8,000 years of El Niño: Towards data-model integration

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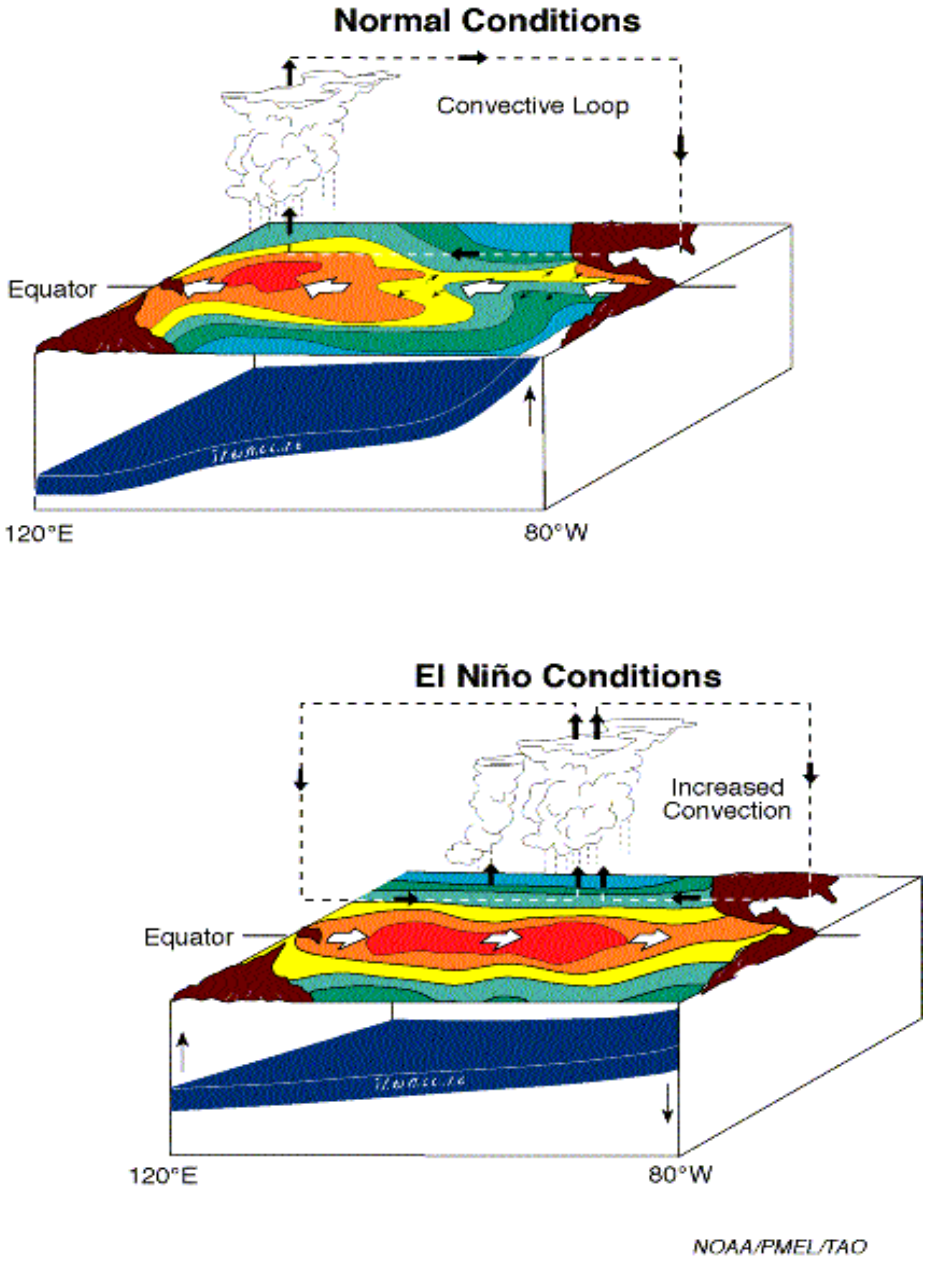
Overview

- El Niño past, present and future
- The coral record
- Climate modelling
- Data-model integration

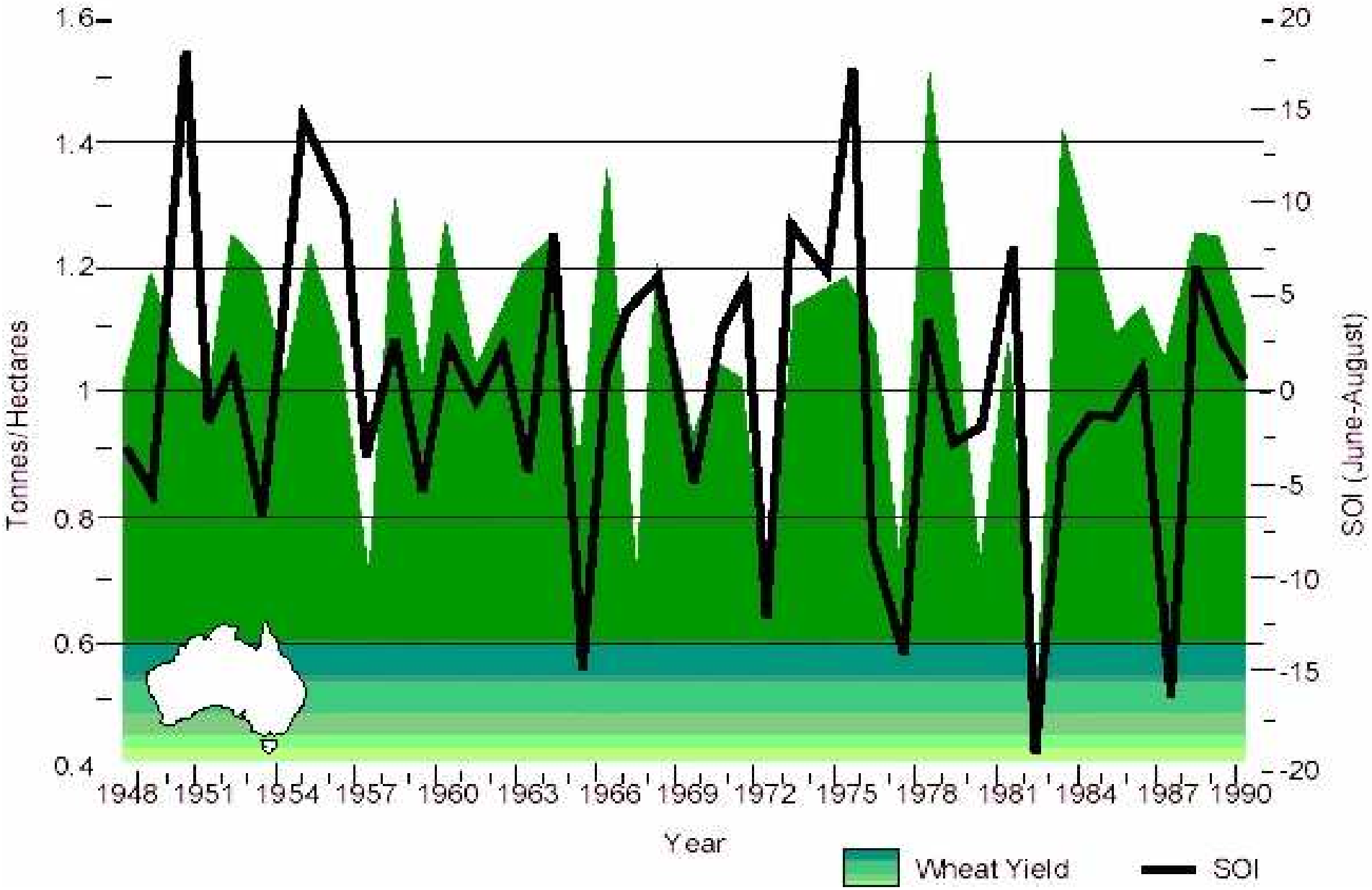
El Niño past, present and future

What is El Niño?

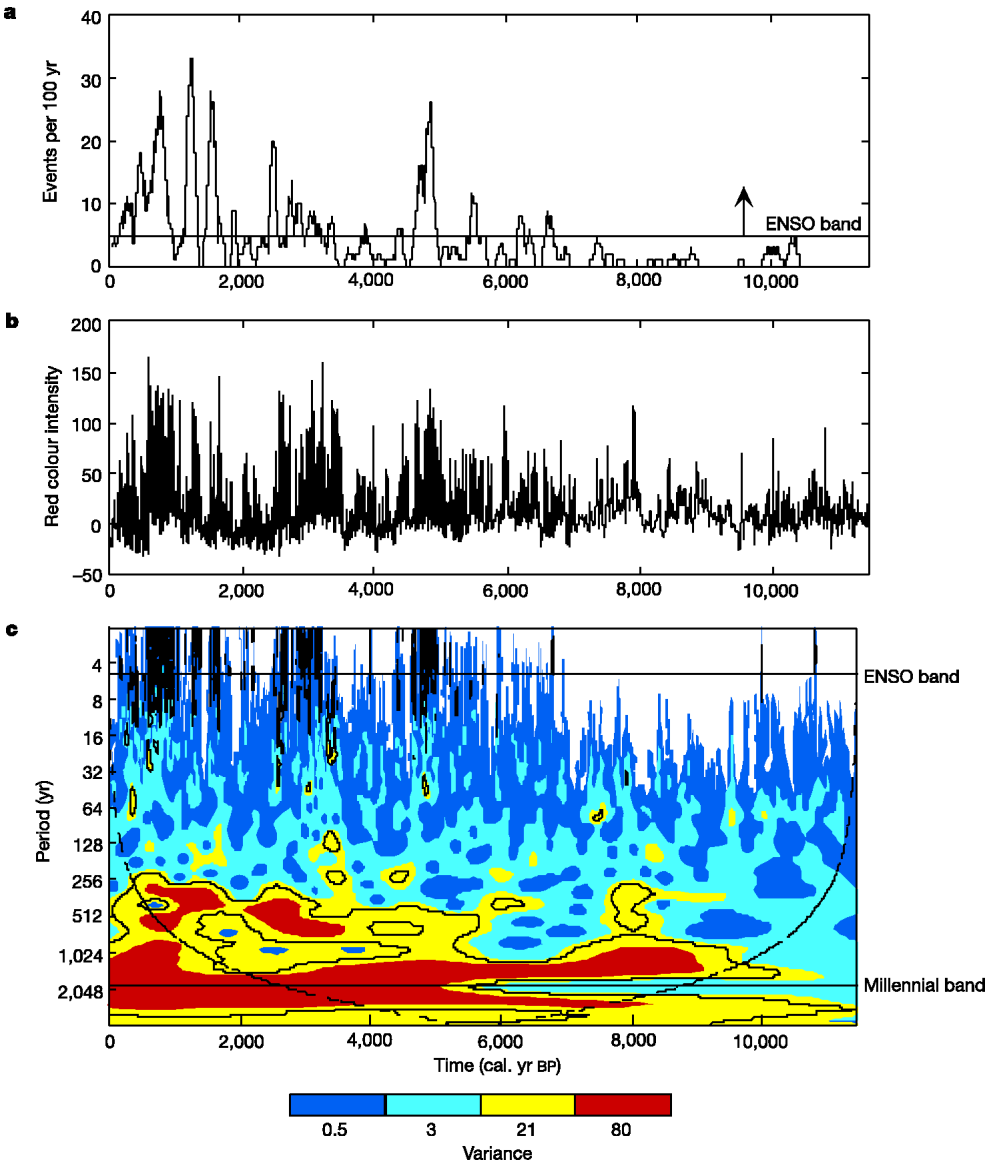


- El Niño–Southern Oscillation (ENSO) is the dominant mode of internal variability within the coupled atmosphere-ocean system
- Irregular period of ∼2–7 years
- Average state of the system involves strong easterly trade winds pushing warm water to the east
- In an El Niño event, these winds slacken and the warm water flows eastwards
- Increased rainfall in the eastern Pacific, reduced rainfall in the west

