General Circulation Modelling

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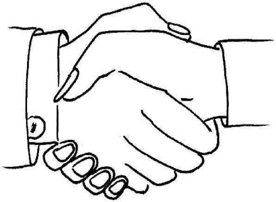
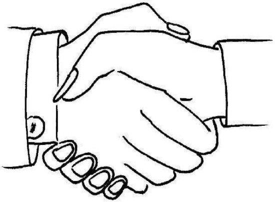
Introduction

The "handshake" question


How do we integrate proxy data and climate models in a way that extracts the maximum possible information about the dynamics of the climate system?

The "handshake" question

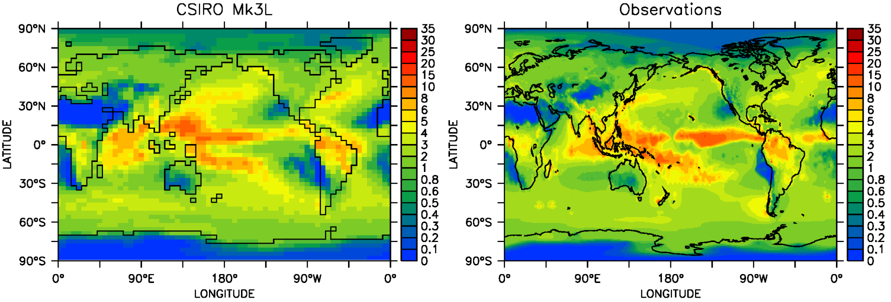


- Data-model integration is a two-way process
- Proxy data can be used to constrain climate model simulations
- Climate models can provide dynamical interpretation of proxy data
- Everyone wins: we learn more about the dynamics of the climate system than when we employ the two approaches separately

The CSIRO Mk3L climate system model

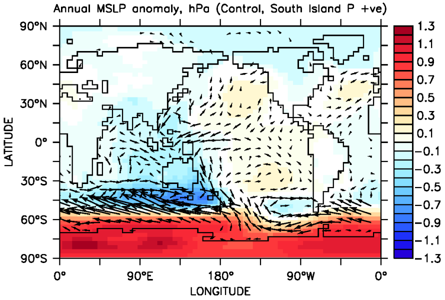
GCM simulations for the Lake Ohau project

- 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



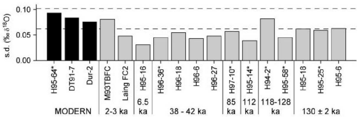
Drivers of New Zealand South Island precipitation

- 10,000-year pre-industrial control simulation
- Composite mean sea level pressure and surface wind stress for years when New Zealand South Island precipitation is more than one standard deviation above or below the long-term mean

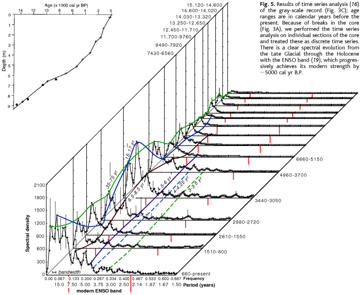


Orbital forcing over the past 8,000 years

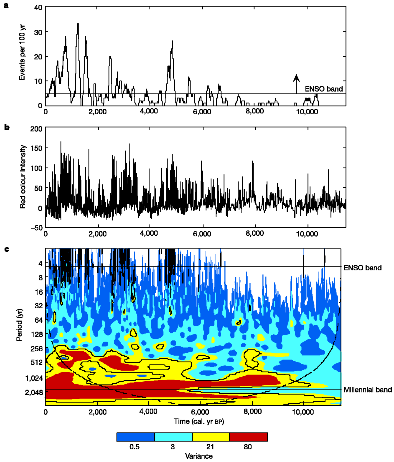
We know that ENSO has changed over the Holocene



