Australasian climate variability and change during the past two millennia: Towards data-model integration

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1. Modelling the recent past

The climate of the recent past provides a valuable opportunity to study the response of the climate system to natural and anthropogenic forcings. Here, the CSIRO Mk3L climate system model (Phipps et al., 2011) is used to simulate the climate of the past 1500 years. The simulations are then compared with two reconstructions derived from multiproxy networks.

The following combinations of forcings are applied to the model (Figure 1):

- orbital + greenhouse gases
- orbital + greenhouse gases + solar
- orbital + greenhouse gases + solar + volcanic

In each case, three independent climate model simulations are conducted. The differences *between* each ensemble of simulations allow the roles of solar and volcanic forcing to be studied. The differences *within* each ensemble allow forced and unforced variability to be distinguished.

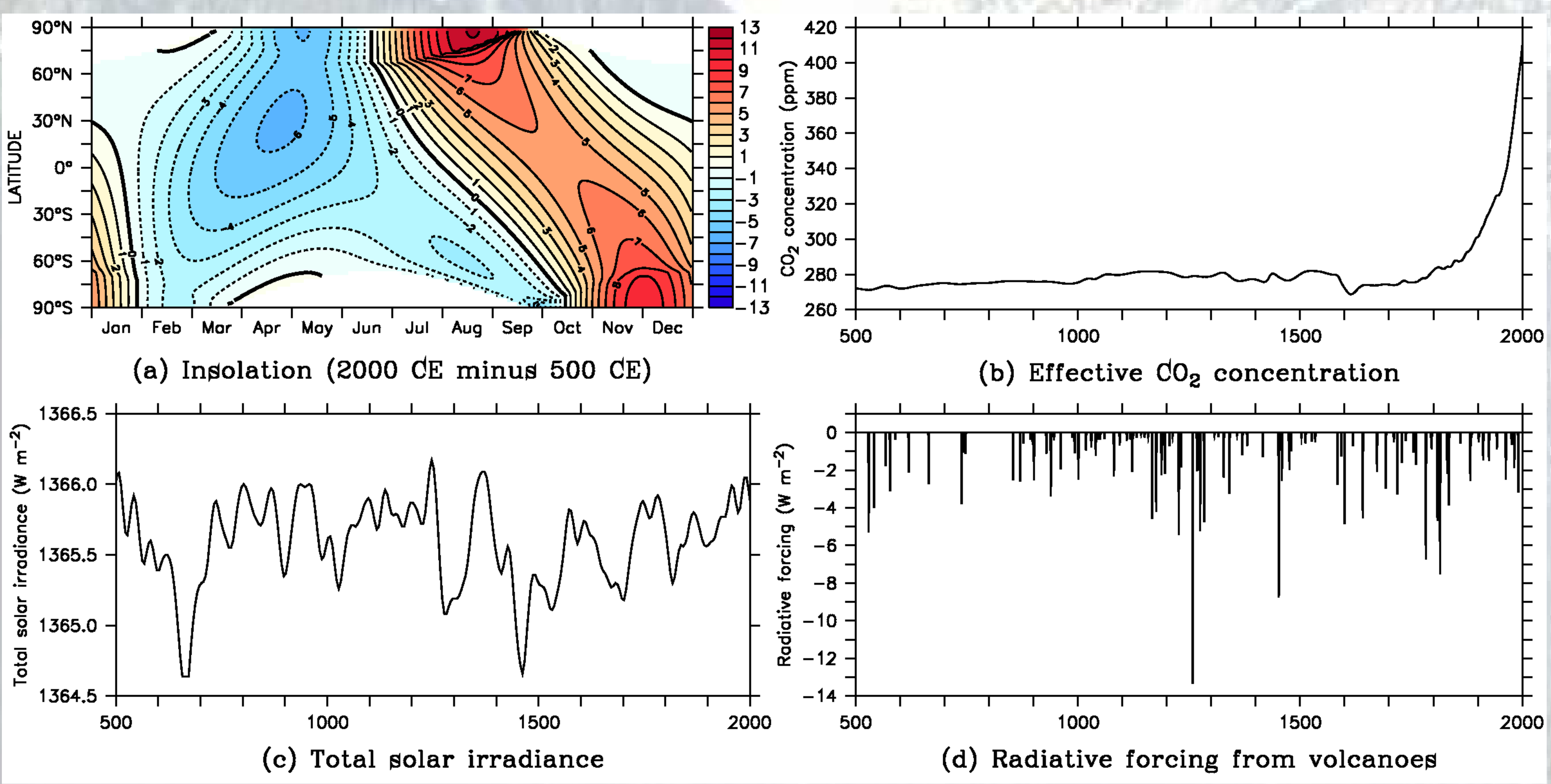

Figure 1. The forcings on the climate system between 500 CE and 2000 CE: **a** the changes in the distribution of insolation due to changes in the Earth's orbital geometry, **b** the effective CO_2 concentration (from MacFarling Meure et al., 2006), **c** total solar irradiance (from Steinhilber et al., 2009), and **d** the radiative forcing due to volcanic eruptions (from Gao et al., 2008).