El Niño and Australian wheat yield



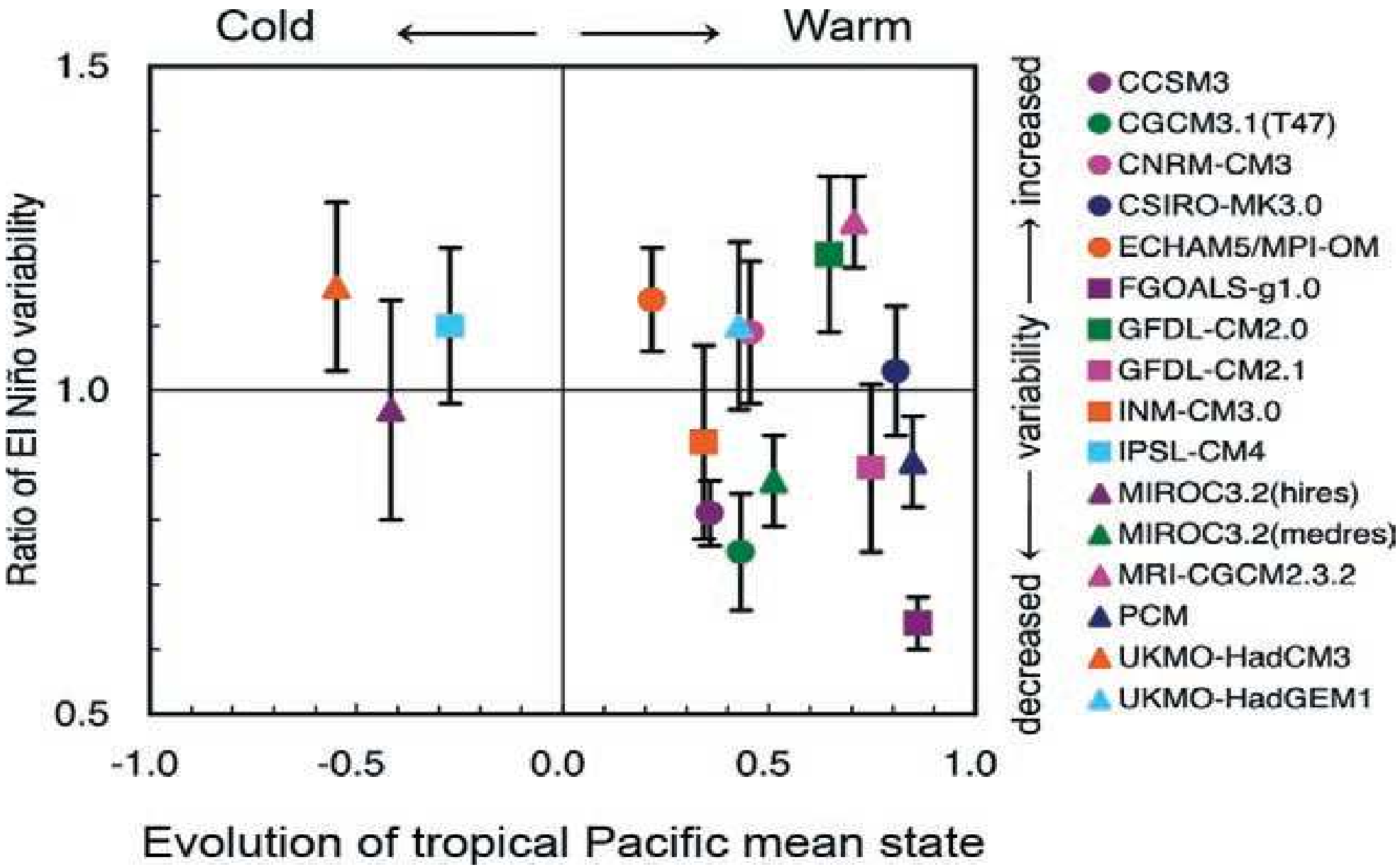
El Niño has changed over the Holocene ...



Moy et al. (2002), *Nature*

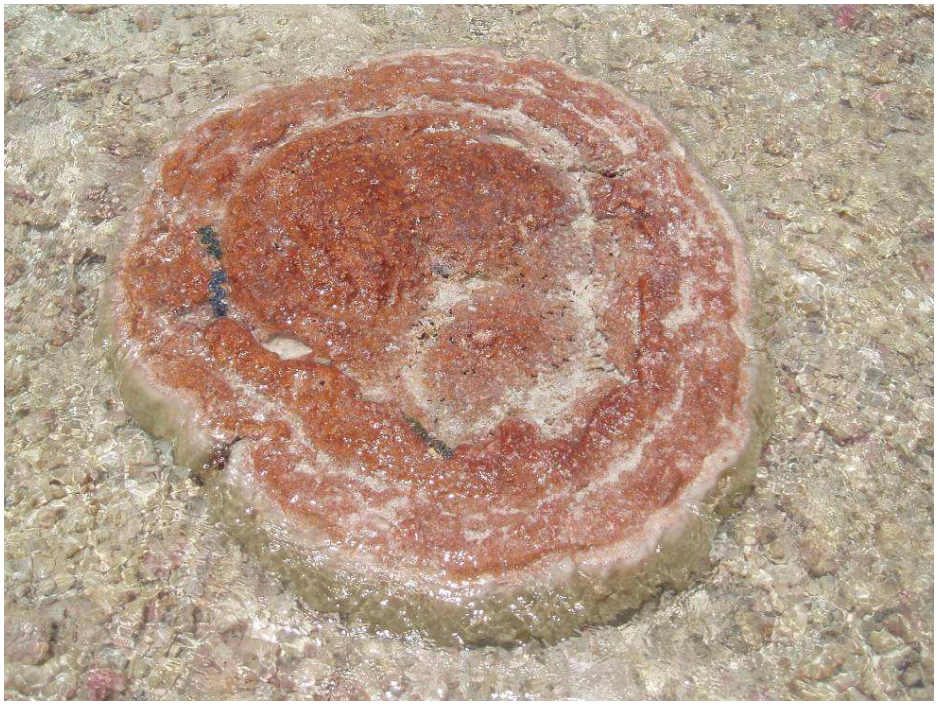
- ENSO variability has increased over the past 8,000 years
- El Niño events have increased in frequency and magnitude
- Evidence of a peak in ENSO variability at 2–1 ka BP
- Strong variability on centennial and millennial timescales
- These changes provide an opportunity to learn more about ENSO dynamics

... but how will it change in future?



