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

Steven J. Phipps
Climate Change Research Centre
ARC Centre of Excellence for Climate System Science
University of New South Wales, Sydney, Australia

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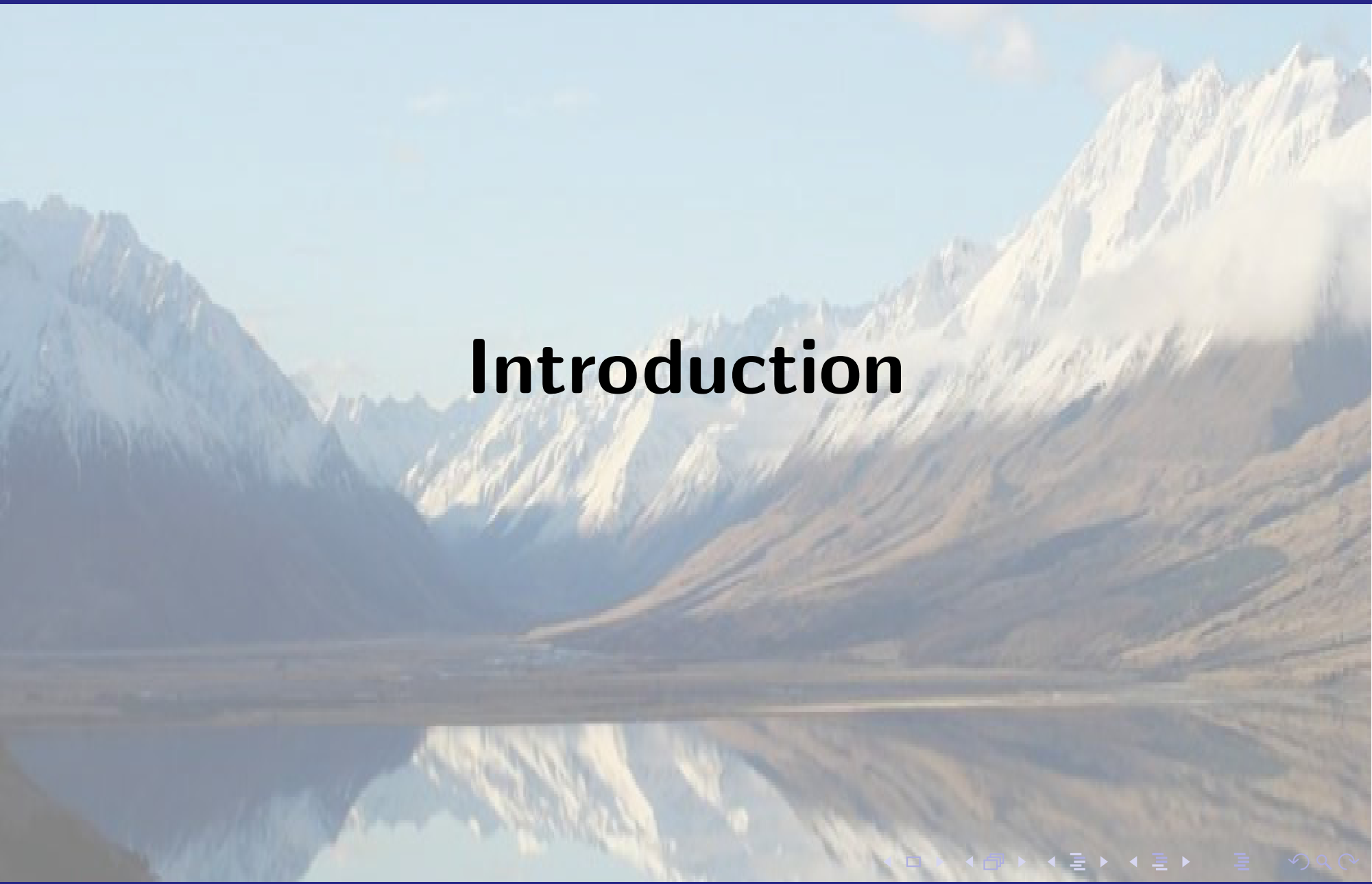
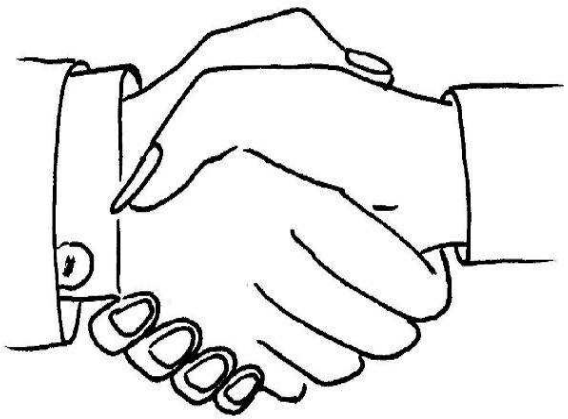
1. Introduction
2. Climate model simulations
3. Simulations of the past 8,000 years
4. Evolution of SAM
5. Conclusions



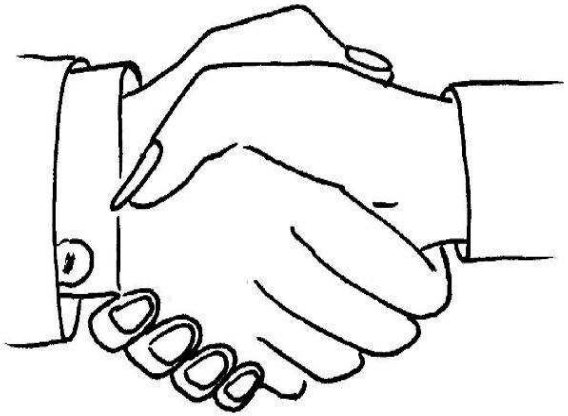
Introduction

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?

