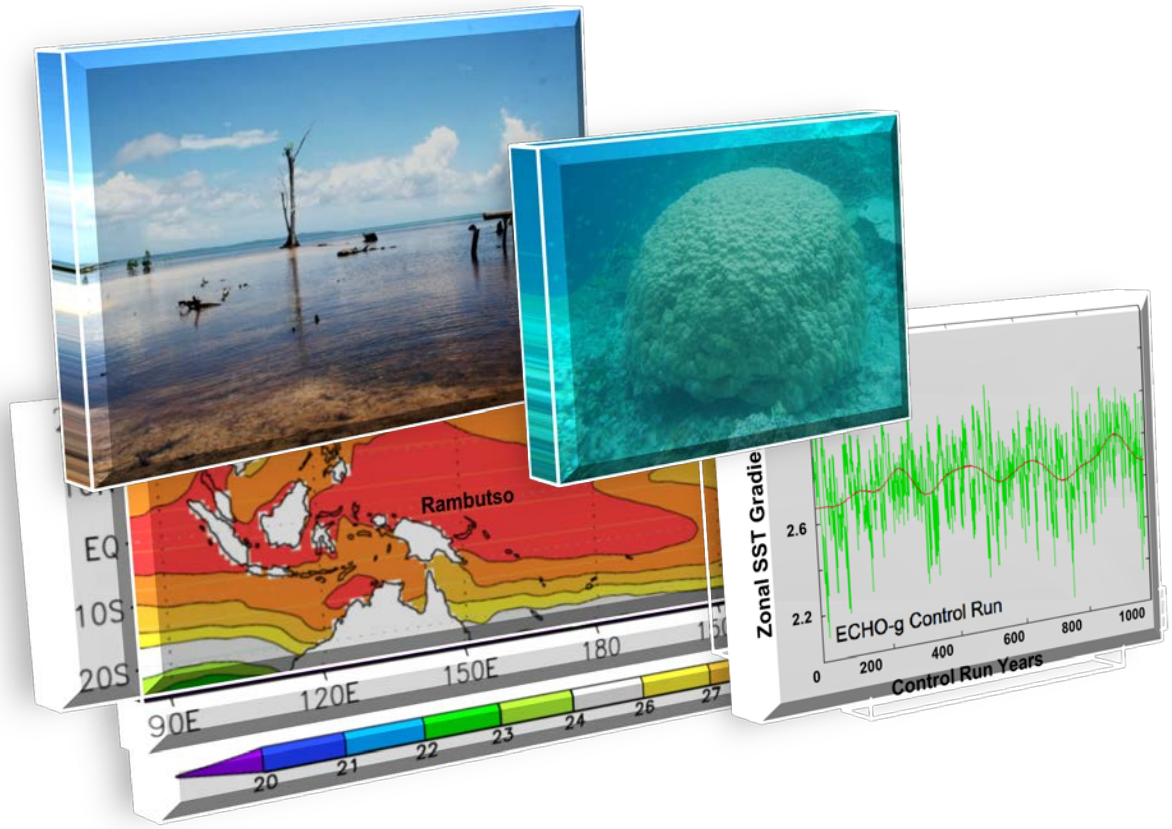
A coral-based picture of ENSO from the mid-Holocene tropical Pacific

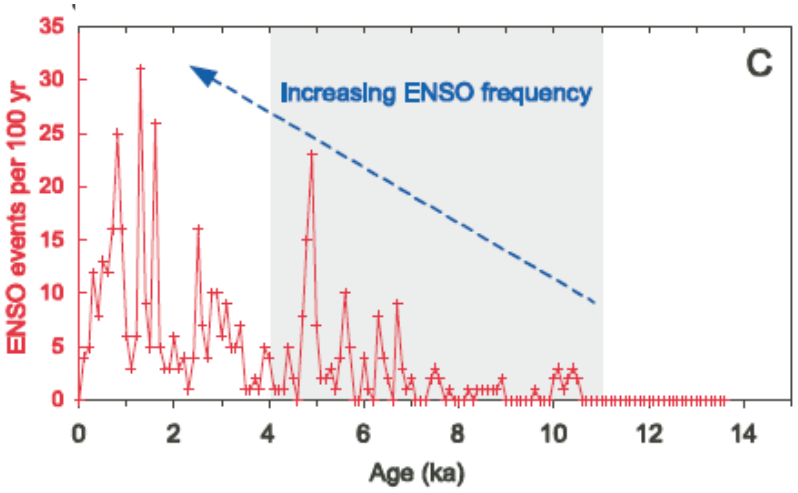


Helen McGregor, University of Wollongong (LDEO Tharp Scholar)

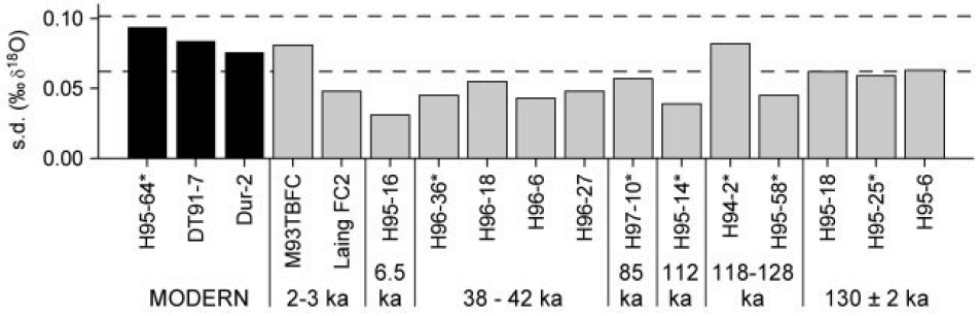
University of Wollongong

Origins of interest in mid-Holocene ENSO

Laguna Pallcacocha (Ecuador) sediment color intensity



Papua New Guinea coral $\delta^{18}O$ ENSO standard deviation



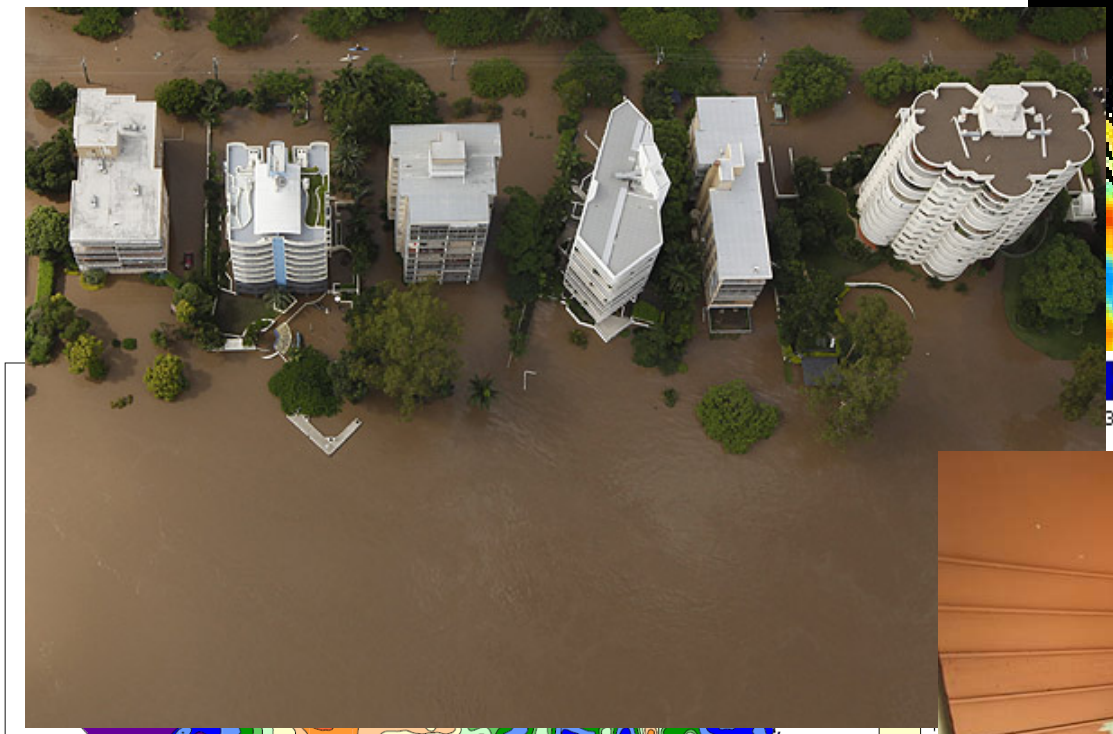
Holocene: 0-10,000 years ago (mid-Holocene: 4,000-6,000 years ago)
Proxy records: Indirect measures of climate from biological or inorganic archives

