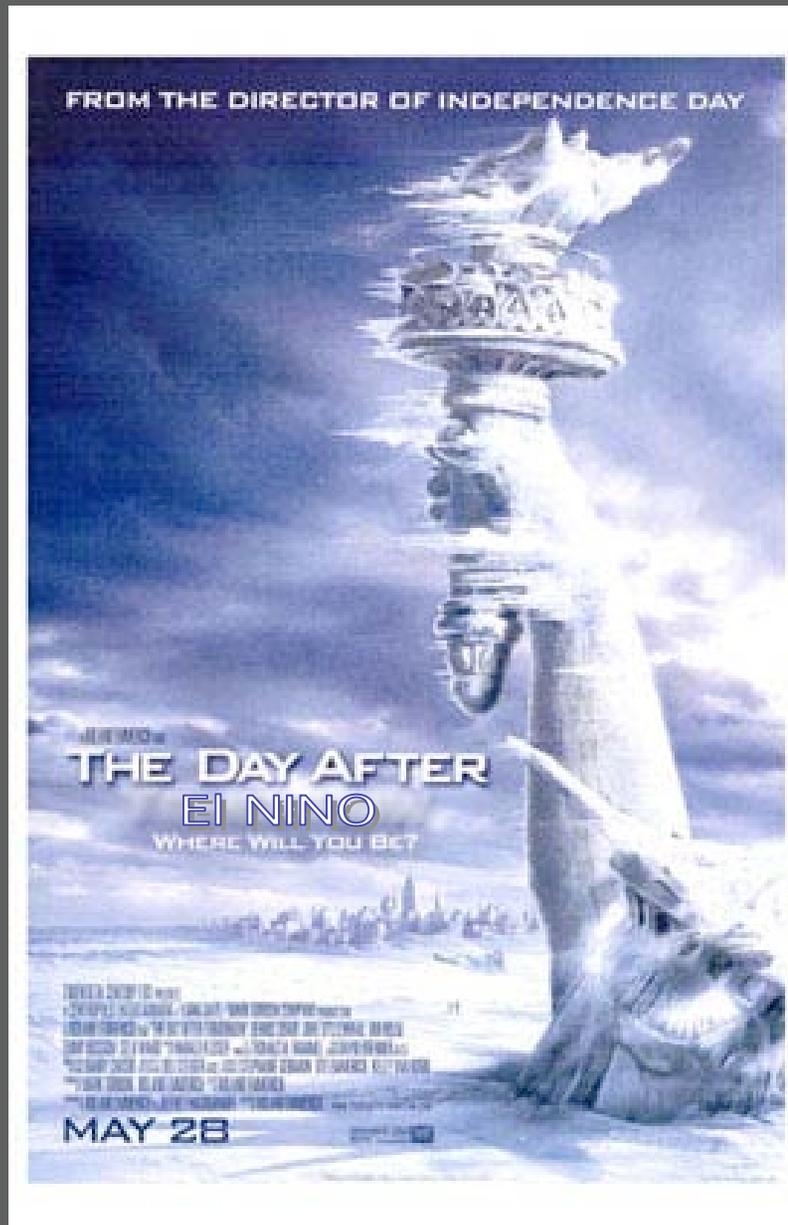


Evidence of ENSO modulation through radiative forcing

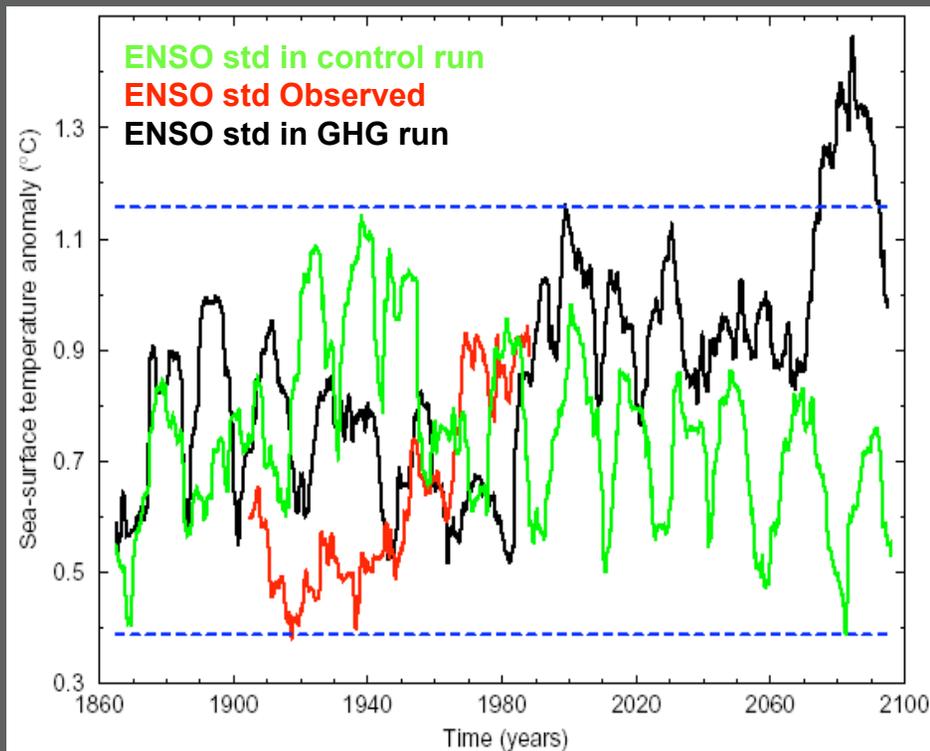
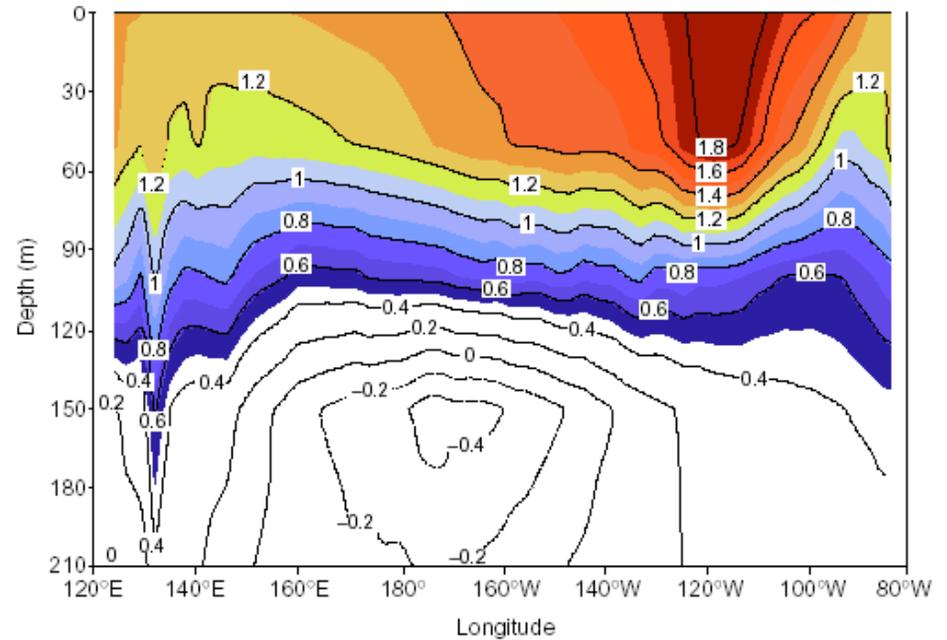
Kim Cobb
Georgia Tech

Coral collaborators:
Chris Charles, SIO
Larry Edwards, UMN



The big question: How will ENSO evolve in a greenhouse world?

