Evolution of the Southern Hemisphere westerly winds over the past 8 ka: a data–model perspective

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SHAPE Westerly Winds Workshop
28–29 January 2014
1. Introduction

2. Climate model simulations

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Introduction
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
Climate model simulations
## PMIP3 transient climate model simulations

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<th>Model name</th>
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<th>Climate components</th>
<th>Transient climate forcings</th>
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Bakker et al. (in revision), *Quaternary Science Reviews*
The CSIRO Mk3L climate system model

- The CSIRO Mk3L climate system model (Phipps et al., 2011, 2012)
  - Atmospheric general circulation model (5.6° × 3.2°, 18 levels)
  - Ocean general circulation model (2.8° × 1.6°, 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
The role of orbital forcing over the past 8,000 years

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)
The role of external 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)
Simulations of the past 8,000 years

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PMIP3: trend in zonal wind speed (m s$^{-1}$ ka$^{-1}$)

Bakker et al. (in revision), *Quaternary Science Reviews*
PMIP3: trend in surface air temperature \((K\ km^{-1})\)

Bakker et al. (in revision), *Quaternary Science Reviews*
Mk3L: Trend in MSLP (hPa ka$^{-1}$) and surface wind stress
Mk3L: Trend in precip (mm ka^{-1}) and surface wind stress
Evolution of SAM
Temperature proxies and correlation with SAM

Abram et al. (in review), *Nature Climate Change*

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Reconstruction of SAM over the last millennium

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

Abram et al. (in review), *Nature Climate Change*
Conclusions
By integrating proxy data with climate modelling, we can use past climatic changes to study the dynamics of the climate system.

Orbital changes can explain long-term trends in the SH westerlies over the past 8 ka, with a shift towards a more $+ve$ phase of SAM.

On shorter timescales, internal variability dominates. GHGs can explain the late 20th Century shift towards a more positive SAM. However, solar/volcanic forcings do not appear to have an influence.

Opportunities:
- SAM reconstruction spanning the past 8,000 years
- Detection/attribution of internal variability/external forcings

Challenges:
- Proxy availability/selection
- Temporal resolution: annual/decadal/centennial?