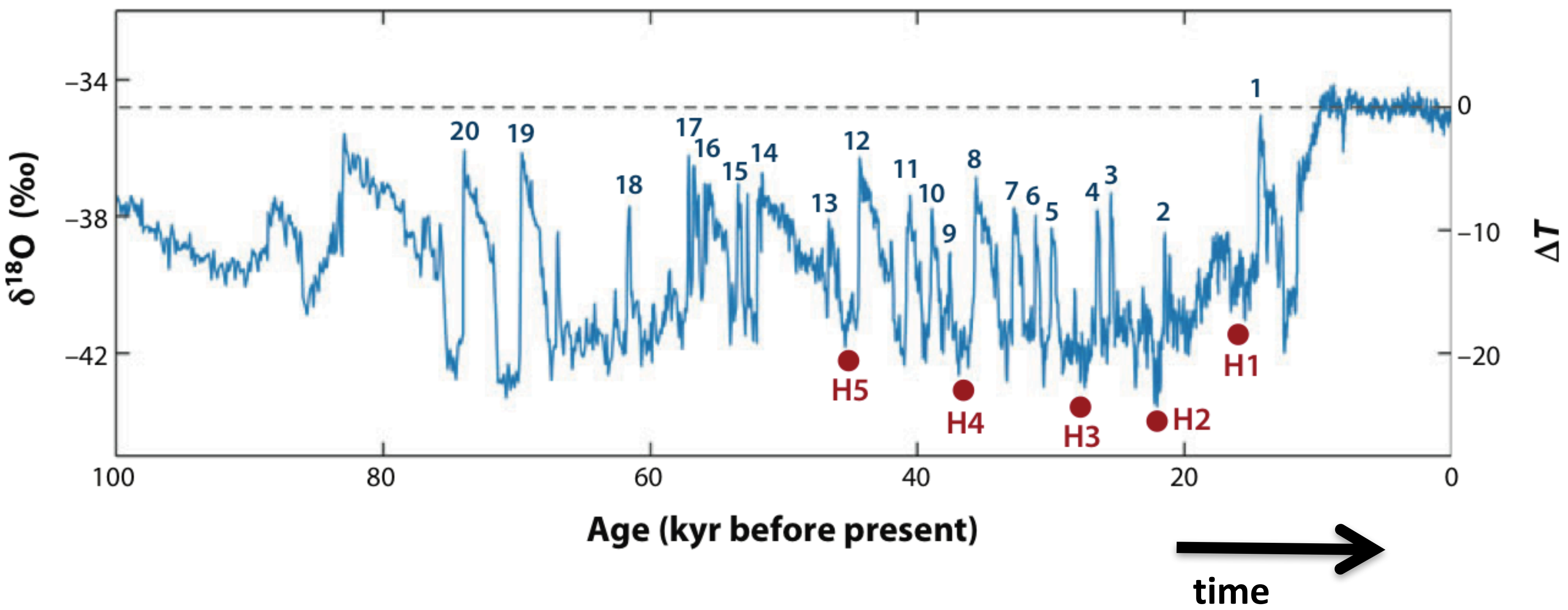
Greenland ice core temperature records show abrupt and large temperature changes



Dansgaard/Oeschger (D/O) events

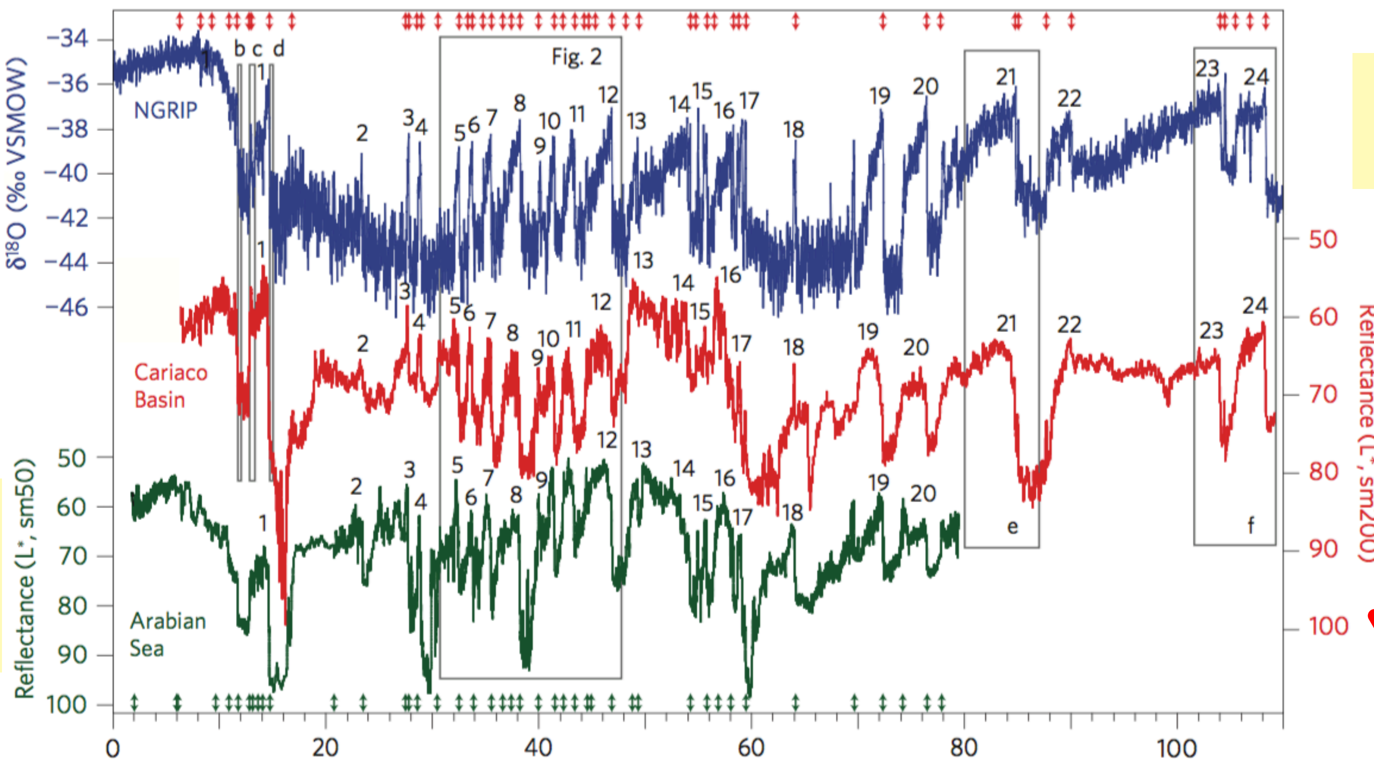
Heinrich (H) events

Ganapolski and Rahmstorf, 2001

Abrupt changes in tropical hydroclimate linked to Greenland temperature

cold

Greenland temp



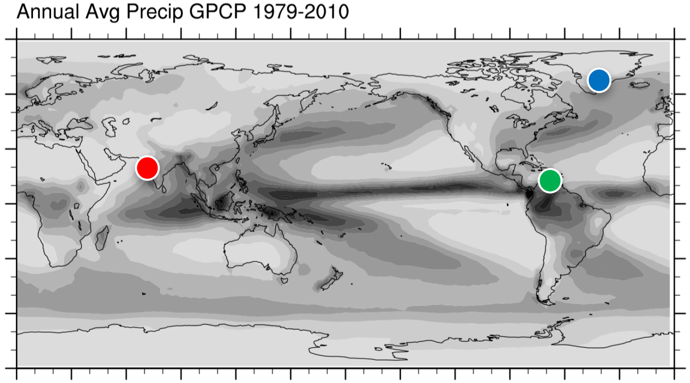
Cariaco Basin reflectance

Arabian Sea reflectance

dry

kyr BP

time



Deplazes et al., *Nature Geoscience*, 2013

Leading cause of abrupt climate changes: slowdown of the Atlantic Thermohaline Circulation