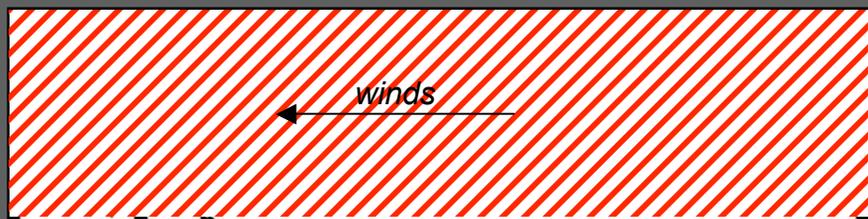
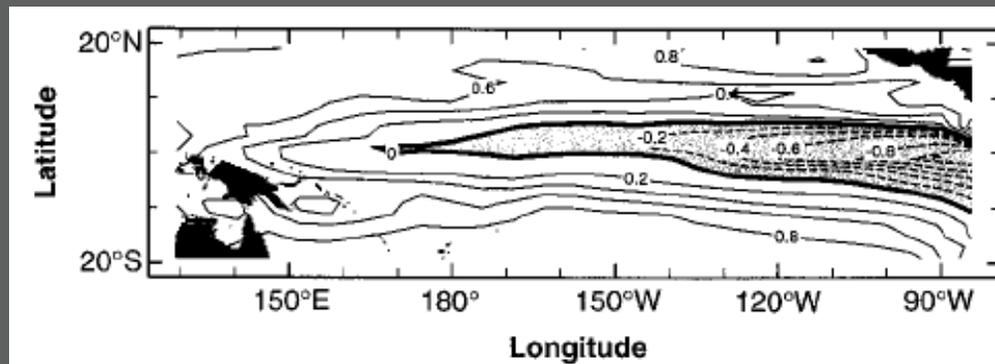
El Niño-like?
Timmermann, 1999:
trend towards El Niño-like
mean state, increased
ENSO variance



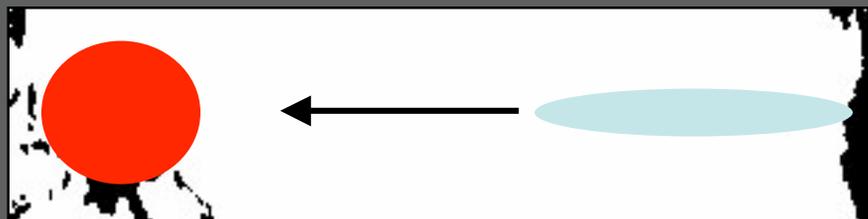
response due to cloud albedo feedbacks?
(Meehl & Washington, 1996)

La Niña-like?
Cane et al, 1997:
“ocean thermostat”
(Clement et al., 1996)
leads to increase of
Pacific zonal SST gradient

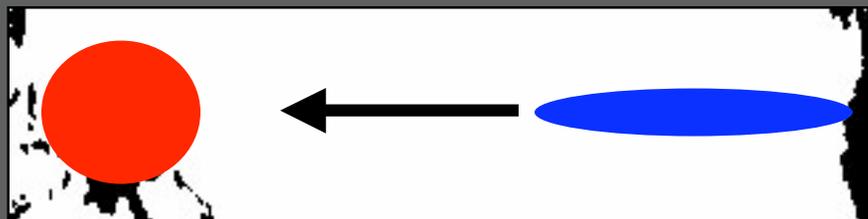
Cane-Zebiak model w/ uniform heating



annual mean SST, begin uniform heating

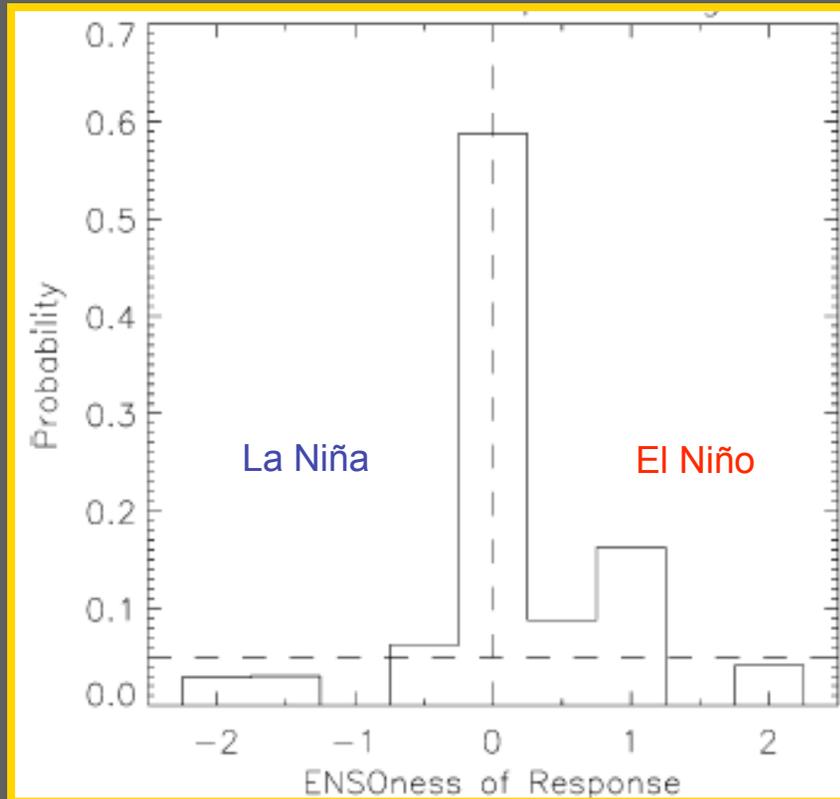


SST increases in West, but SST in East is buffered by upwelling of cool waters, zonal SST gradient increases



Bjerknes feedback: trades strengthen, zonal SST gradient increases

Histogram of ENSO-like responses in 20 AOGCMs



So results are extremely
model-dependent

(Collins et al., 2000b, 2004)

Paleo-analogues: has radiative forcing affected paleo-ENSO?

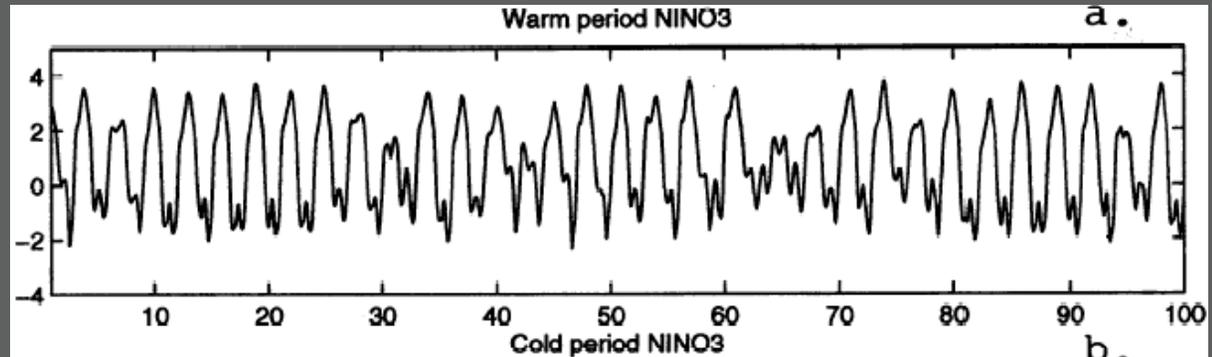
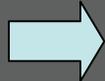
We can examine three different time-scales:

1. orbital (Milankovitch forcing)
2. abrupt climate change (stage 3 & Younger Dryas)
3. last millennium

