T03: Holocene and last 2000 year climate forcings and variability

Solar and volcanic forcing of the Southern Hemisphere climate over the past 2000 years

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SHAPE
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1. Introduction

- The past 2000 years provides a valuable opportunity to study the role of external forcings in driving the global climate. Proxy data spanning this period covers a wide area and has high temporal resolution. Natural and anthropogenic forcings are also reasonably well constrained.
- Previous studies have found a significant role of volcanic eruptions in driving the Northern Hemisphere (NH) climate. However, the drivers of the Southern Hemisphere (SH) climate are less well understood.
- Here, we use a climate system model to simulate the evolution of the global climate over the past 2000 years. Different combinations of natural and anthropogenic forcings are applied, and the simulations are then compared with reconstructions of hemispheric temperature.

2. Data and model simulations

- Hemispheric-mean temperature reconstructions (Mann et al., 2008):
  - Global network of 1209 annually- and decadally-resolved proxies
  - Decadal temperature for 300–2006 CE (NH) and 400–2006 CE (SH)
- The CSIRO Mk3L climate system model (Phipps et al., 2011, 2012):
  - Atmosphere-land-sea ice-ocean general circulation model
  - Multiple transient simulations using three-member ensembles
  - Natural and anthropogenic forcings applied (Table 1 and Figure 1)

Ensemble	Years (CE)	Forcing(s)
O	1–2000	Orbital (Berger, 1978)
OG	1–2000	O + GHGs (MacFarling Meure et al., 2006)
OGS	1–2000	OG + solar irradiance (Steinhilber et al., 2009)
OGSV	501–2000	OGS + volcanic aerosols (Gao et al., 2008)
OGSV-CEA	801–2000	OGS + volcanic aerosols (Crowley and Unterman, 2013)

Table 1. The simulations presented here: the ensemble name, the duration, and the forcing(s) applied.

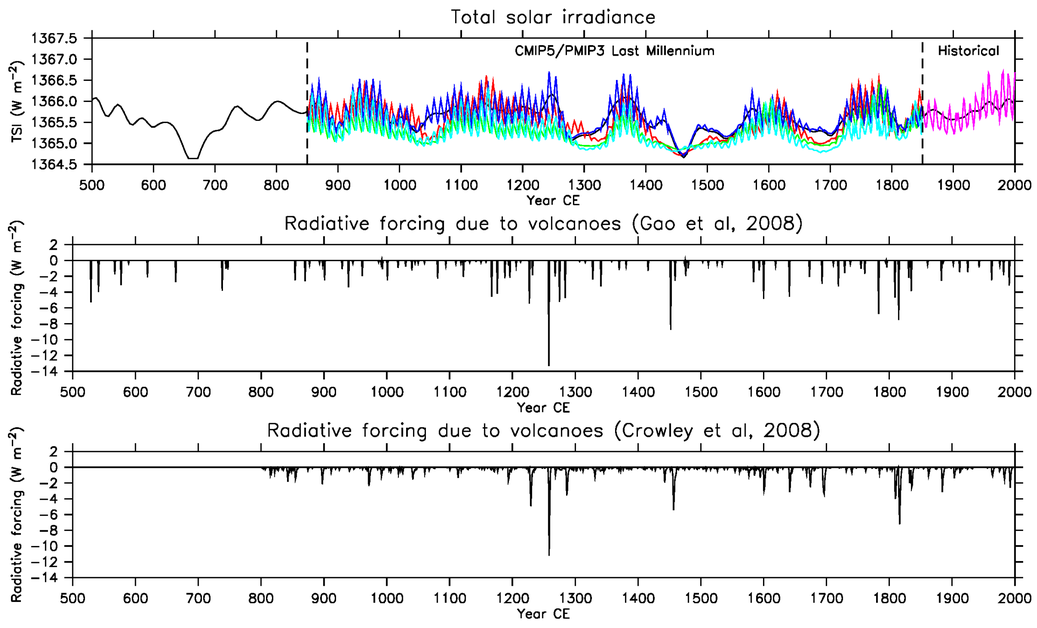

Figure 1. The reconstructions of solar and volcanic forcing used to drive the model.