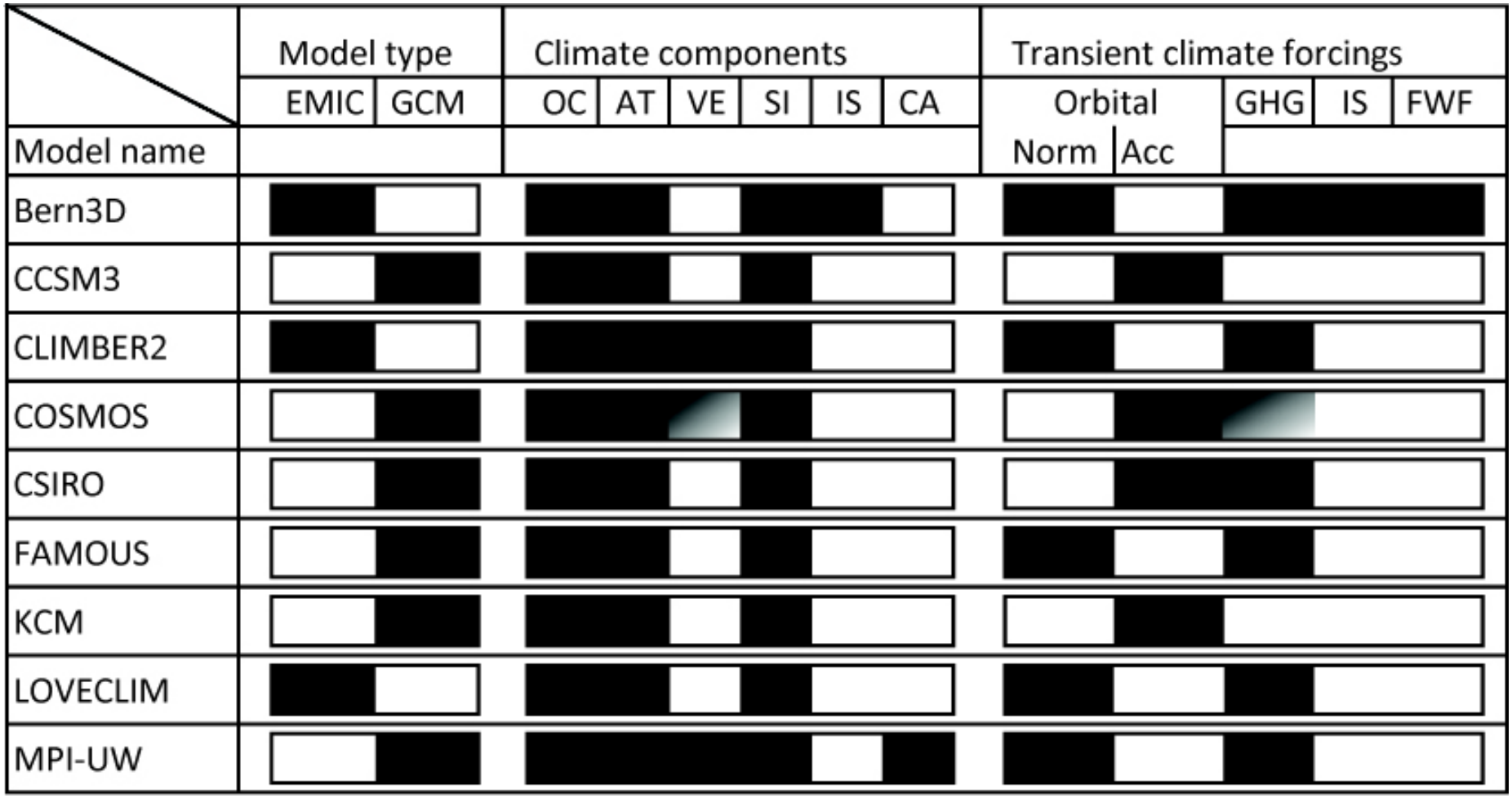
The "handshake" question



- 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

Climate model simulations

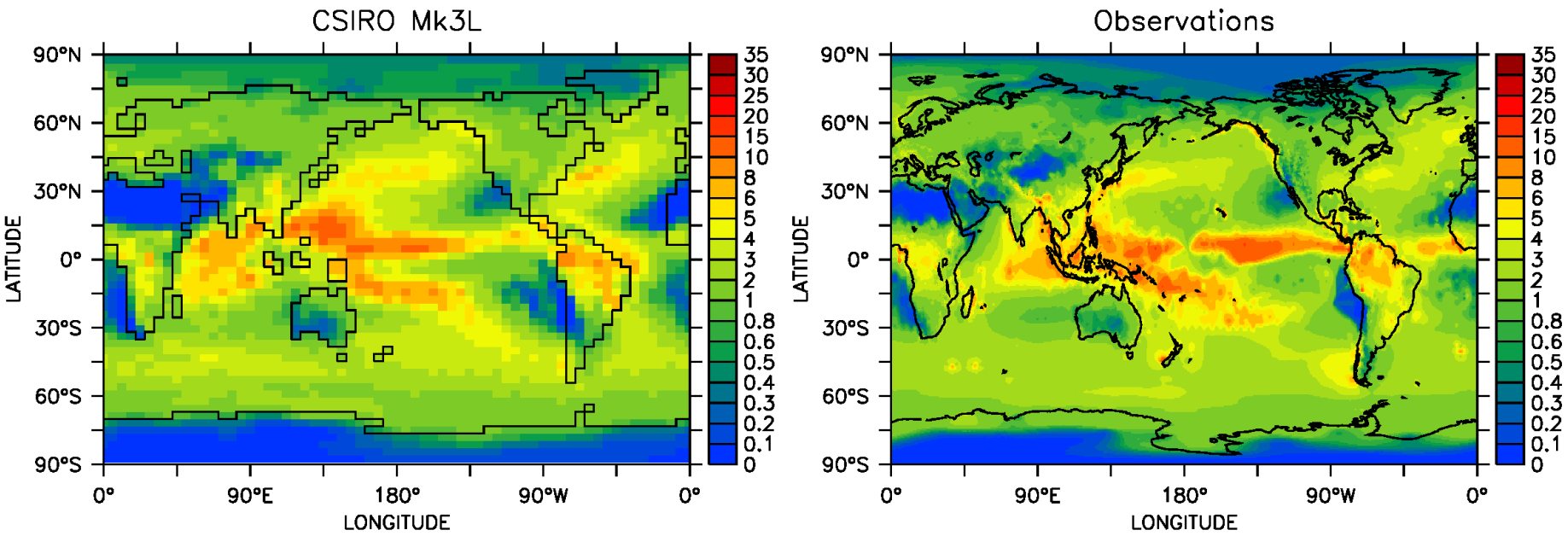
PMIP3 transient climate model simulations