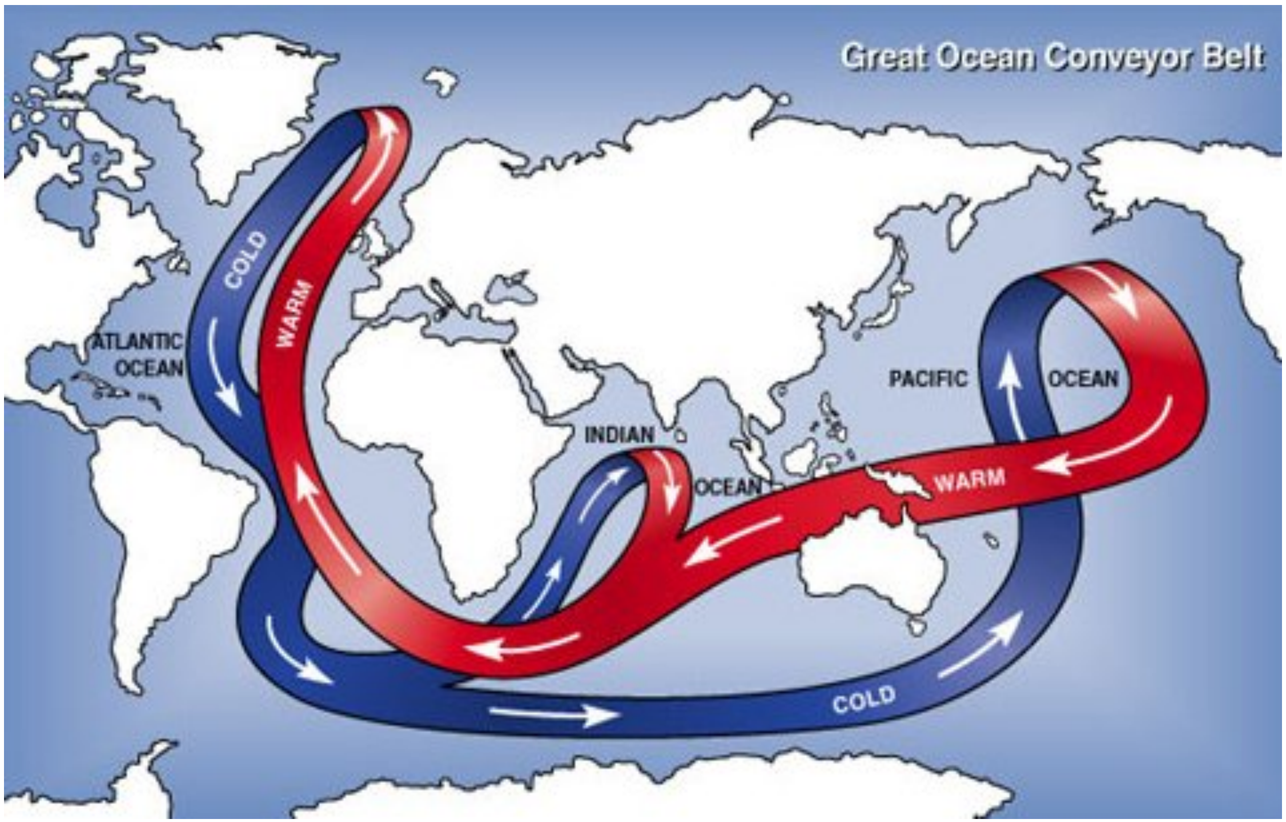
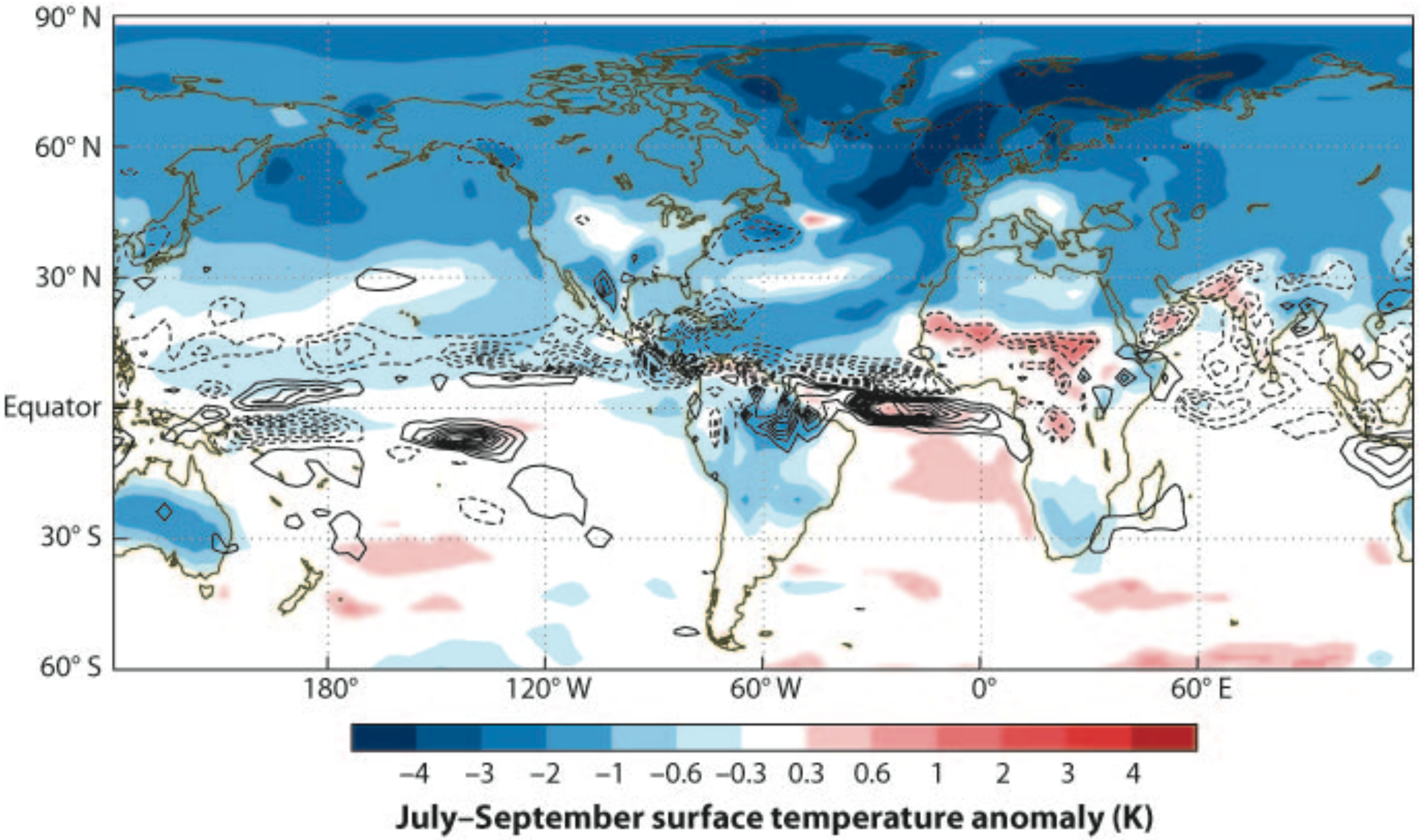


Figure source: Argonne National Laboratory

Atlantic thermohaline shutdown has global impact on climate



JJAS surface temperature and rainfall response to North Atlantic 'hosing' (CCSM3 coupled model)

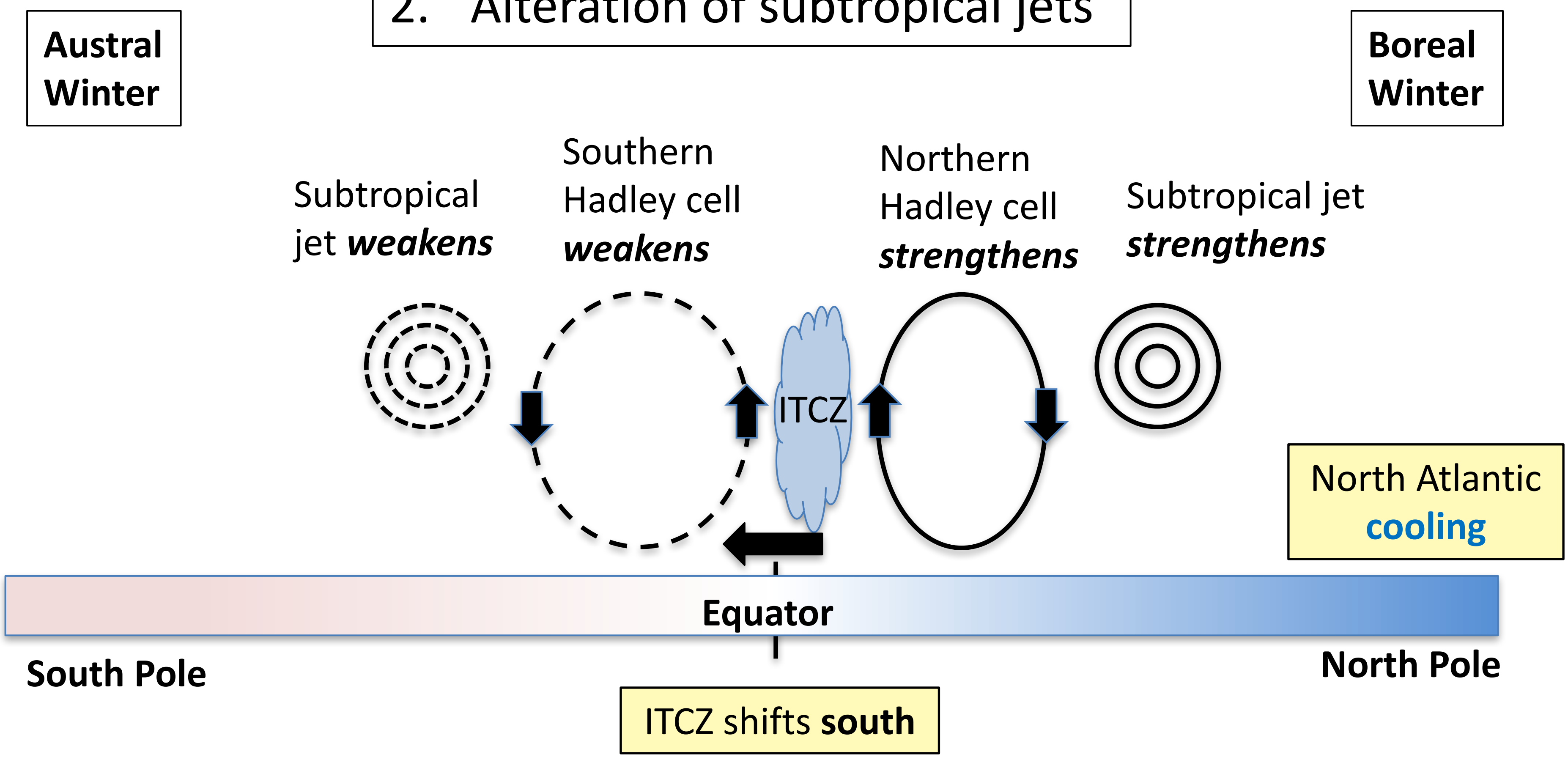
Cheng et al. 2007

Key features

- Interhemispheric Pattern in temperature
- Southward shift in tropical rainbands (ITCZ)

A hypothesis for the global atmospheric reorganization to North Atlantic cooling
(Chiang et al., 2014)

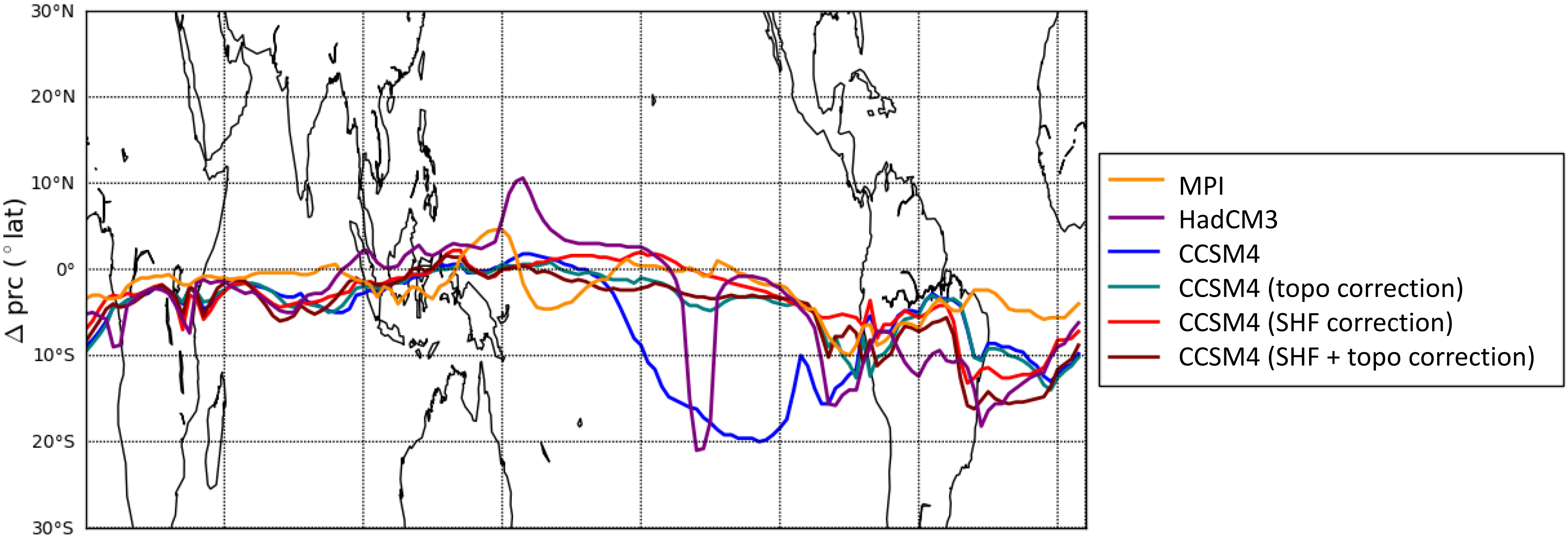
1. Southward shift of ITCZ
2. Alteration of subtropical jets