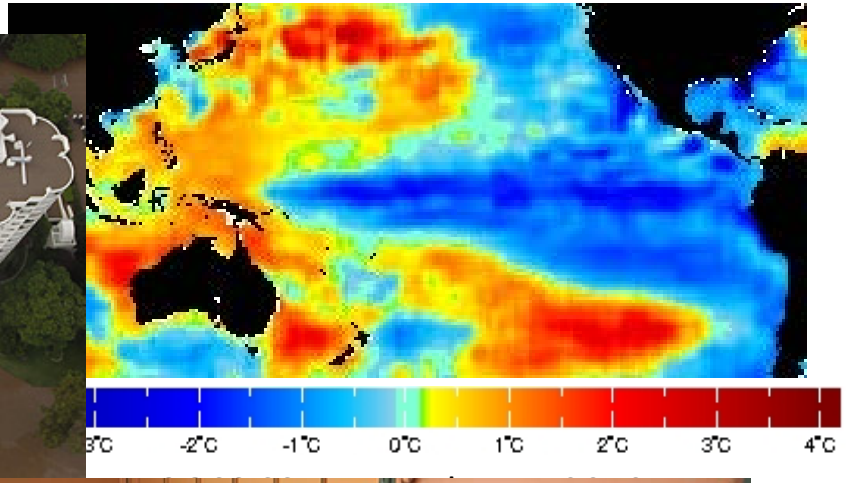
Early work: Pollen records from lakes, lake sedimentation records, mollusc species changes, model studies, coral oxygen isotope records ($\delta^{18}O$)
- Indicated ENSO had strengthened since the early to mid-Holocene

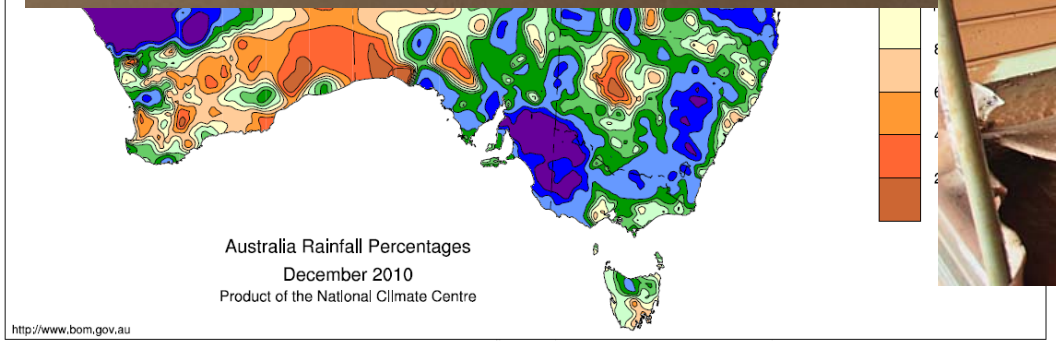
Could the mid-Holocene be a test-bed for improving our understanding of ENSO?
- Similar but different (orbital forcing)
- Longer records
- Alternate ENSO behaviours

Tudhope et al. 2001; Koutavas et al. 2006 after Moy et al. 2002

Interest in understanding ENSO...





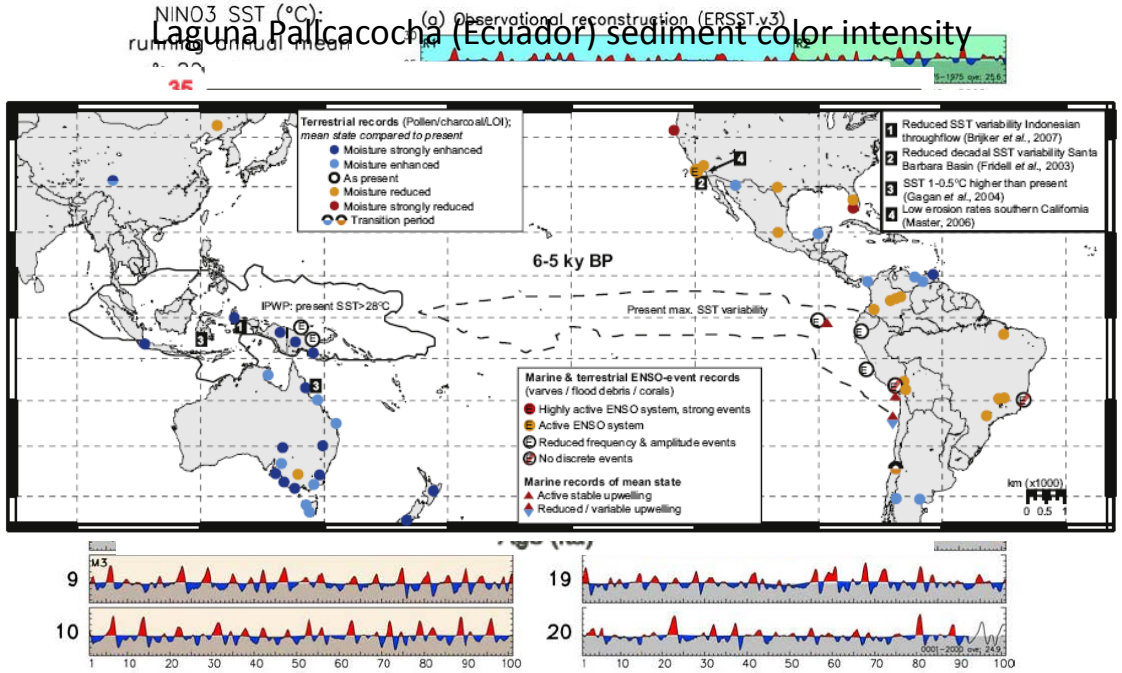


Challenges to understanding ENSO from proxy records

1. Seasonally-resolved records capture the full range of ENSO variance but are not long enough (e.g. Wittenberg 2009)

2. If long enough then do not have the seasonal resolution and/or only sample part of ENSO variance (e.g. Moy et al. 2002)

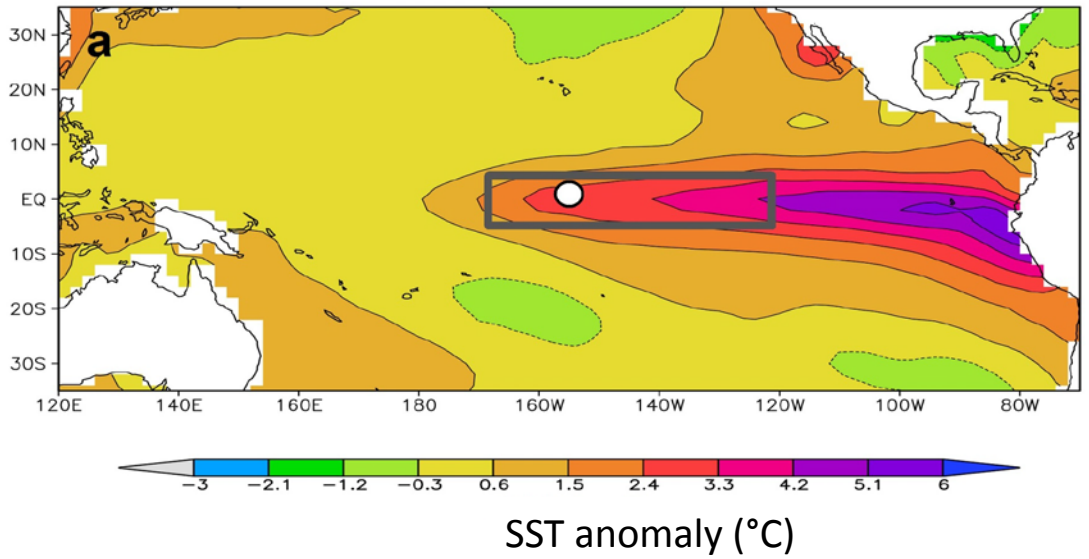
3. Many records are from teleconnected regions (e.g. Donders et al. 2008)



Kiritimati (Christmas) Island coral records of ENSO

Talk outline

1. Modern Kiritimati coral microatolls and their climate signal
2. Seasonal cycle and ENSO results from fossil coral microatolls
3. Equatorial Pacific paleo-SST gradient and what I'll be working on at Lamont



