ENSO variability during the Holocene: an integrated data-model perspective

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1. Introduction

- Past changes can provide insights into the dynamics of El Niño–Southern Oscillation (ENSO).
- Long-term trends allow us to explore the sensitivity of ENSO to external forcings.
- Changes on shorter timescales allow us to explore the role of internal variability.
- Here, we study past changes in ENSO using geochemical data from central Pacific corals and a suite of climate model simulations.

2. Data and methods

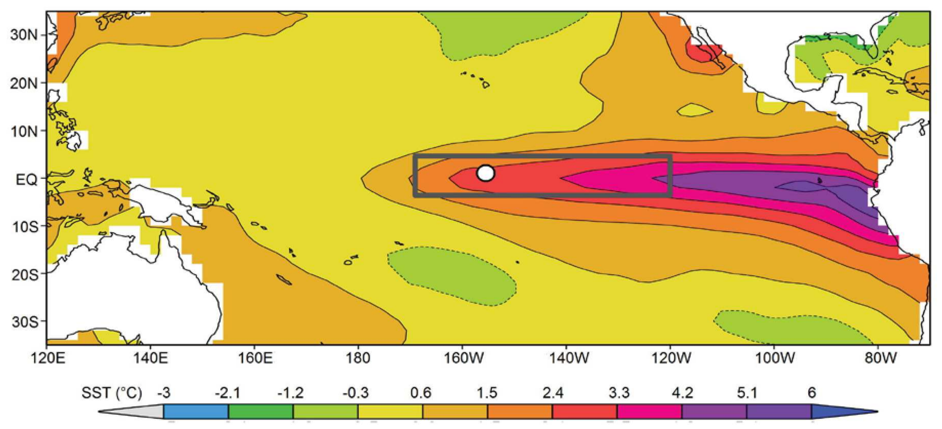

Figure 1. Kiritimati Island (from McGregor et al., 2013a).

- Corals are obtained from Kiritimati Island, an optimal site located in the Niño 3.4 region.
- Simulations are conducted using the CSIRO Mk3L climate system model (Phipps et al., 2011, 2012).
- The model is run with and without the application of natural (orbital, solar, volcanic) and anthropogenic (greenhouse gas) forcings.

