The impact of natural and anthropogenic forcings on ENSO: insights from the past

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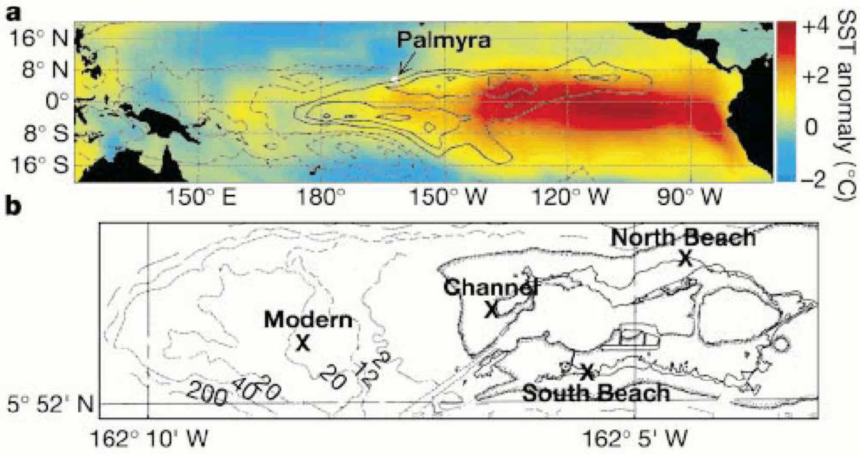
Motivation

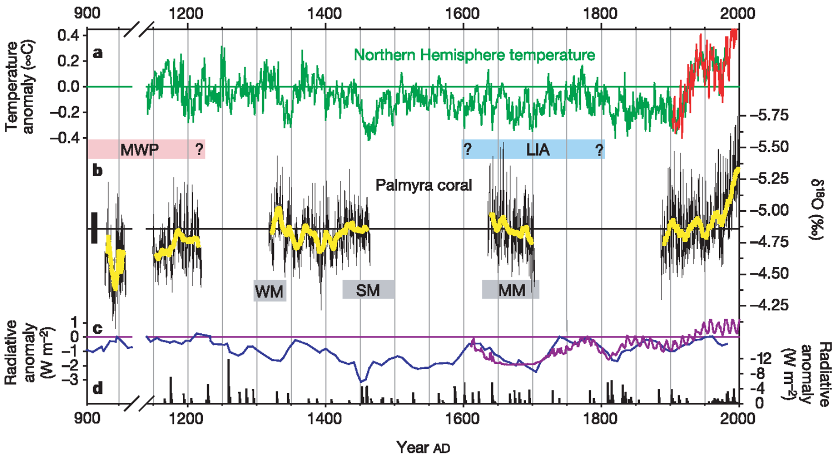
- We want to study the role of natural and anthropogenic forcings in driving the climate of the central Pacific.
- In particular, we want to test the conclusion of Cobb et al. (2003) that changes in ENSO variability are decoupled from the mean state and instead arise from within the internal dynamics of the ENSO system itself.
- The observational record is too short to adequately explore this.
- We need to use palaeoclimate proxy data to reconstruct past changes in the climate of the central Pacific.
- We need to use climate modelling to test dynamical hypotheses.