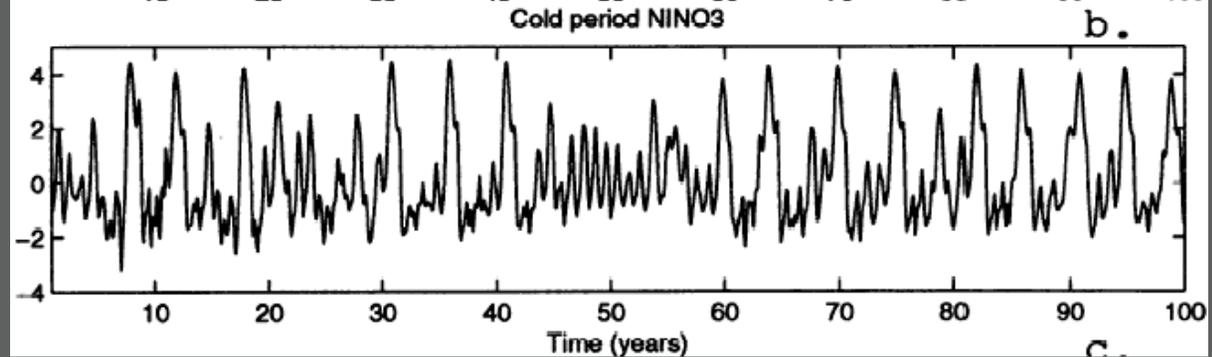
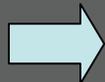


Orbital forcing – Cane-Zebiak model w/ precessional forcing

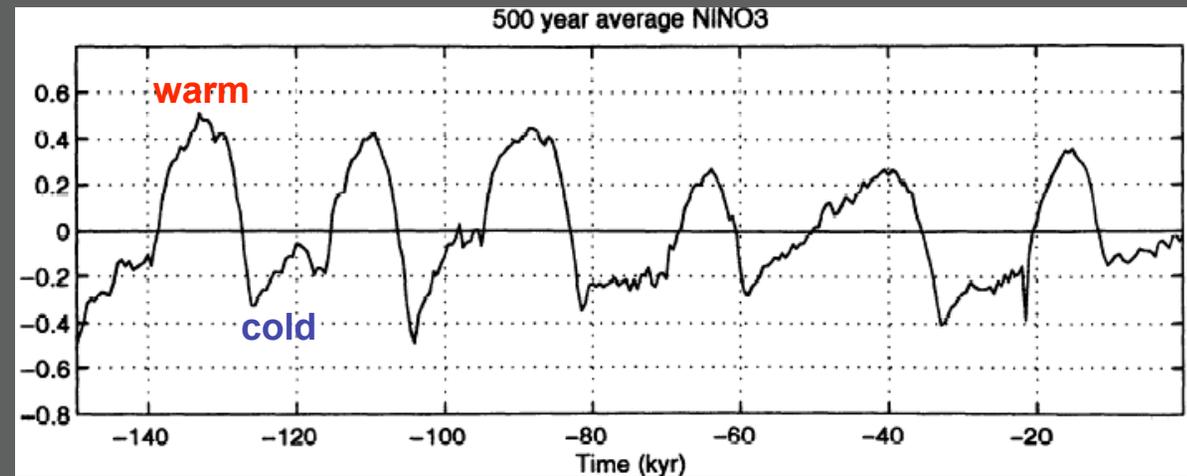
Warm period NINO3, more frequent, regular



Cool period NINO3, less frequent, irregular



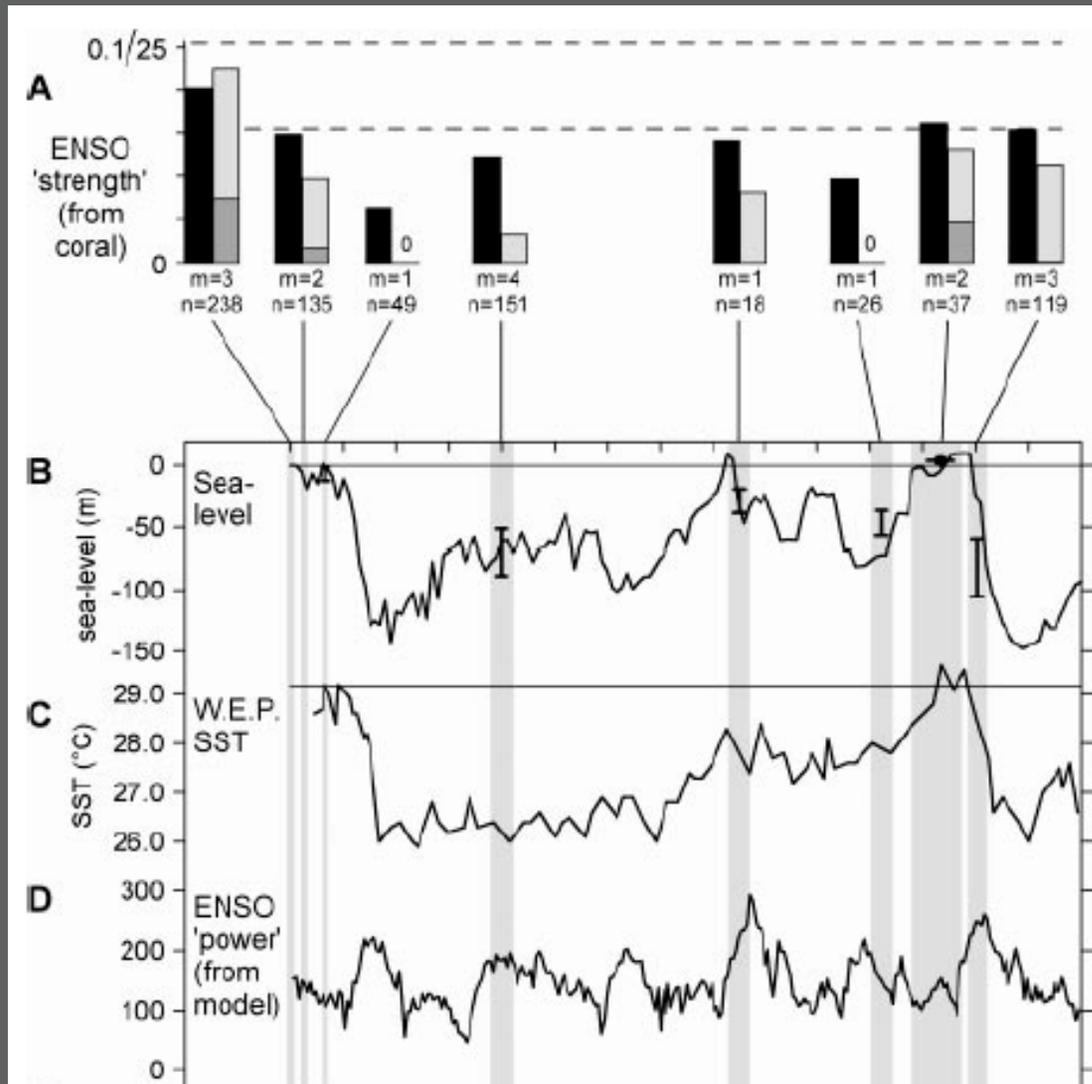
Time-averaged NIÑO3 over last glacial cycle