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

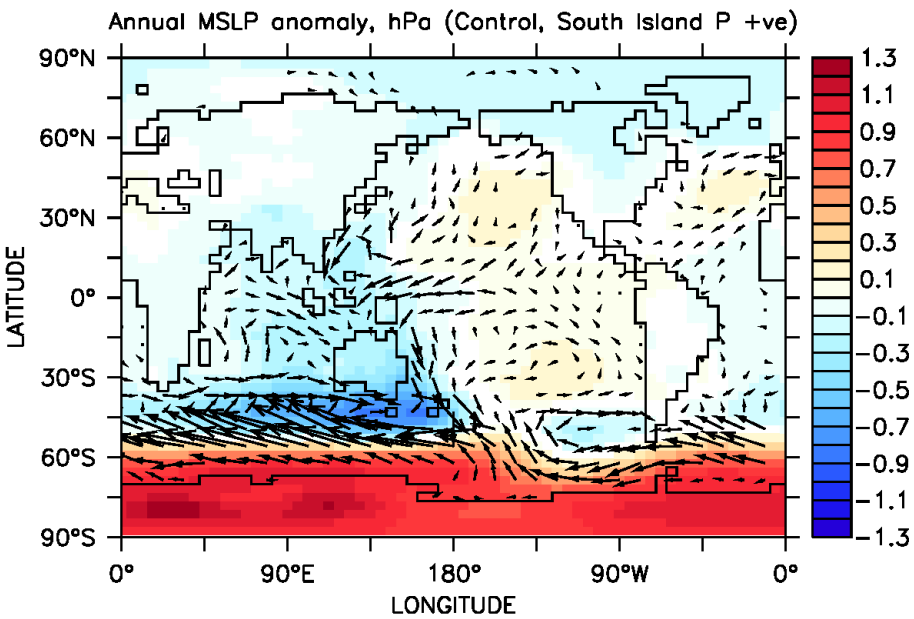
The CSIRO Mk3L climate system model

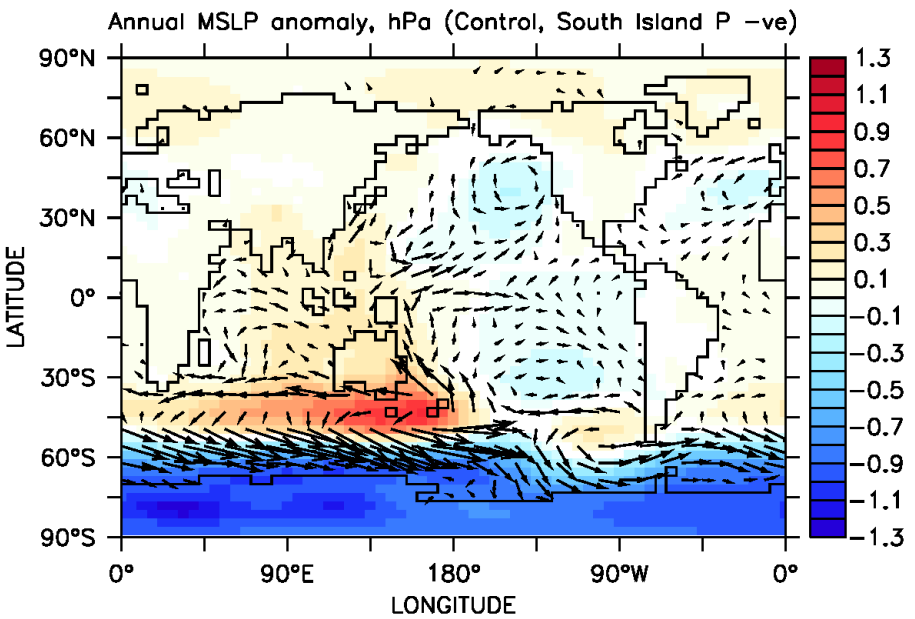
- The CSIRO Mk3L climate system model (Phipps et al., 2011, 2012)
  - Atmospheric general circulation model ($5.6° \times 3.2°$, 18 levels)
  - Ocean general circulation model ($2.8° \times 1.6°$, 21 levels)
  - Dynamic-thermodynamic sea ice model
  - Land surface scheme



Drivers of New Zealand South Island precipitation

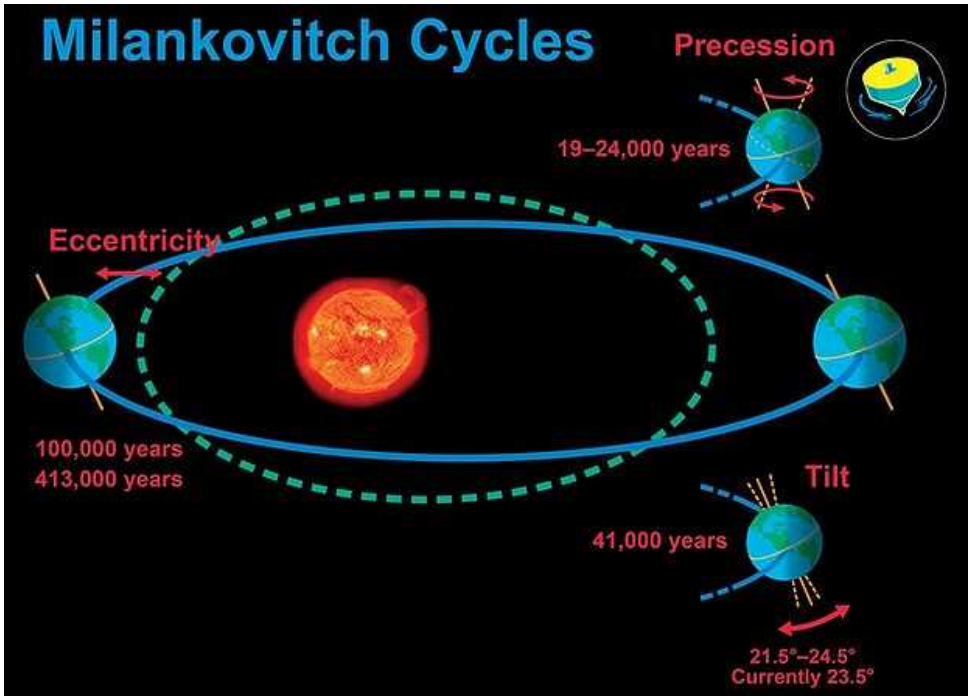
- 10,000-year pre-industrial control simulation
- Composite mean sea level pressure and surface wind stress for years when New Zealand South Island precipitation is more than one standard deviation above or below the long-term mean





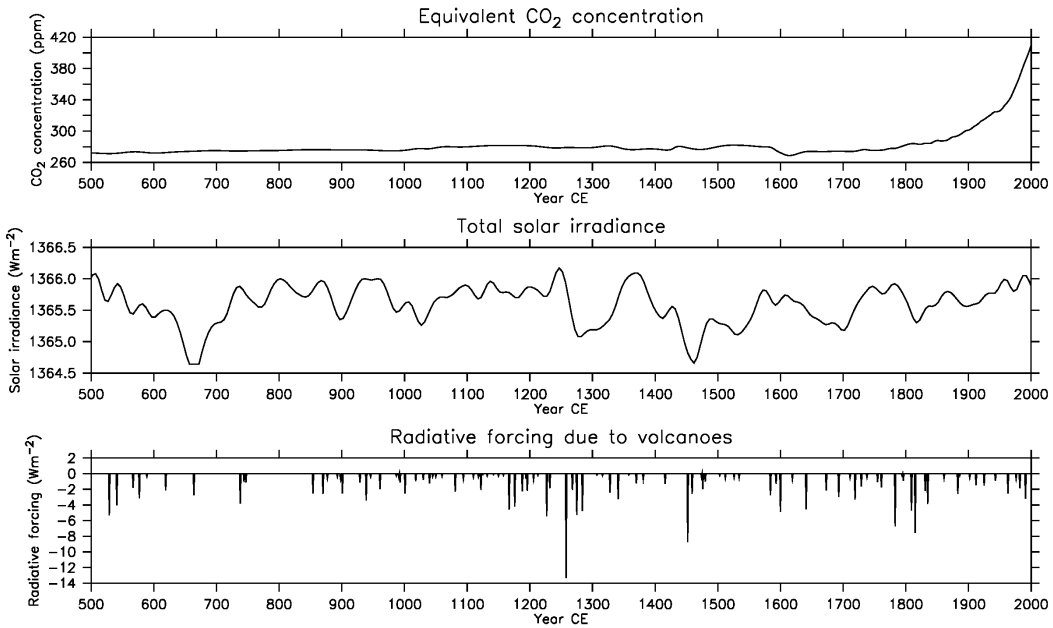
The role of orbital forcing over the past 8,000 years