Slide modified from J. Chiang

Spatial signature of the ITCZ shift varies widely across models

- Differences most pronounced in eastern/central Pacific and Atlantic
- Tropical mean state biases likely play a large role

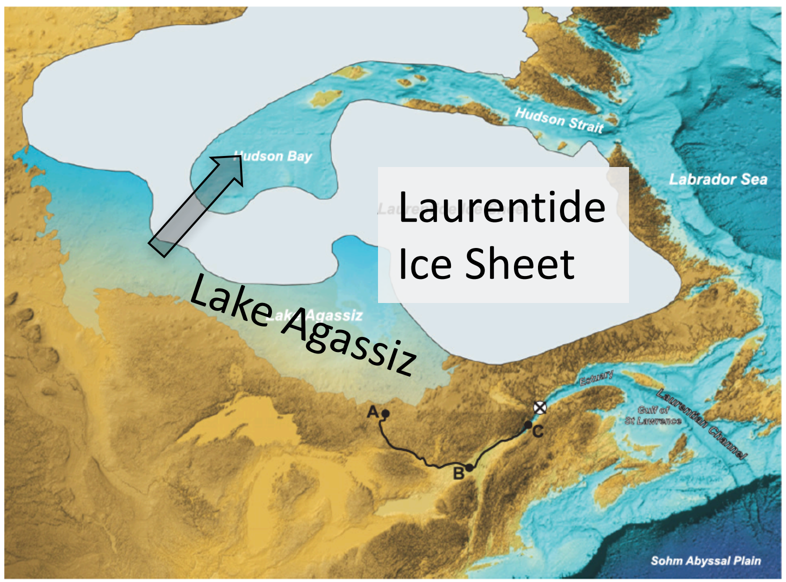


Tropical Pacific mean state changes under North Atlantic cooling

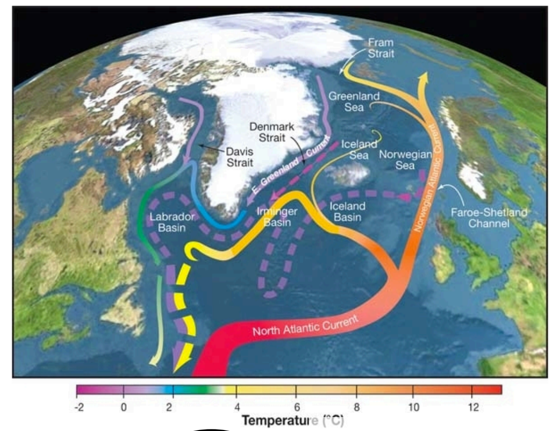
A case study of the 8200 BP event

Abrupt climate change 8200 yr BP

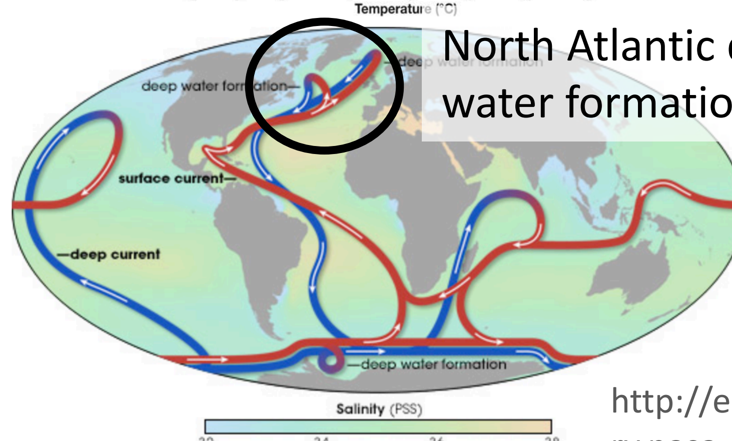
Outburst of ~160,000 km³ of glacial meltwater caused a slowdown of the Atlantic Meridional Overturning Circulation