Coral microatolls from Kiritimati Island may avoid some of these issues

- Seasonally resolved
- multi-century length
- Optimally located

Funding

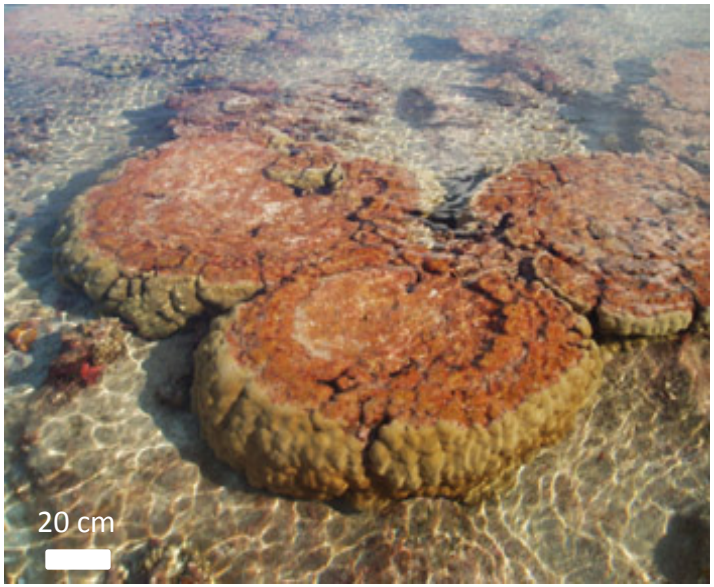
- Australian Research Council
- Australian Institute of Nuclear Science and Engineering
- Marie Tharp Fellowship

Collaborators

Matt Fischer
Mike Gagan
Colin Woodroffe
David Fink
Steven Phipps
Jian-xin Zhao
Harrison Schofield
Linda Glasbergen
David Zeko
Richard Seager
Jason Smerdon

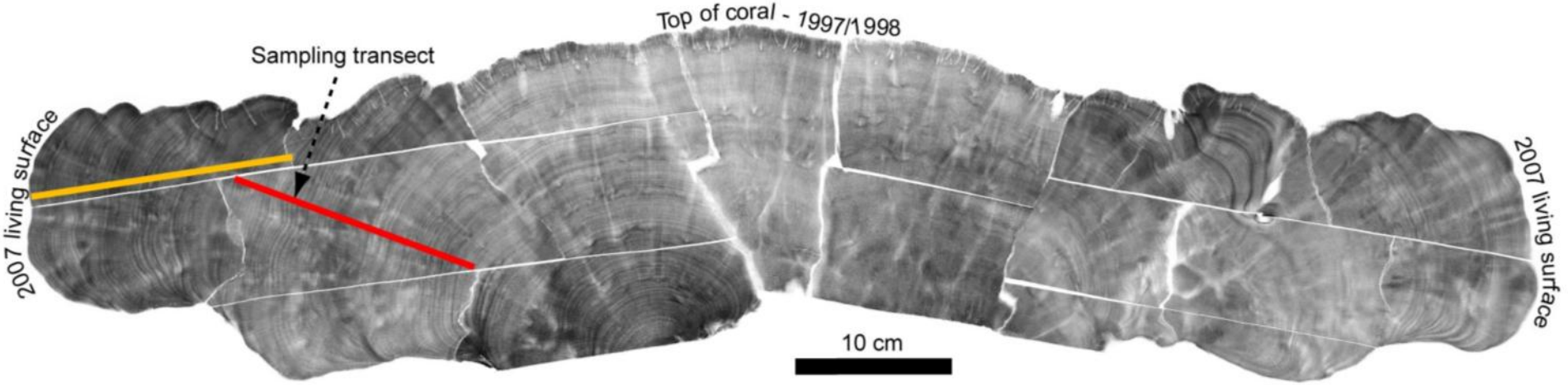
1. MODERN CORAL

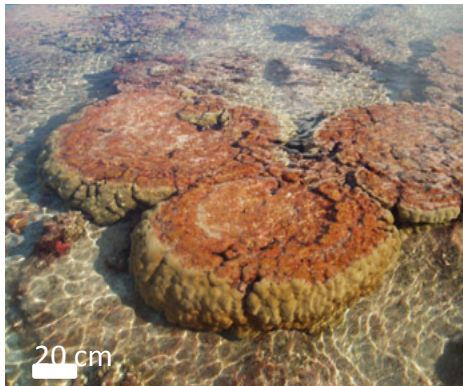
Porites coral microatolls at Kiritimati Is.



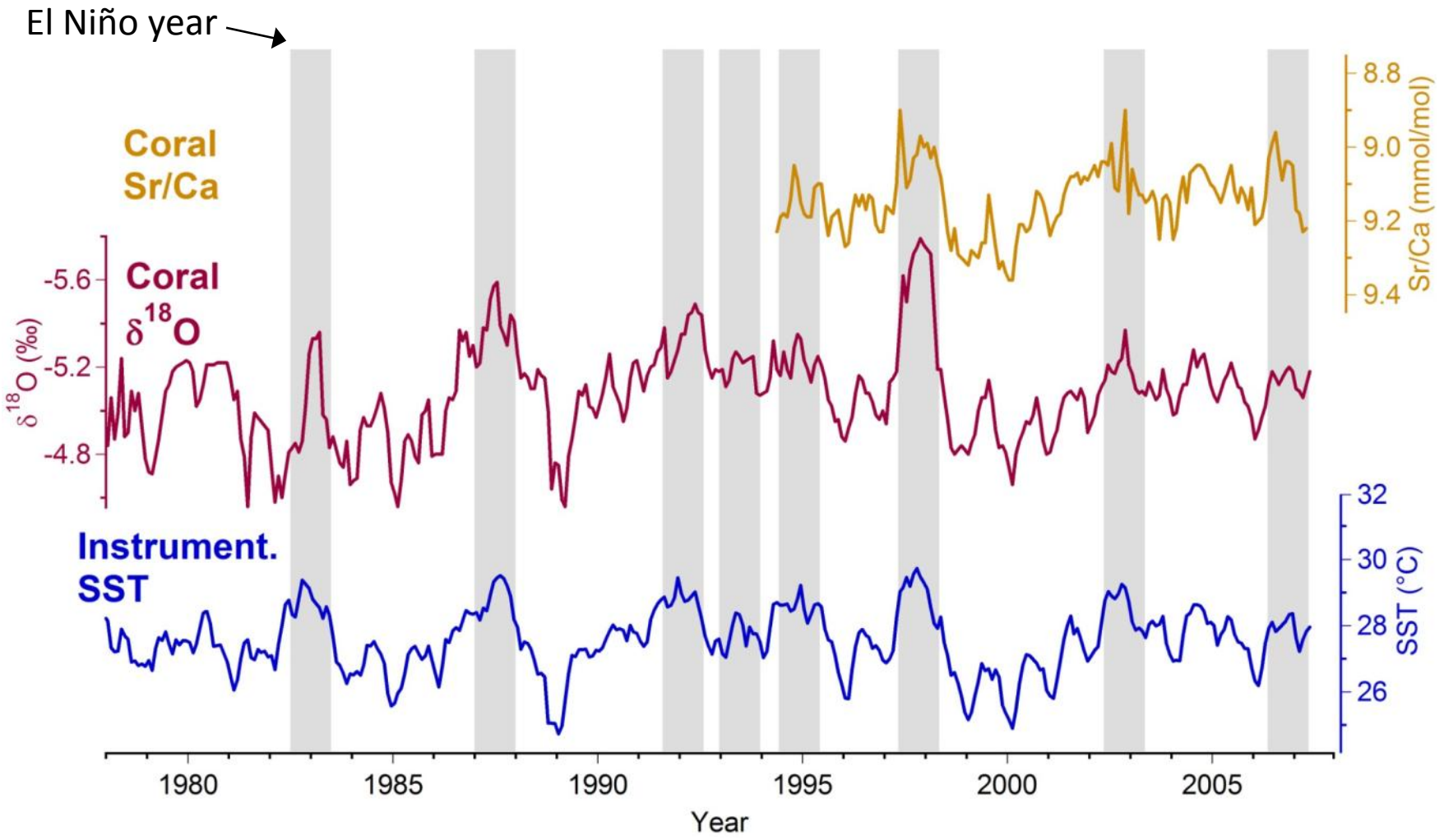
Porites coral microatoll growth and sampling