- 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

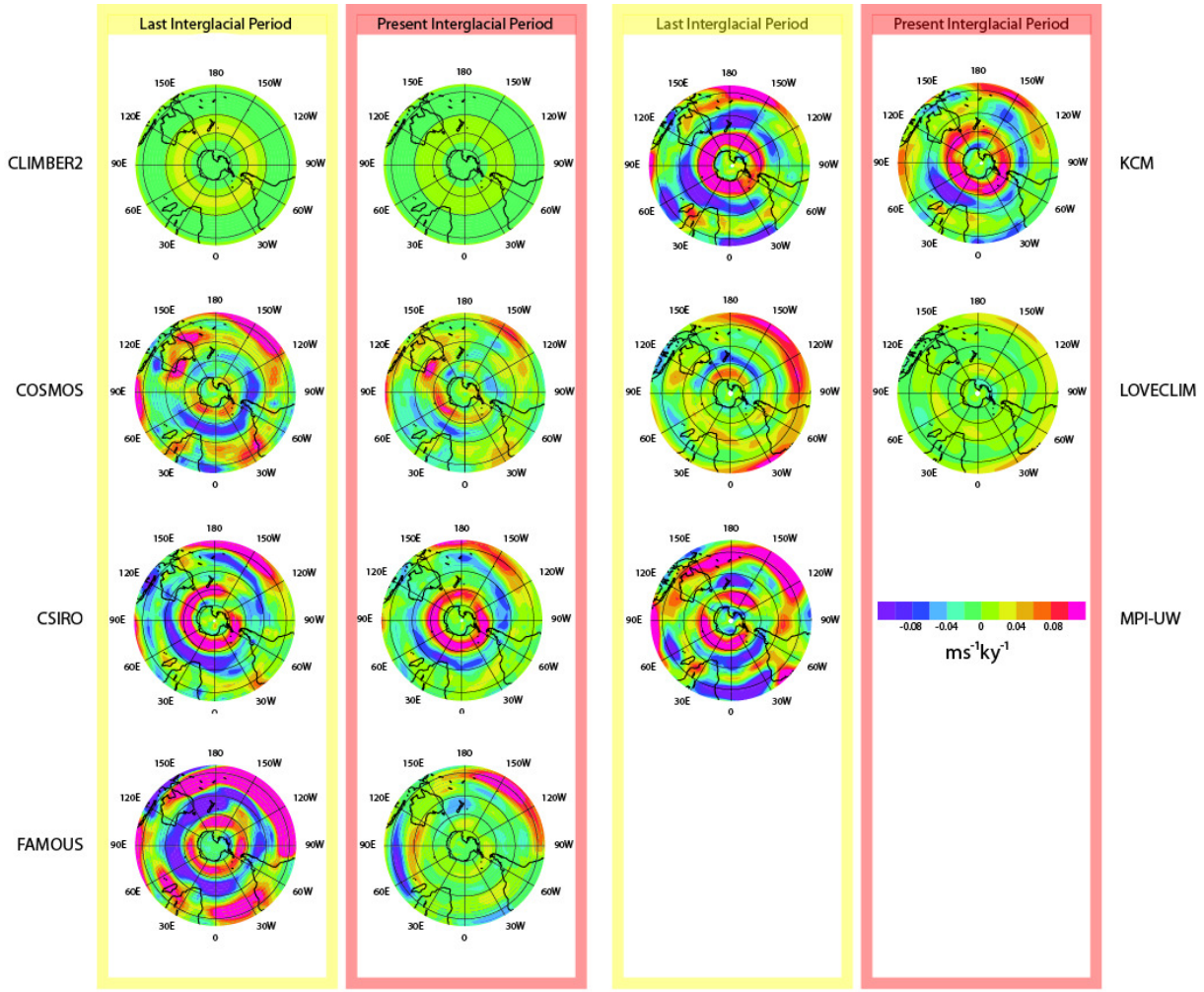
- Multiple ensembles of transient simulations of the past 1500 years:
  - Orbital changes (Berger, 1978)
  - Anthropogenic greenhouse gases (MacFarling Meure et al., 2006)
  - Solar irradiance (Steinhilber et al., 2009)
  - Explosive volcanism (Gao et al., 2008)



Simulations of the past 8,000 years

Steven J. Phipps, Climate Change Research Centre and ARC CoE for Climate System Science, UNSW, Sydney, Australia