Clarke et al., 2009



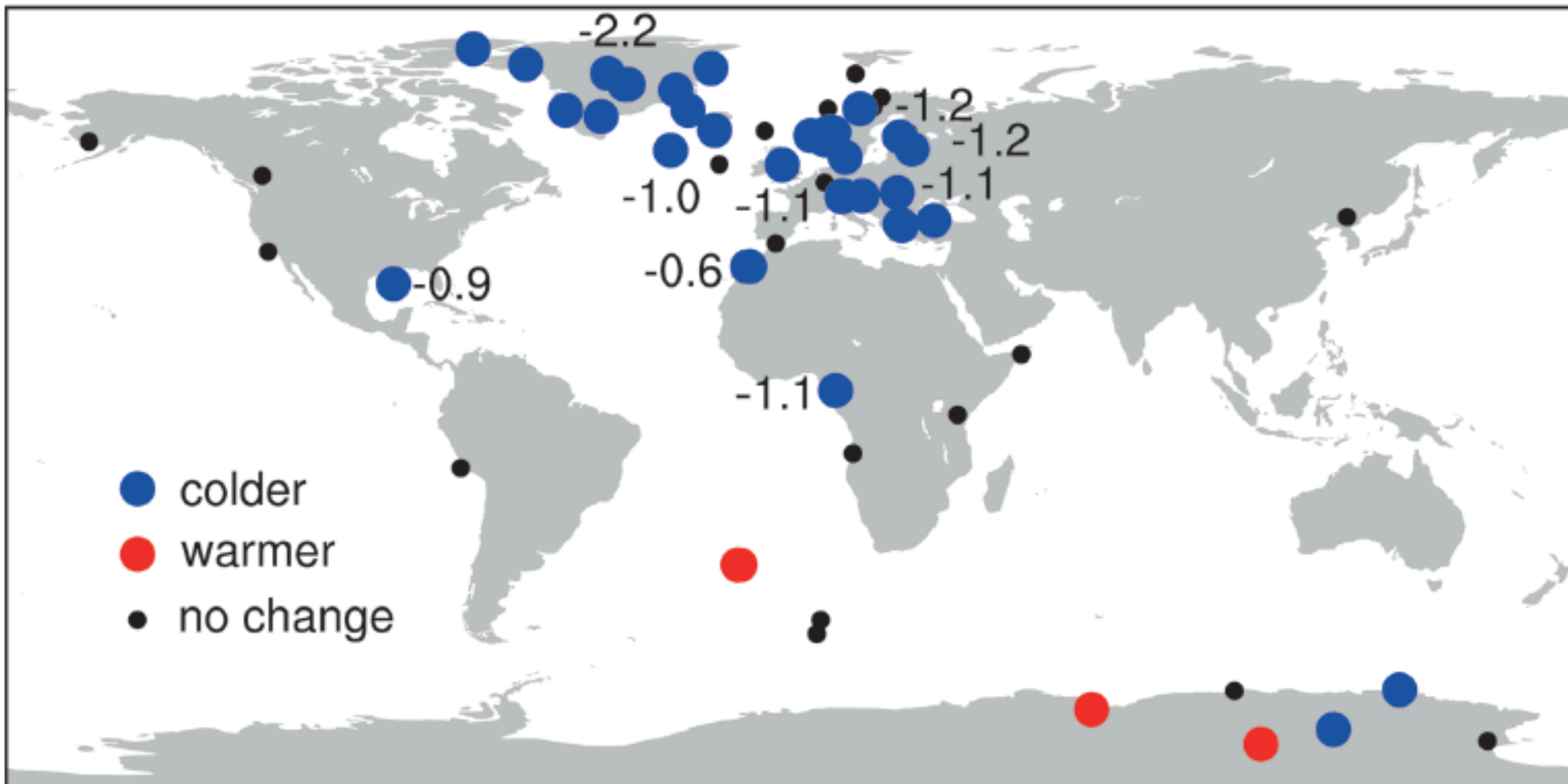
R. Curry, WHOI
www.eoearth.org



http://earthobservatory.nasa.gov/

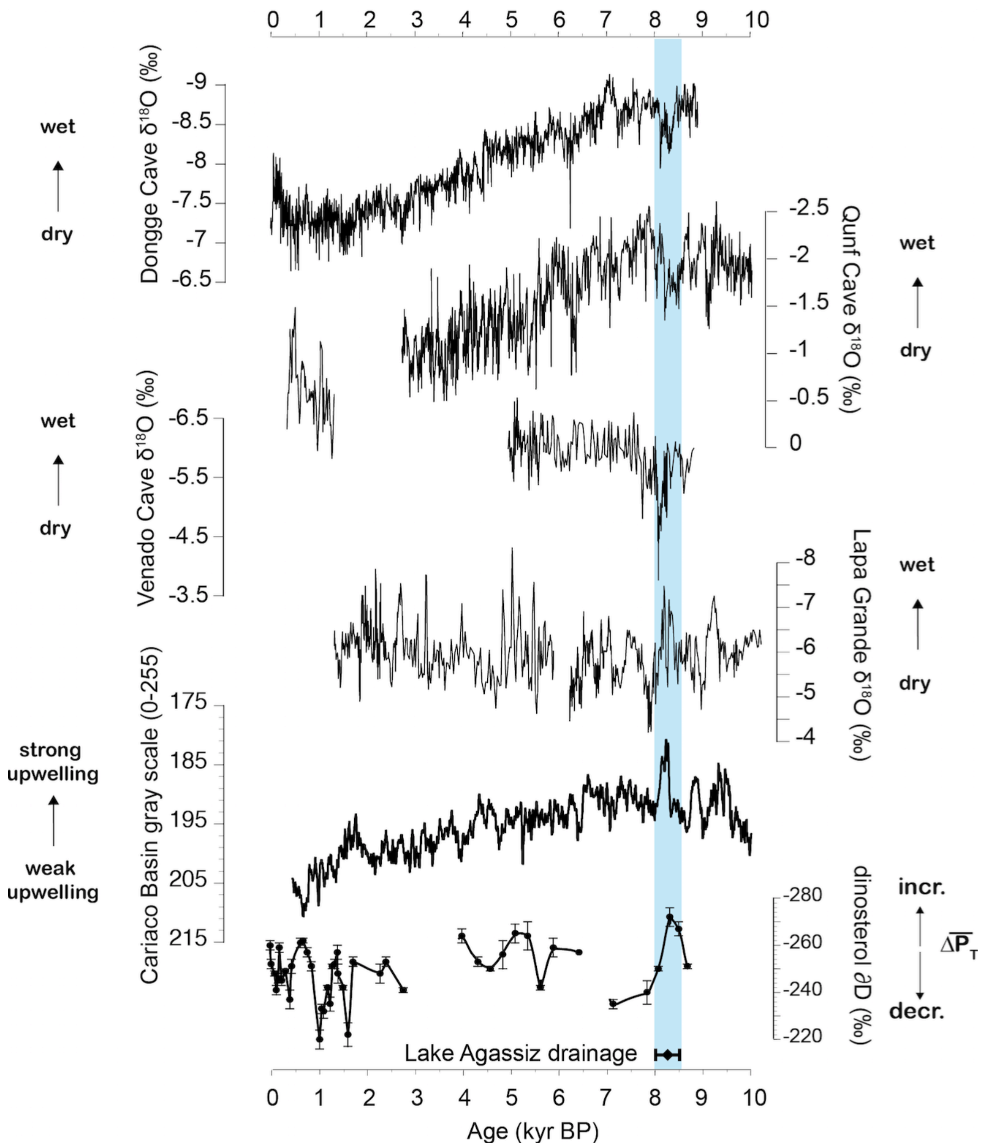
The 8200 BP event

Cooling: 2-6°C in Central Greenland,
1-3°C in Europe/N. Atlantic



Morrill et al., 2013

Southward shift of tropical rainfall during 8200 BP event



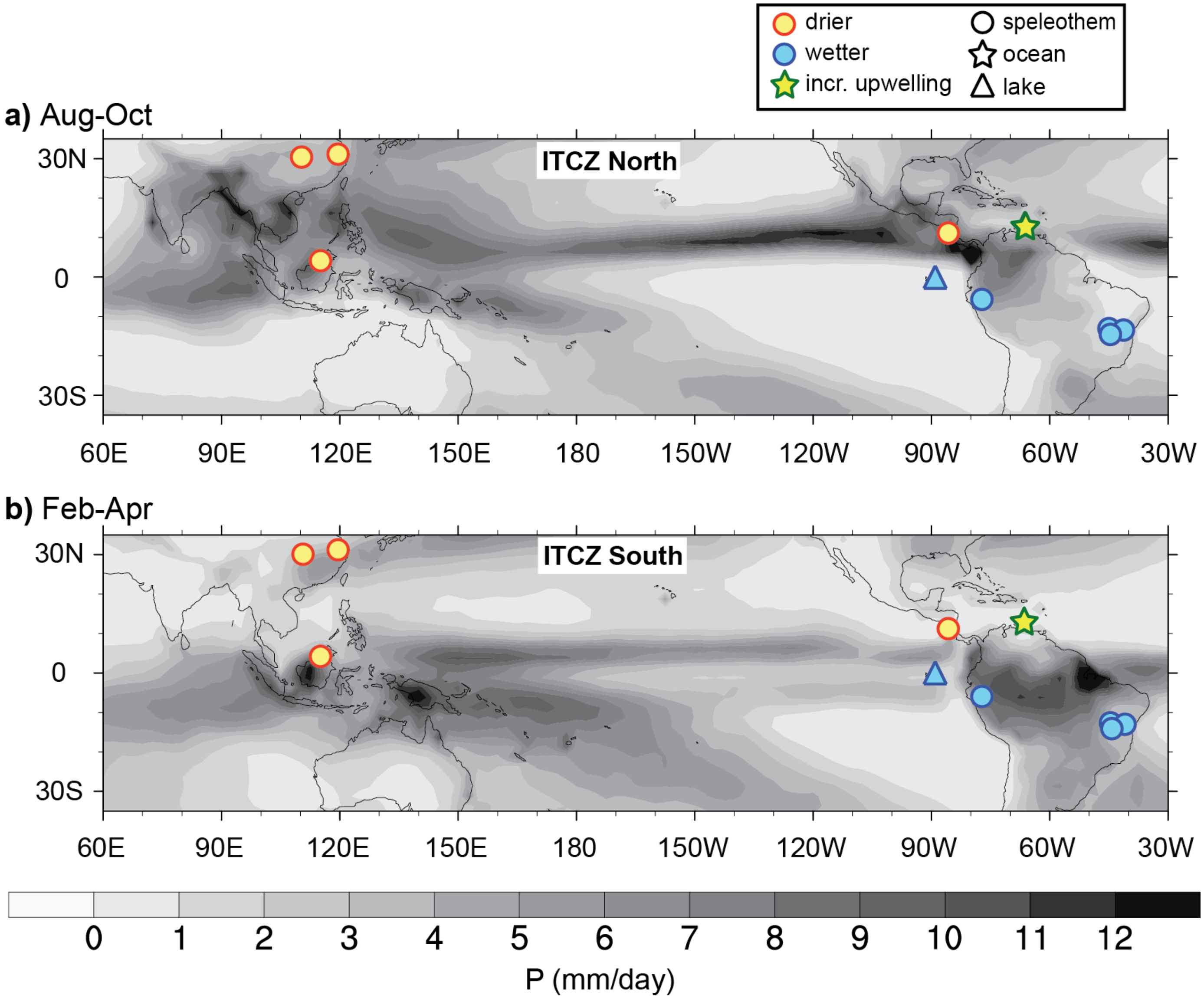
Atwood et al. (in review at *Nat. Geo.*)

Data from: Cheng et al. (2009); Fleitmann et al. (2003); Hughen et al. (1996); Lachniet et al. (2004); Strikis et al. (2011); van Breukelen et al. (2008); Wang et al. (2005)

Southward shift of Eastern Pac. ITCZ during 8200 BP event

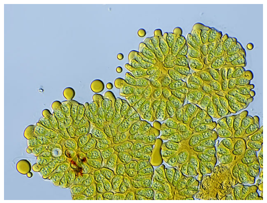
Boreal fall

Boreal spring

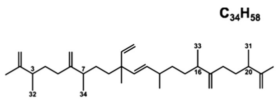


GPCP precip

Evidence of decreased El Nino activity during 8200 BP event

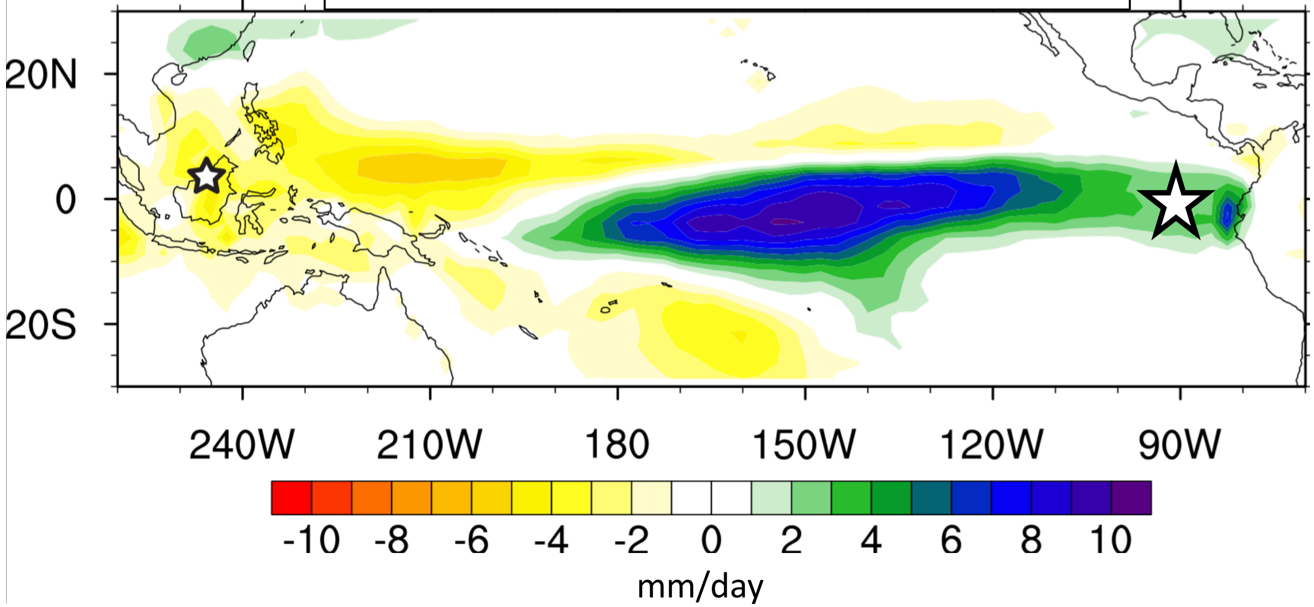


C34 botryococcene



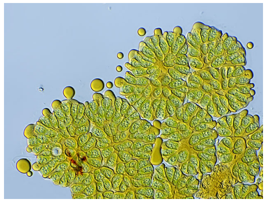
Green algae that blooms during El Nino events

Composited El Nino rainfall anomalies

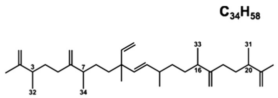


Atwood, PhD thesis (2015); Zhang et al. (2014); Conroy et al. (2008)

Evidence of decreased El Nino activity during 8200 BP event



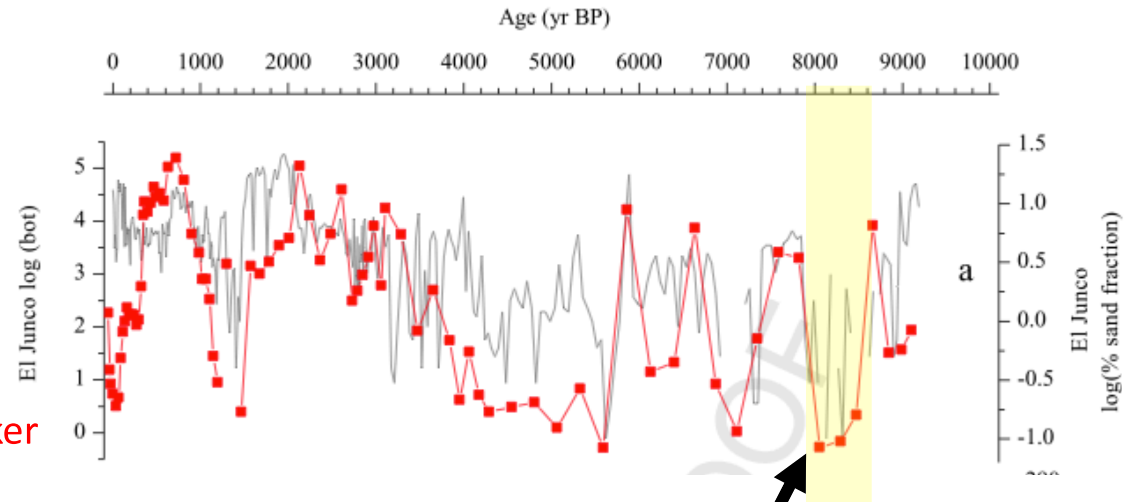
C34 botryococcene



Green algae that blooms during El Nino events

time

Low biomarker conc.