Coral from Palmyra Island



Cobb et al. (2003), *Nature*

Coral from Palmyra Island

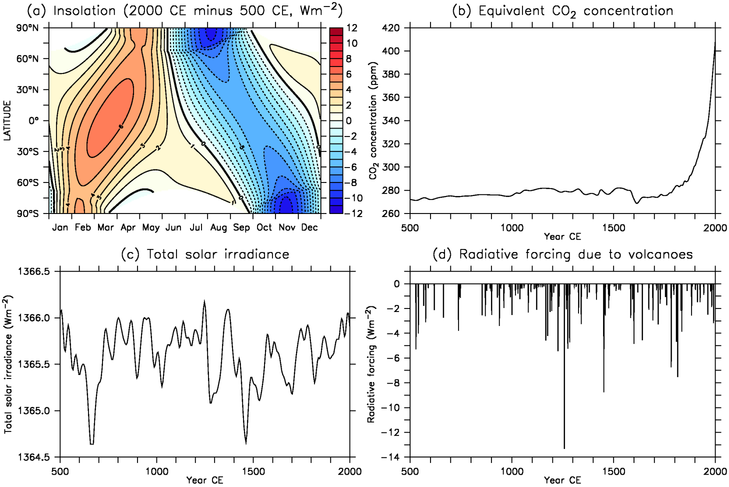


Cobb et al. (2003), *Nature*

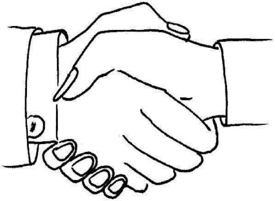
Climate model simulations

- The CSIRO Mk3L climate system model (Phipps et al., 2011, 2012)
  - Atmospheric general circulation model ($5.6^\circ \times 3.2^\circ$, 18 levels)
  - Ocean general circulation model ($2.8^\circ \times 1.6^\circ$, 21 levels)
  - Dynamic-thermodynamic sea ice model
  - Land surface scheme
- 10,000-year pre-industrial control simulation
- Three transient simulations of the past 1500 years
  - Orbital forcing
  - Anthropogenic greenhouse gases
  - Solar irradiance
  - Volcanic aerosols

Climate forcings



The “handshake” question



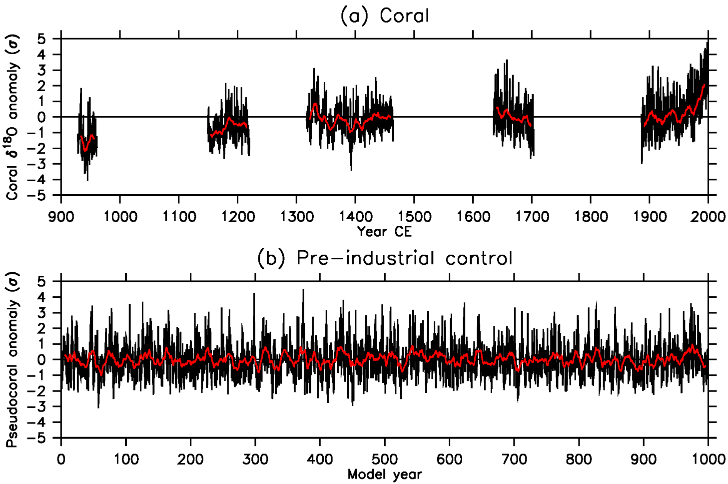
Deriving a pseudocoral

- Corals provide a single chemical variable: δ^{18}O
- The climate model simulates physical variables: SST, SSS, P, E...
- These variables are not directly comparable
- The solution is to construct a "pseudocoral" (Brown et al., 2008)
- Using the pre-industrial control simulation, we regress a set of potential predictors (SST, SSS, P, E) onto the simulated Niño 3.4 SST anomaly
- We obtain the following pseudocoral:

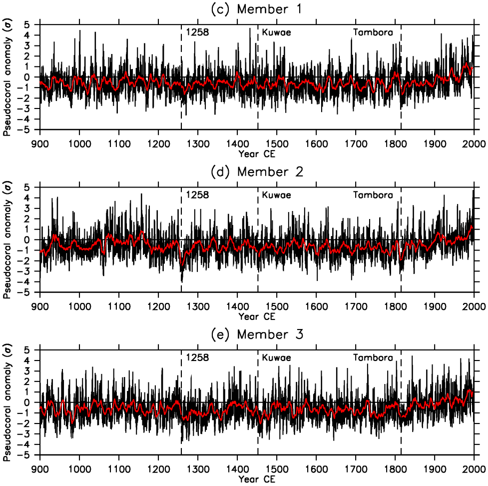
$$C = \underset{(\pm 0.015)}{0.692}\,\Delta SST - \underset{(\pm 0.056)}{0.708}\,\Delta SSS + \underset{(\pm 0.002)}{0.023}\,\Delta P + \underset{(\pm 0.013)}{0.248}\,\Delta E$$