Clement et al., 1999

* ENSO vs. ENSO-like change

Paleo-ENSO over the last glacial cycle from fossil corals



← Fossil coral ENSO strength

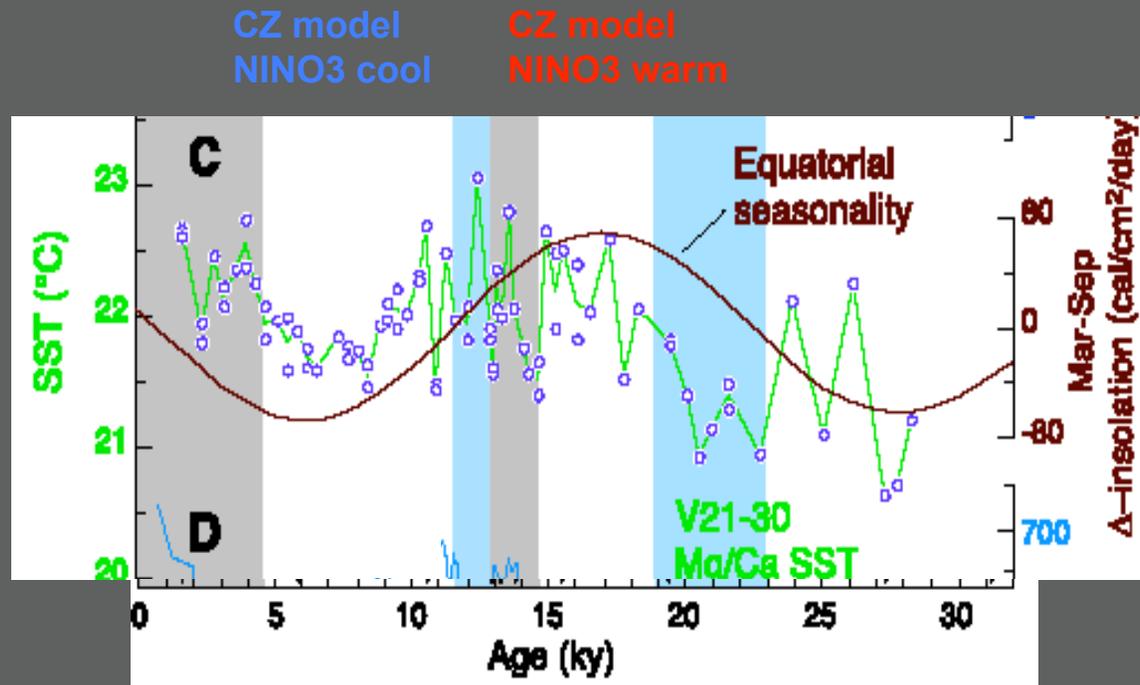
Coral evidence suggests that mean state (glacial vs. interglacial) may be important

does not confirm or deny precessional control

← CZ model NIÑO3 power

Tudhope et al., 2001

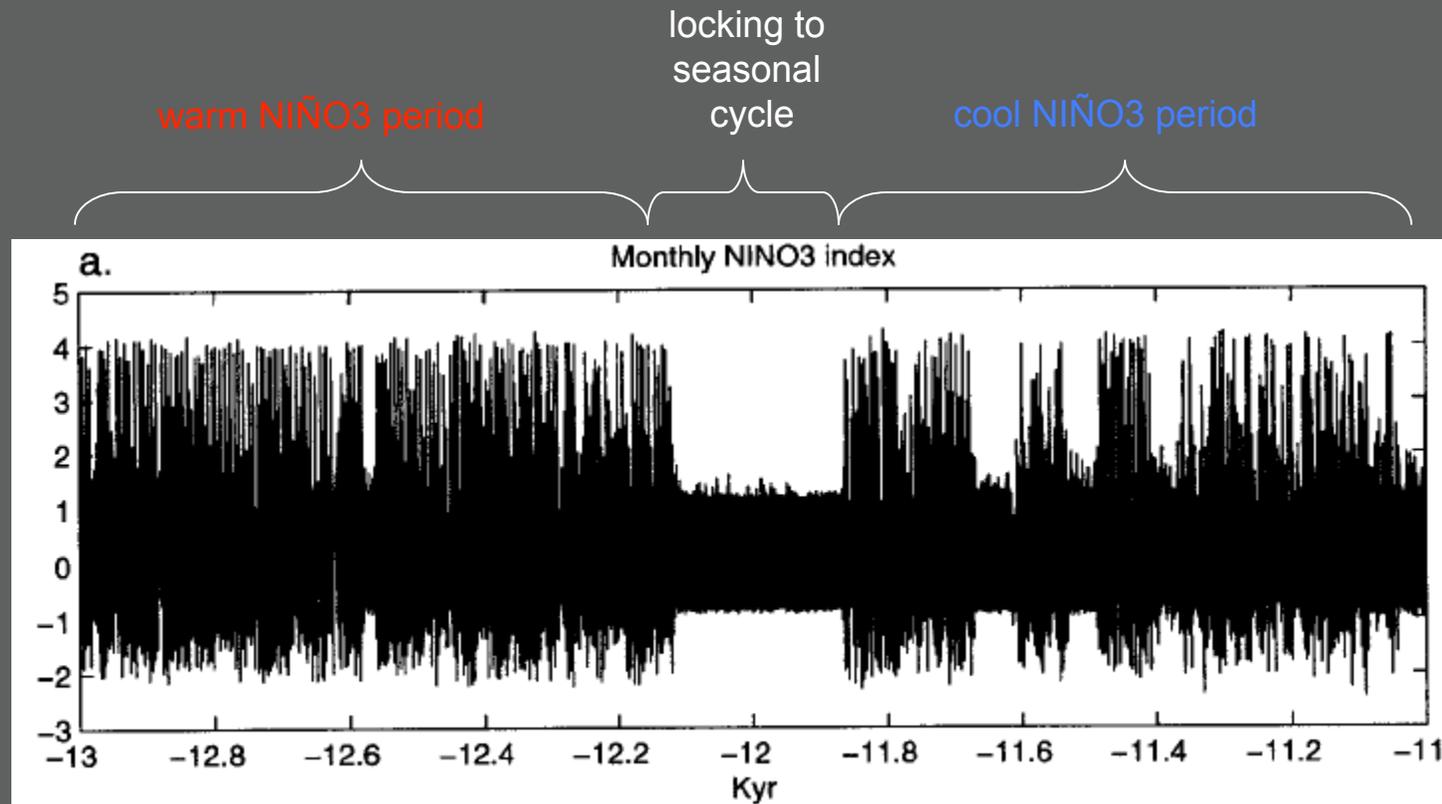
Eastern equatorial SST record from LGM to present



Koutavas et al., 2002

SST proxy record bears resemblance to precession, but noisy

Abrupt climate change in the Cane-Zebiak model – non-linear response to smooth radiative forcing