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



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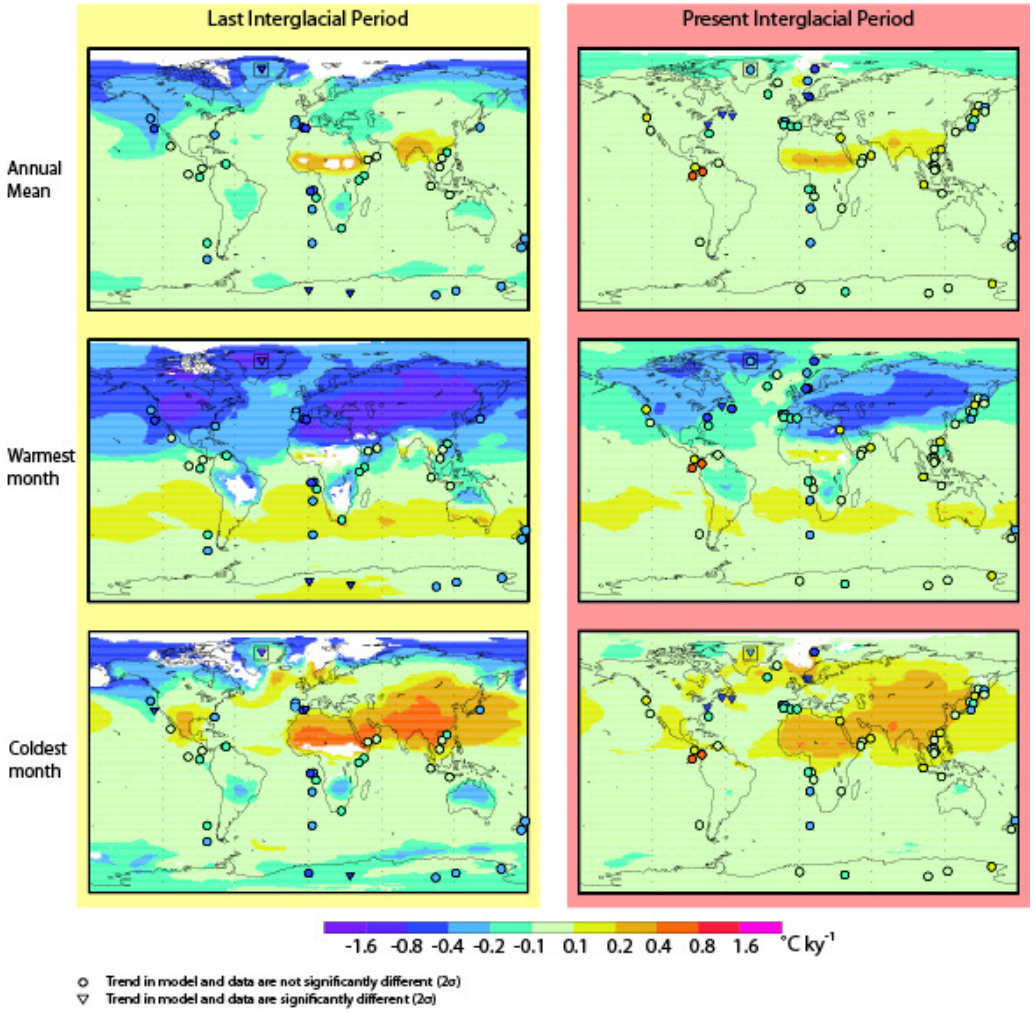
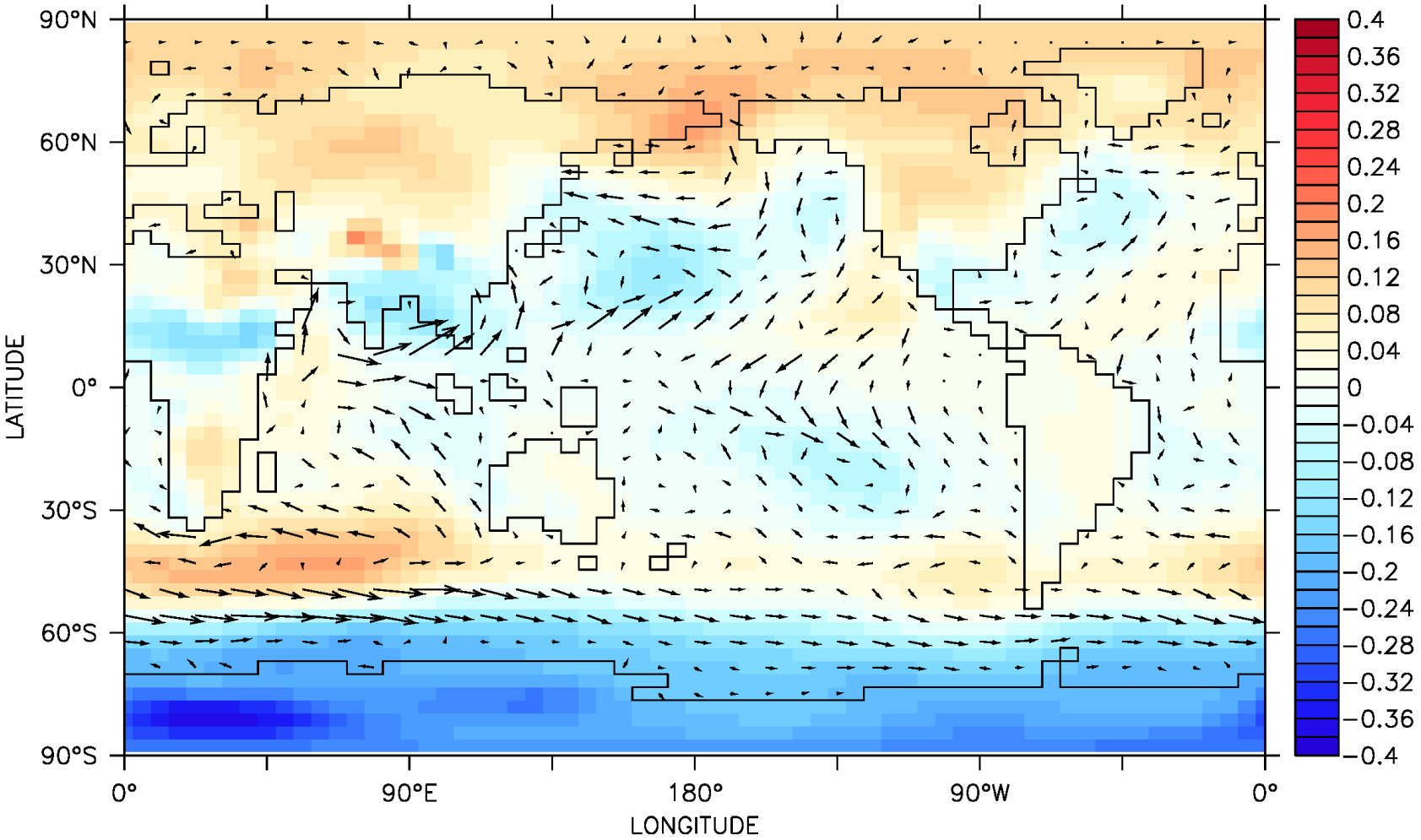
PMIP3: trend in surface air temperature (K ka^{-1})