Modern coral X-ray



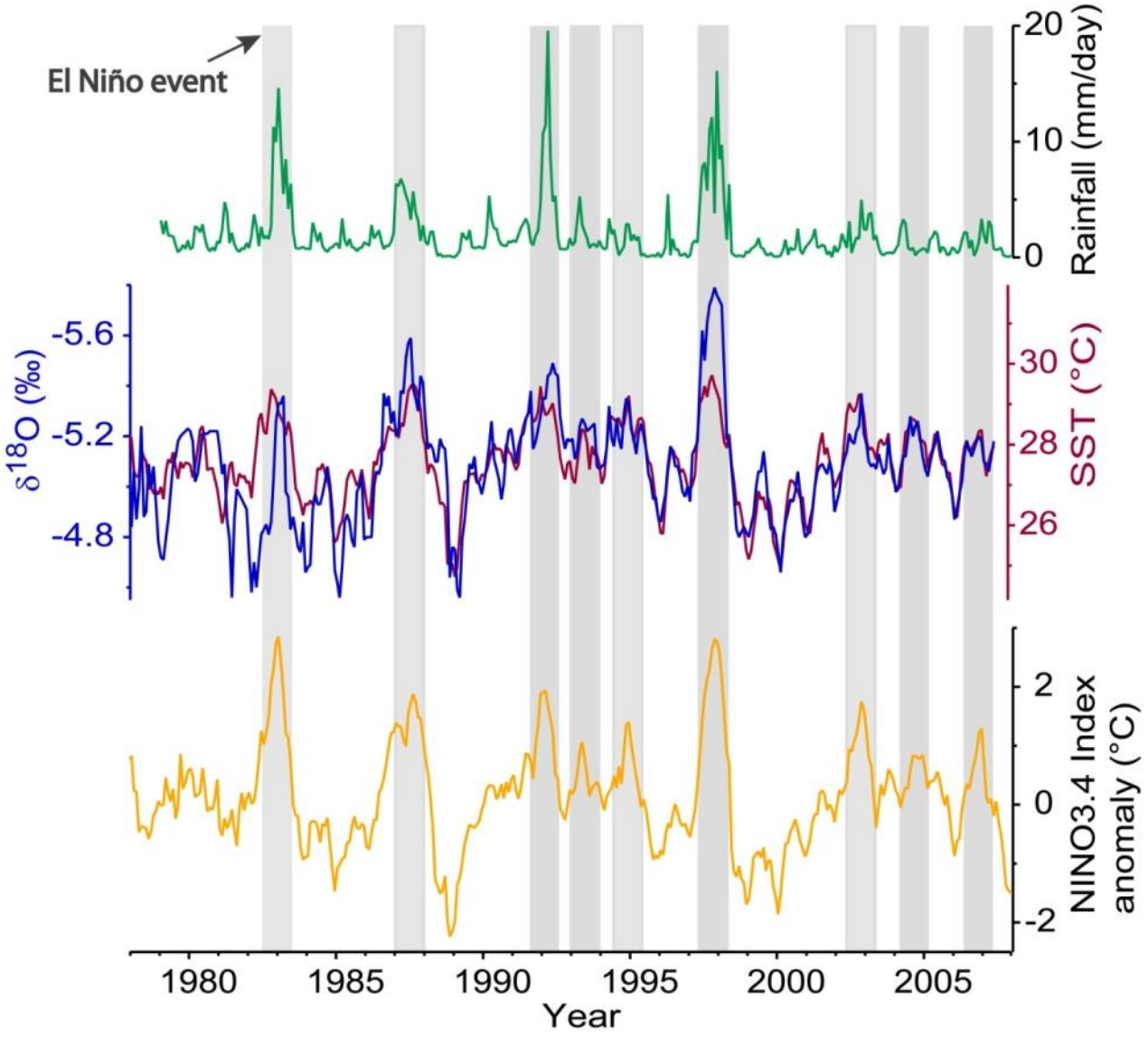


Kiritimati *Porites* microatoll $\delta^{18}O$ and Sr/Ca



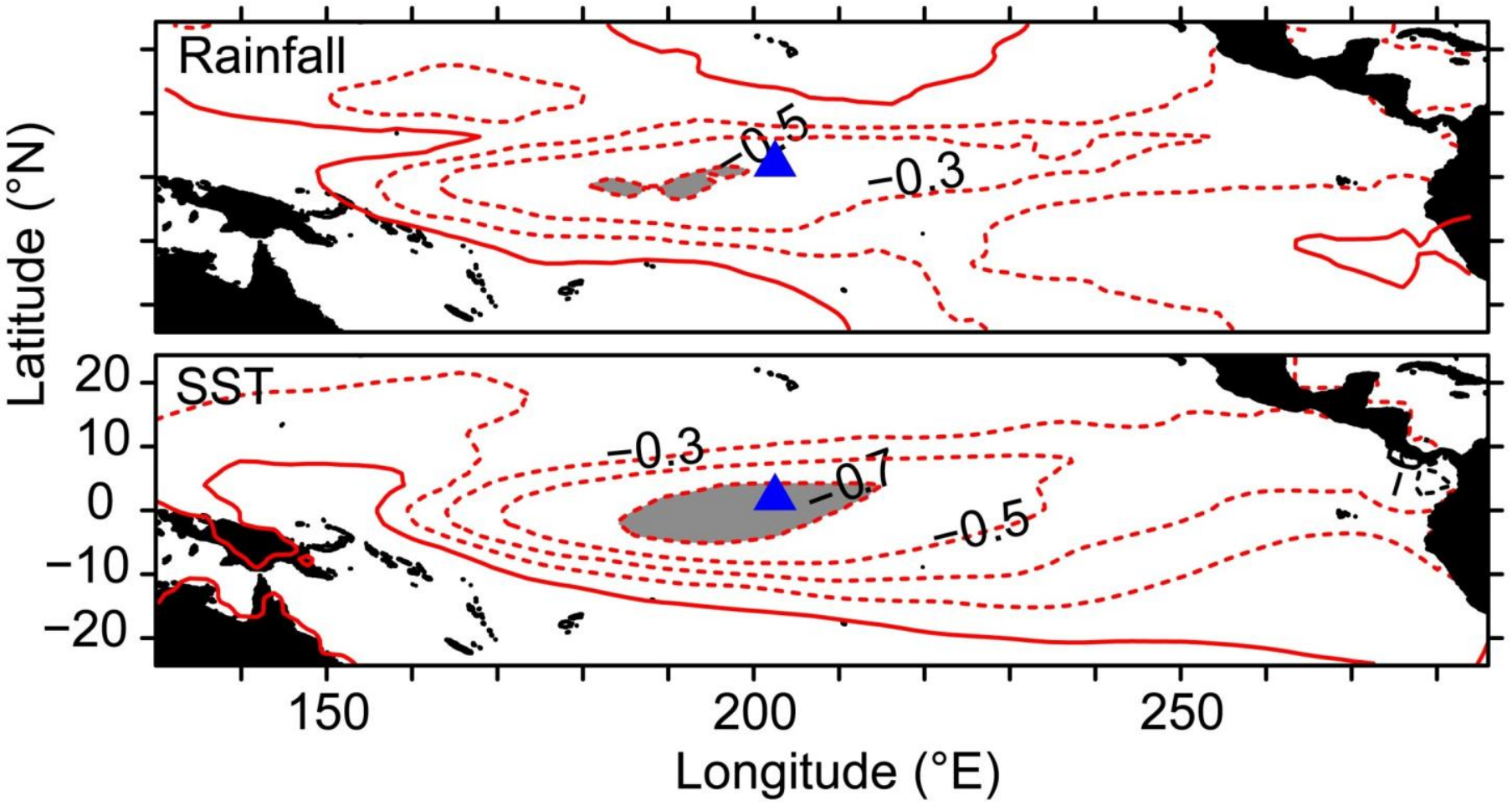
Woodroffe et al. 2000, 2003; McGregor et al. 2011; Glasbergen, McGregor, Zeko et al. (in prep)