- This indicator describes 70% of the simulated ENSO variance

Reconstructed and simulated mean state



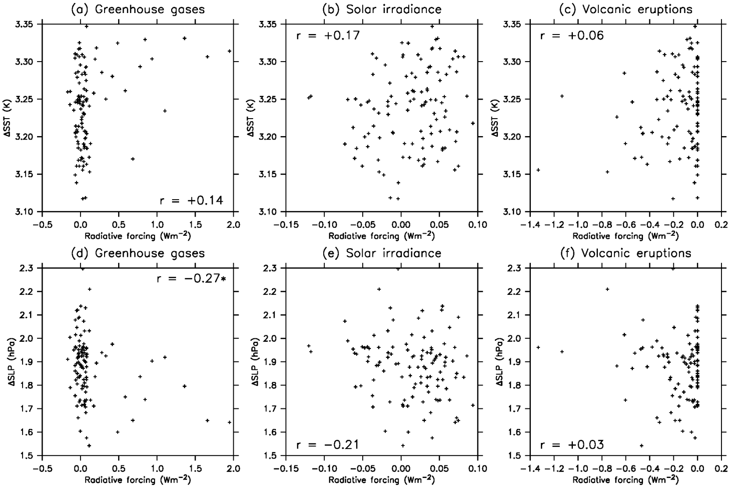
Reconstructed and simulated mean state



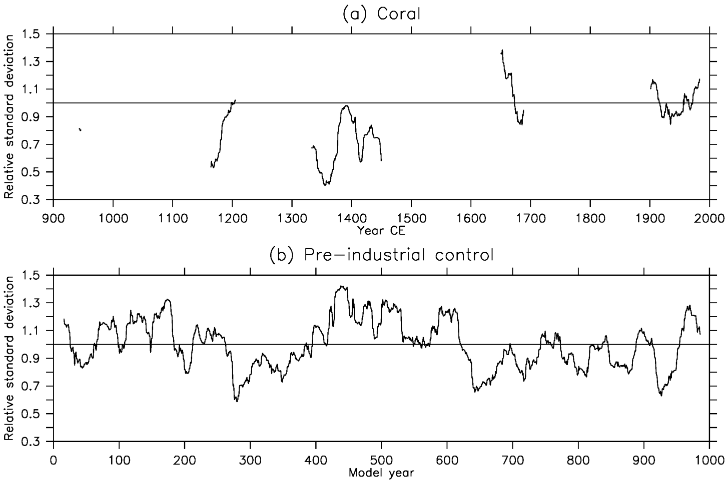
Mean state versus individual forcings

Ensemble member	Greenhouse gases	Solar irradiance	Volcanic eruptions
(a) Annual mean			
1	**+0.31**	+0.11	0.00
2	**+0.28**	**+0.17**	+0.04
3	**+0.31**	**+0.19**	+0.05
Mean	**+0.47**	**+0.25**	+0.04
(b) Decadal mean			
1	**+0.59**	+0.22	+0.12
2	**+0.50**	**+0.29**	**+0.33**
3	**+0.59**	**+0.35**	**+0.23**
Mean	**+0.71**	**+0.37**	**+0.29**

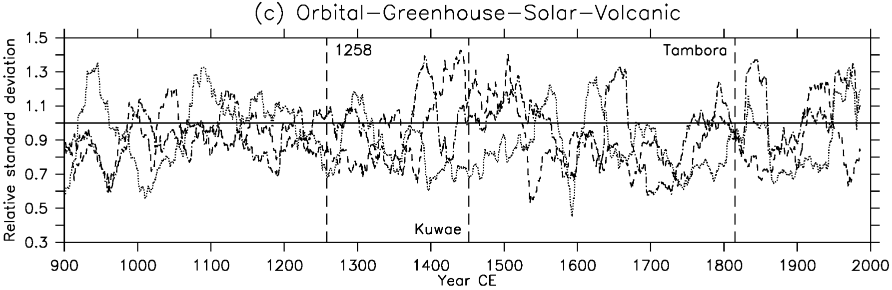
Mean state versus individual forcings



Reconstructed and simulated ENSO amplitude



Reconstructed and simulated ENSO amplitude



ENSO amplitude versus individual forcings

Ensemble member	Greenhouse gases	Solar irradiance	Volcanic eruptions
1	+0.02	-0.24	0.00
2	+0.14	+0.27	+0.10
3	**+0.32**	-0.09	+0.03
Mean	+0.30	-0.04	+0.09

Conclusions

- There are statistically-significant roles of solar irradiance, volcanic eruptions and greenhouse gases in driving changes in the mean state of the central Pacific over the past 1100 years.
- The dynamical response of the model on decadal timescales appears to be characterised by a "Weaker Walker" response to changing anthropogenic greenhouse gases.
- There is no evidence of any systematic influence of natural or anthropogenic forcings on the amplitude of the simulated ENSO variability.
- Our results are therefore consistent with the conclusion of Cobb et al. (2003) that changes in ENSO variability are uncorrelated with either external forcings or changes in the mean state.
- This supports the notion that ENSO is a system where variability arises from internal dynamics, independent of external forcing.

References

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