3. Long-term trends: the Holocene

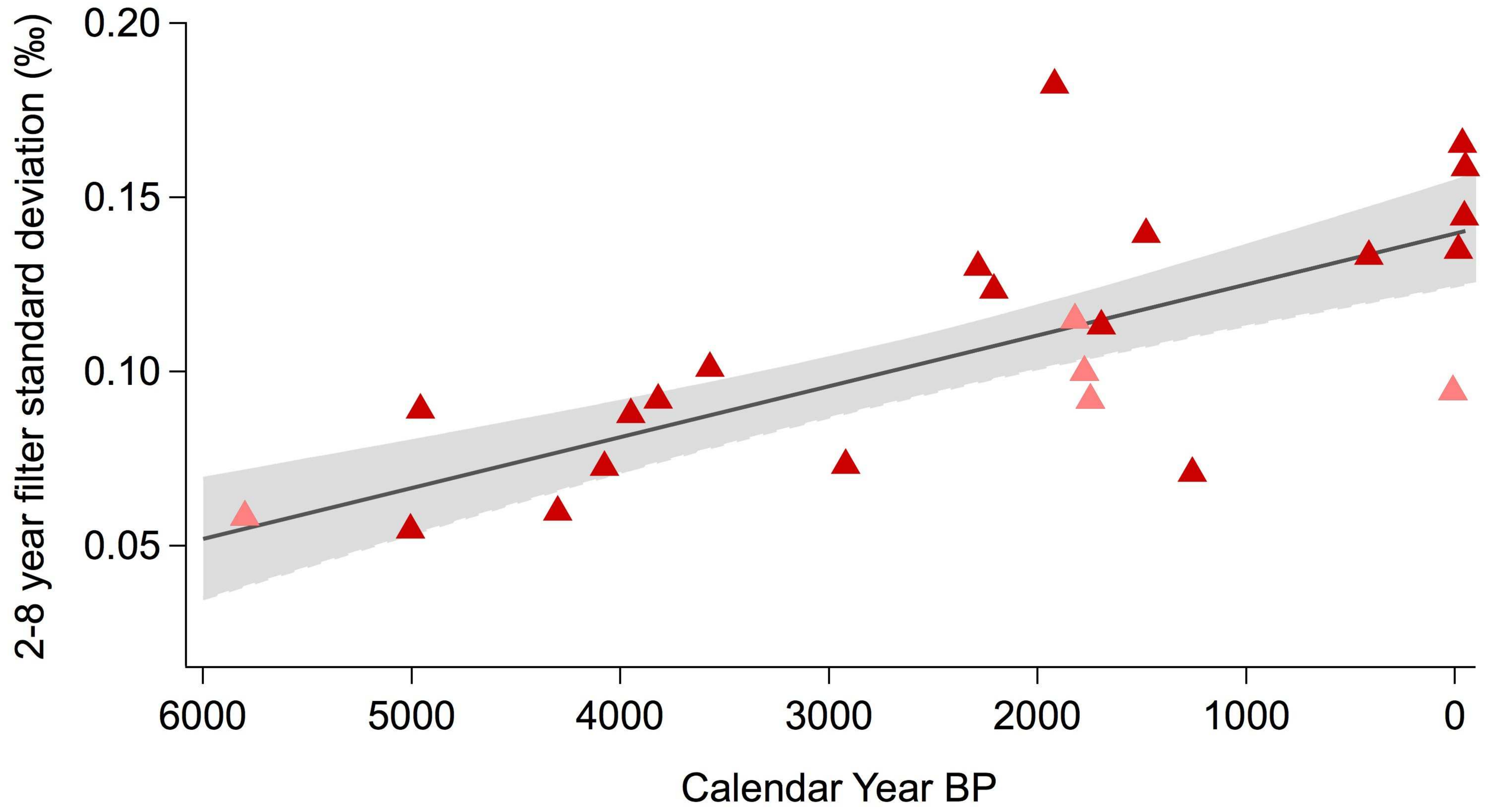

Figure 2. The standard deviation in coral δ^{18}O records. Red triangles = existing records (Cobb et al., 2013; McGregor et al., 2011; McGregor et al., 2013a; Woodroffe and Gagan, 2000; Woodroffe et al., 2003); pink triangles = new records (Devriendt et al., in prep.; McGregor et al., in prep.); black line = line of best fit; grey shading = 95% confidence interval.

- Applying linear regression to coral δ^{18}O records from Kiritimati Island, we find a statistically-significant increase in ENSO variance over the past 6,000 years.

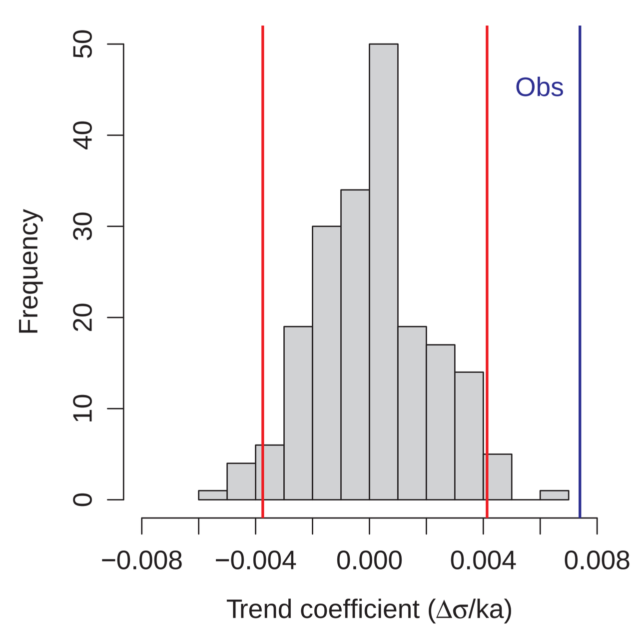

Figure 3. Linear trends sampled from a 10,000-year unforced model simulation. Red lines indicate 95% confidence interval.