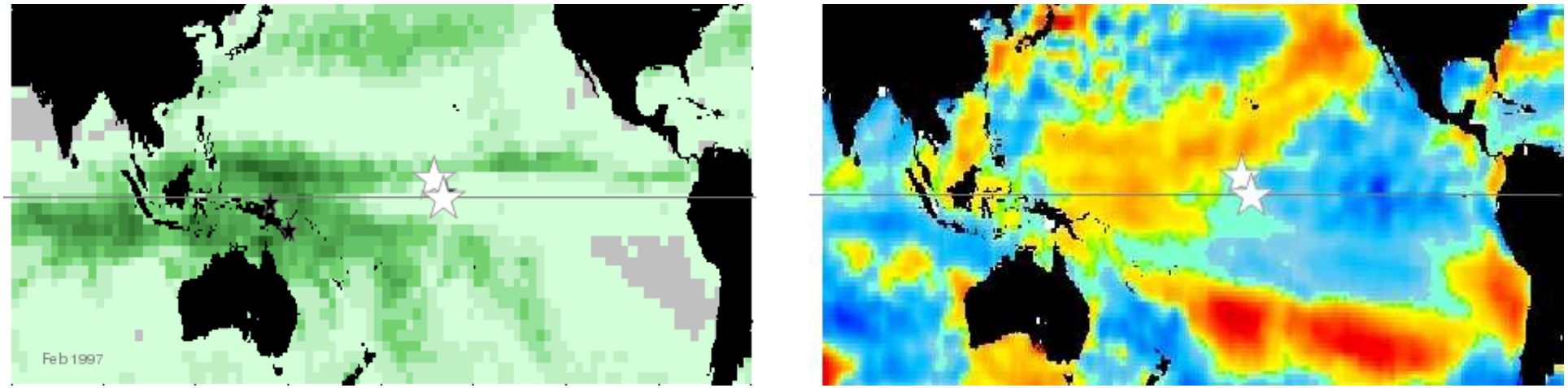
Guilyardi et al. (2009), *BAMS*

The coral record

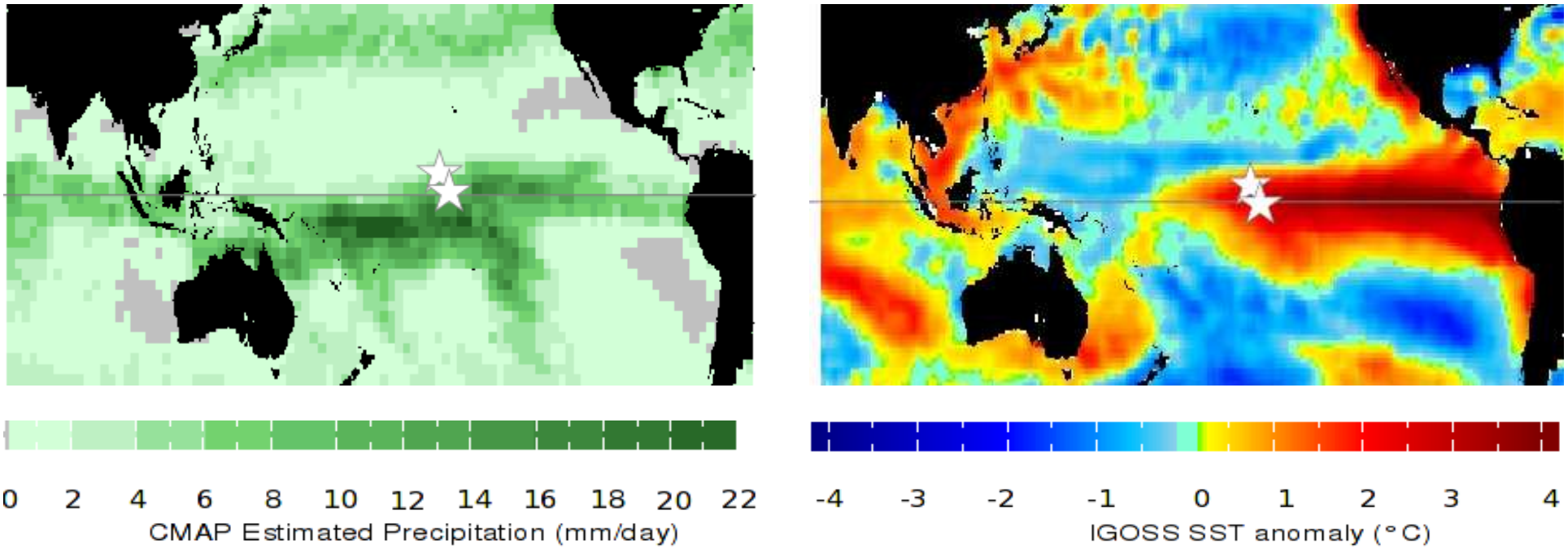


El Niño centres of action

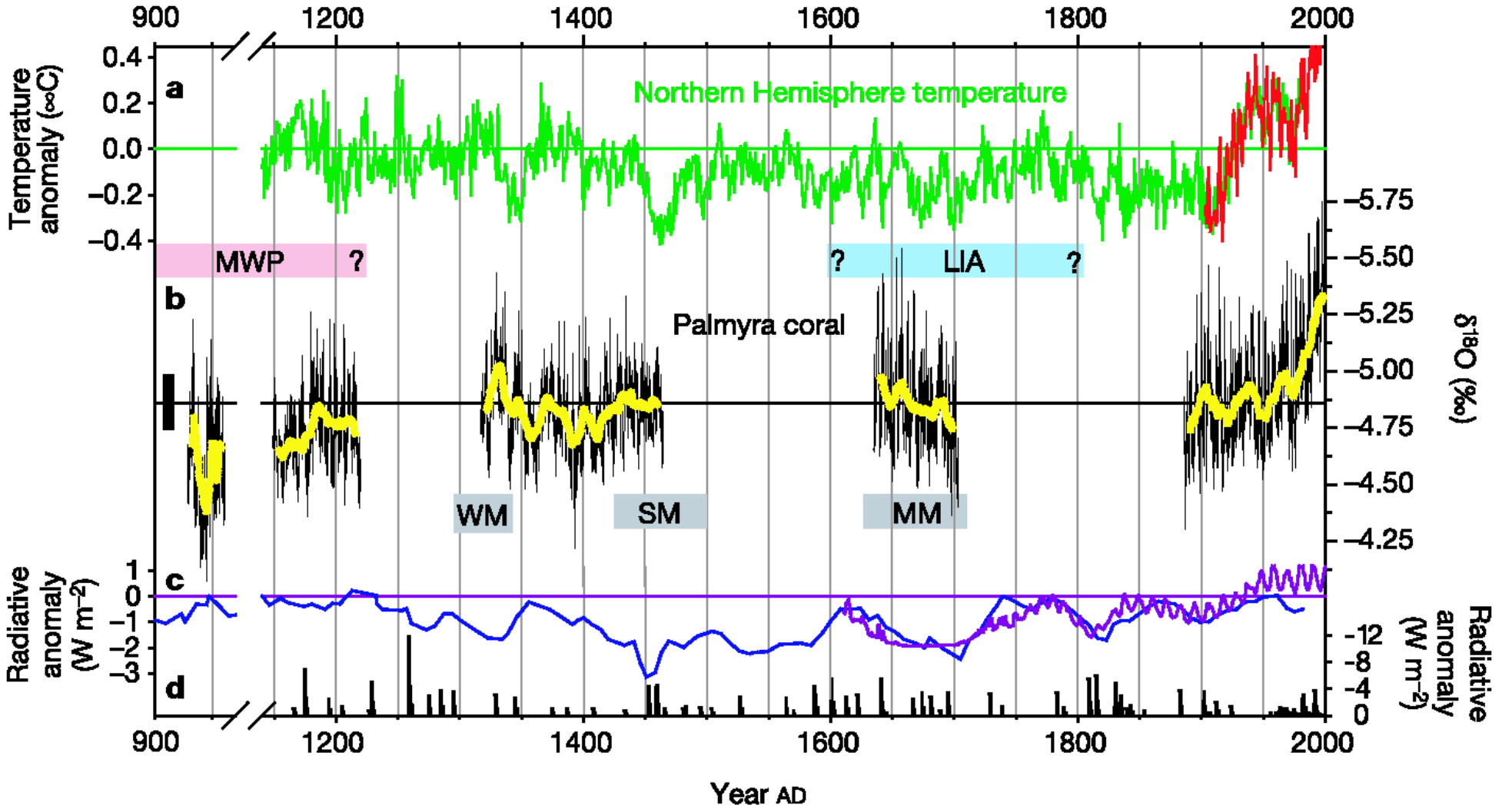
Normal years



El Niño years

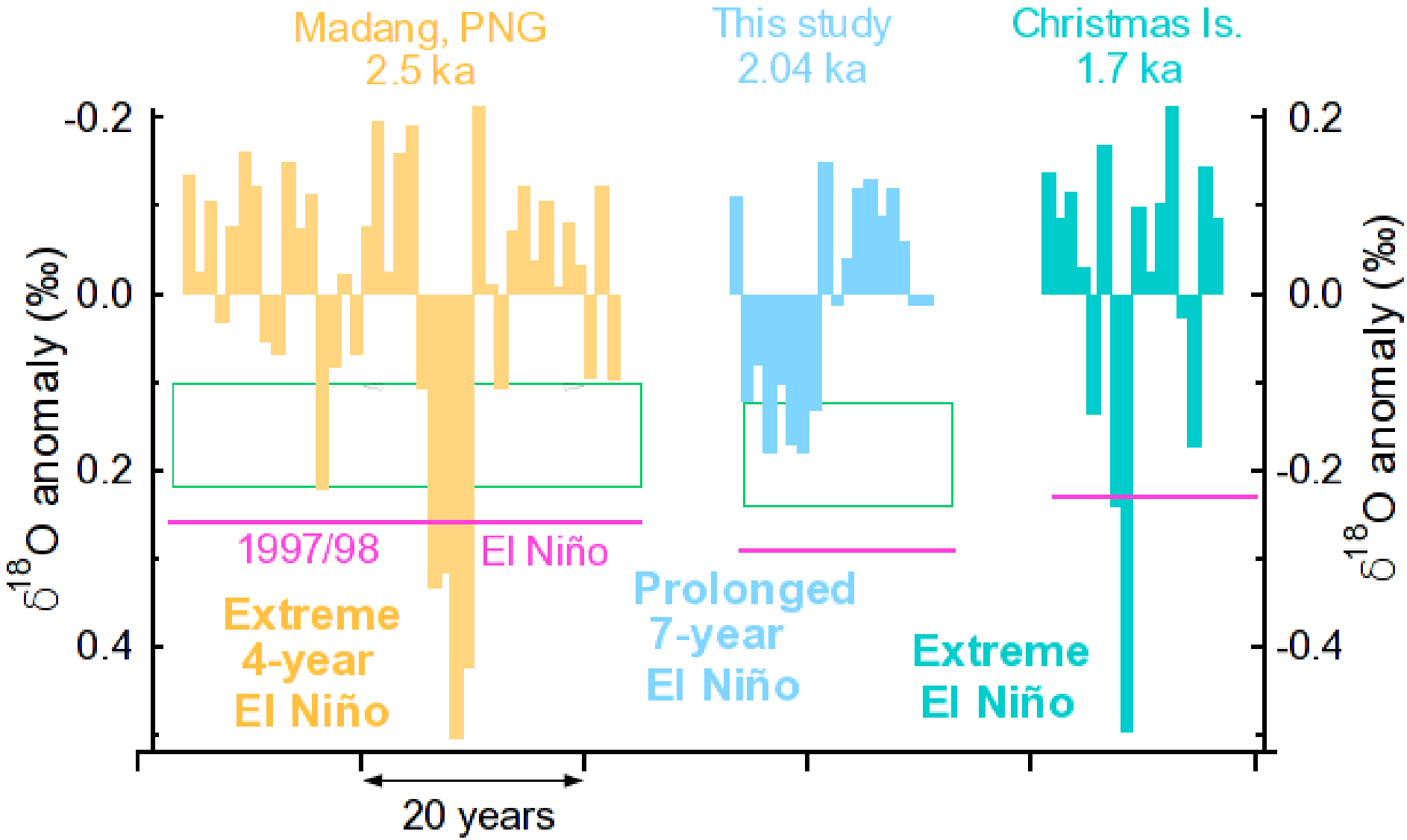


Palmyra Island: El Niño over the past millennium



Cobb et al. (2003), *Nature*

Severe El Niño events at ∼2 ka?

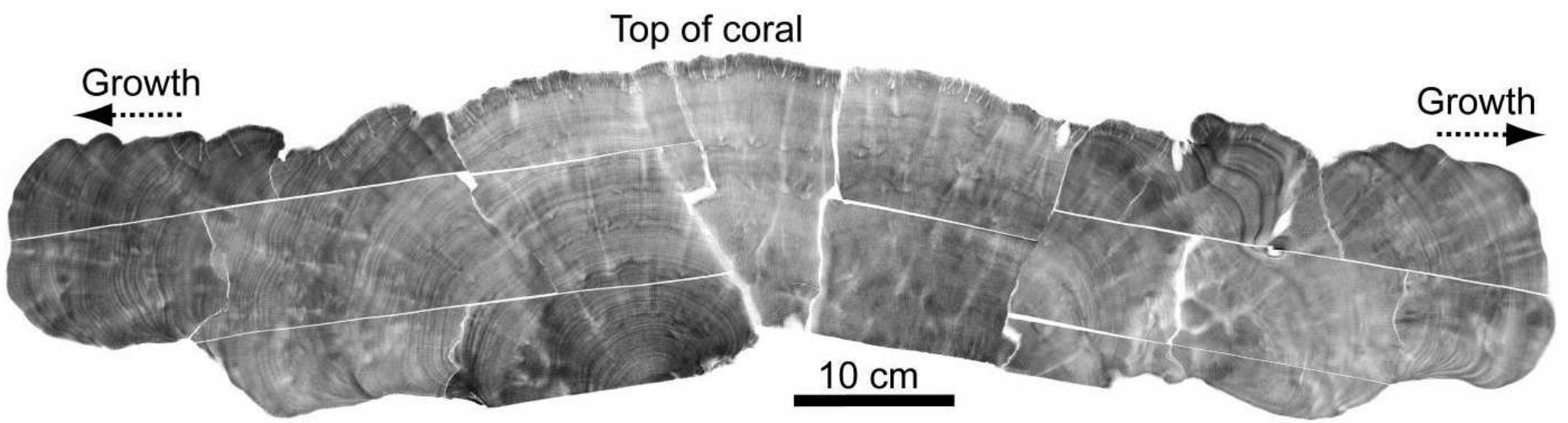


McGregor and Gagan (2004), *GRL*

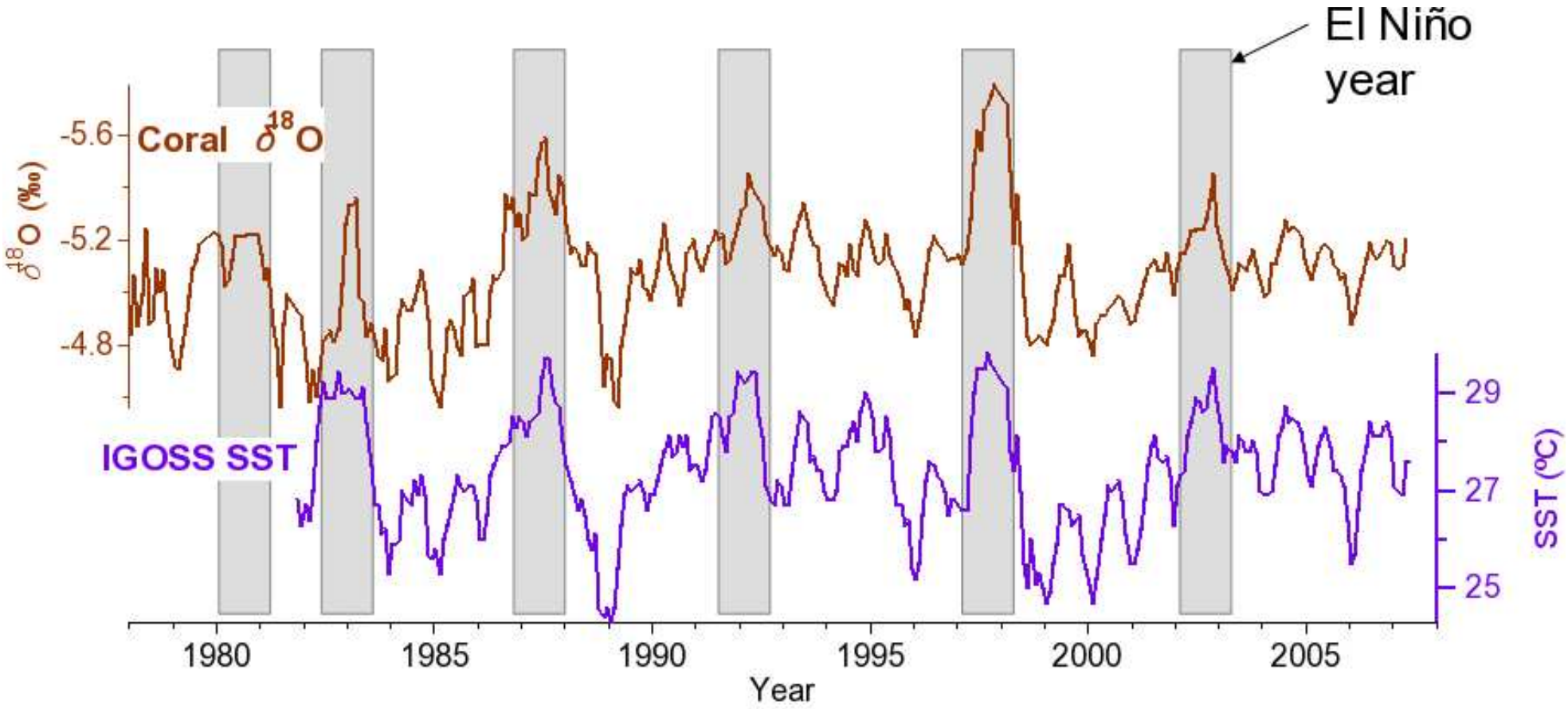
Filling the gaps: Microatolls from Kiritimati