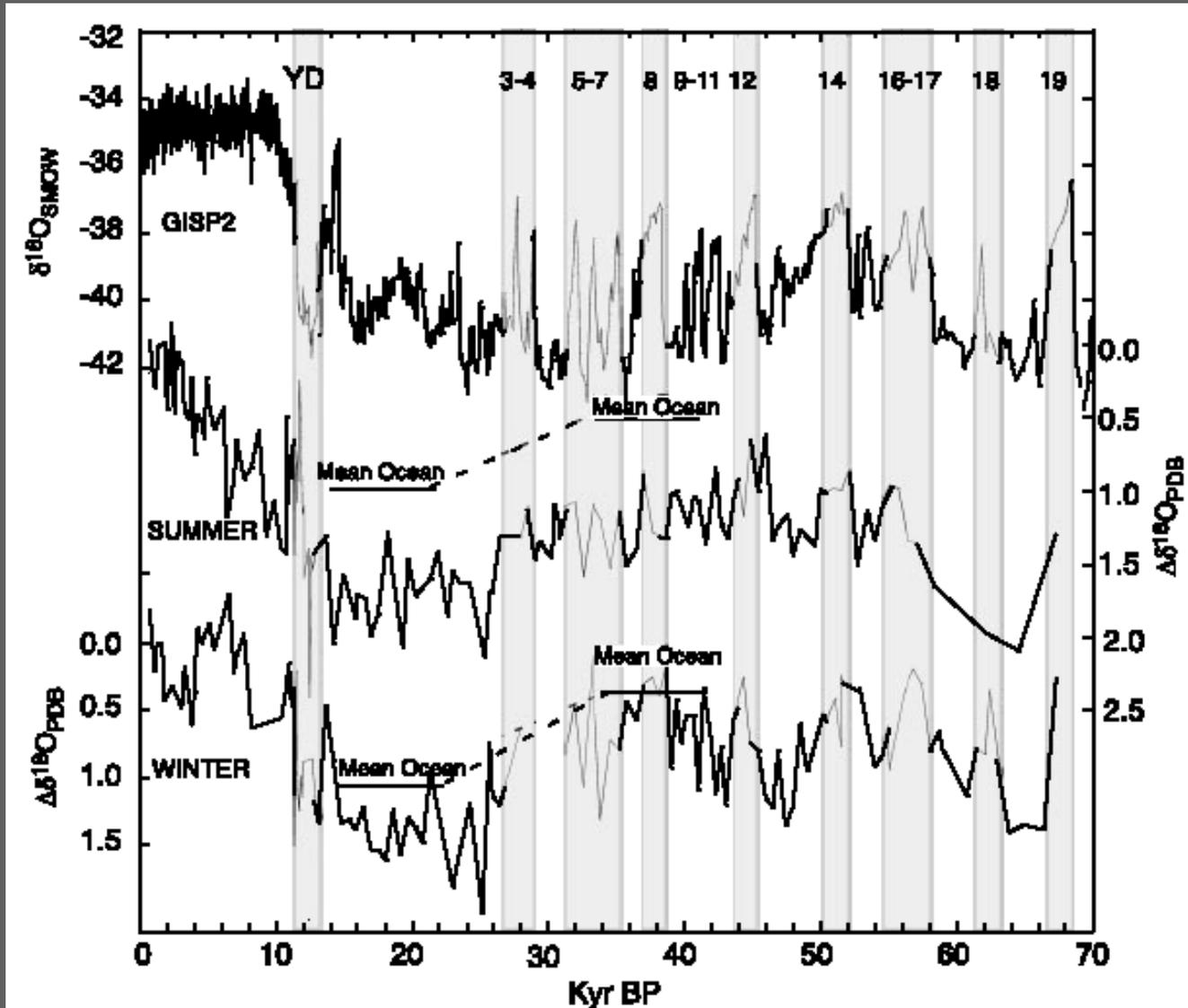
Clement et al., 2001

Idea: change in ENSO from “warm” precessional characteristics to “cool” precessional characteristics can lead to locking of seasonal cycle

Abrupt climate change recorded in tropical Pacific proxy records Stage 3

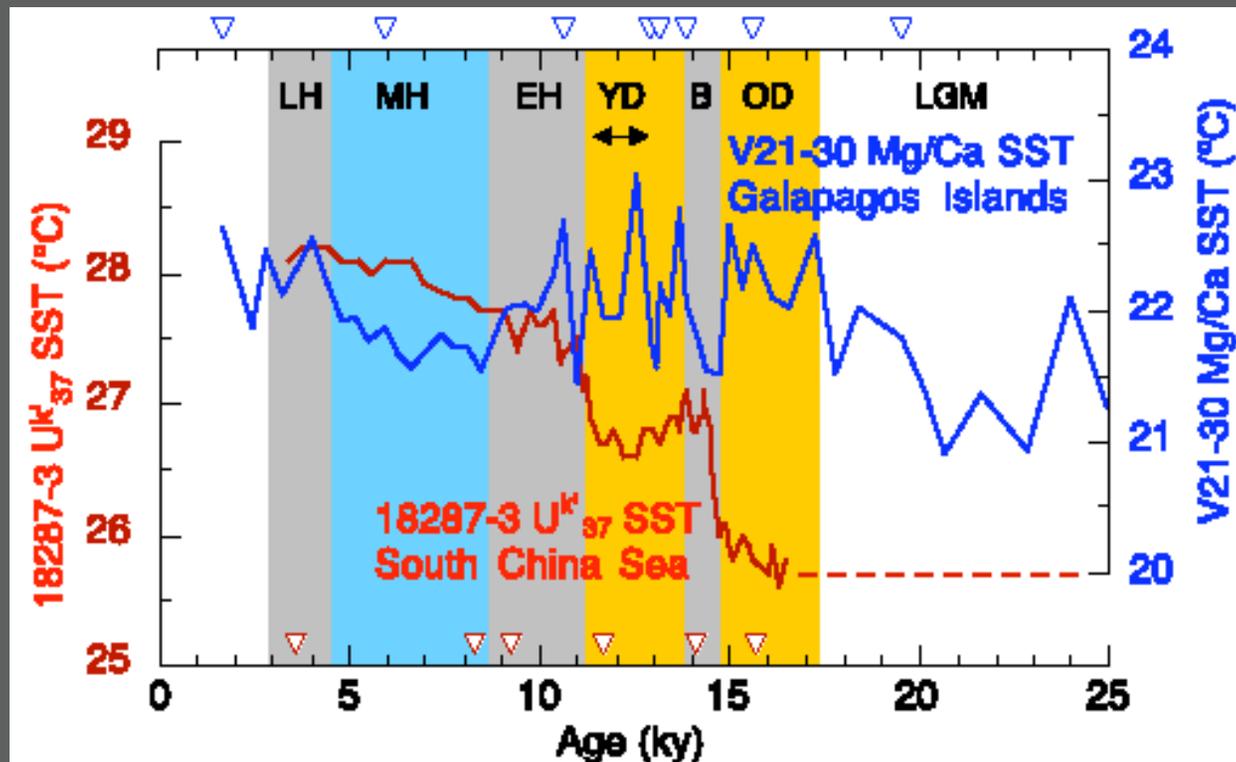
Positive salinity excursions during warm interstadials

warm North Atlantic = El Niño-like Pacific?



Stott et al., 2002

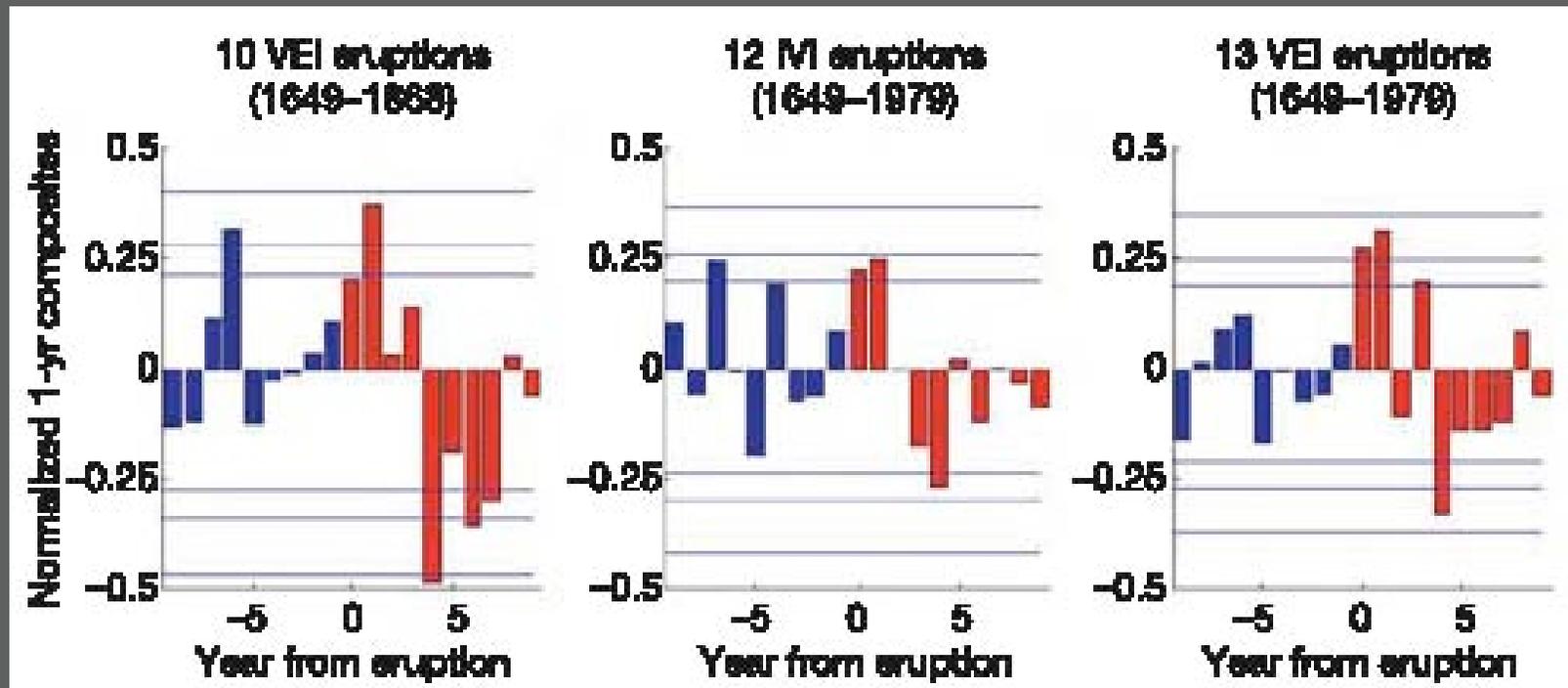
Abrupt climate change recorded in tropical Pacific proxy records Younger Dryas