3. Hemispheric temperature

- Progressively adding external forcings to the model improves the fit between the model simulations and the reconstructions (Figure 2).

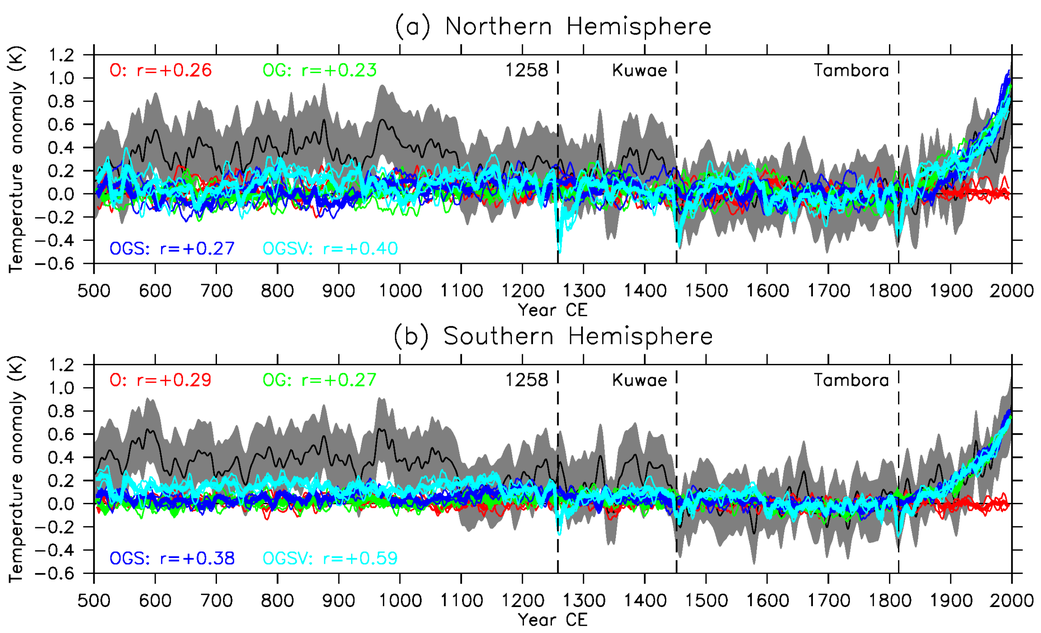

Figure 2. Hemispheric temperature: reconstructed (black), plus ensembles O (red), OG (green), OGS (dark blue) and OGSV (light blue). r is the correlation between each ensemble and the reconstructions.

4. Detection and attribution

- The addition of greenhouse gases, the sun and volcanoes all improve the agreement between the model and the reconstructions, as can be seen by the reductions in the errors (Figure 3). All of these forcings therefore appear to play a role in driving hemispheric temperature.
- The role of the sun and volcanoes appears to be stronger in the SH than in the NH.
- The model agrees better with the reconstructions when driven with the volcanic reconstruction of Crowley and Unterman (2013), suggesting that it may be more reliable than the reconstruction of Gao et al. (2008).