Porites microatoll $\delta^{18}O$ and instrumental climate data



McGregor et al. 2011

Correlation of Kiritimati microatoll $\delta^{18}O$ with rainfall and SST



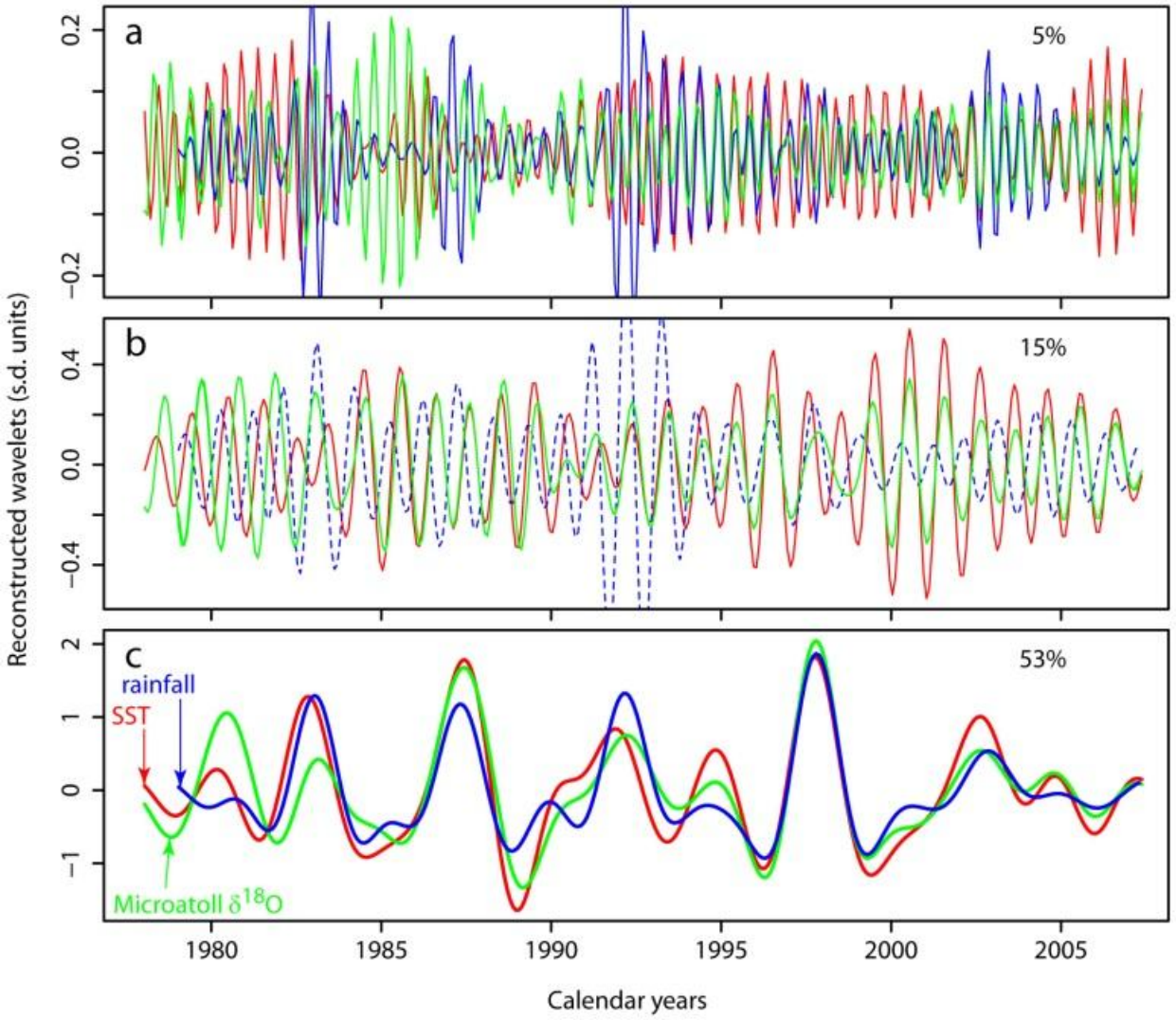
McGregor et al. 2011

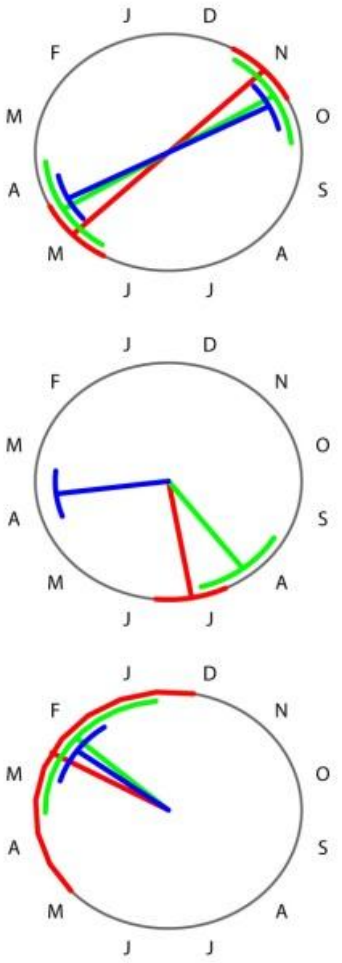
Wavelet & phase plots for Kiritimati microatoll $\delta^{18}O$, ERSST, & rainfall