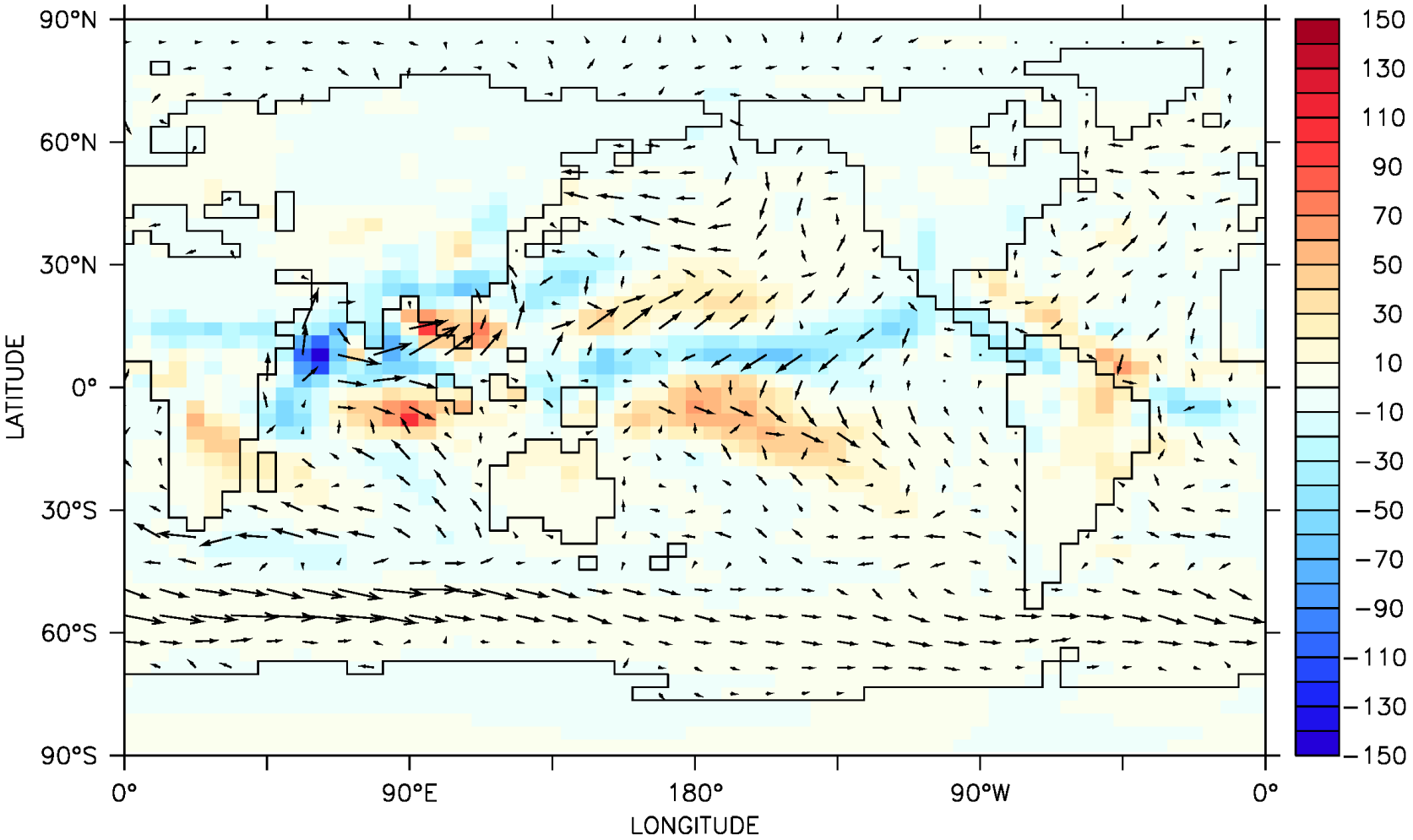


Bakker et al. (in revision), *Quaternary Science Reviews*

Mk3L: Trend in MSLP (hPa ka^{-1}) and surface wind stress



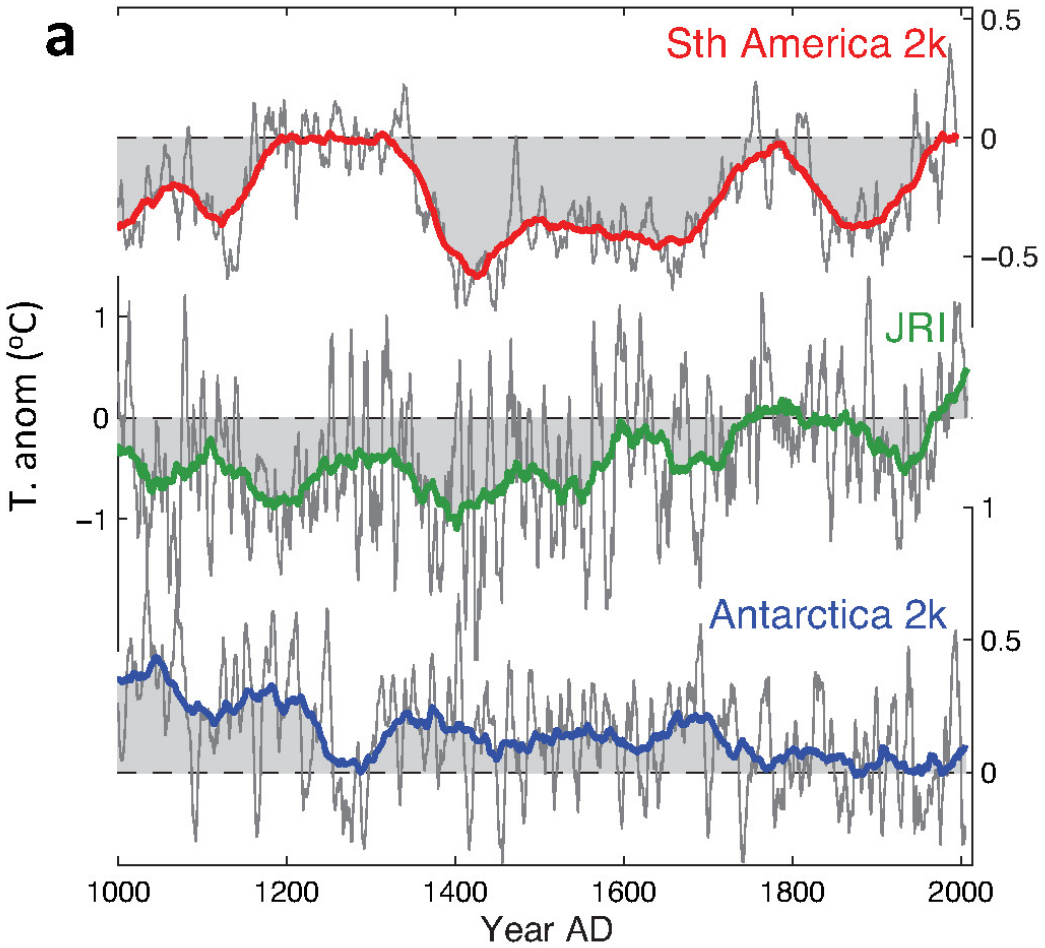
Mk3L: Trend in precip (mm ka^{-1}) and surface wind stress