Tudhope et al. (2001), *Science*



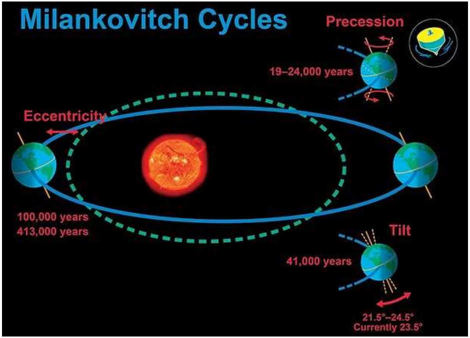
Rodbell et al. (1999), *Science*



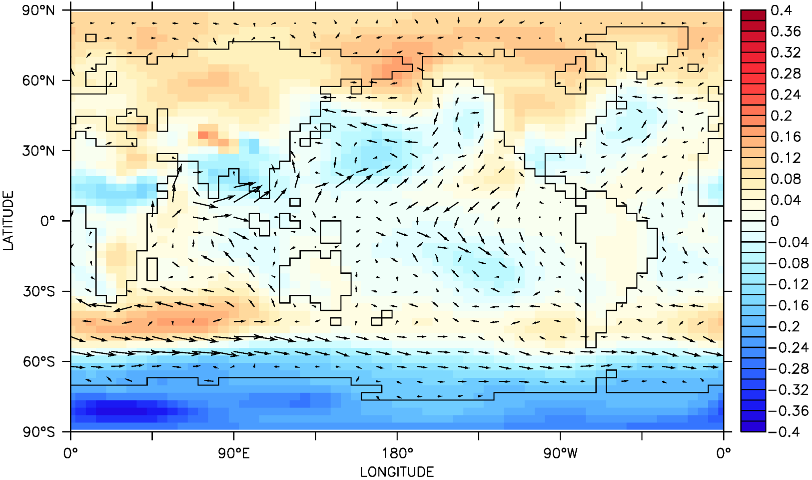
Moy et al. (2002), *Nature*

Climate model simulations

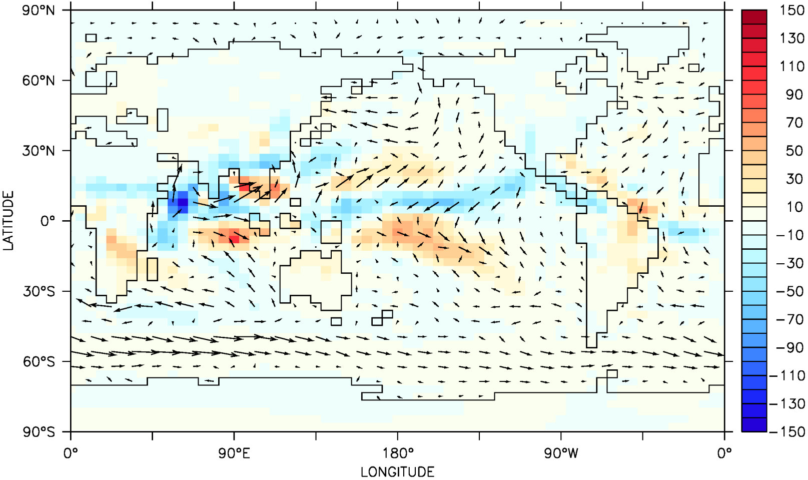
- Three transient simulations of the past 8,000 years:
  - Only the Earth's orbital geometry is varied (Berger et al., 1978)
  - Each ensemble member is initialised from different years of the control simulation (i.e. a perturbed initial conditions ensemble)



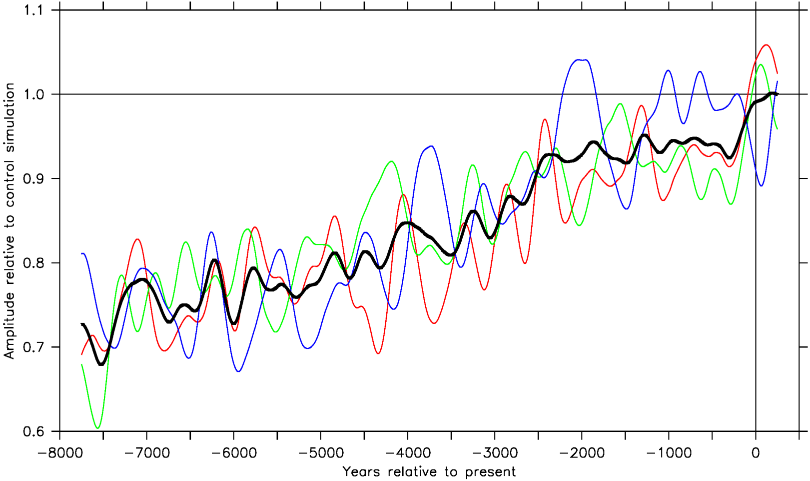
Trend in annual MSLP (hPa ka^{-1}) and surface wind stress