Porites **head coral**

Porites **microatoll**

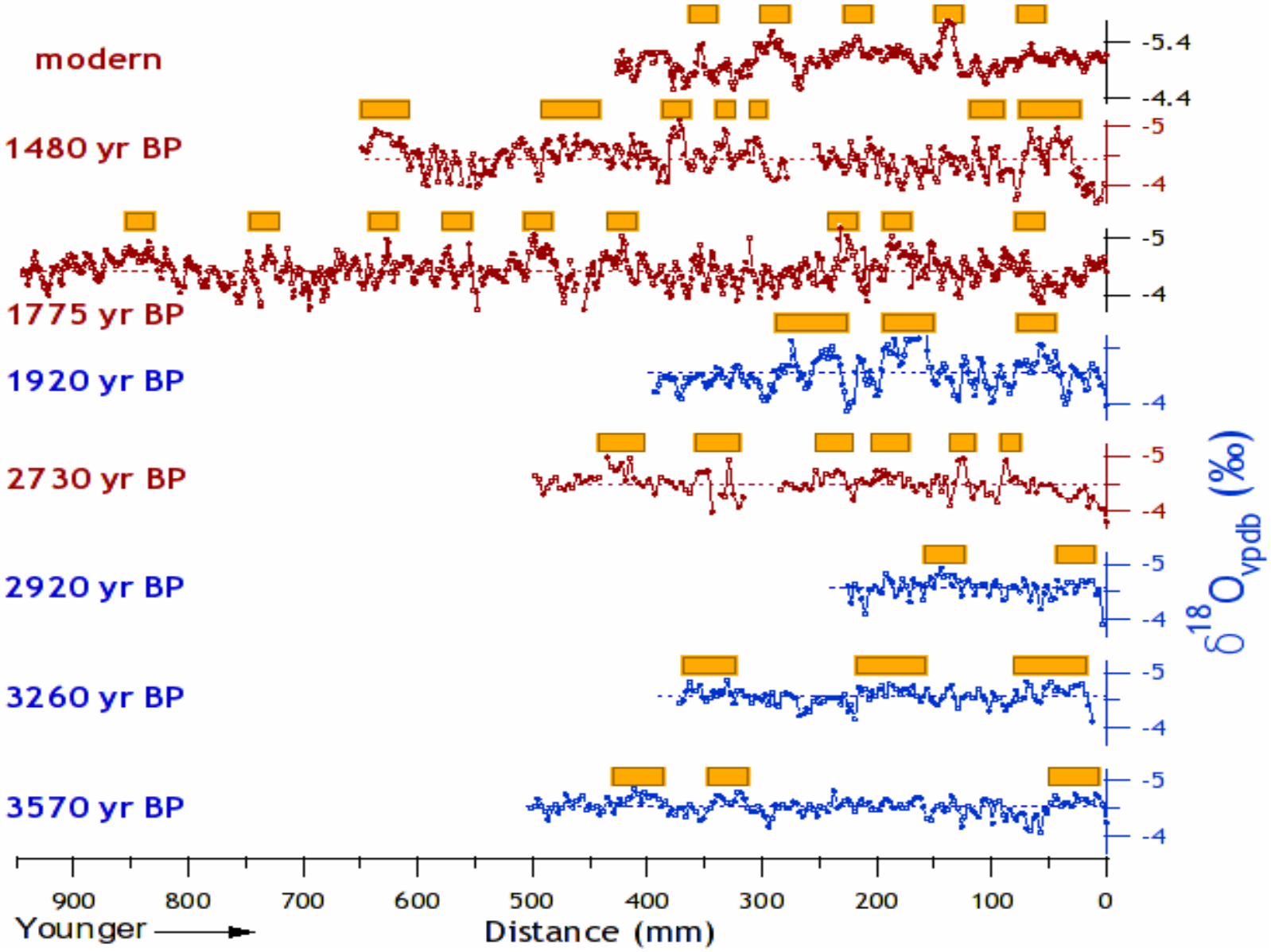


Modern coral δ^{18}O from Kiritimati calibrated against satellite sea surface temperature



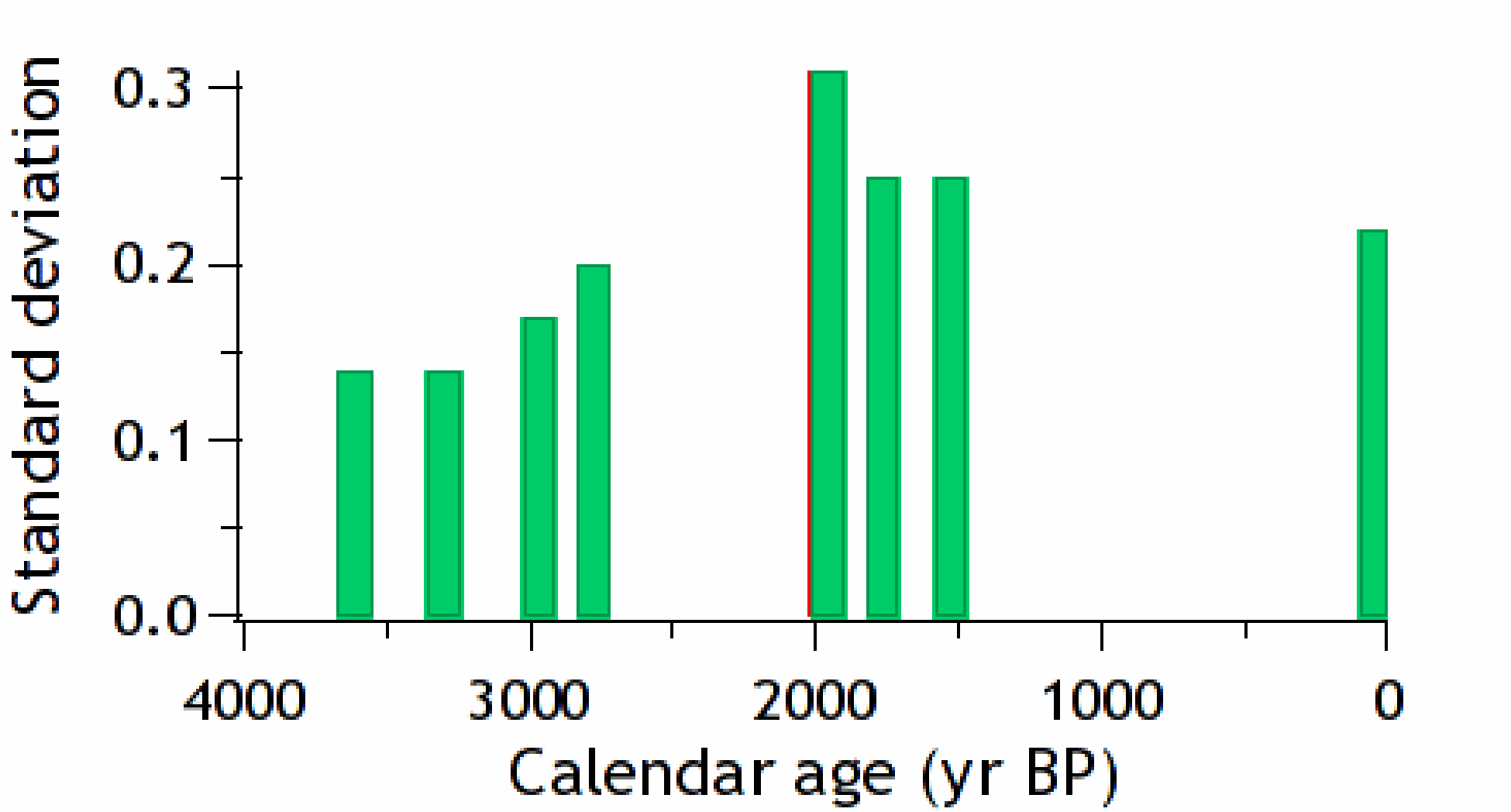
McGregor et al. (in prep.), *Geochimica et Cosmochimica Acta*

The Holocene $\delta^{18}O$ record from Kiritimati

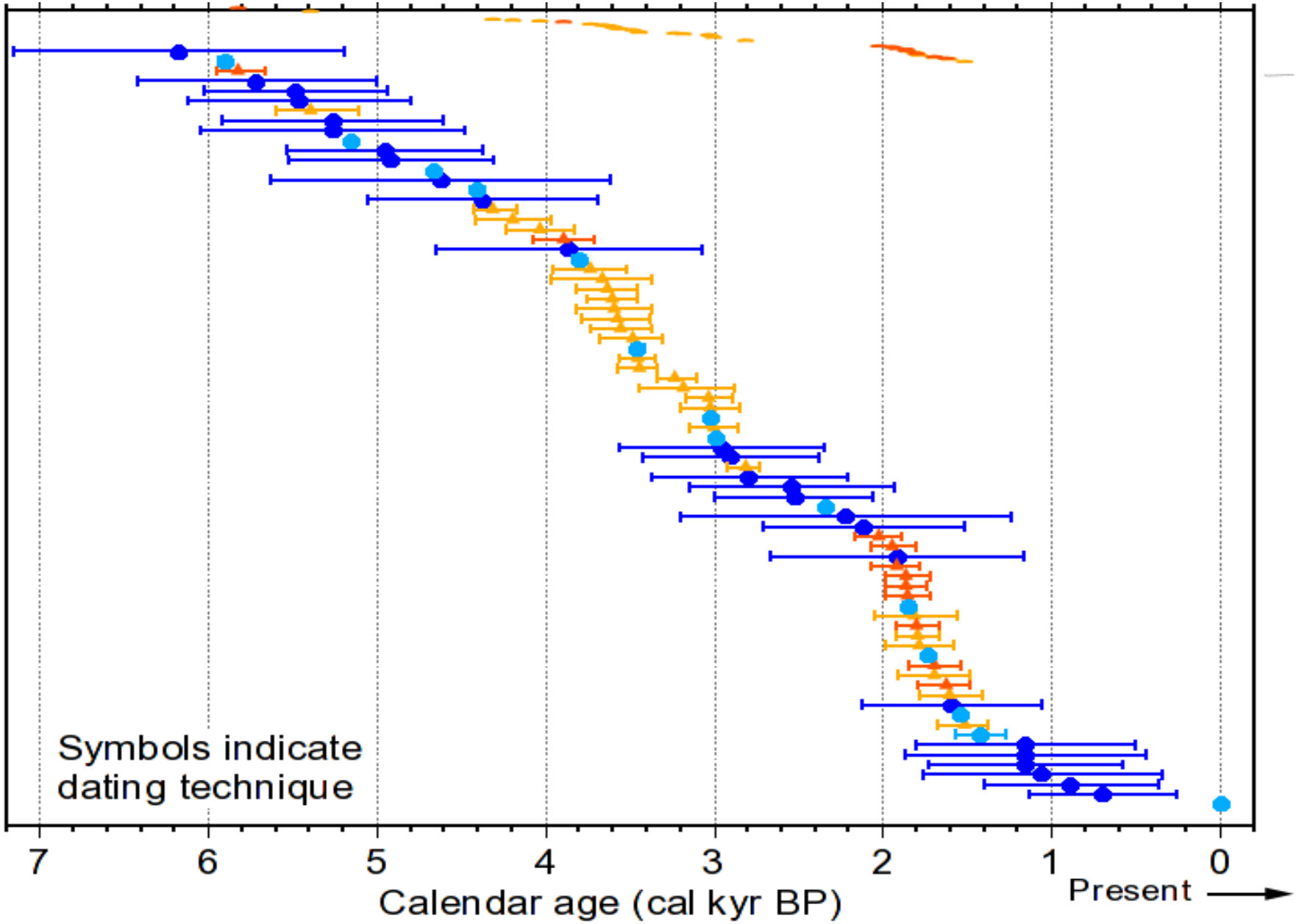


Woodroffe et al. (2003), *GRL*

Standard deviation of Kiritimati δ^{18}O: a measure of El Niño variability

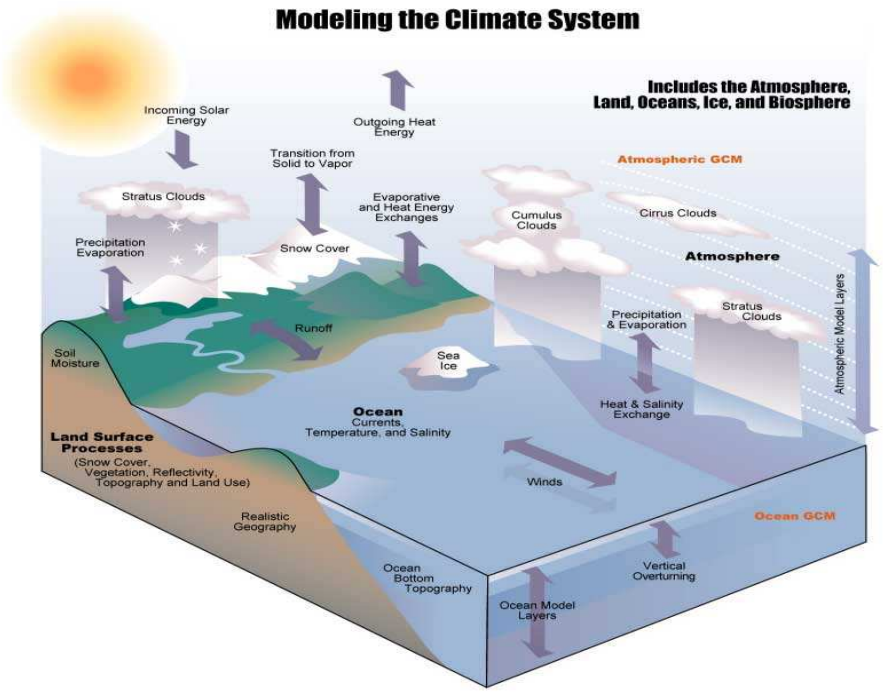


Prospects to extend the record further ...