Semi-annual

Annual

Inter-annual



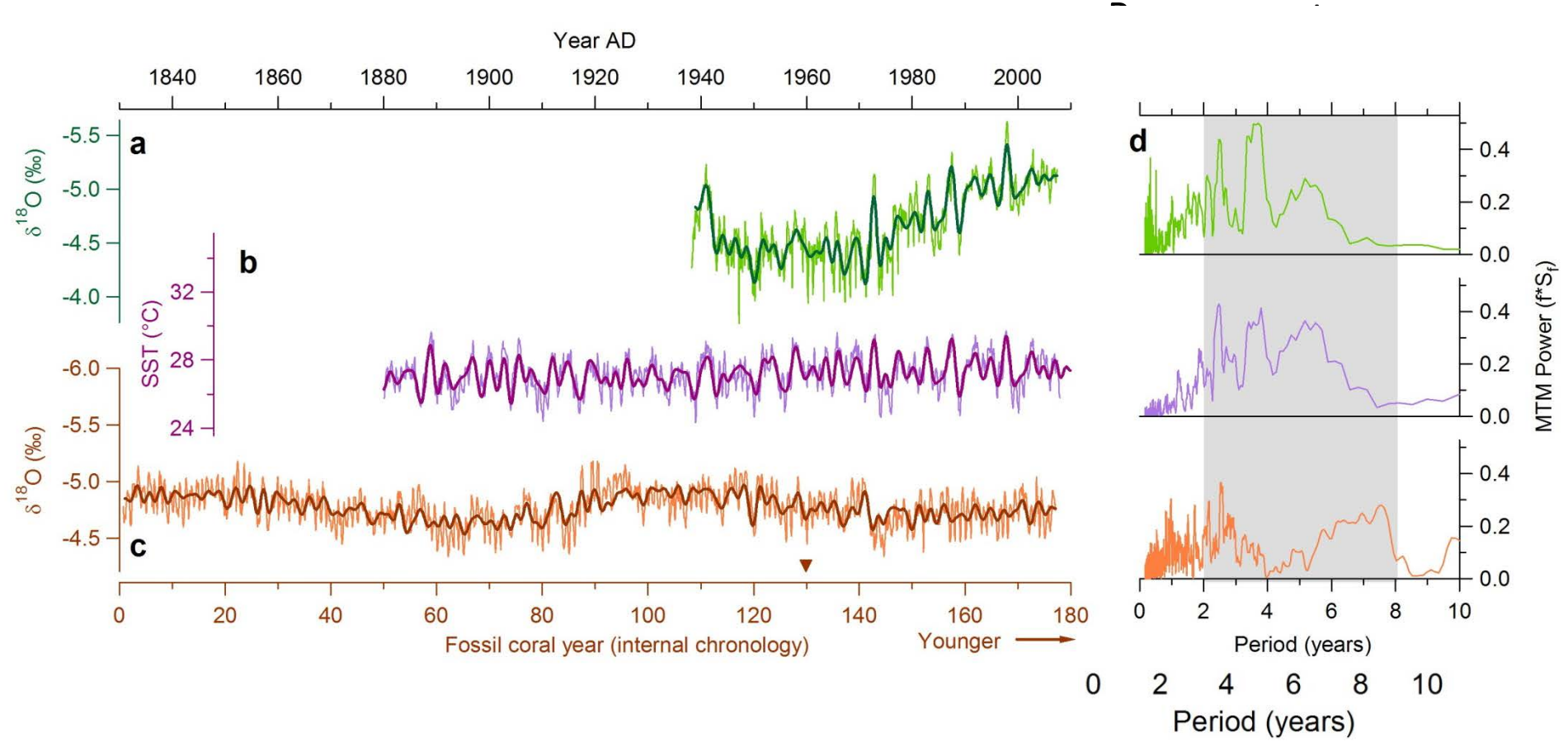


McGregor et al. 2011

1. SEASONALLY-RESOLVED FOSSIL COARL MICROATOLL RESULTS

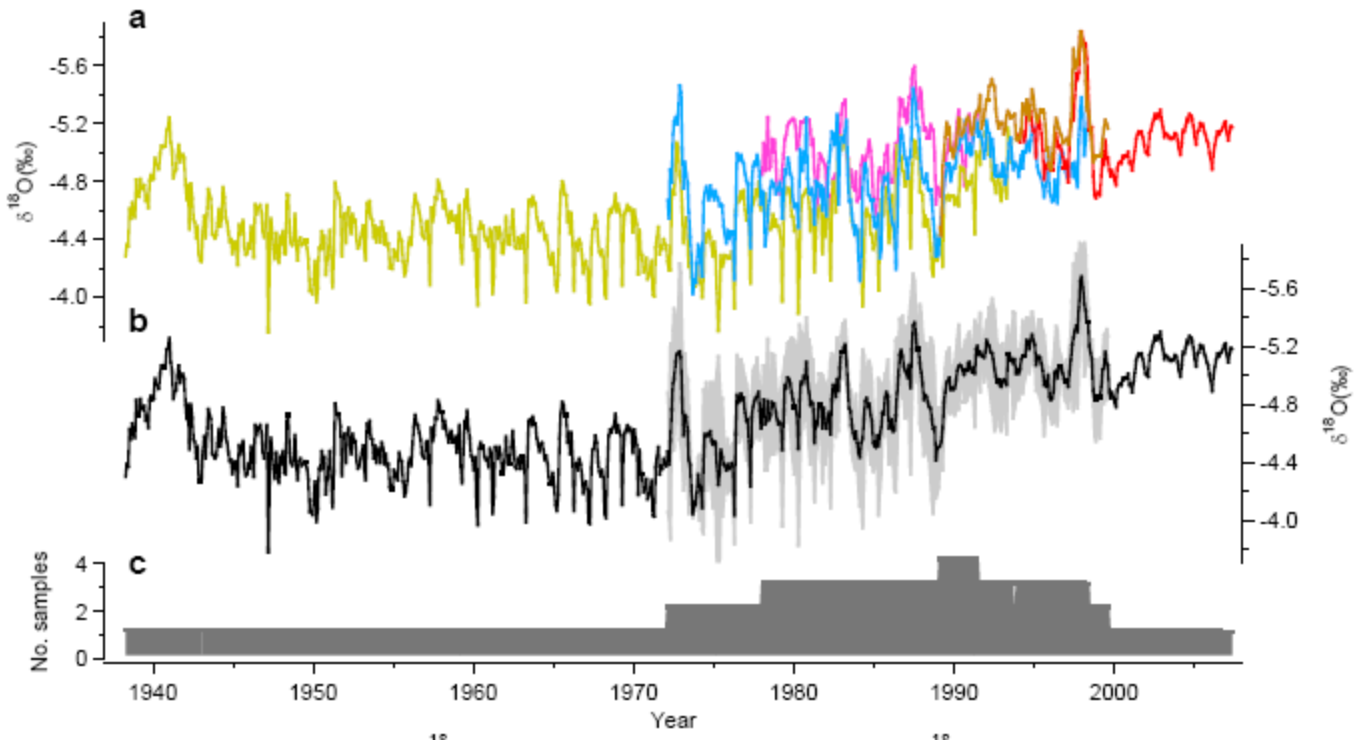
Fossil microatolls at Kiritimati Is.

ENSO frequency 4,300 yr BP



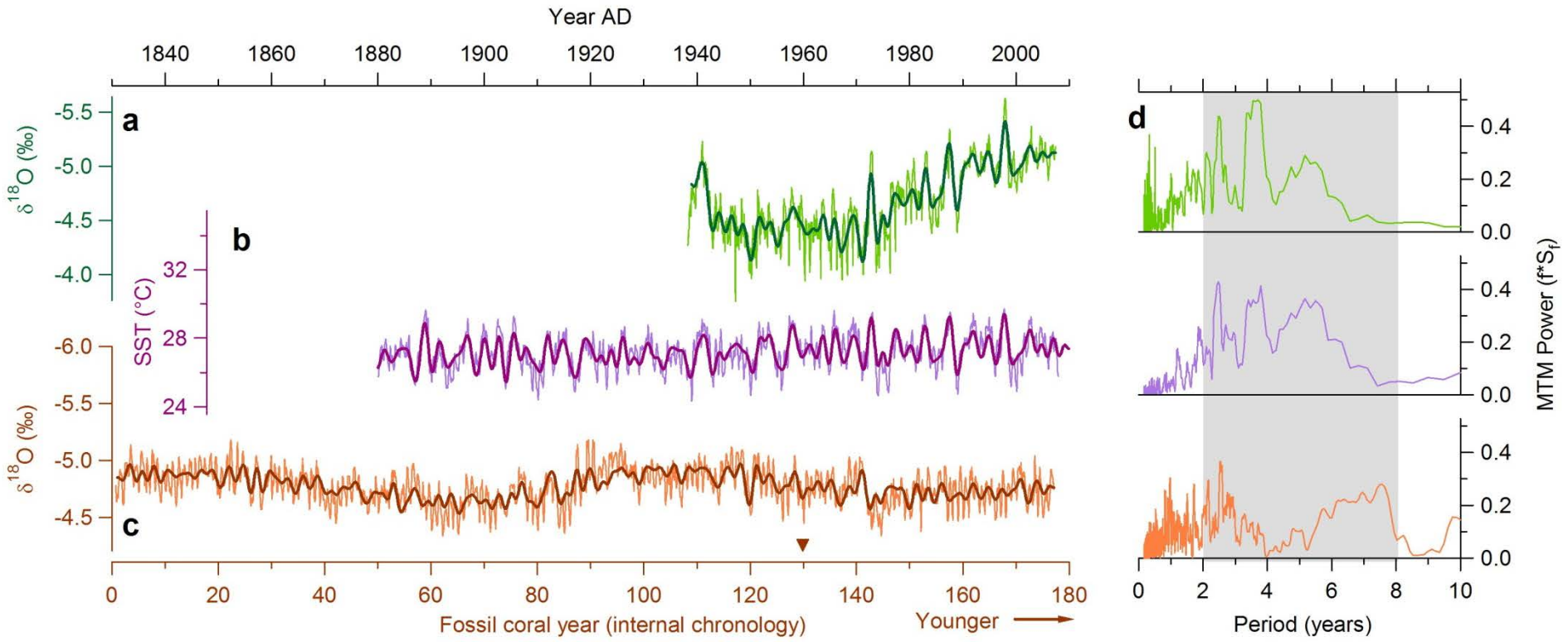
McGregor et al. In prep; Smith et al. 2008

Compilation of modern $\delta^{18}O$ coral records from Kiritimati Island



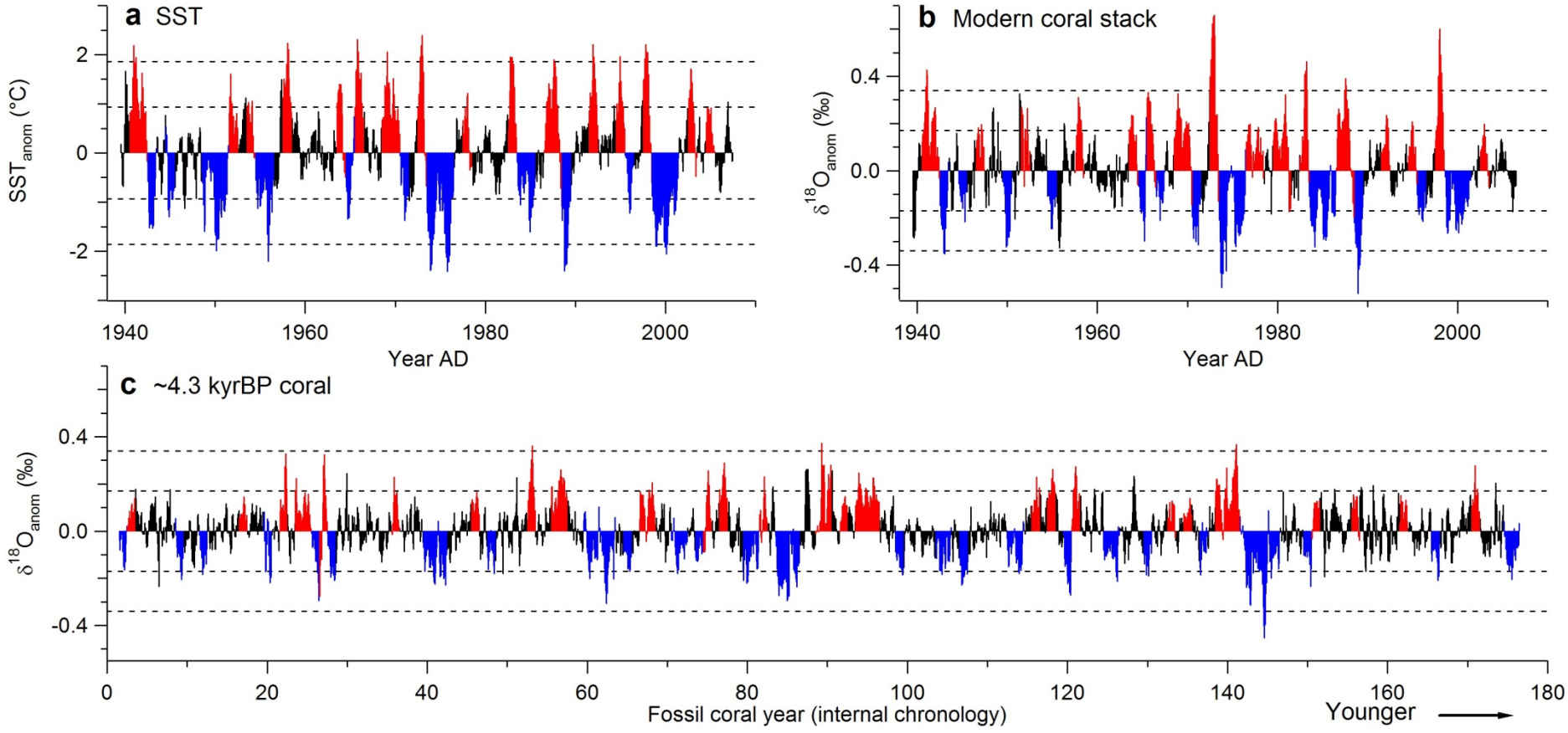
Evans et. al 1998; Nurhati et. al 2009; McGregor et al. 2011a; McGregor, et al. (in prep)