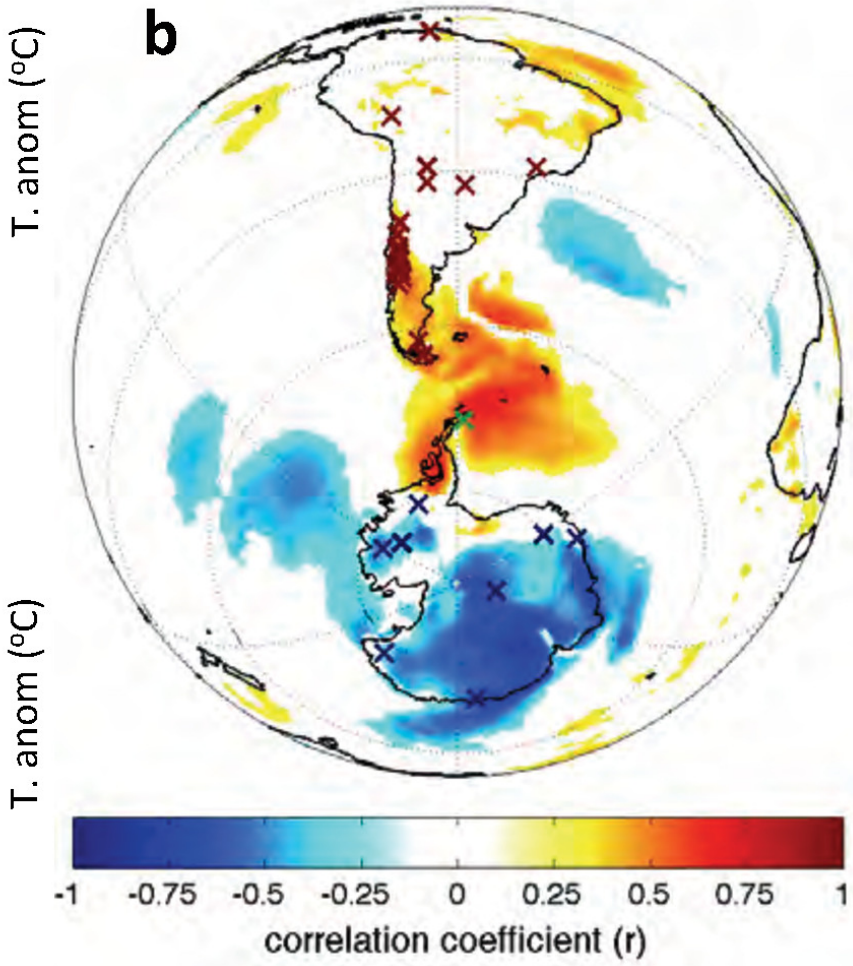


Evolution of SAM

Steven J. Phipps, Climate Change Research Centre and ARC CoE for Climate System Science, UNSW, Sydney, Australia

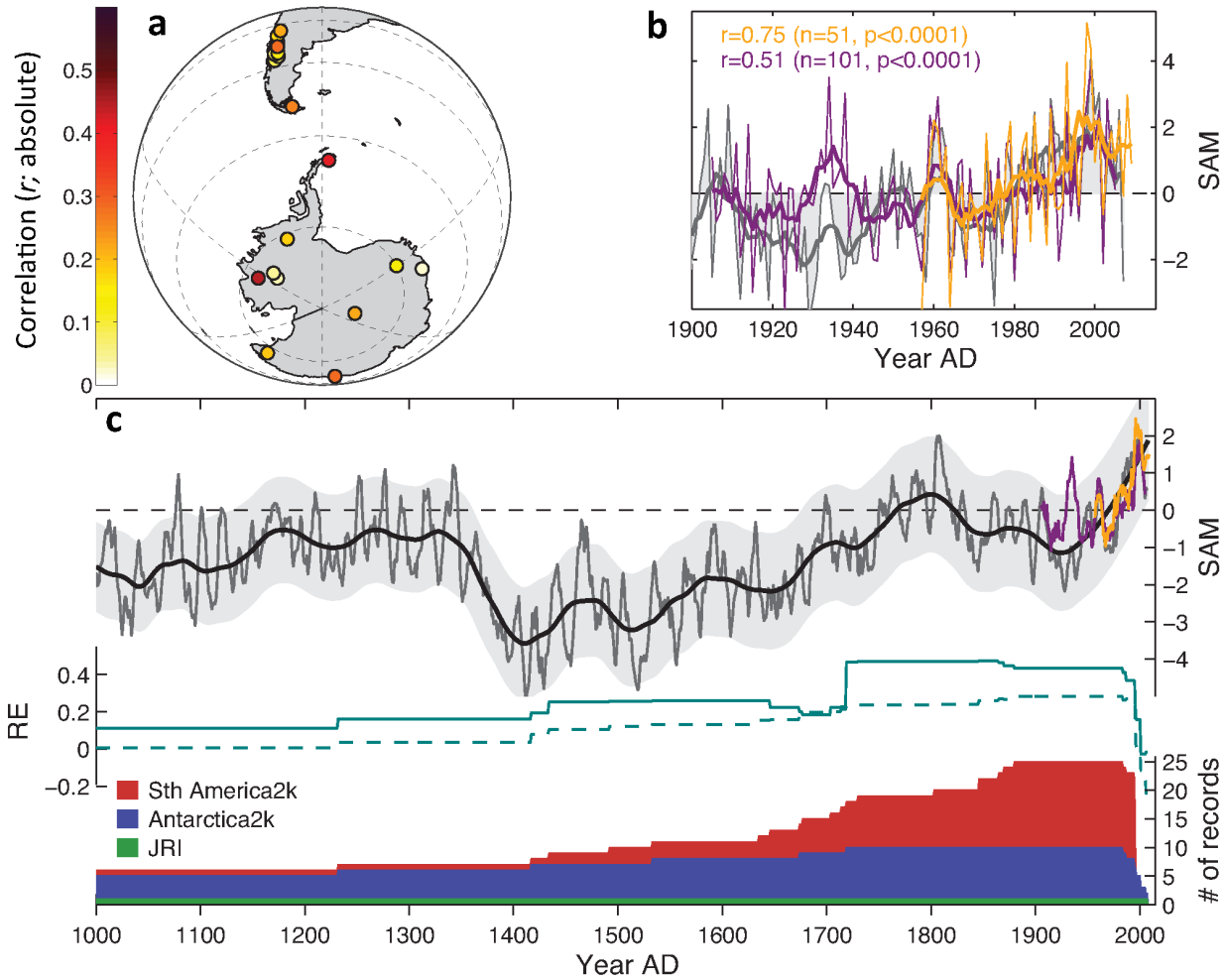
Temperature proxies and correlation with SAM