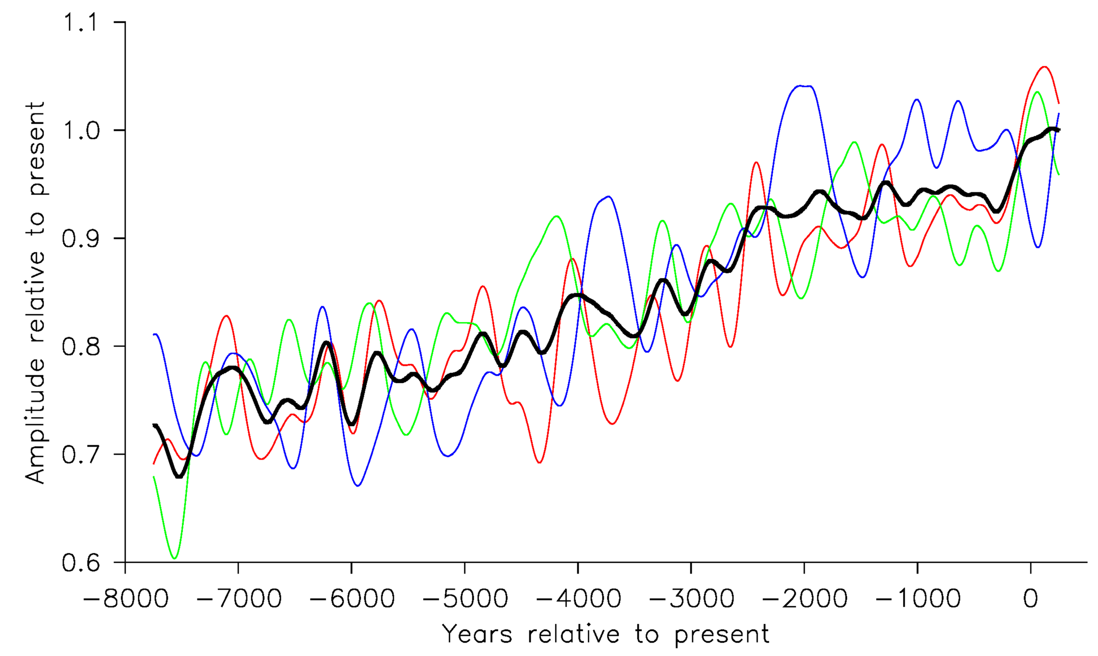

Figure 4. Simulated changes in ENSO amplitude, from an ensemble of three model simulations driven with orbital forcing. Coloured lines indicate individual simulations; black line indicates ensemble mean.

- The reconstructed trend is not consistent with the unforced model simulations.
- However, it can be reproduced once orbital forcing is taken into account.
- The trend therefore appears to represent a response to external forcing, possibly modulated by changes in ENSO flavours (Karamperidou et al., 2015).

4. How does orbital forcing drive ENSO?

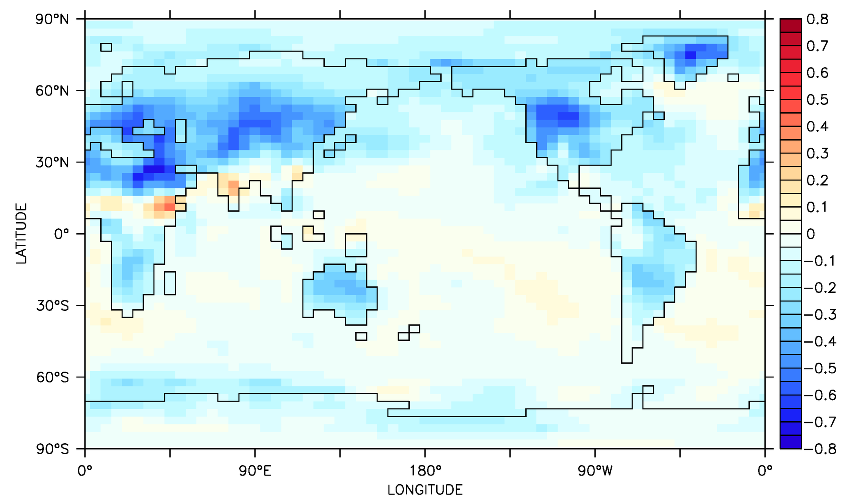

Figure 5. The simulated linear trend in August surface air temperature (°C/ka) over the past 8 ka.

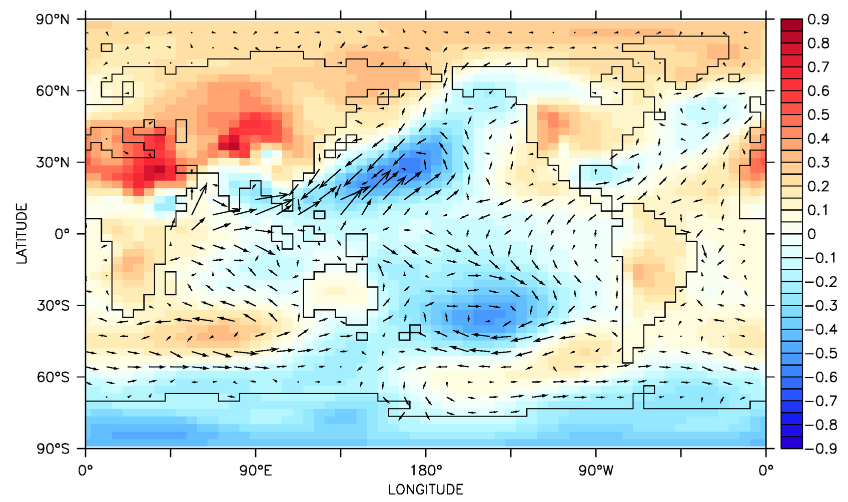

Figure 6. The simulated linear trend in August MSLP (hPa/ka) and surface wind stress over the past 8 ka.