~0.5 to 1°C cooling in West Pacific Warm Pool, no change in East Pacific hints at El Niño-like change during Younger Dryas?

Kienast et al., 2001; Koutavas et al., 2002

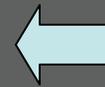
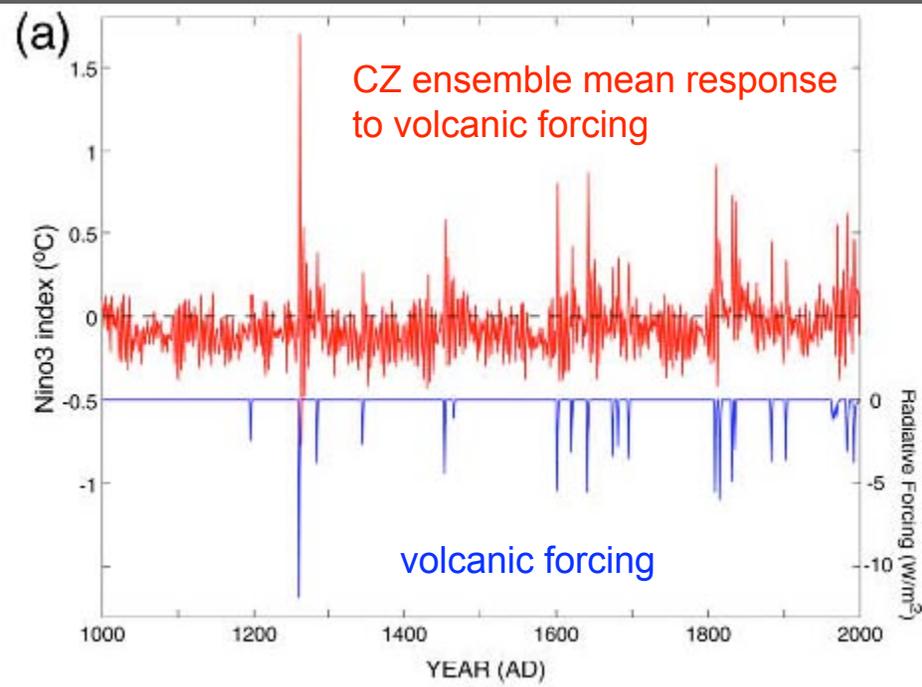
The last millennium – volcanic eruptions and El Niño link?



Adams, 2003

- composited NINO3 evolution before and after known eruptions
- El Niño event statistically more likely following medium to large volcanic eruption
- mechanism: ocean thermostat?

The last millennium – volcanic and solar forcing effects on ENSO

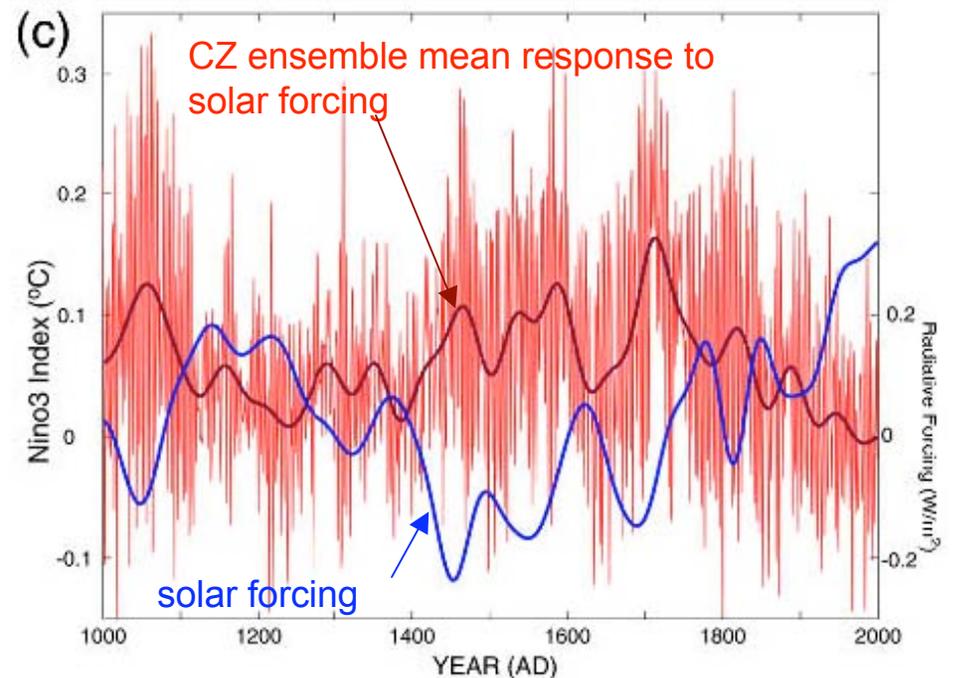
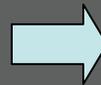