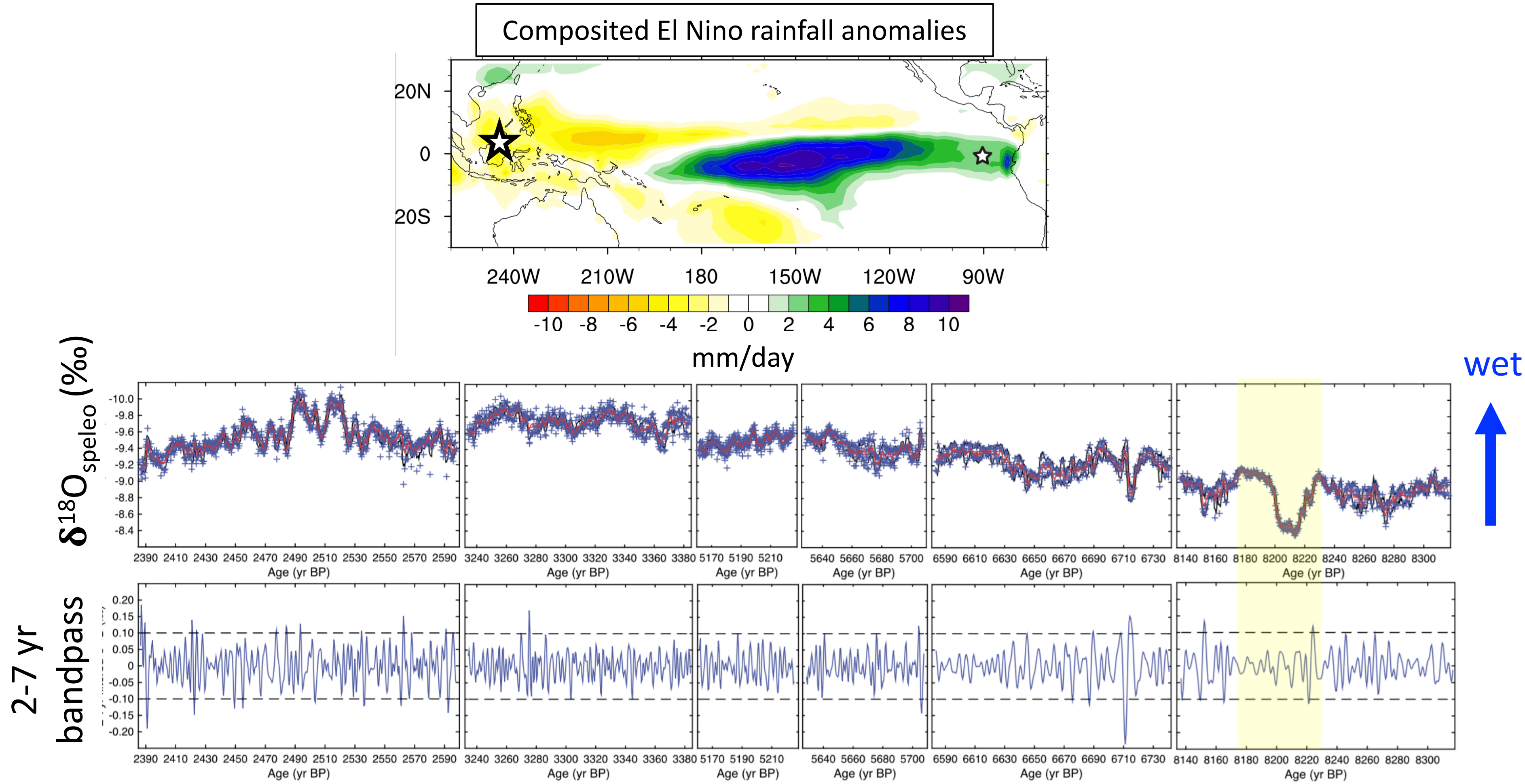


Low sand fraction

Low flux of sand and algal biomarker to sediment: decreased frequency and/or intensity of El Nino events ~8200 BP

Atwood, PhD thesis (2015); Zhang et al. (2014); Conroy et al. (2008)

Evidence of decreased El Nino activity during 8200 BP event

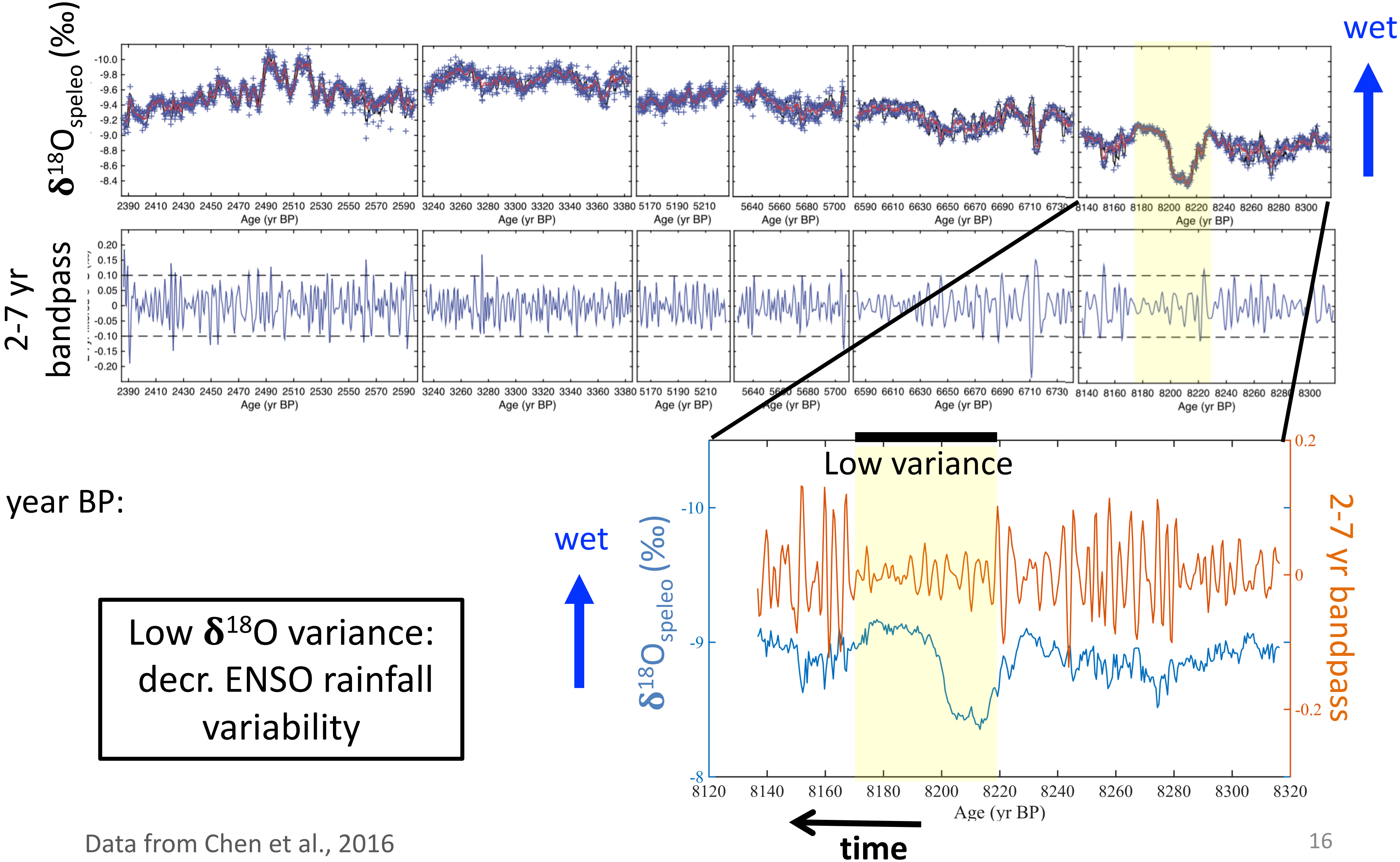


year BP: 2400-2600 3200-3400 5200-5700 6600-6700 **8100-8300**

← **time**

Chen et al., 2016

Evidence of decreased El Nino activity during 8200 BP event

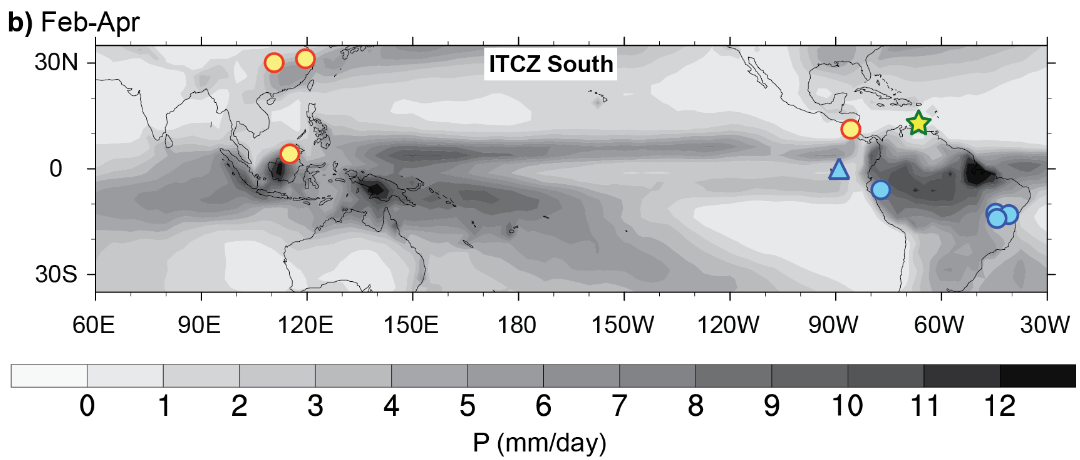


Low $\delta^{18}O$ variance: decr. ENSO rainfall variability

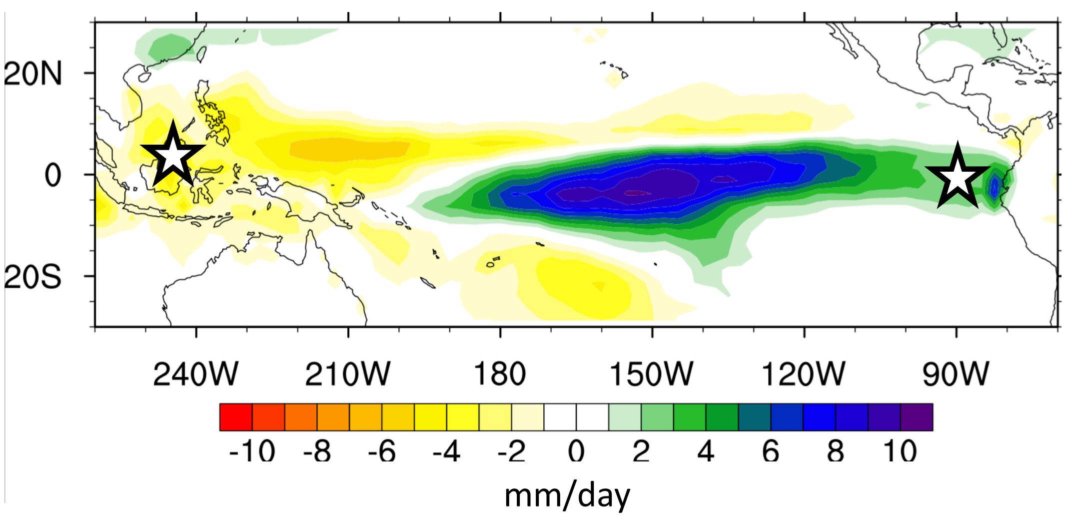
Data from Chen et al., 2016

Tropical Pacific climate change during 8200 BP event:

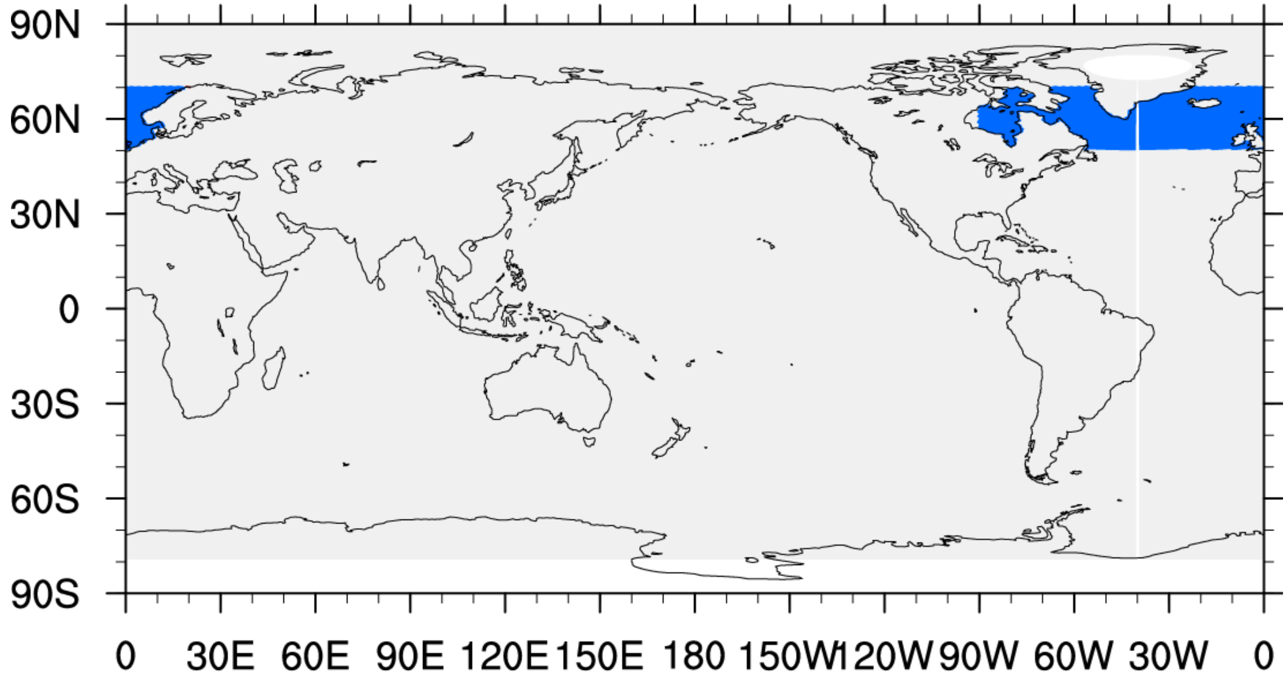
Southward shifted ITCZ in eastern Pacific



Reduced ENSO variability



Simulations with the Community Earth System Model (CESM)

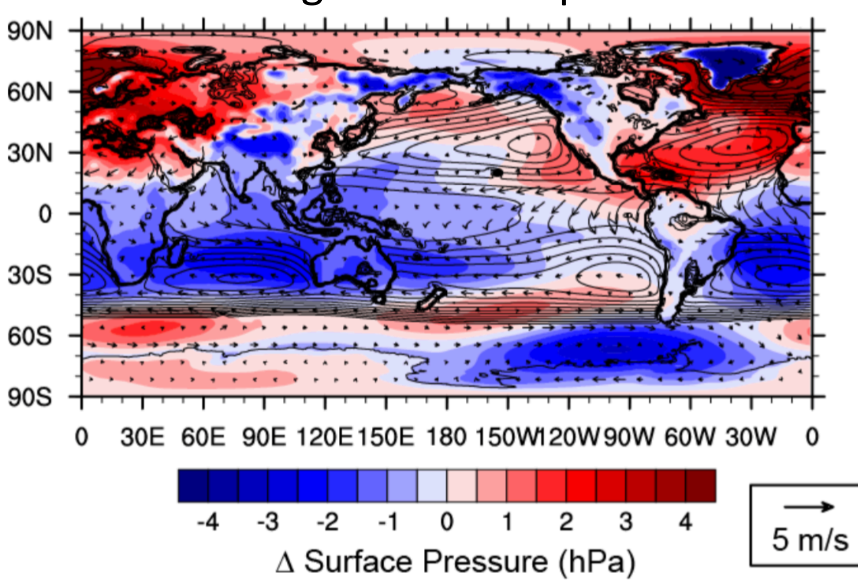


Freshwater input **(PMIP2 hosing configuration)**:
1 Sv (10^6 m^3/s) applied across North Atlantic (50:70N) for 100 years

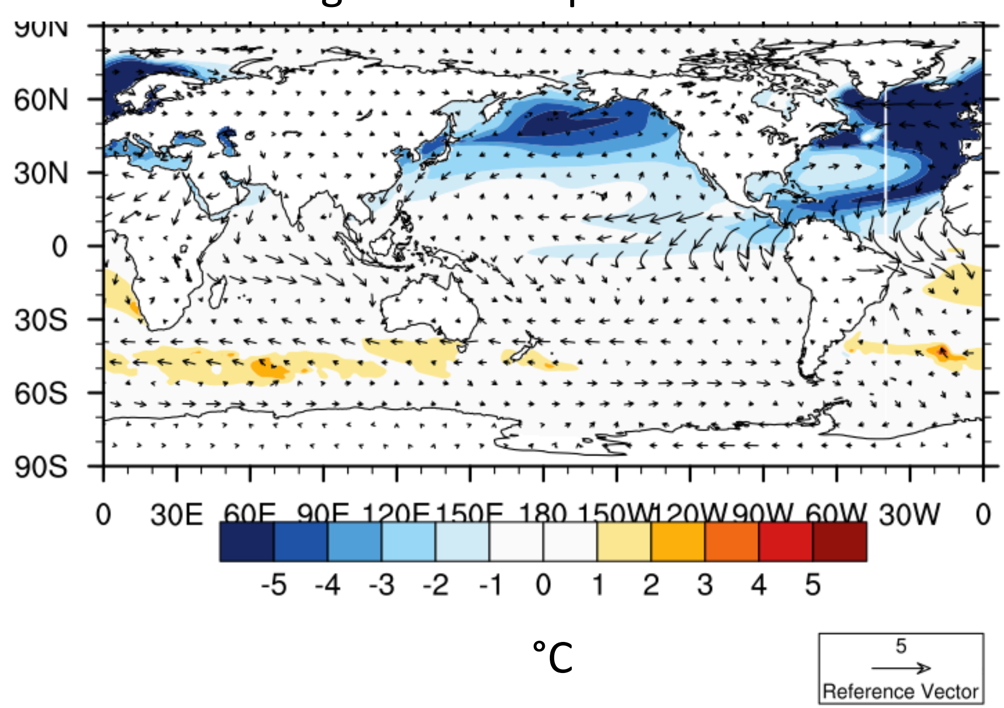
North Atlantic cooling causes:

- Increased Atlantic-to-Pacific surface pressure gradient
- Cooling propagates into tropical Pacific via enhanced easterlies