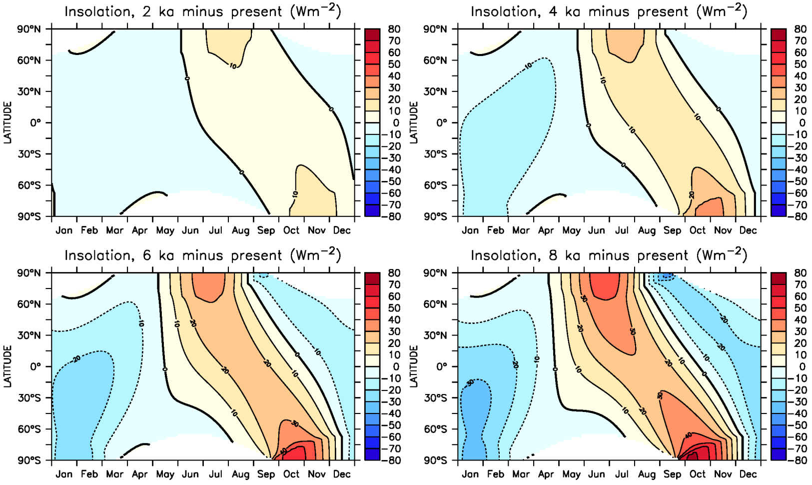
Trend in annual precip (mm ka^{-1}) and surface wind stress



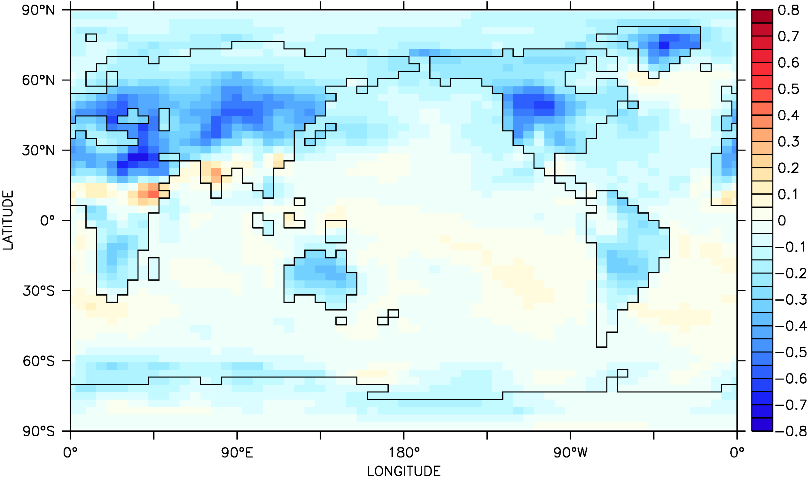
Simulated amplitude of ENSO variability (500-year mean)



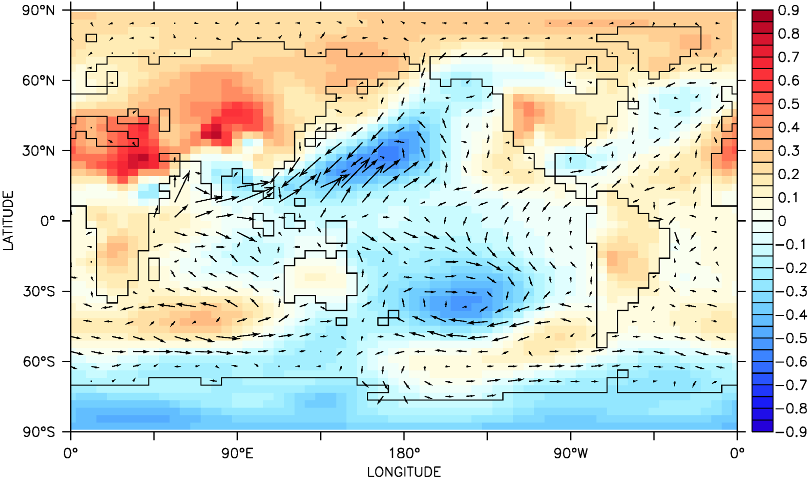
Orbital forcing causes large seasonal changes in insolation