ENSO frequency 4,300 yr BP



McGregor et al. In prep; Smith et al. 2008

ENSO amplitude 4,300 yr BP

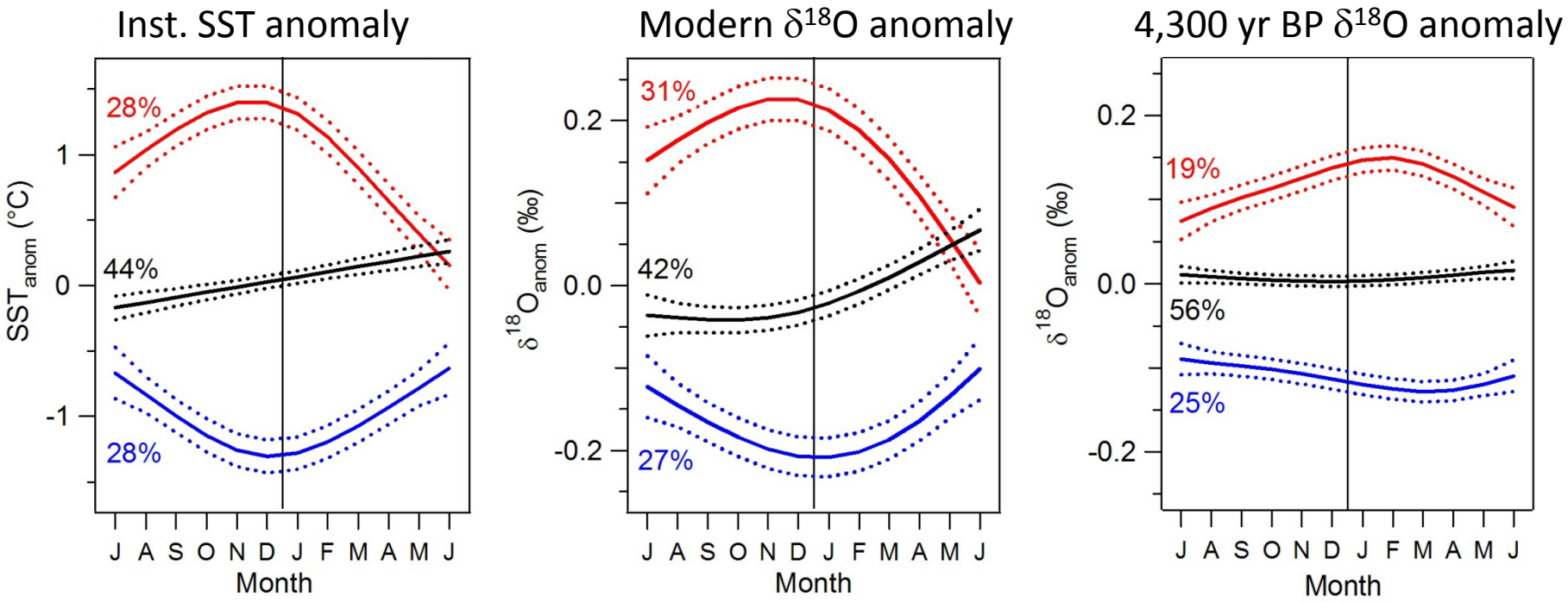


Positive anomaly years (El Niño)

Negative anomaly years (La Niña)

Neutral years

Seasonal timing of ENSO 4,300 yr BP



Positive anomaly years (El Niño)

Negative anomaly years (La Niña)

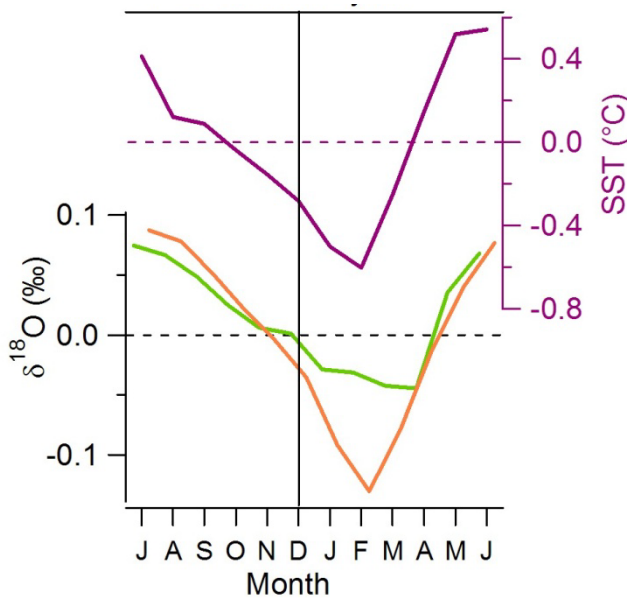
Neutral years

% of interannual record explained by the each year type

What was different 4,300 yr BP?

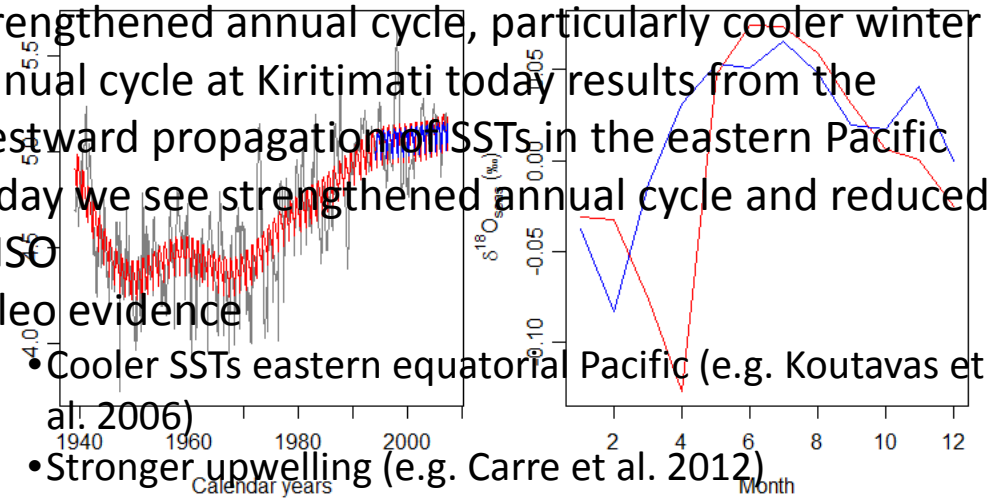
- Changes in timing and seasonality of incoming solar radiation due to orbital forcing
  - Strengthened zonal SST gradient (Clement et al. 1999)
    - Evidence from proxy SST reconstructions from east and west equatorial Pacific
    - Expect the El Nino peak earlier in the calendar year
  - Strengthened Asian monsoon and Walker Circulation (Liu et al. 2000; Zheng et al. 2009)
    - Reduced annual cycle

Changes in the annual cycle 4,300 yrBP

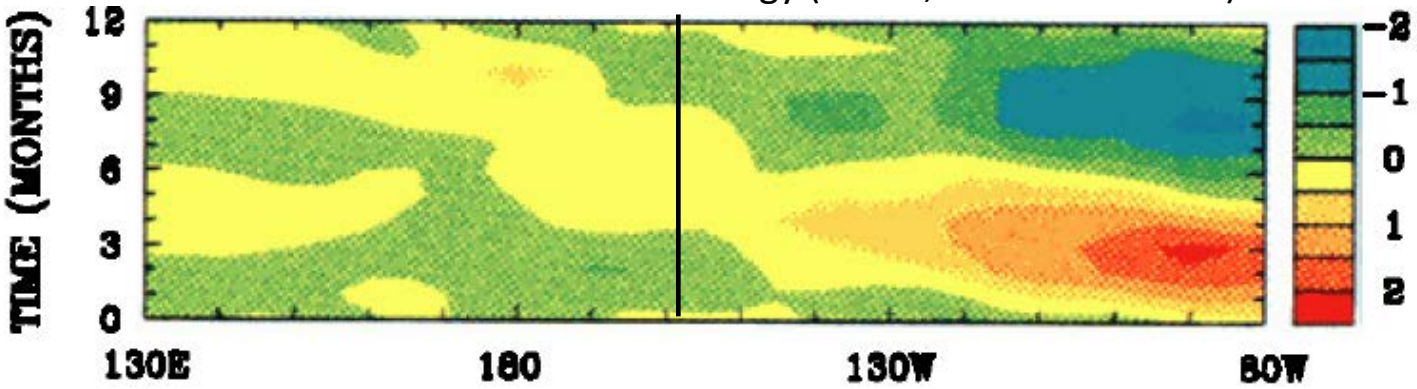


Green = modern, orange = 4,300 yrBP

- Strengthened annual cycle, particularly cooler winter
- Annual cycle at Kiritimati today results from the westward propagation of SSTs in the eastern Pacific
- Today we see strengthened annual cycle and reduced ENSO
- Paleo evidence
  - Cooler SSTs eastern equatorial Pacific (e.g. Koutavas et al. 2006)
  - Stronger upwelling (e.g. Carre et al. 2012)
  - More northerly position of the ITCZ (Haug et al. 2001) increased cross-equatorial winds, stronger meridional SST gradient, stronger annual cycle