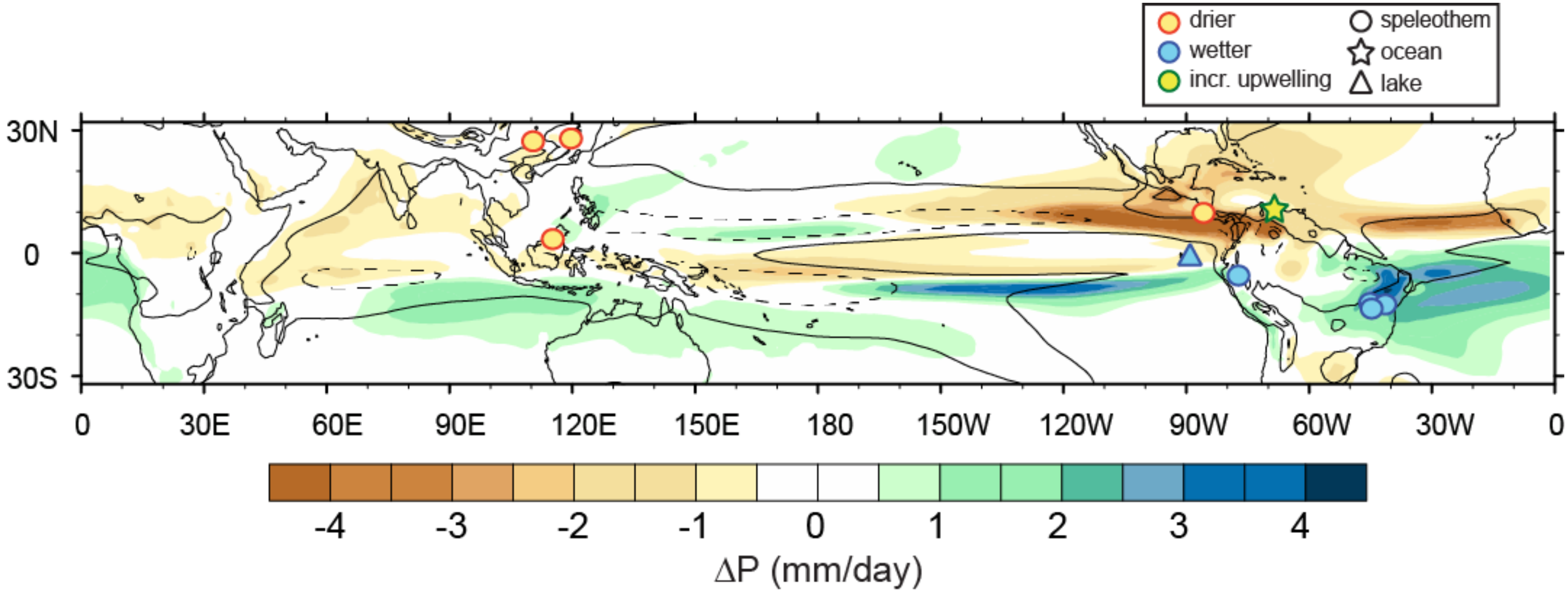
Change in surface pressure



Change in sfc temp and winds

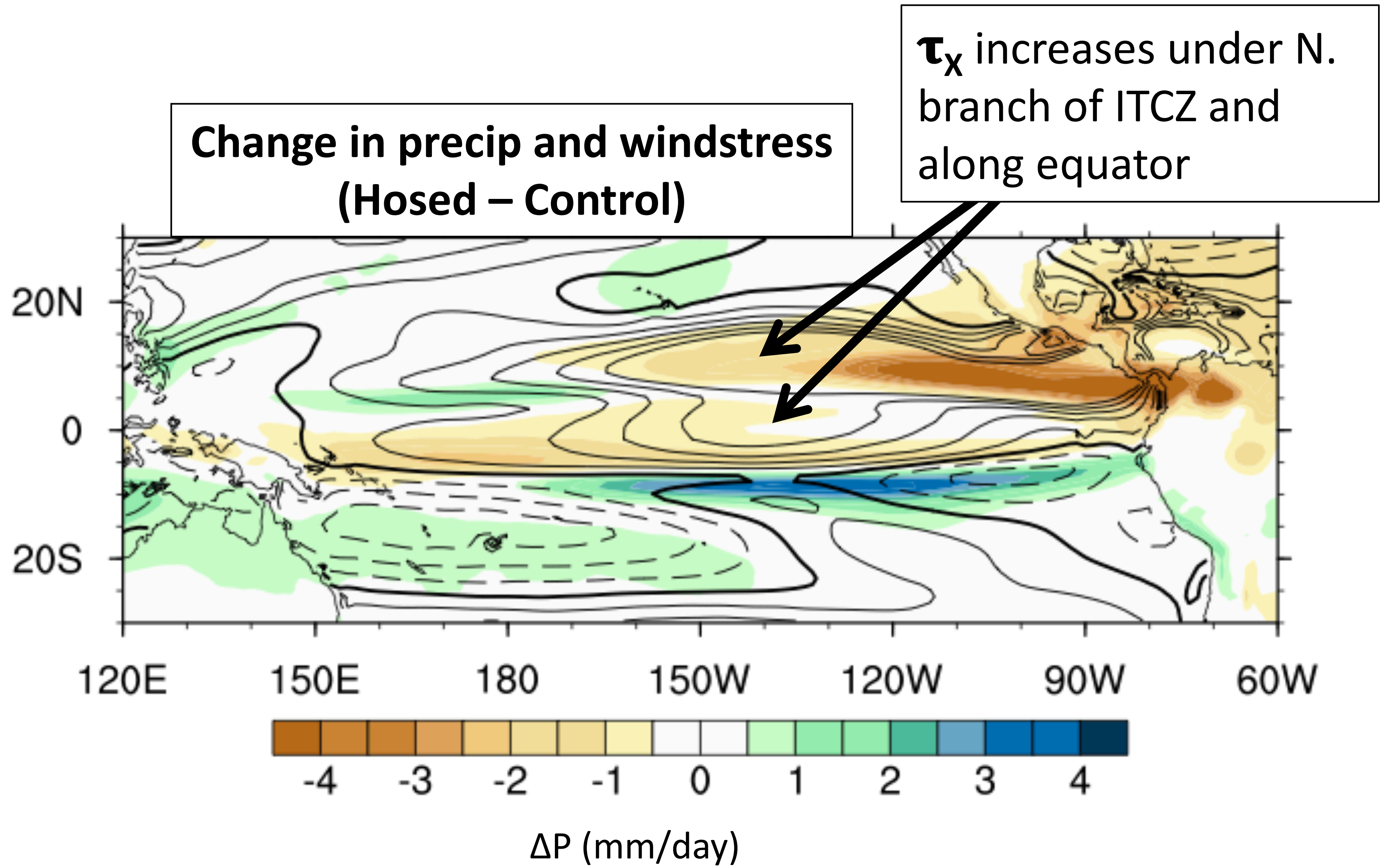


Southward shift of tropical rainfall during 8200 BP event

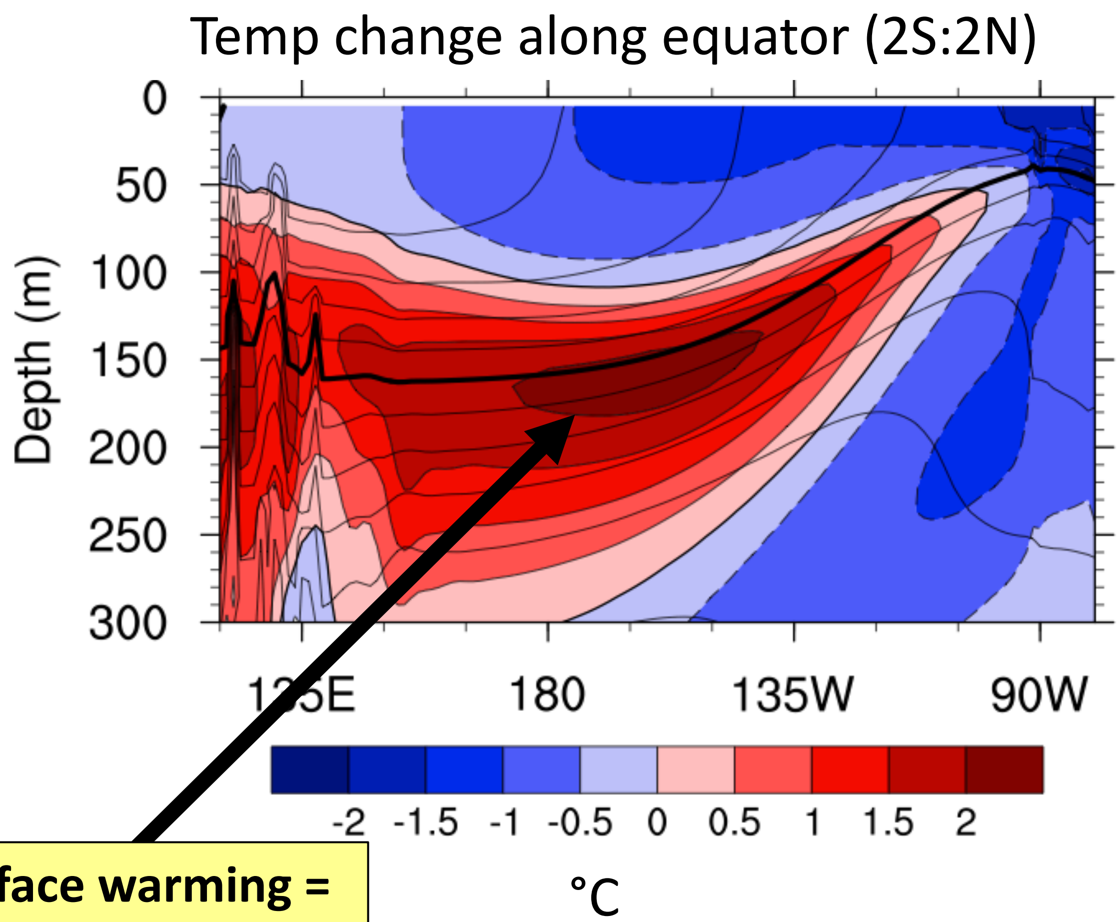


Atwood et al. (in review at *Nat. Geo.*)

Pacific ITCZ shifts south under hosing



Equatorial Pacific subsurface warms



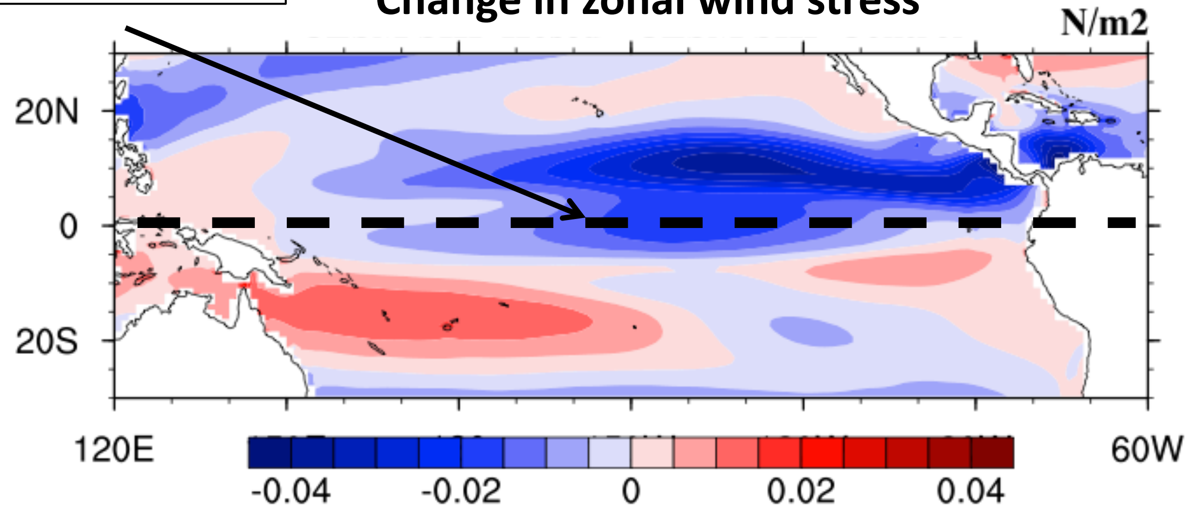
Subsurface warming up to 2°C in eq. Pacific