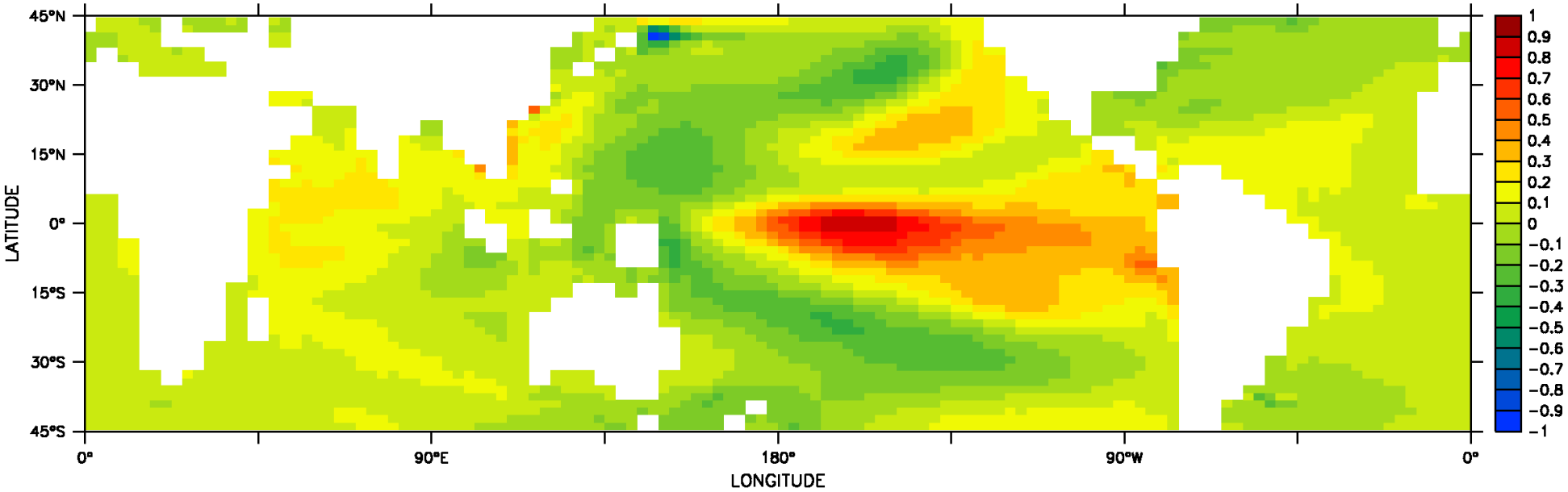
... including some very large corals

Climate modelling



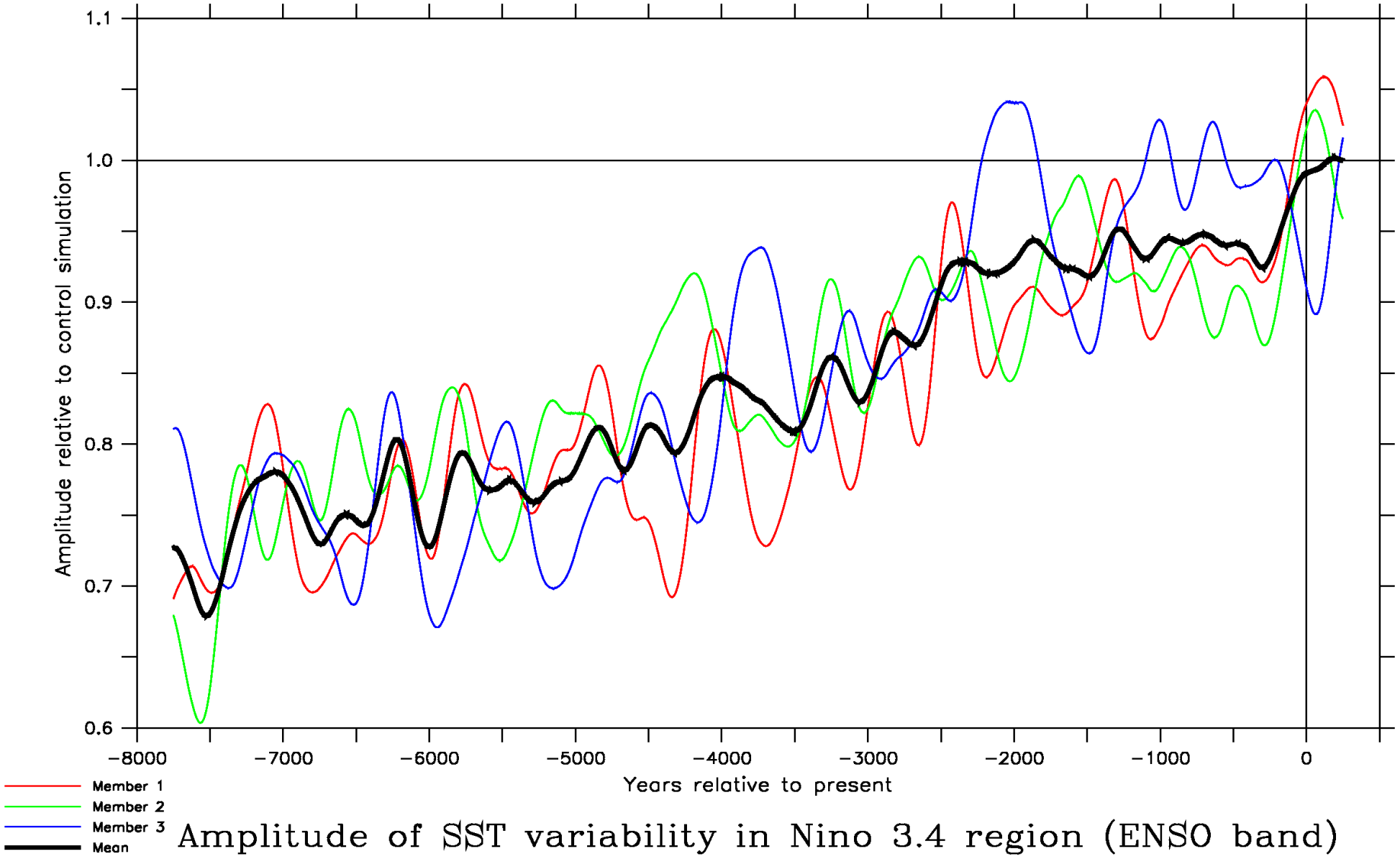
The CSIRO Mk3L climate system model

- Low-resolution coupled general circulation model:
  - Atmosphere: $5.6^\circ \times 3.2^\circ$, 18 vertical levels
  - Ocean: $2.8^\circ \times 1.6^\circ$, 21 vertical levels
  - Sea ice: Dynamic-thermodynamic
  - Land surface: Static vegetation
- One 10,000-year pre-industrial control simulation
- Three transient simulations of the past 8,000 years



Pre−industrial control simulation: PC1 of monthly SST anomalies

Simulated changes in El Niño variability

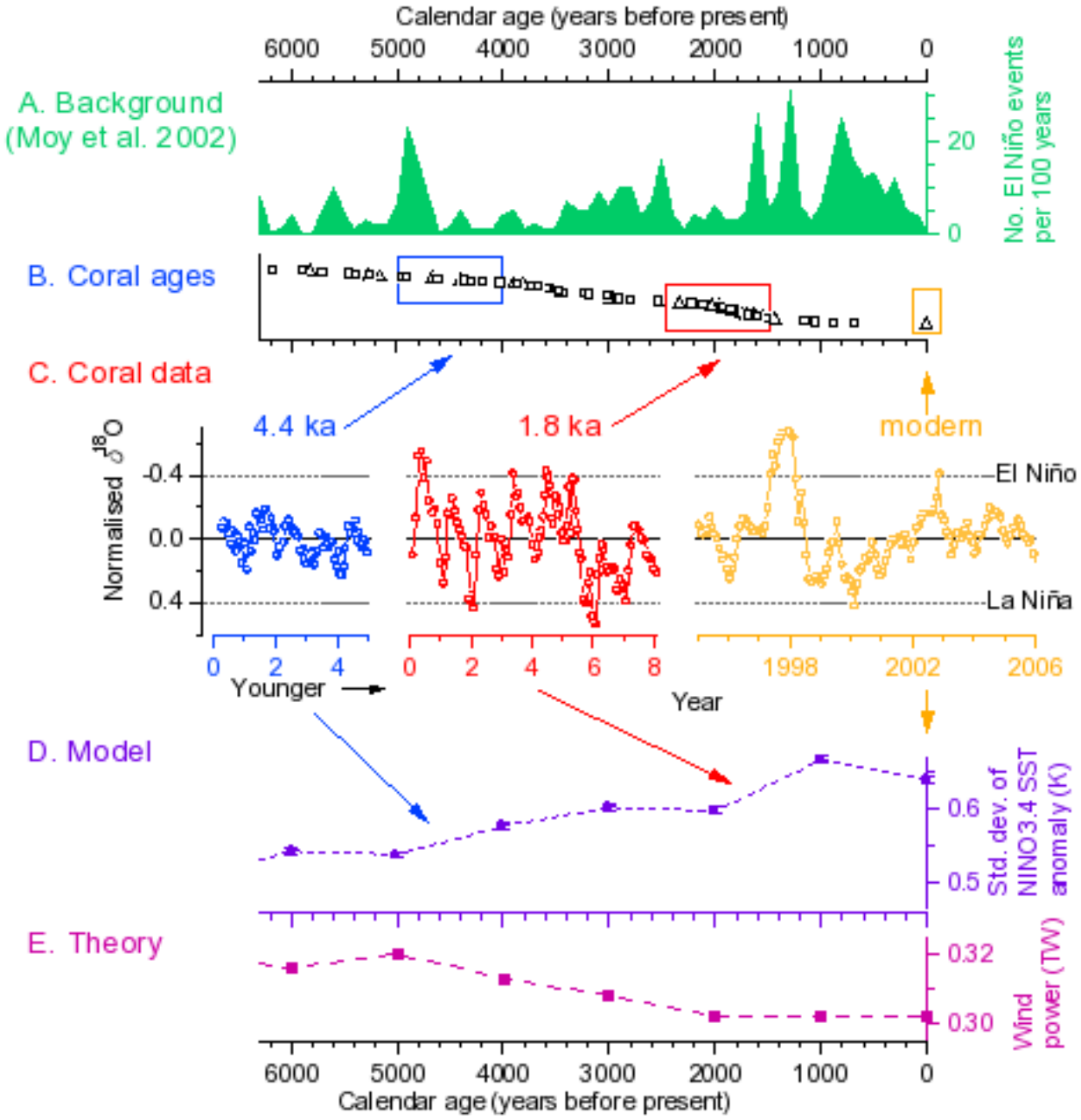


Amplitude of SST variability in Nino 3.4 region (ENSO band)

Phipps and McGregor (in prep.), *GRL*

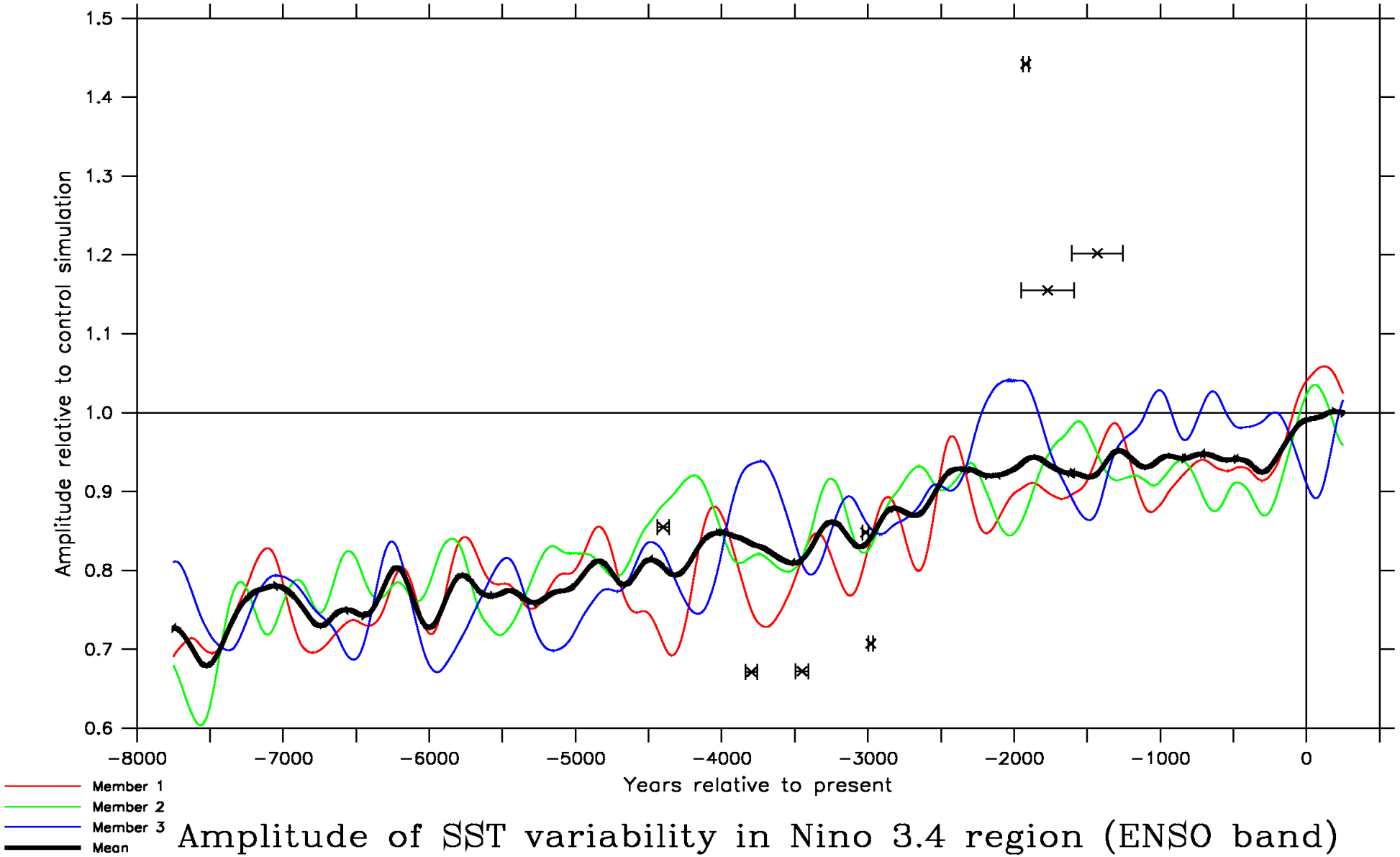
Data-model integration

Integrating the data and the models



- Data-model integration is a two-way process
- The data constrains the model simulations
- The models provide the dynamical interpretation of the data