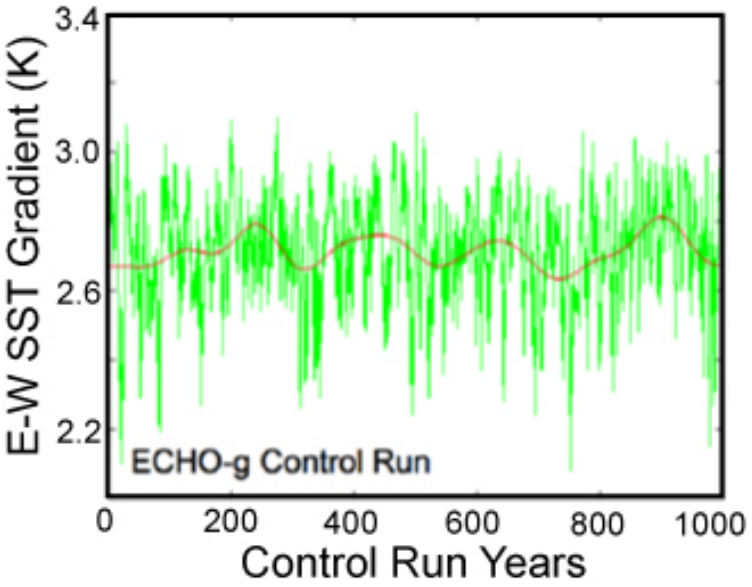


Seasonal SST climatology (4N-4S; Chen et al. 1994)

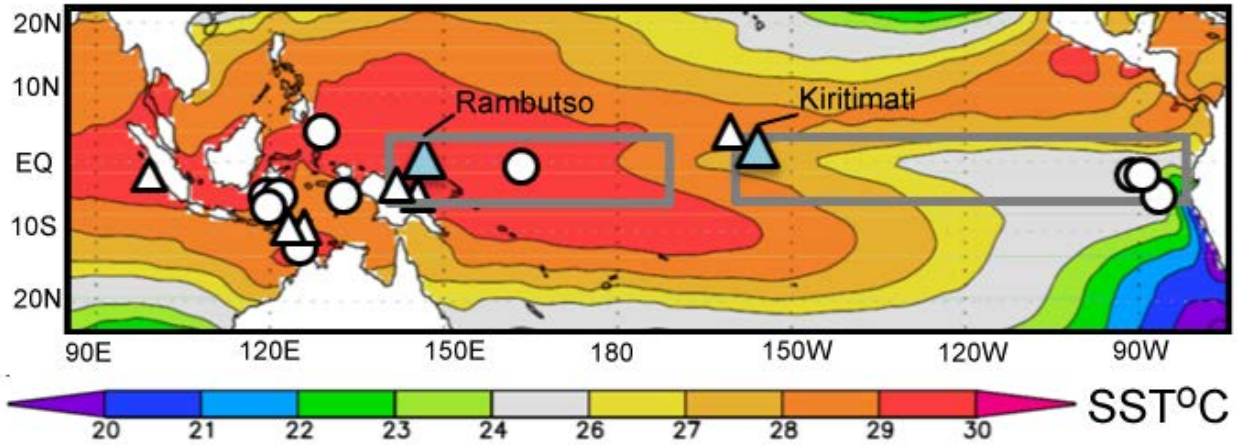


1. CENTENNIAL-SCALE VARIABILITY IN THE EQUATORIAL PACIFIC SST GRADIENT

Centennial-scale variability in model equatorial Pacific SST gradient

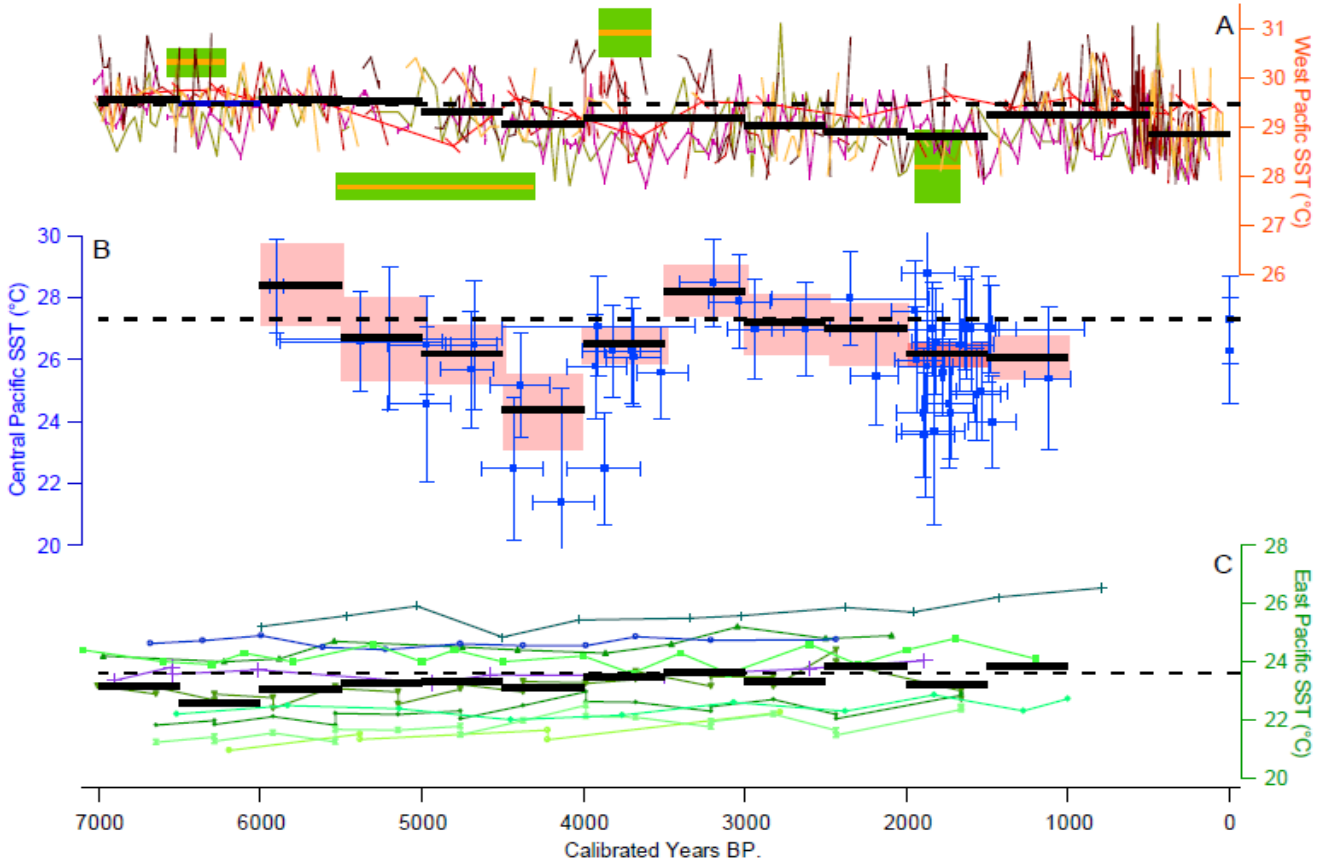


Is there evidence for centennial-scale variability in the E-W equatorial Pacific SST gradient in paleo records?



Model run figure c/o J. Smerdon

Paleo SST compilation to date



Schofield (in prep); Abram et al. 2009; Stott et al. 2004; Koutavas et al. 2002; Koutavas et al. 2006; Koutavas, Sachs 2008; Lea et al. 2006

Key Points

- Modern microatoll a faithful recorder of ENSO
- Changes in ENSO 4,300 yr BP
  - reduced frequency and amplitude
  - El Niño subdued growth and decay and peaks 2-3 months later than today
  - La Niña events also suppressed
  - Strengthened seasonal cycle
  - Changes reflect the influence of the East Pacific dynamics on ENSO
- Looking forward to working here as a Tharp Scholar