Subsurface warming = deeper and more diffuse thermocline

Subsfc warming driven by wind stress changes on equator

Easterly wind stress anomaly maxima **on the equator**

Change in zonal wind stress

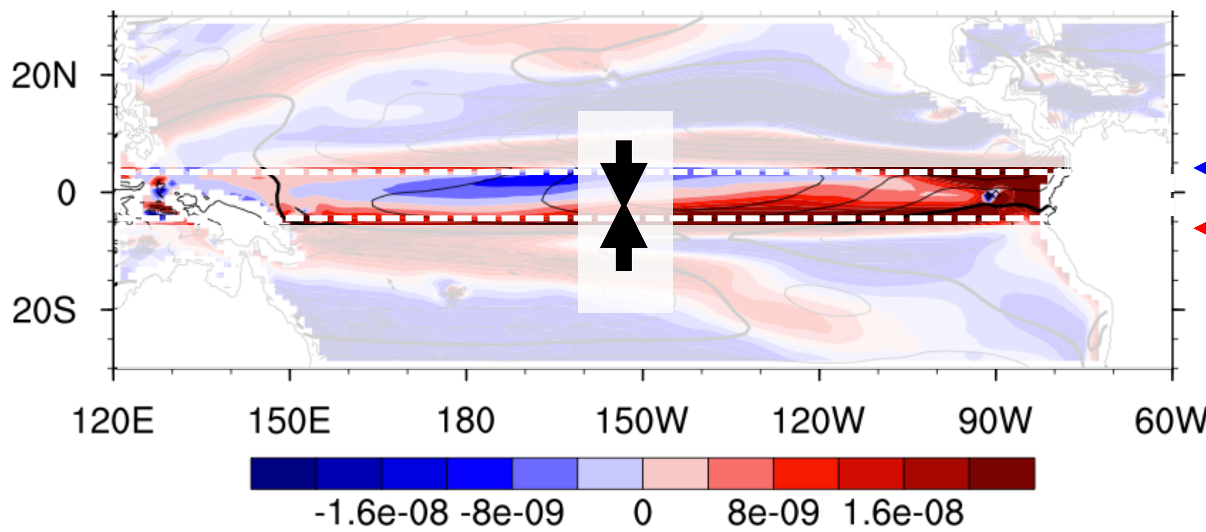


$d\tau_x'/dy = -$

$d\tau_x'/dy = +$

Subsfc warming driven by wind stress changes on equator

Change in wind stress curl



Negative wind stress curl anomaly to the N

Positive wind stress curl anomaly to the S

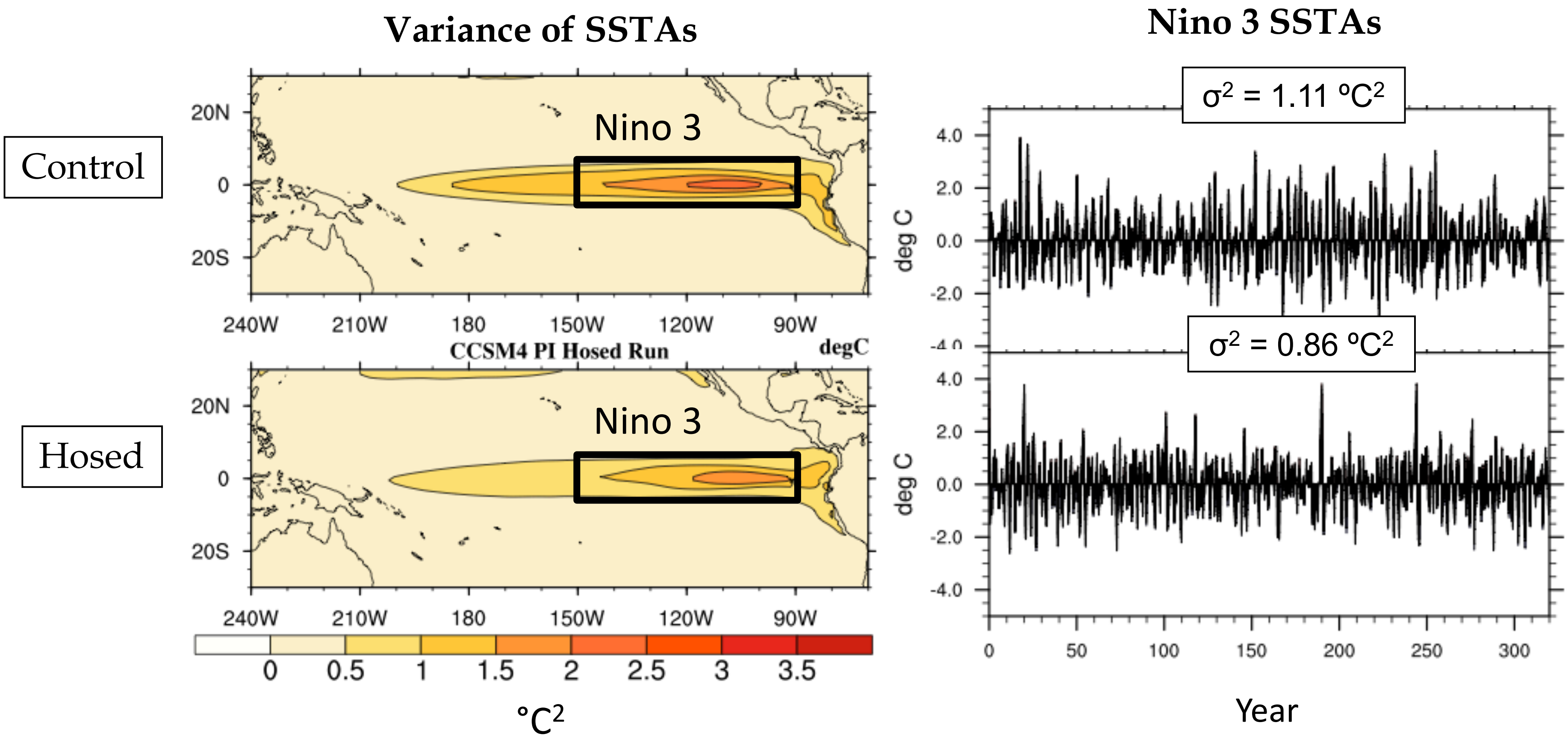
Sverdrup transport
$\boldsymbol{\beta} V = \rho^{-1}(\mathbf{k}\cdot\nabla\times\boldsymbol{\tau})$

$$\frac{\partial}{\partial t}\left(\int_A h\,dA\right) + \frac{\partial}{\partial t}\left(\frac{f_N}{\beta}\int_0^{L_N} h\,dx - \frac{f_S}{\beta}\int_0^{L_S} h\,dx\right) = -\frac{1}{(\rho\beta)}\int_0^{L_N} \mathrm{curl}\tau\,dx + \frac{1}{\rho\beta}\int_0^{L_S} \mathrm{curl}\tau\,dx + T_W,$$

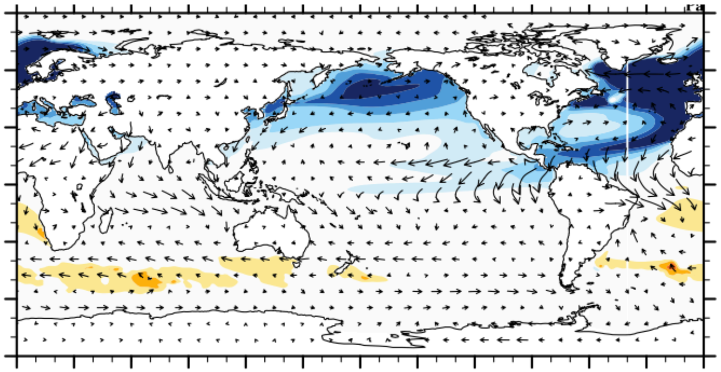
Change in thermocline depth integ. over equatorial box	~	Difference in wind stress curl anom integrated along N and S edges of box

Clarke et al., 2007

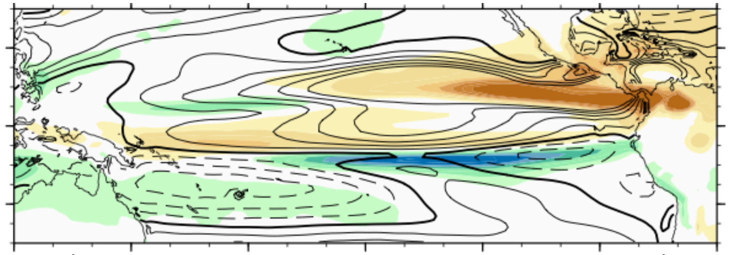
ENSO variance **decreases** under hosing in CESM, consistent with proxy reconstructions



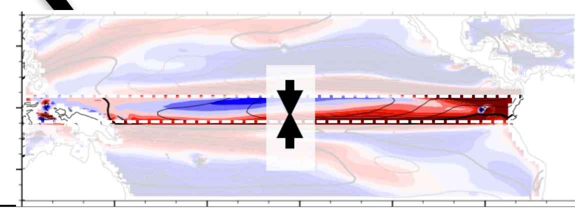
Links between abrupt N. Atlantic cooling, ITCZ and ENSO



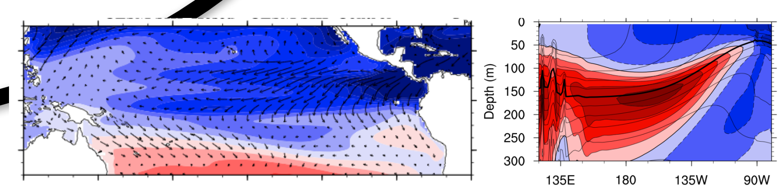
N. Atlantic hosing



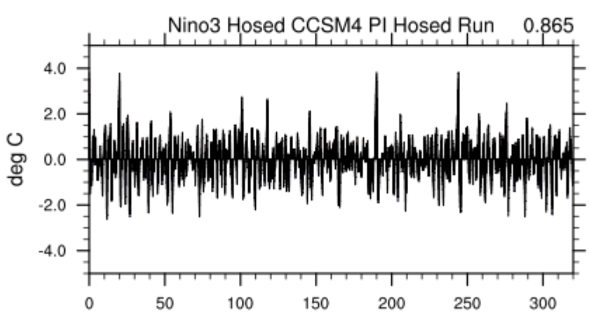
Trop. Atlantic cooling
Southward ITCZ shift



Wind stress curl anom. along equator



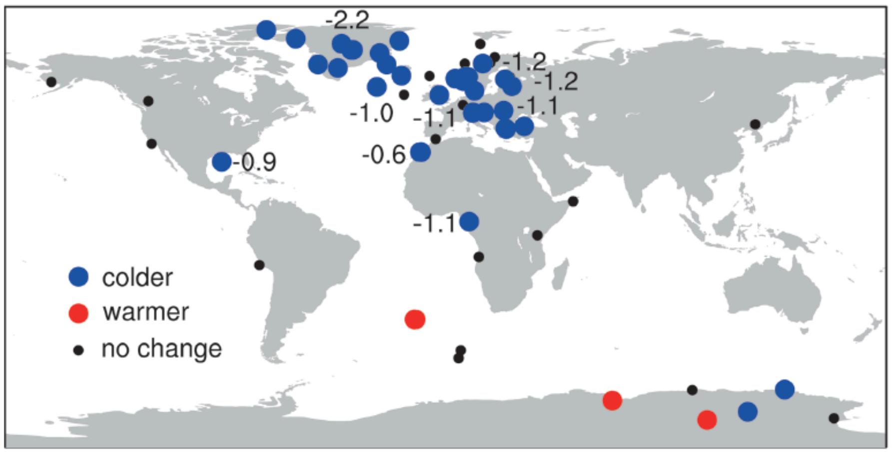
Eq. subsurface warming
Tropical Pacific cooling



Reduced ENSO variability

Proxy reconstructions of the 8200 BP event

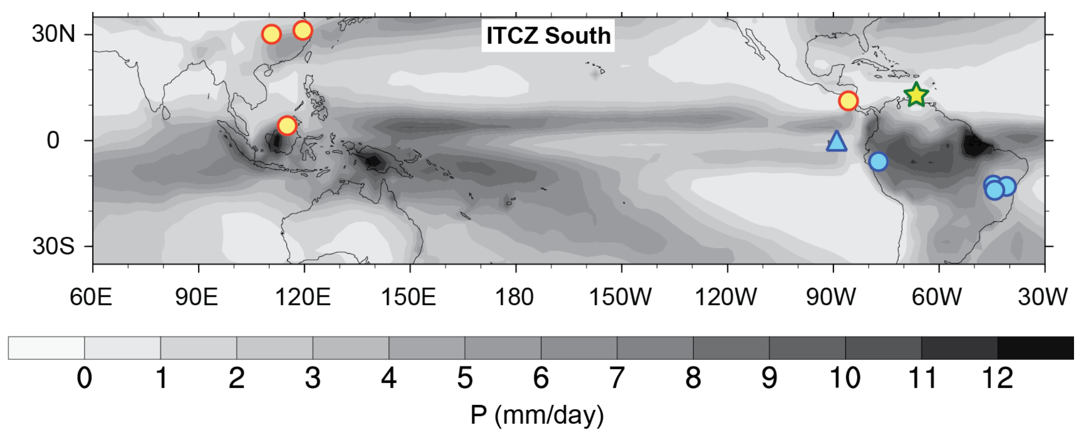
Temp records



Morrill et al., GRL, 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

- Proxies can provide novel insight into climate teleconnection patterns for which no modern analogue exists
- Proxy reconstructions indicate that during 8200 BP event, abrupt North Atlantic cooling led to:
  - Southward shift of ITCZ in eastern Pacific
  - Weakened ENSO variability
- These changes are reproduced in CESM under North Atlantic freshwater forcing
  - But the tropical Pacific response is highly model dependent (likely due to large tropical mean state biases)
- More high-resolution proxy records needed from the tropical Pacific to better understand the global response to this event