Coral records of ENSO through the late Holocene

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A composite of available Holocene coral ENSO activity

- scant fossil coral ENSO reconstructions during Holocene
- no statistically significant reduction in ENSO variance from fossil corals
- primary evidence of reduction comes from 2 lake and 1 marine sediment records (Moy et al., 2002; Conroy et al., 2008; Koutavas et al., 2006)

**but these do not agree!**

Model: Clement et al., 2000; Lake P: Moy et al., 2002; Corals: Cobb et al., 2003; Tudhope et al., 2001; Woodruffe et al., 2003; McGregor and Gagan 2004; Correge et al., 2001
Coral δ¹⁸O decreases when warm (thermodynamics)
Coral δ¹⁸O decreases when rainy (lower seawater δ¹⁸O)
Palmyra coral $\delta^{18}O$ is a sensitive proxy for ENSO

\[ R = -0.66 \]

\[ R = -0.84 \]

Cobb et al., 2003
Overlapping fossil coral $\delta^{18}O$ records during last millennium

But with $\pm 0.09\%$ offsets in mean coral $\delta^{18}O$

Cobb et al., in prep
The Line Islands Coral Collection

1. splice overlapping cores in last millennium
2. modern cores from three islands
3. many cores in mid-Holocene

Palmyra
50 cores U/Th dated
18 cores undated

Christmas
25 cores U/Th dated
51 cores undated

Fanning
17 cores U/Th dated
19 cores undated
Strengths of Line Islands Fossil Corals

1. Modern coral $\delta^{18}$O has high correlations with NIÑO3.4 SST index

2. Overlapping fossil coral $\delta^{18}$O records highly correlated during last millennium; provide uncertainty estimates for single fossil coral reconstructions

3. New collection of >100 fossil corals extends back 7000 years (20-100yrs each)
New fossil coral $\delta^{18}O$ records from Fanning: 6-7kybp

- Fanning 6ky fossil corals show reduction in ENSO variance

- Shift towards cooler and/or drier conditions?

  or

- Role for diagenesis in large mean coral $\delta^{18}O$ shifts?
SEM screening of “coolest” 6ky fossil coral looks OK

- surface coatings represent no more than ~10% by mass
- not enough diagenesis to explain high fossil coral $\delta^{18}O$ values
New Line Islands Fossil Coral Data → no change in ENSO

- added 650 years of monthly-resolved data
- we have tripled the amount of fossil coral data available from the mid- to late-Holocene
- why are most fossil coral ENSO variances less than present?

Model: Clement et al., 2000; Lake P: Moy et al., 2002; Single-foram (purple): Koutavas et al., 2006
Corals: Cobb et al., 2003; Tudhope et al., 2001; Woodruffe et al., 2003; McGregor and Gagan, 2004; Correge et al., 2001
Factors that could compromise fossil coral ENSO reconstructions

1. Location in restricted lagoon setting? NO
   - but Woodruffe et al., 2003 document similar ENSO variance for lagoon micro-atolls and open ocean corals at Xmas
   - and our work documents much larger (2x) ENSO variance for lagoonal corals at Fanning

2. Diagenesis dampened coral δ¹⁸O variability? NO
   - but need ~50% replacement of skeleton to get 50% reduction
   - and our work indicates that an altered young fossil coral has similar ENSO variance to modern coral
   - and diagenesis would predict that heavy coral d18O and reduced ENSO should go together, which is not the case in our reconstruction
A modern-young fossil comparison

Crespo et al., in prep

![Graph showing Coral δ¹⁸O, Fossil coral, Modern coral, Palmyra SST, Coral Sr/Ca, and R values.](image)

- Coral δ¹⁸O
  - R = 0.81
- Fossil coral
- Modern coral
- Palmyra SST
- Coral Sr/Ca
  - R = 0.50
- R(SST, Sr/Ca₉₉ mod) = -0.66
- R(SST, Sr/Ca₉₉ foss) = -0.58

Images of fossil coral surfaces:
- Pore infilling; surface coating
- Smooth, pristine coral surface
- Secondary needles coating surface

Crespo et al., in prep
Factors that could compromise fossil coral ENSO reconstructions

3. Different pattern of ENSO SST and/or precipitation than present?

  e.g. the coral δ¹⁸O signature of the 1982/83 El Niño event was ~50% of expected amplitude because convection “skipped” over the central Pacific
Palmyra coral Sr/Ca as paleo-temperature proxy: Preliminary results

Nurhati et al., 2009

So coral Sr/Ca promises a means of quantifying low-frequency SST and seawater $\delta^{18}O$ variability in Line Island fossil corals

Coral $\delta^{18}O = \text{SST} + \delta^{18}O_{sw}$
Modern coral contains SST trend similar to instrumental record; Reveals large negative $\delta^{18}O_{sw}$ trend $\rightarrow$ anthropogenic freshening
Conclusions

- No fossil coral support for reduced mid-Holocene ENSO variance

- Reduced ENSO variance throughout late Holocene, combined with evidence for cooler and drier conditions

- Difficult to explain observed changes with diagenesis

- Strong evidence for late 20th century freshening in the central tropical Pacific (-0.4\%), consistent with GCMs response to anthropogenic forcing

→ role for large hydrological and/or circulation changes in mid- to late-Holocene (+0.5-1.0\%)?
What’s next?

How much does seawater $\delta^{18}O_{sw}$ vary today across Line Islands?

*Postdoc Jess Conroy*

Careful diagenetic investigations on fossil corals & Micro-scale Sr/Ca analyses of pristine sections of fossil coral skeletons

*Student Hussein Sayani*

We probably need many more corals! Koutavas-like approach applied to 5-10yr-long sequences?