El Niño variability: data-model comparison



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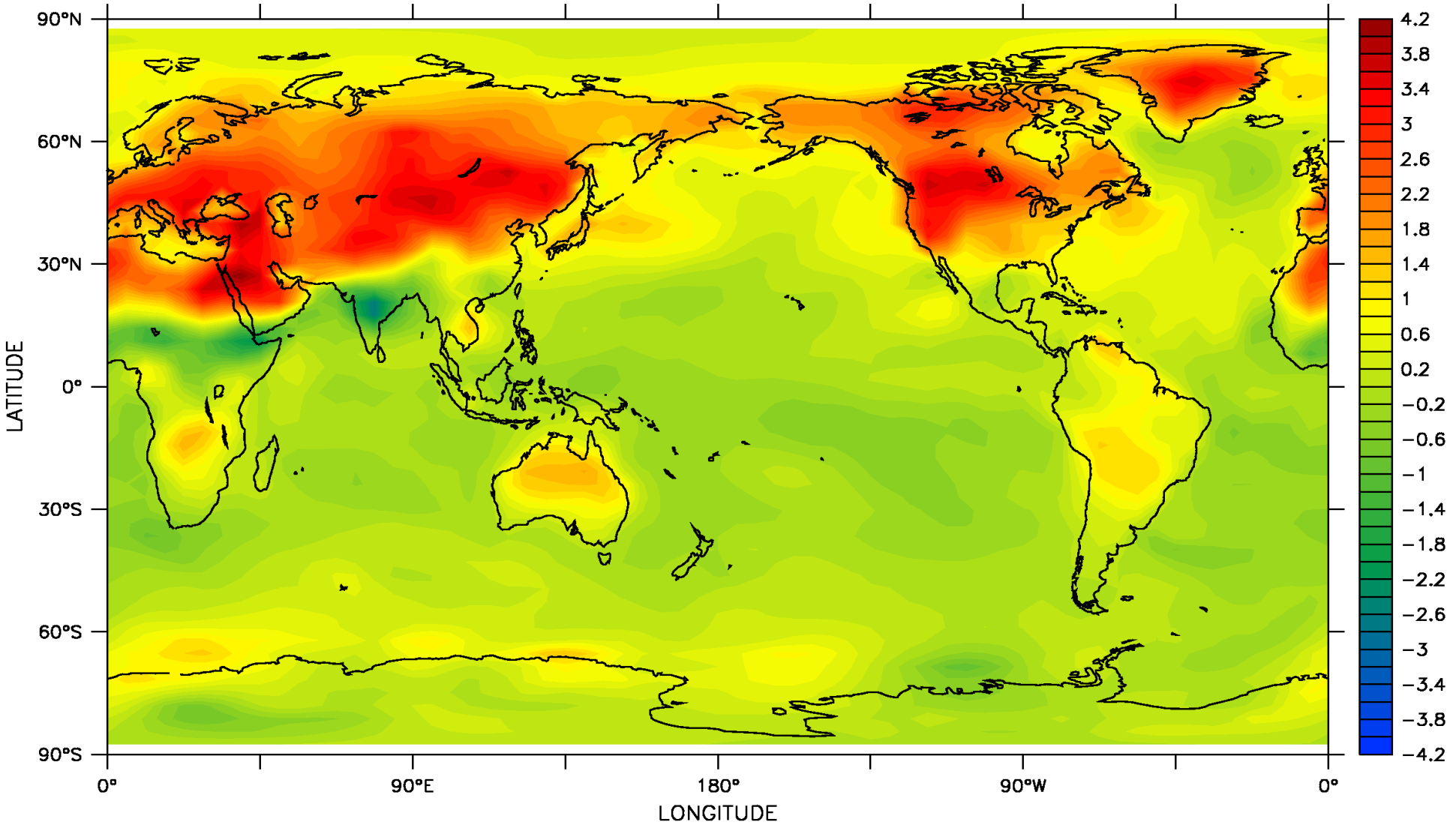
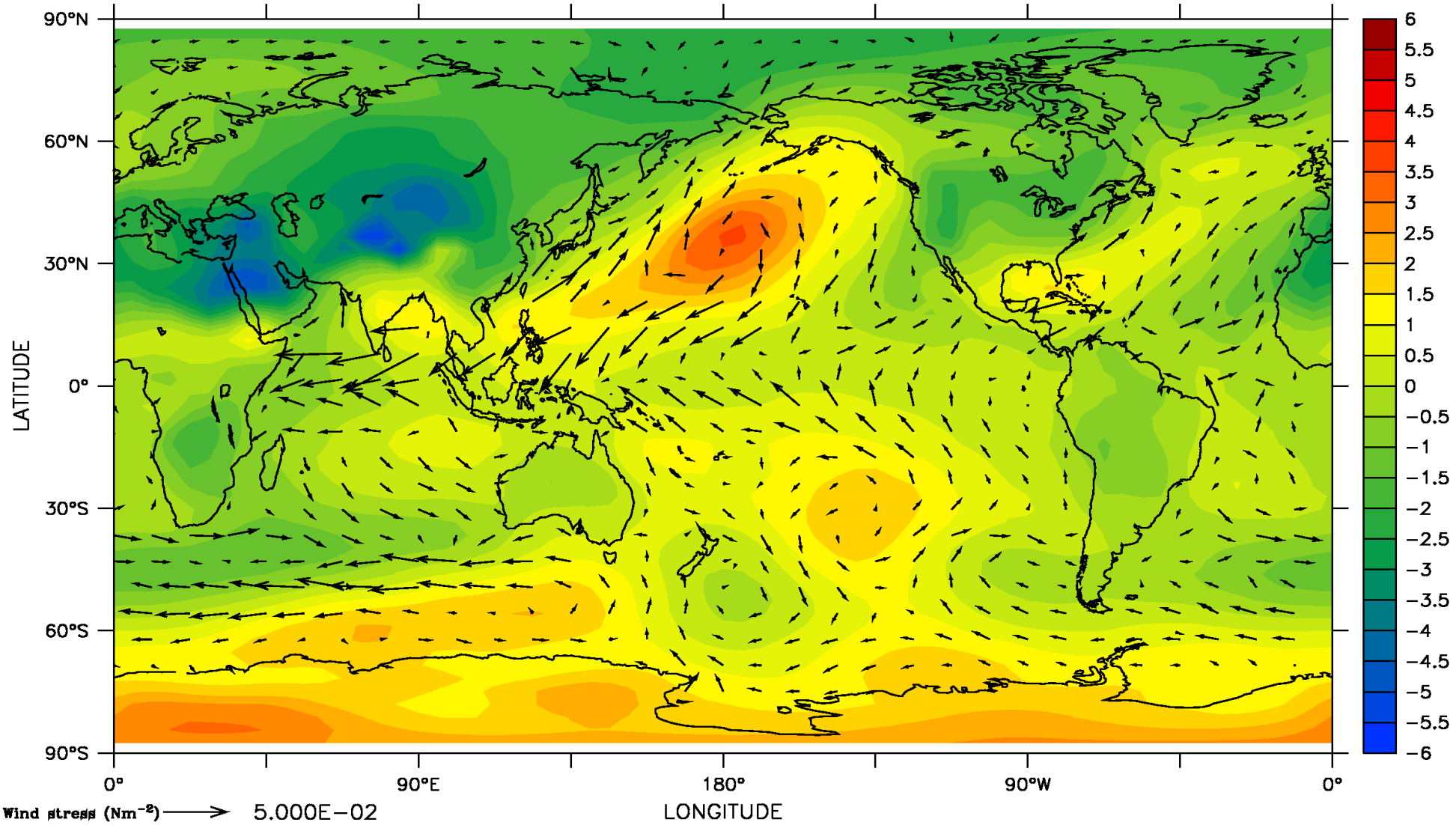
NH summers were warmer at 8 ka ...



June–July–August surface air temperature, 8 ka minus 0 ka BP (K)

Phipps and Brown (2010), *IOP Conf. Series: Earth and Env. Sci.*

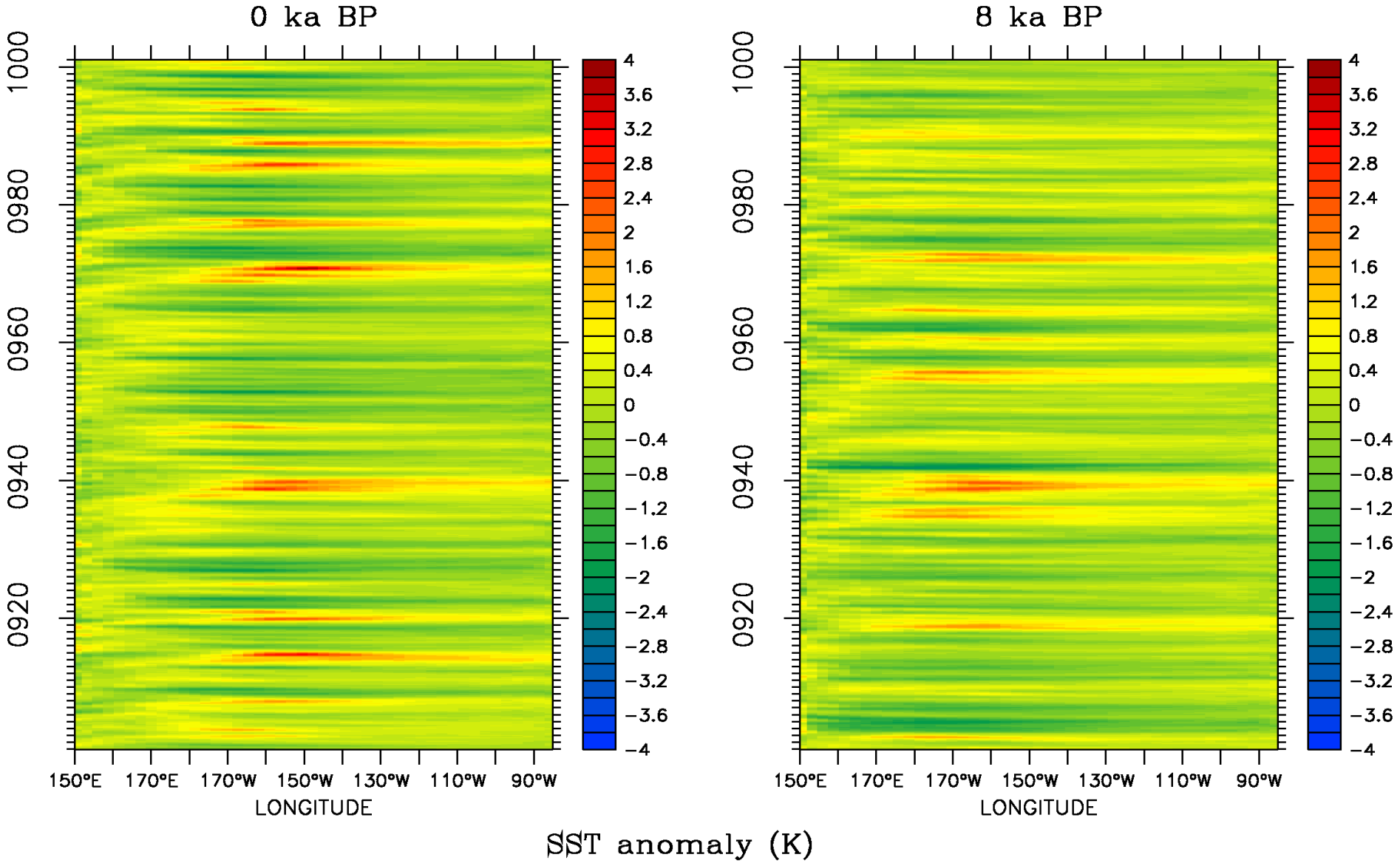
... which enhanced the Asian summer monsoon ...