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

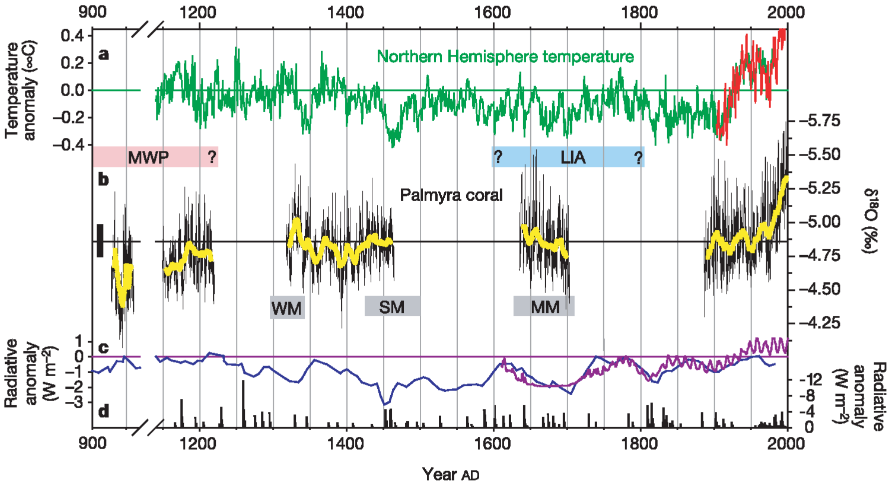


Trend in August MSLP (hPa ka^{-1}) and surface wind stress



External forcing and internal variability over the past 1,500 years

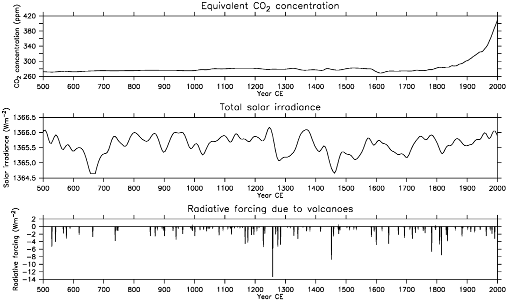
ENSO also changes on shorter timescales



Cobb et al. (2003), *Nature*

Climate model simulations

- 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)



Changes in the SAM Index

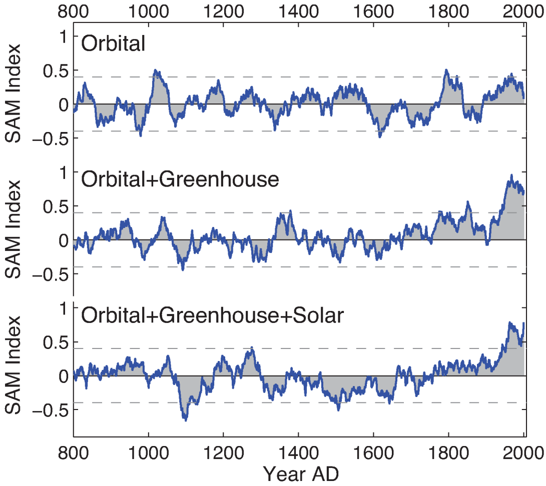
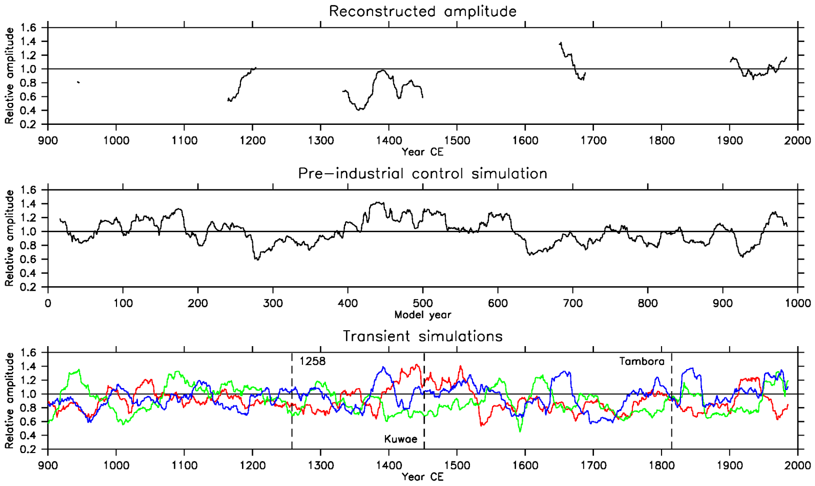


Figure courtesy of Nerilie Abram

Reconstructed/simulated ENSO amplitude (30-year mean)



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

Conclusions

- By integrating proxy data with climate modelling, we can use past climatic changes to study the dynamics of the climate system.
- Simulated New Zealand South Island precipitation is influenced by both SAM and ENSO/IPO.
- Orbital changes can explain long-term trends in the SH westerlies and ENSO over the past 8,000 years, with a shift towards a more positive phase of SAM and increasing ENSO variability.
- On shorter timescales, internal variability dominates. GHGs can explain the late 20th Century shift towards a more positive SAM, with the sun driving centennial-scale variability. However, there is no evidence that external forcings influence the amplitude of ENSO.
- Dynamical downscaling would be needed to capture the interactions between large-scale circulation changes and fine-scale topography.
- What can Lake Ohau tell us?