- In transient model simulations, an orbitally-driven decrease in summer insolation over the Asian landmass causes cooling from the past into the present.
- This results in a weakening of the Asian summer monsoon system, leading to a weakening of the easterly trade winds in the western Pacific.
- A similar mechanism has been found in previous snapshot simulations (Liu et al., 2000; Zheng et al., 2008; Phipps and Brown, 2010), although a more localised response to precessional forcing has also been suggested (Liu et al., 2014).

5. Decadal changes: the last millennium

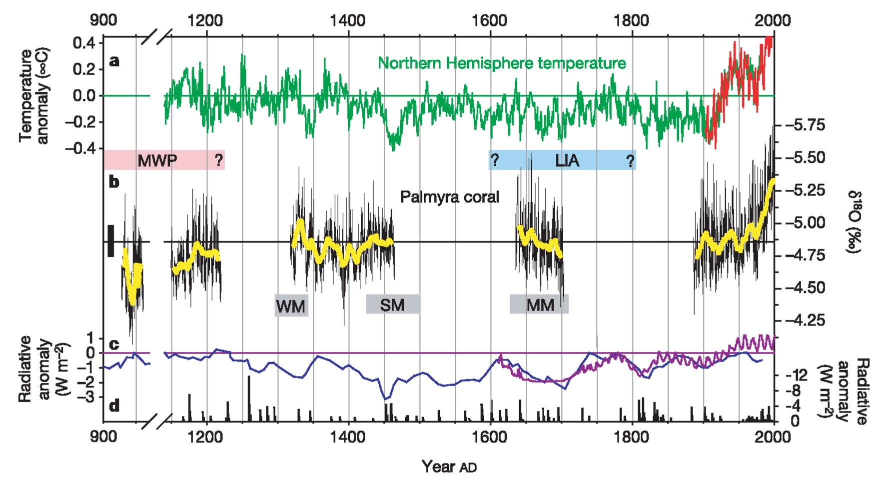

Figure 7. Proxy climate records and external forcing during the last millennium (from Cobb et al., 2003).

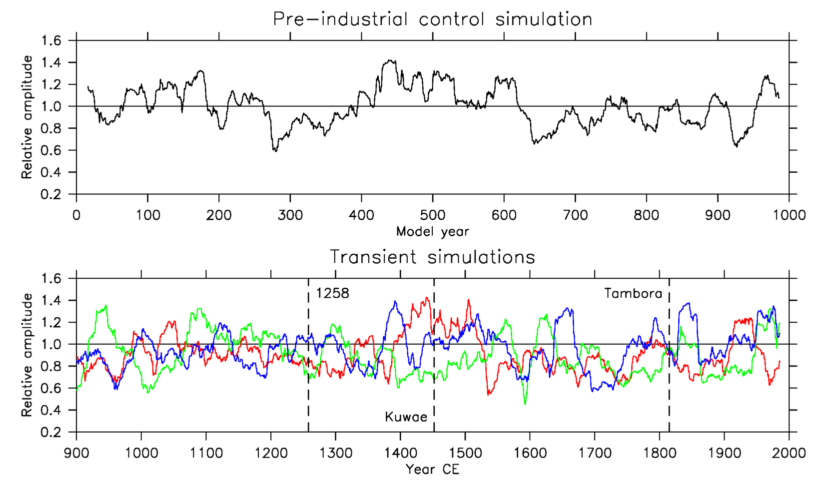

Figure 8. Changes in ENSO variance in unforced and forced model simulations (from Phipps et al., 2013).

- Using corals from the central Pacific, Cobb et al. (2003) concluded that the majority of ENSO variability over the last millennium may have arisen internally.
- Our results support this conclusion: in transient model simulations spanning the last millennium, ENSO variance is uncorrelated with external forcings.
- Nonetheless, reconstructions do suggest that ENSO activity has increased in recent decades (e.g. McGregor et al., 2013b).

6. Conclusions

- By combining central Pacific corals with a suite of climate model simulations, we gain the following insights:
  - on long timescales, ENSO can exhibit a strong and systematic response to external forcing
  - on decadal timescales, variability appears to arise predominantly from within the ENSO system itself.

References

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