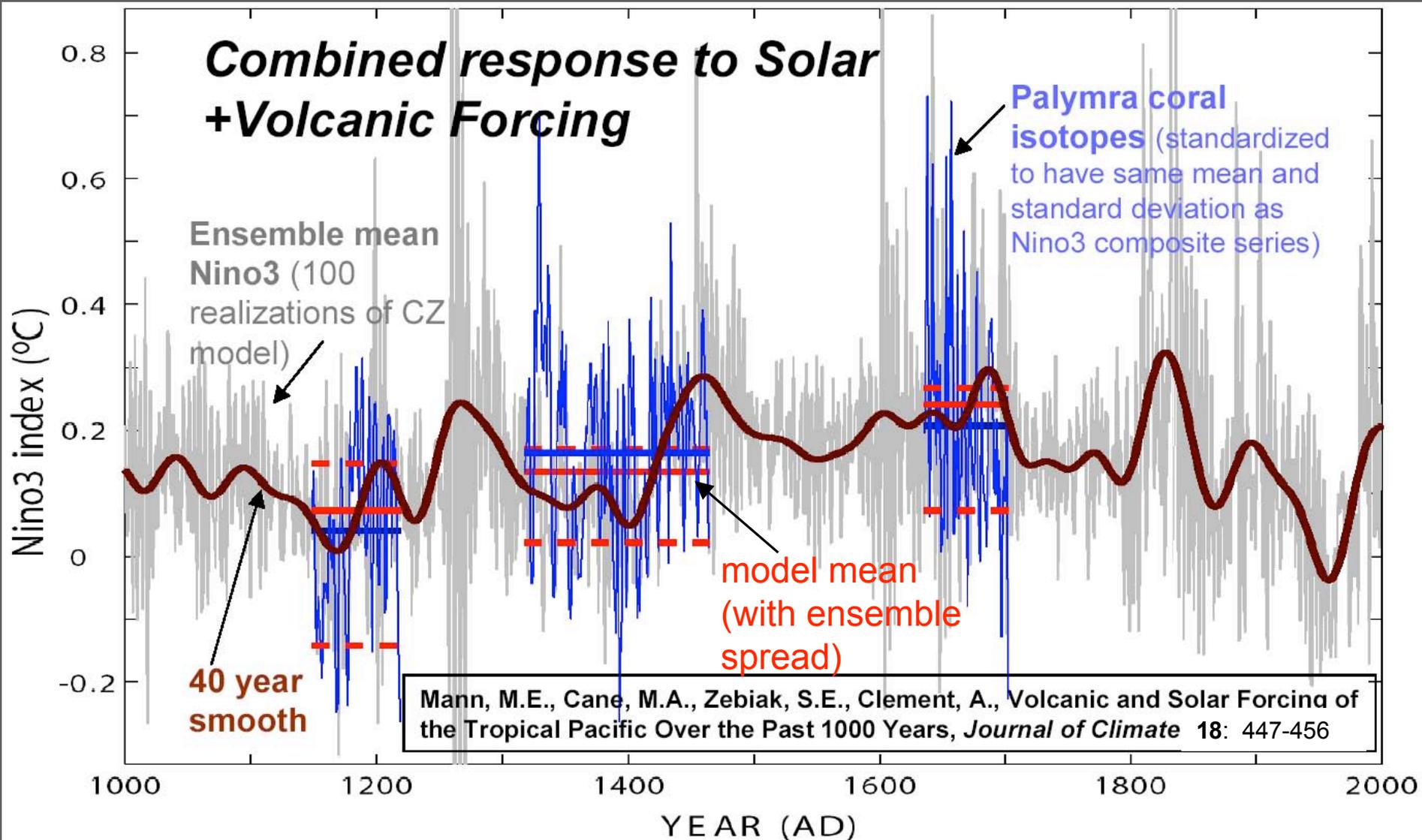
decreased radiative forcing over tropical Pacific causes increase in Nino3 SST