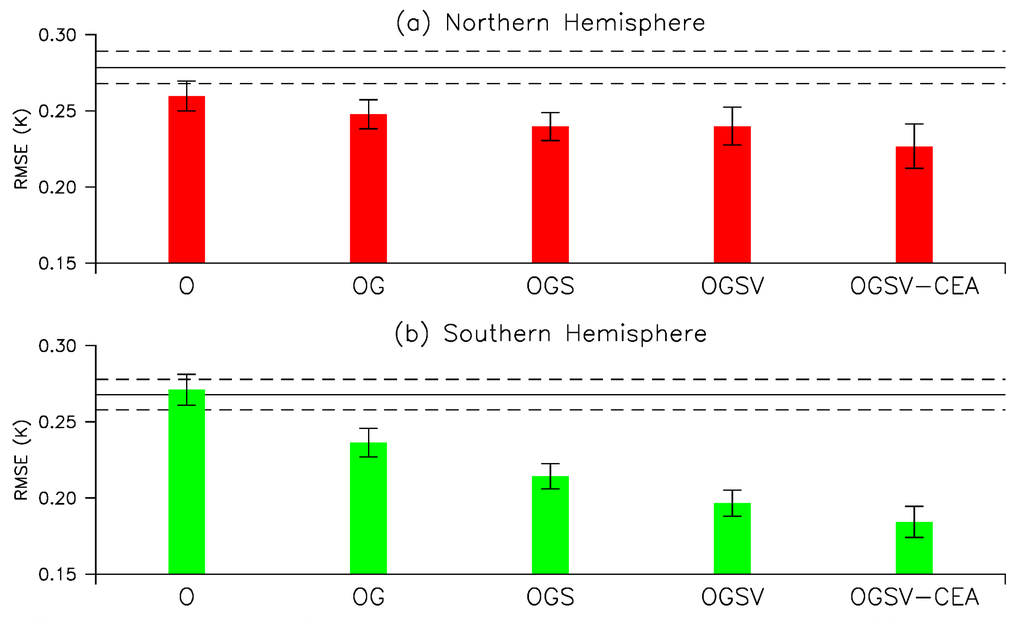

Figure 3. The root-mean-square (RMS) errors in the model simulations (801–2000 CE). A smaller error indicates better agreement. Horizontal lines show the RMS error for a pre-industrial control simulation.

5. Dating uncertainty

- The dating of past volcanic eruptions is uncertain. To explore this, we repeat ensemble OGSV but adjust the date of the Kuwae eruption within the volcanic reconstruction used to drive the model. Following Plummer et al. (2012), we change the date from 1452 to 1459 CE.
- We find that this change improves the agreement between the model and the reconstructions (Figure 4).

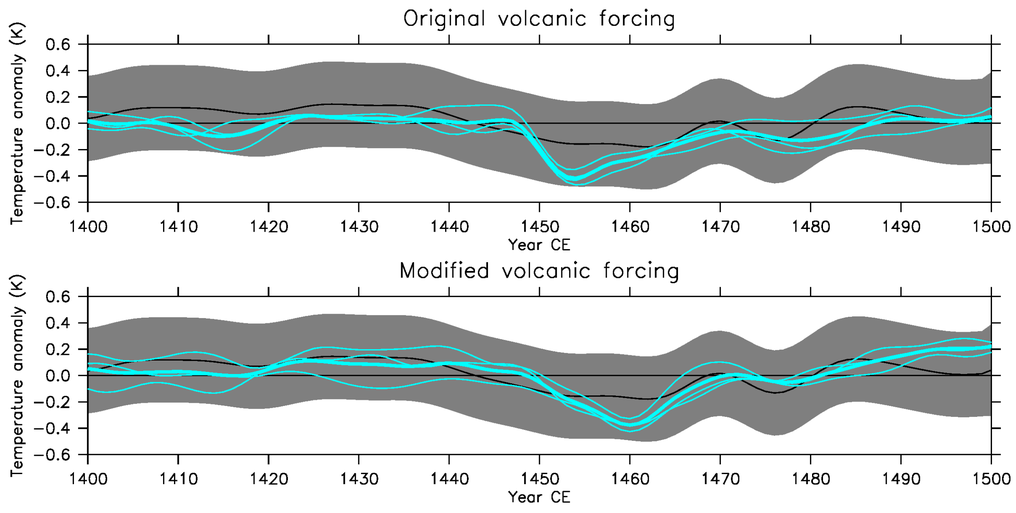

Figure 4. Simulated and reconstructed NH temperature, for the original and modified versions of ensemble OGSV. Thin lines are individual simulations; thick lines are the ensemble mean.

6. Conclusions

- We find strong evidence of solar and volcanic influences on the SH climate over the past 1500 years.
- However, the results are sensitive to the specific reconstruction of volcanic activity that is used to drive the model. We also find that the dating of major eruptions can impact upon the agreement between the model and the proxy record.
- If we are to learn all that we can from the climate of recent millennia, a critical challenge is therefore to develop better reconstructions of past climatic forcings – particularly volcanic eruptions.

References

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