June–July–August mean sea level pressure, 8 ka minus 0 ka BP (hPa)

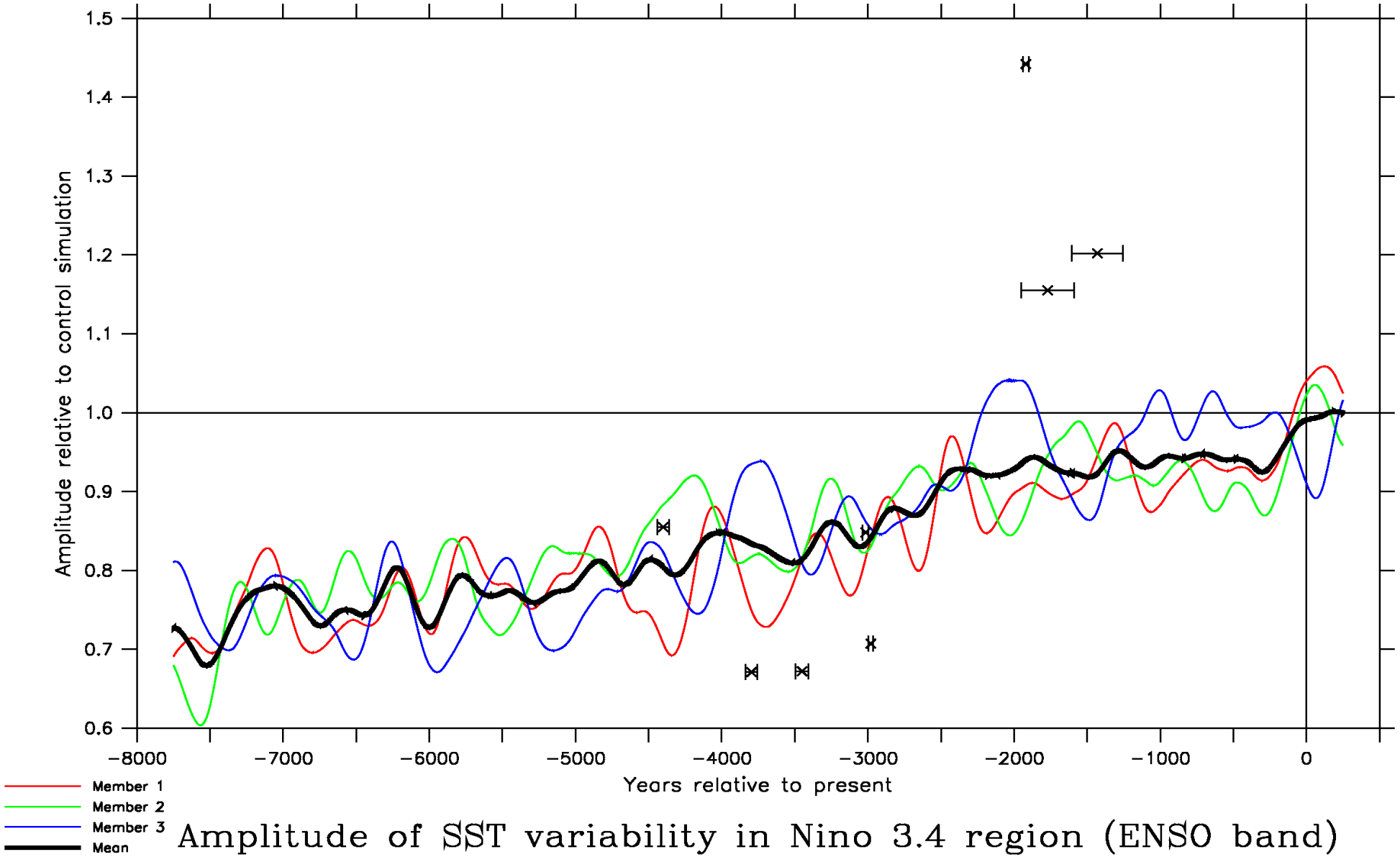
Phipps and Brown (2010), *IOP Conf. Series: Earth and Env. Sci.*

... and made it harder for El Niño events to develop



Phipps and Brown (2010), *IOP Conf. Series: Earth and Env. Sci.*

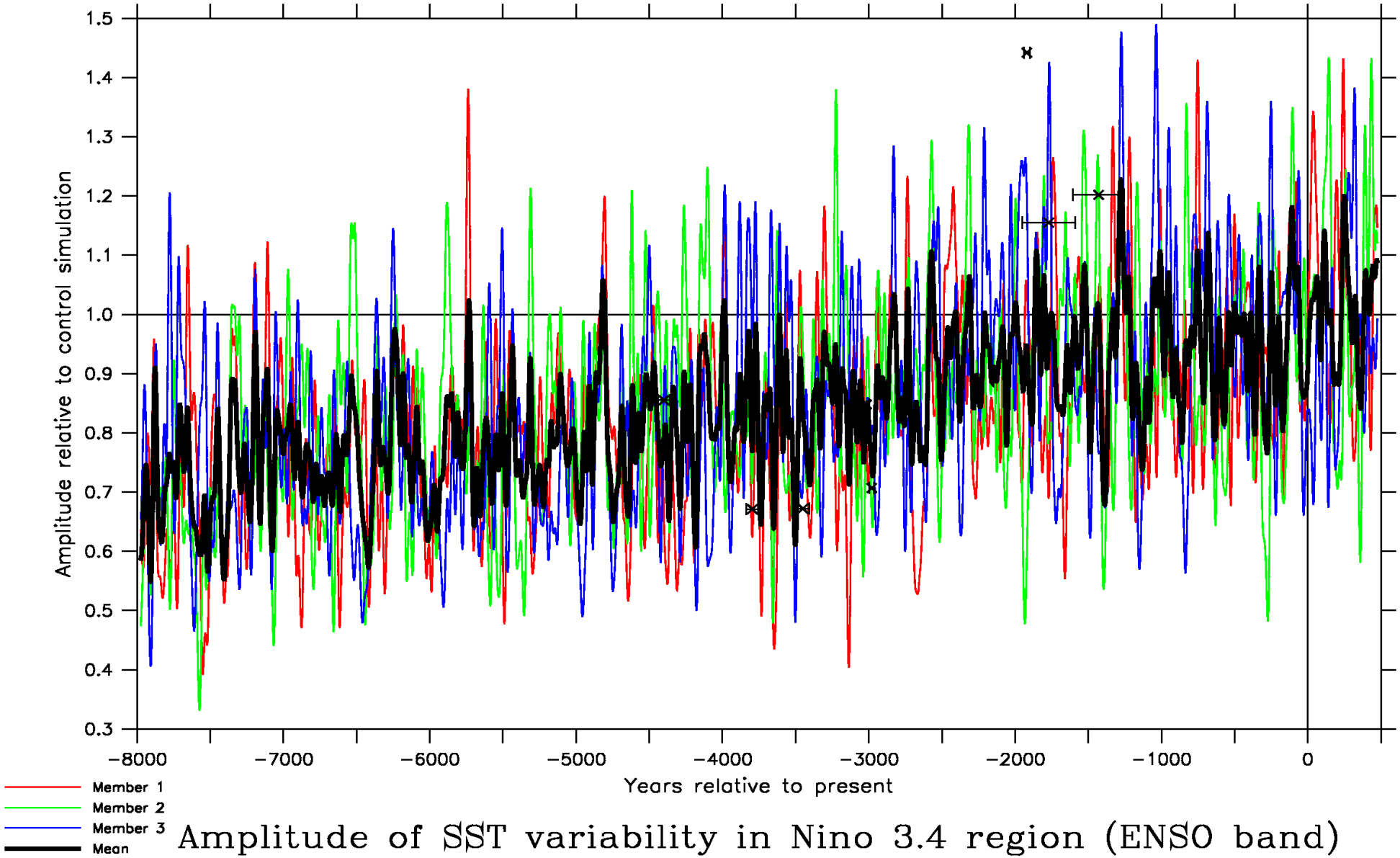
El Niño variability: data-model comparison



Amplitude of SST variability in Nino 3.4 region (ENSO band)

Phipps and McGregor (in prep.), *GRL*

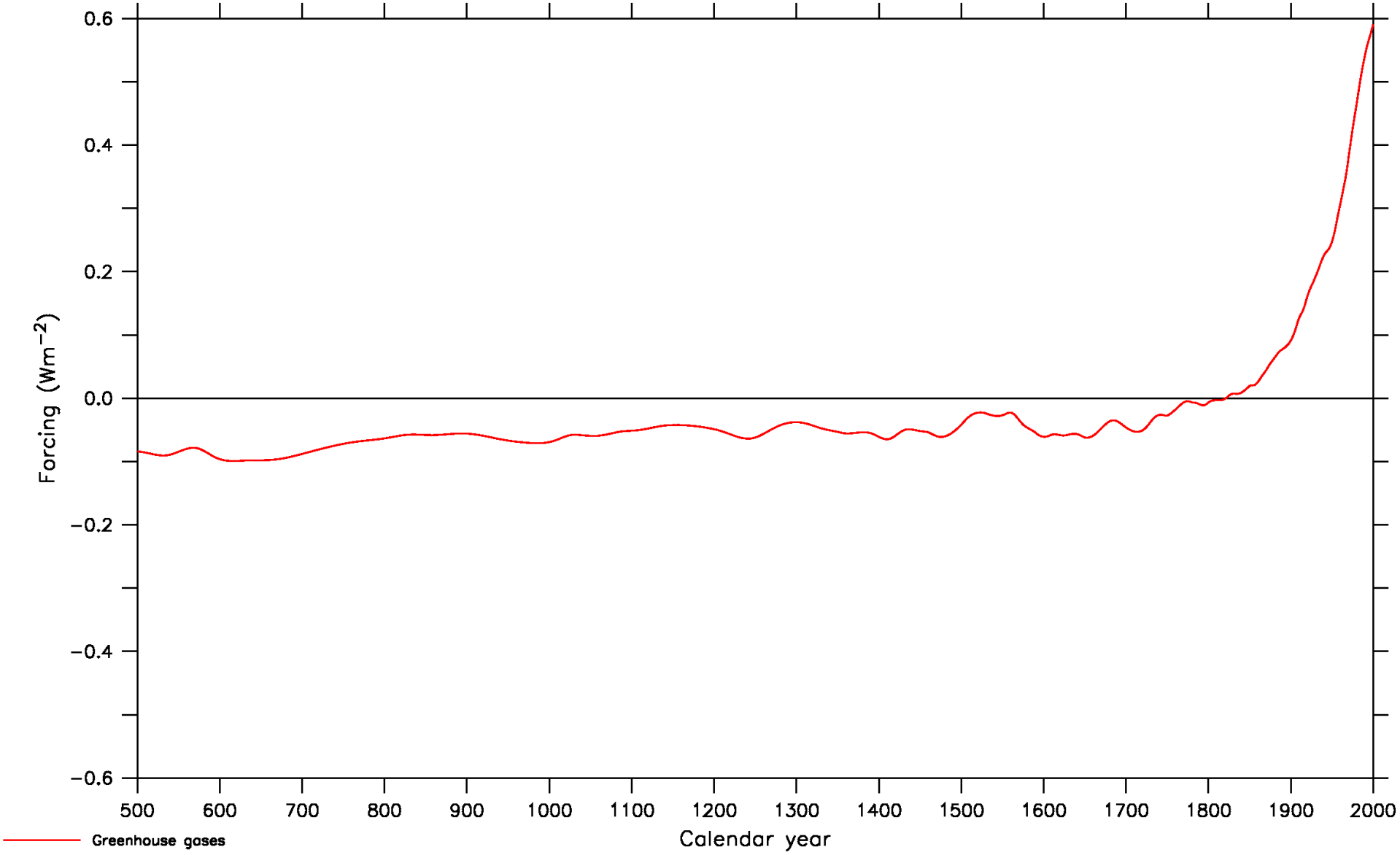
But what about decadal variability?