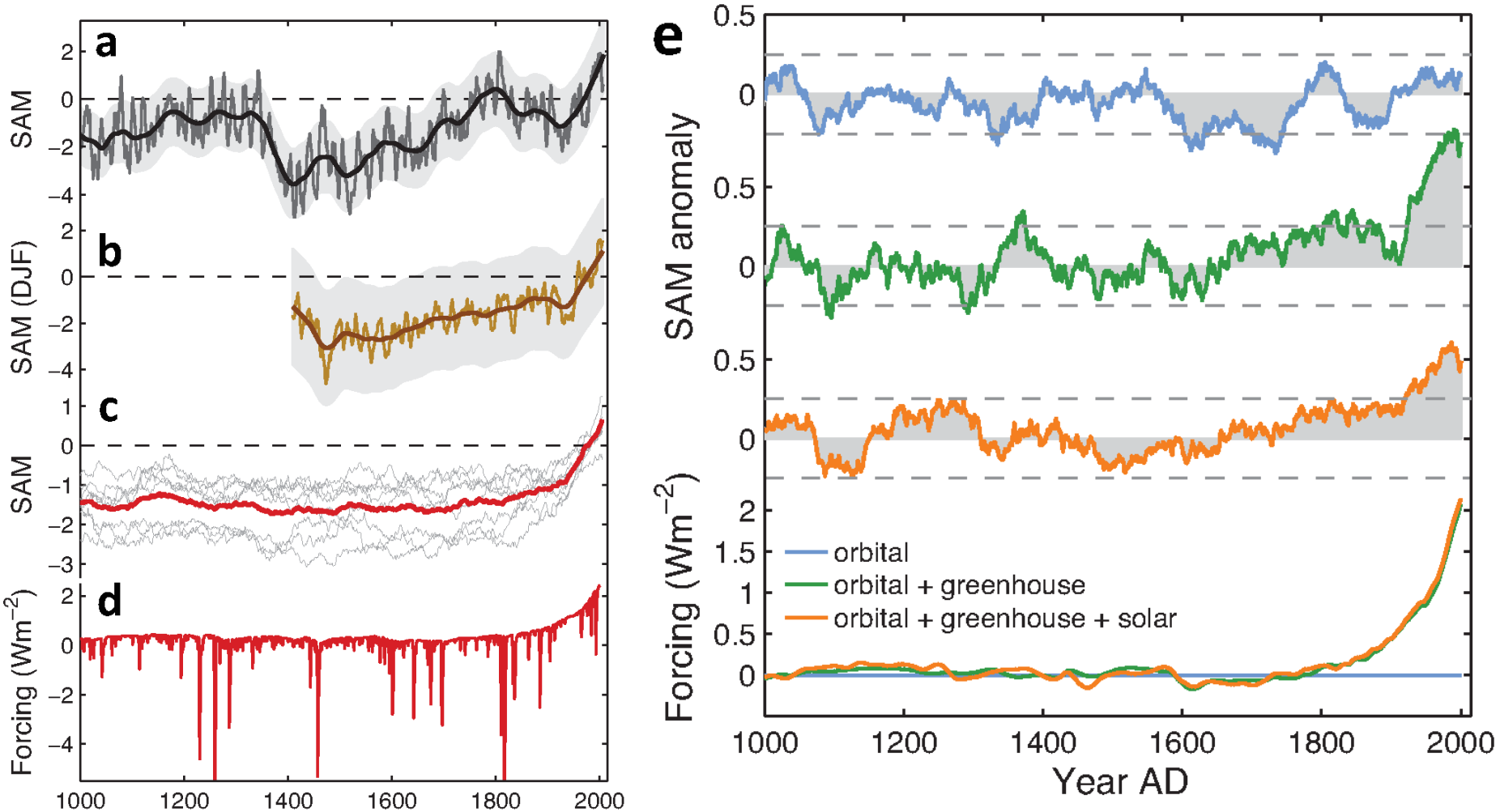
Abram et al. (in review), *Nature Climate Change*

Reconstruction of SAM over the last millennium



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

Data–model comparison and role of external forcings



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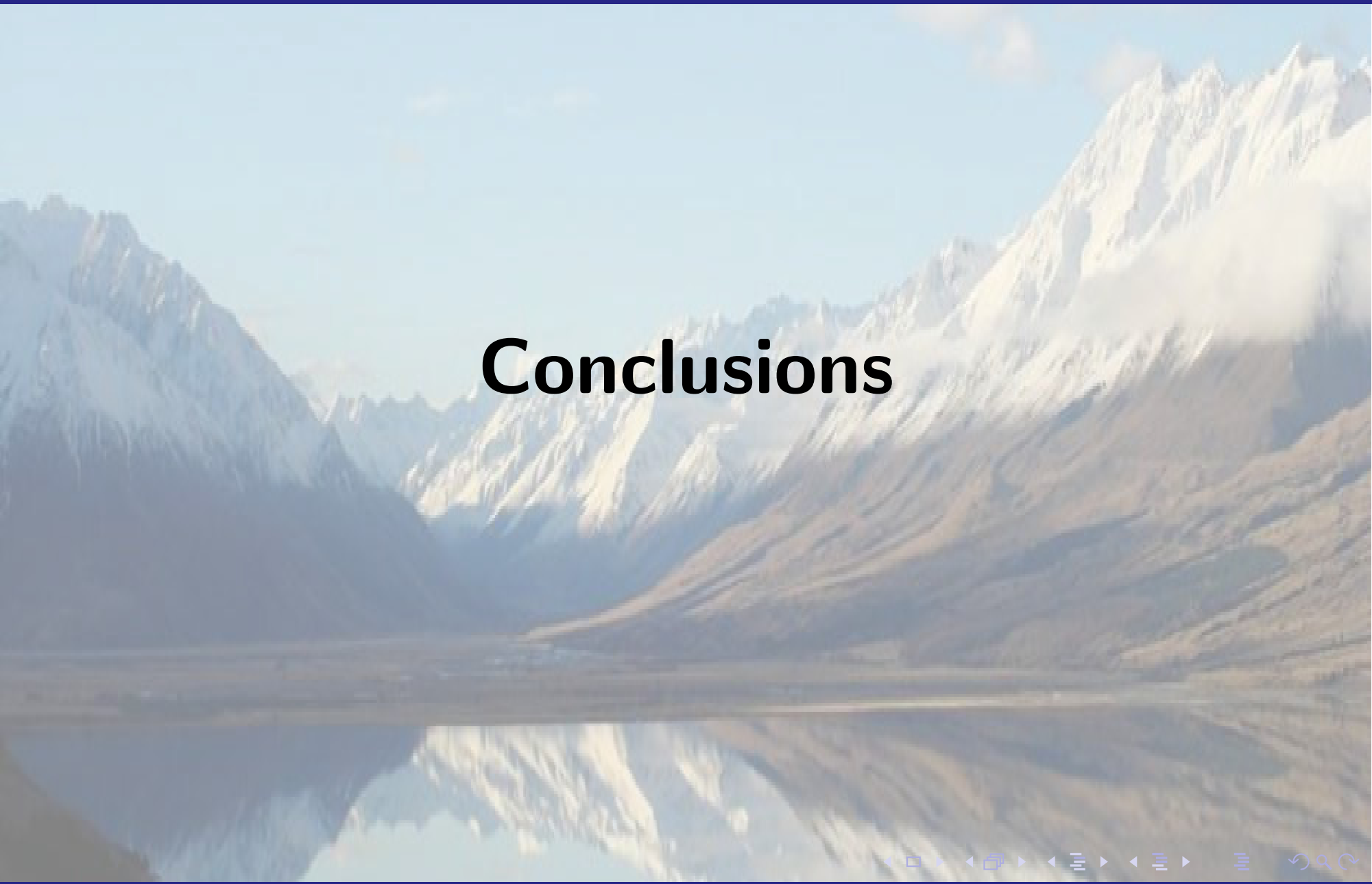

Conclusions

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?