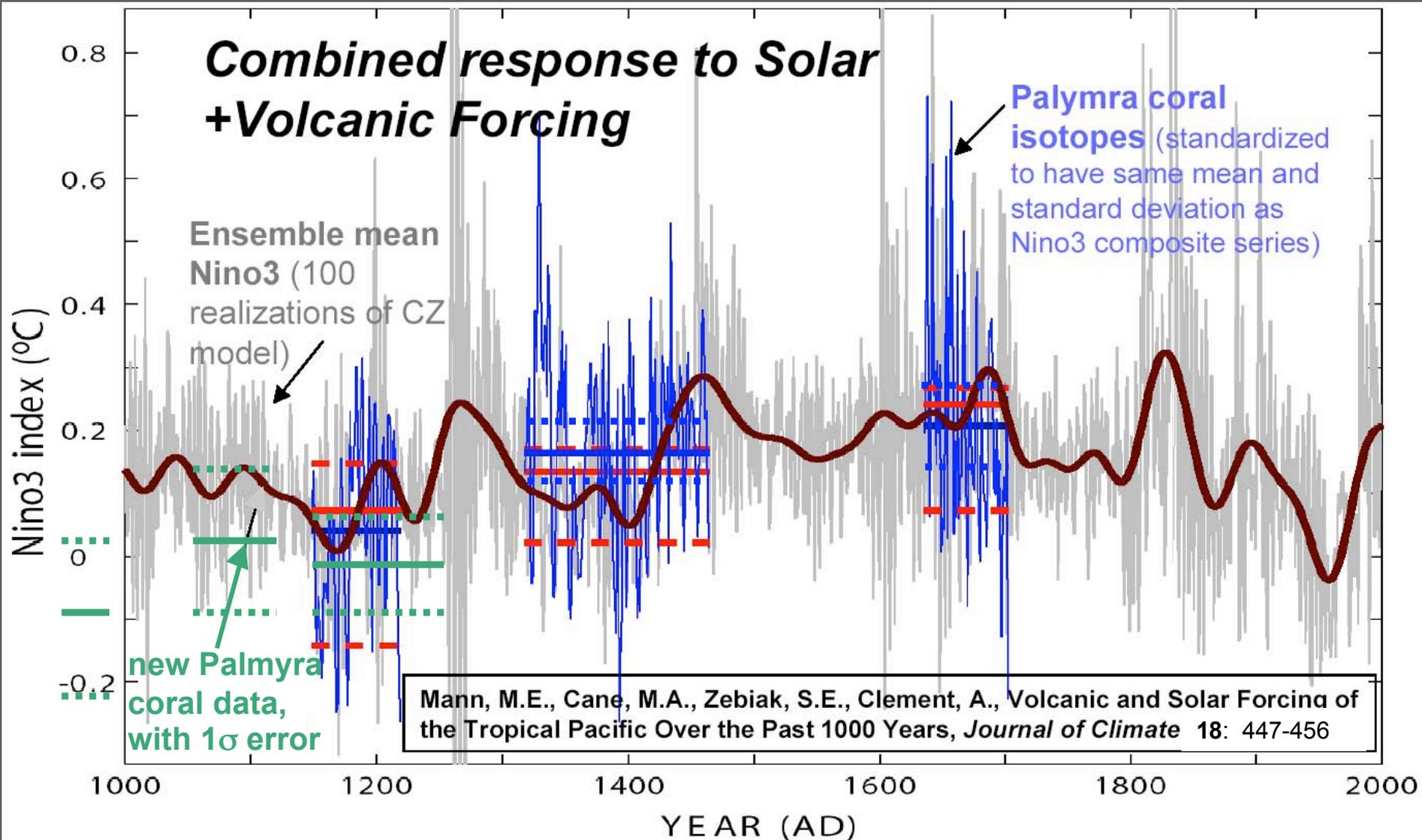
explanation: ocean thermostat

Mann et al., 2005

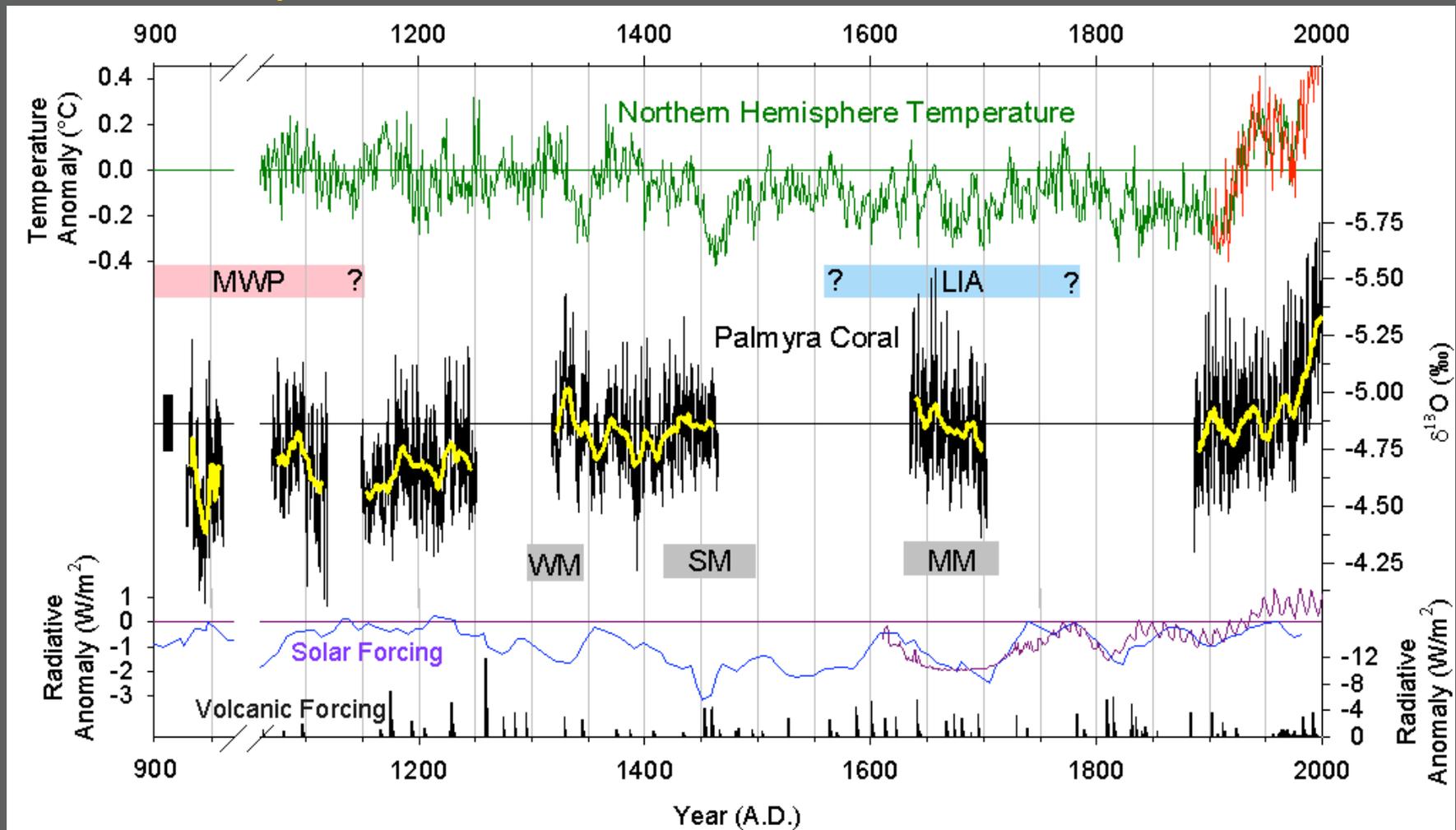
increased radiative forcing over tropical Pacific causes decrease in Nino3 SST







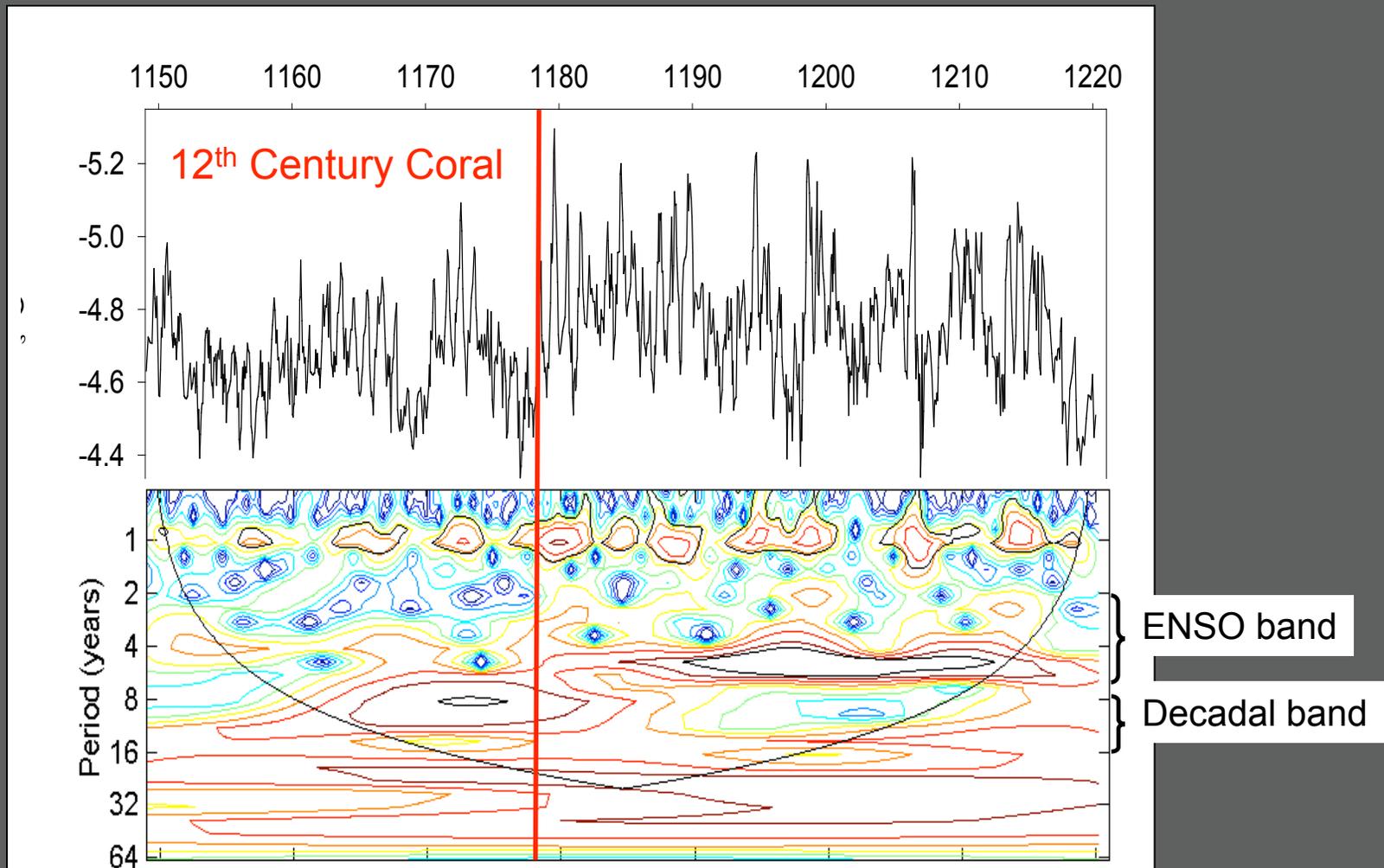
The Palmyra coral reconstruction to date



Cobb et al., 2003

- *confirmation of cooler, drier conditions early in the millennium
- *most intense El Niño activity (still) in the mid 17th century

An ENSO 'Regime Shift' in Palmyra coral?



Did radiative forcing (solar or volcanic?) play a role in this shift, or is this another example of intrinsic variability?

Lessons relevant to ENSO in a greenhouse world

- * if the “ocean thermostat” theory is right, then mean state should be moving towards La Niña-like response, all else being equal
- * ENSO models and Palmyra corals show that abrupt changes in ENSO properties are fundamental to the tropical Pacific ocean-atmosphere system (whether forced or unforced)
- * the tropical Pacific definitely played a role in abrupt climate change events during MIS 3 and the deglacial, whether as amplifier or trigger

There are still more questions than answers....

Does radiative forcing explain a significant amount of ENSO variance – keep looking for unambiguous case of ENSO response to radiative forcing in paleo-record

How does mean state affect the response of TP climate to radiative forcing?
(incorporate both models and paleo)