Amplitude of SST variability in Nino 3.4 region (ENSO band)

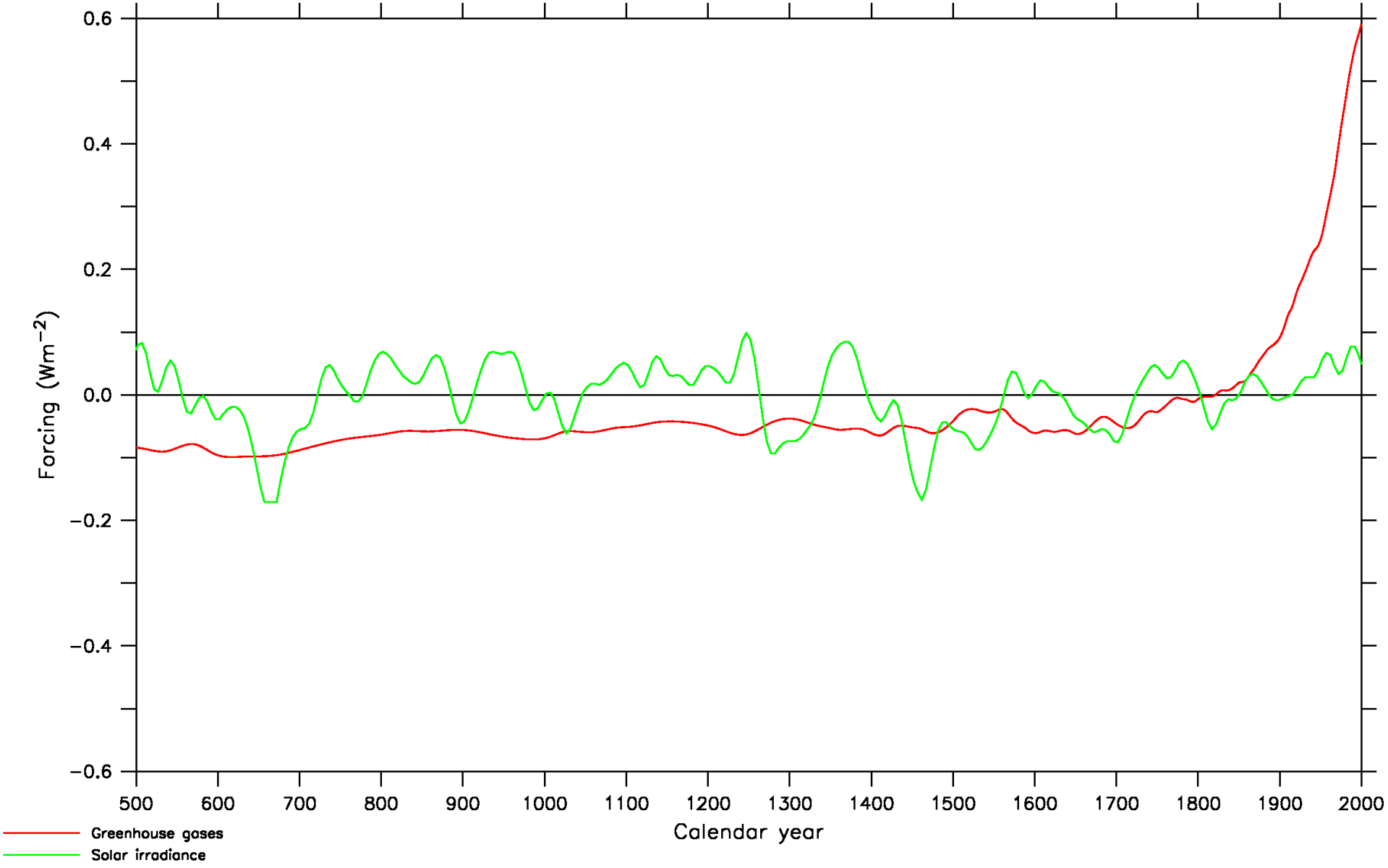
Phipps and McGregor (in prep.), *GRL*

Radiative forcing: GHGs



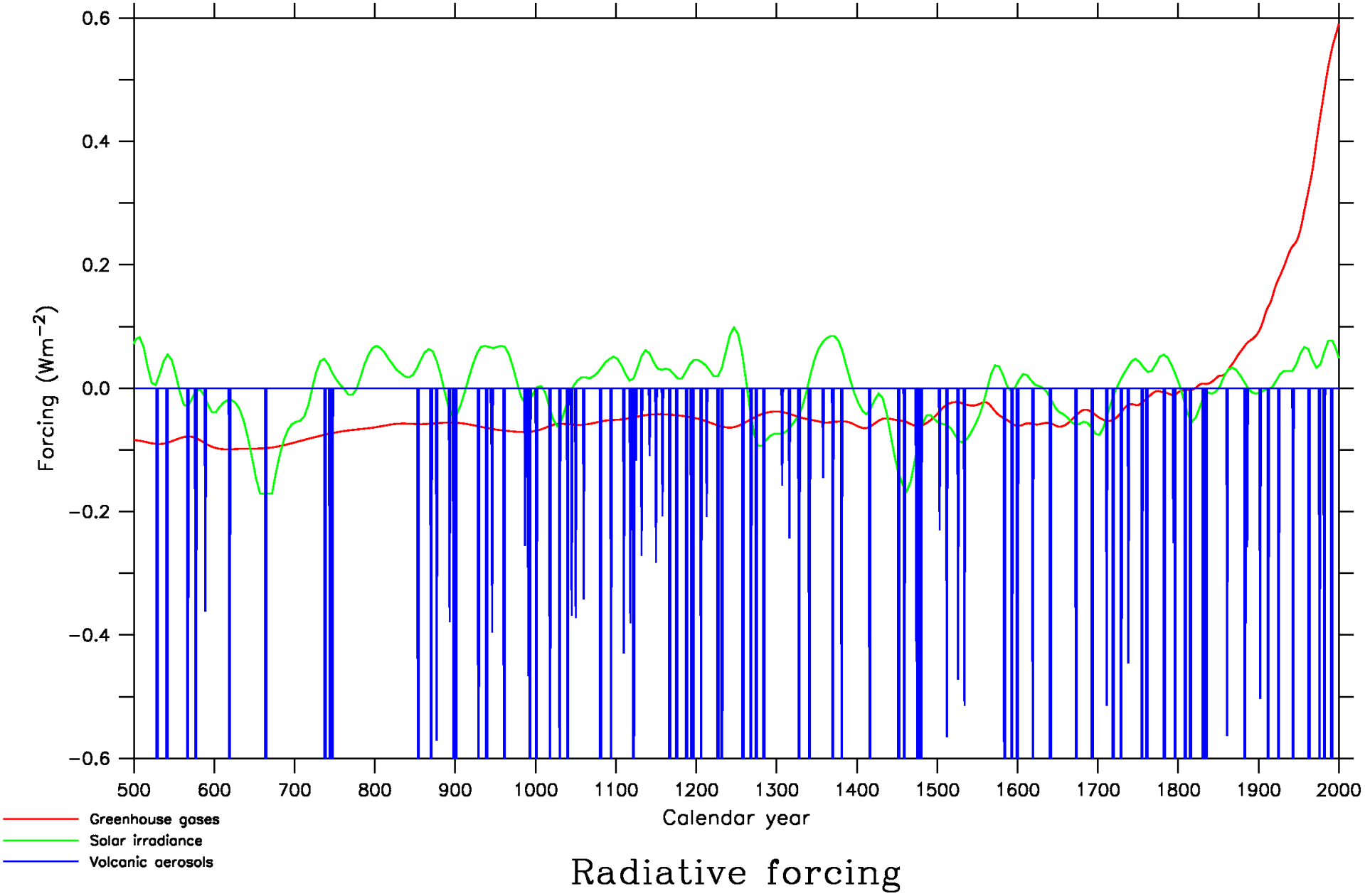
Radiative forcing

Radiative forcing: GHGs+solar

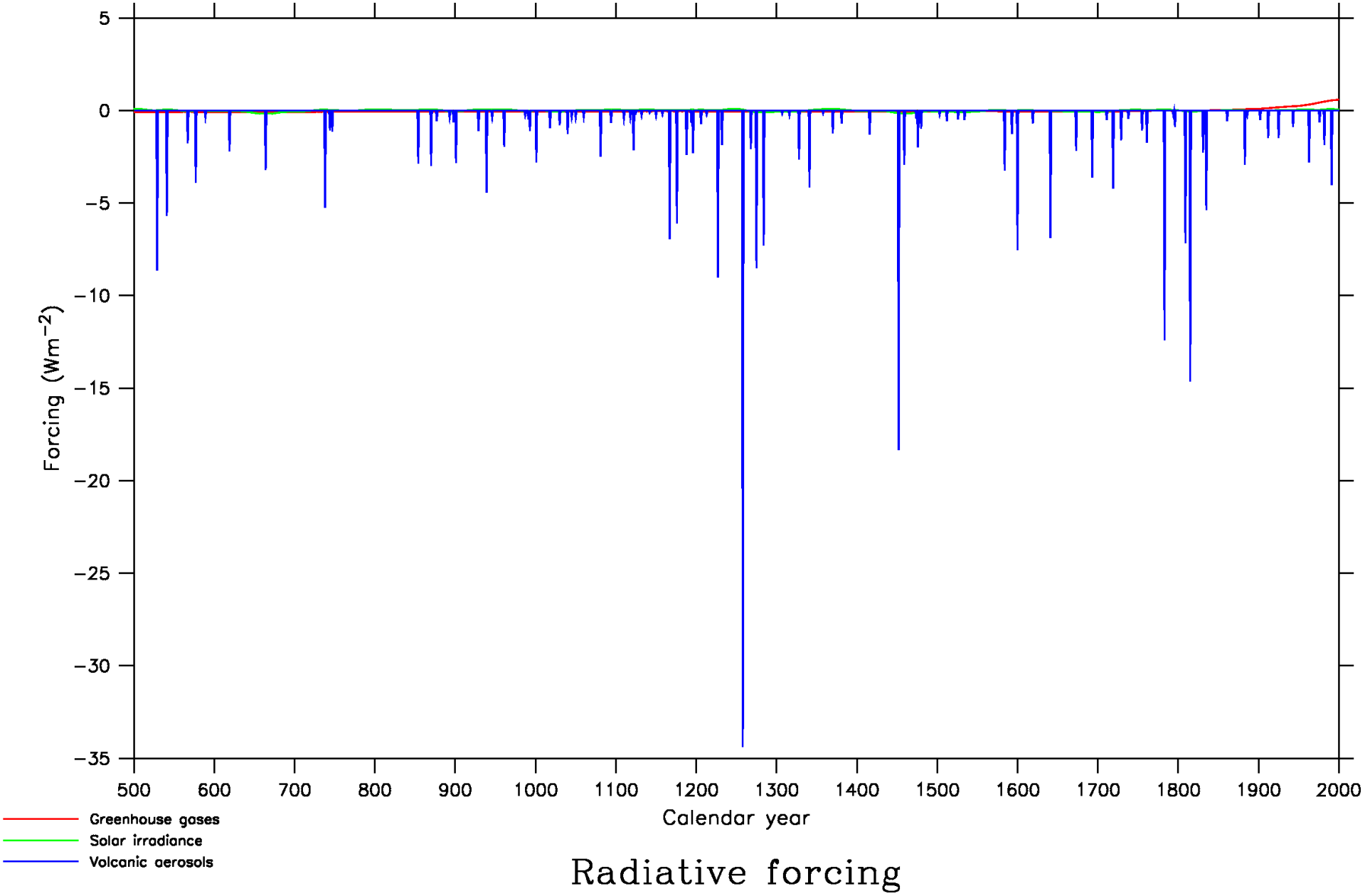


Radiative forcing

Radiative forcing: GHGs+solar+volcanic



Radiative forcing: GHGs+solar+volcanic



Conclusions

- Past changes in El Niño-Southern Oscillation provide an opportunity to learn more about ENSO dynamics, enhancing our ability to predict future changes. However, to realise this opportunity, we will need to integrate the data and the models.
- Microatolls from Kiritimati offer the possibility of producing multiple-century, seasonally-resolved reconstructions of ENSO variability over the Holocene. Initial results for ∼2 ka suggest that large-amplitude ENSO events may have been commonplace.
- A climate system model is able to reproduce the long-term upward trend in ENSO variability over the past 8,000 years. The model suggests that this trend is driven by increasing summer insolation over the Asian landmass.
- Both the coral data and the model show strong variability on decadal timescales. This represents both a challenge and an opportunity for data-model integration.