Southern Hemisphere climate variability over the past 8,000 years: an integrated data–model perspective

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Background

The climate of the past 8,000 years

- A smorgasbord of climate model simulations

The climate of the past 1500 years

Conclusions

A smorgasbord of climate model simulations

Come and see the SHAPE Climate Modelling Group poster this afternoon...

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The “handshake” question

- Data-model integration is a two-way process
- Proxy data can be used to constrain climate model simulations
- Climate models can provide dynamical interpretation of proxy data
- Everyone wins: we learn more about the dynamics of the climate system than when we employ the two approaches separately
We know that ENSO has changed over the Holocene

Tudhope et al. (2001), Science

Cobb et al. (2013), Science

Moy et al. (2002), Nature
The dynamics of the El Niño–Southern Oscillation

- El Niño–Southern Oscillation (ENSO) is the dominant mode of internal variability within the coupled atmosphere-ocean system
- Irregular period of $\sim2$–$7$ years
- Average state of the system involves strong easterly trade winds pushing warm water to the west
- During an El Niño event, these winds slacken and the warm water flows eastwards
Simulating the role of orbital forcing

- 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

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Simulating the role of orbital forcing

- Three transient simulations of the past 8,000 years:
  - Only the Earth’s orbital geometry is varied (Berger et al., 1978)
  - Each ensemble member is initialised from different years of the control simulation (i.e. a perturbed initial conditions ensemble)
Orbital cycles cause large seasonal changes in insolation
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Simulated ENSO amplitude (with 500-year smoother)

Updated from Phipps and Brown (2010), *IOP C. S. Earth Env.*

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Trend in August surface air temperature (K ky$^{-1}$)

Updated from Phipps and Brown (2010), *IOP C. S. Earth Env.*
Trend in August MSLP (hPa ky$^{-1}$) and surface wind stress

Updated from Phipps and Brown (2010), *IOP C. S. Earth Env.*
PMIP3: simulated trends in the SH westerly winds

Bakker et al. (in press), *Quaternary Science Reviews*

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ENSO also changes on shorter timescales

Cobb et al. (2003), *Nature*
Simulating the role of forcings over the past 1500 years

- Multiple ensembles of transient simulations of the past 1500 years:
  - Orbital changes (Berger, 1978)
  - Anthropogenic greenhouse gases (MacFarling Meure et al., 2006)
  - Solar irradiance (Steinhilber et al., 2009)
  - Explosive volcanism (Gao et al., 2008)
Reconstructed/simulated ENSO amplitude (30-year mean)

Phipps et al. (2013), *Journal of Climate*

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Reconstructing the Southern Annular Mode (SAM)

Abram et al. (2014), *Nature Climate Change*

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Reconstruction of SAM over the last millennium

Abram et al. (2014), *Nature Climate Change*
Data–model comparison and role of external forcings

Abram et al. (2014), *Nature Climate Change*

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Conclusions

- Orbital changes can explain long-term trends in ENSO and SAM over the past 8 ka. These are driven by changes in the seasonal and meridional distribution of insolation, which cause large-scale changes in the atmospheric circulation.

- On shorter timescales, internal variability dominates. There is no evidence that natural forcings influence ENSO or SAM, although anthropogenic forcings have caused a shift in the SAM.

- Overall, a picture emerges of high-frequency internal variability, superimposed on top of long-term trends driven by orbital changes.

- This suggests that care should be taken when interpreting proxy records, and particularly when synchronising records from different sites, as variations on sub-millennial timescales may simply represent random internal variability.