2. The Northern Hemisphere

The simulated annual-mean Northern Hemisphere surface air temperature is shown in Figure 2, and is compared with the multiproxy reconstruction of Mann et al. (2009).

In the absence of solar and volcanic forcing, the model simulates no trend in the hemispheric-mean temperature during the pre-industrial era. Only when all forcings are applied does the model simulate centennial-scale warm and cold periods. However, the model is generally too cold prior to 1100 CE, and fails to capture the relative warmth associated with the Mediaeval Climate Anomaly.

When all forcings are applied, the model is in remarkably good agreement with the reconstruction throughout the period 1400–1850 CE. The increasingly poor agreement prior to this time suggests deficiencies in either the model or the forcing datasets.

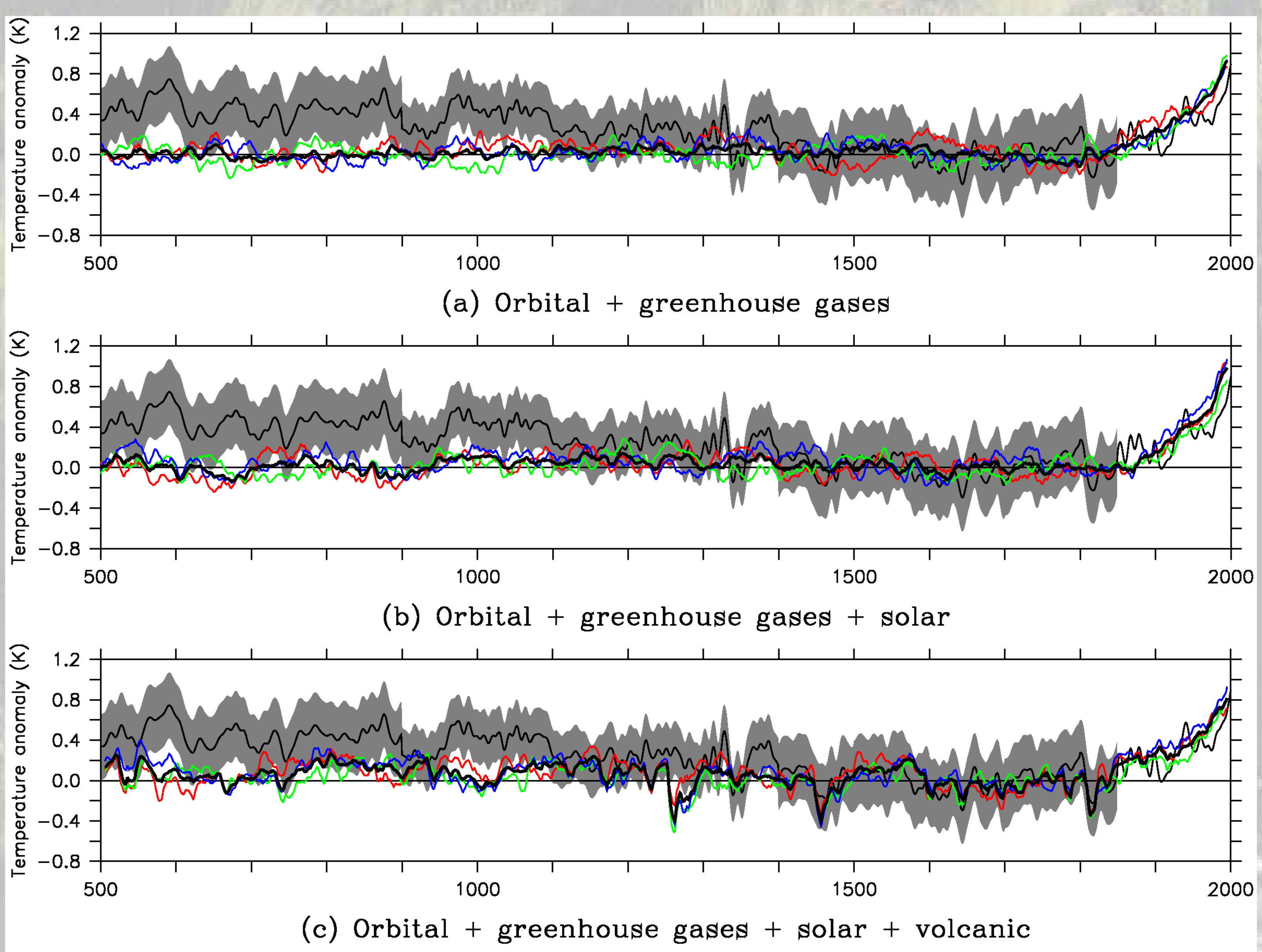

Figure 2. The simulated annual-mean Northern Hemisphere surface air temperature, compared with the "all proxy" timeseries of Mann et al. (2009). The red, blue and green lines show the ten-year running means for individual climate model simulations, and the thick black lines show the ensemble mean. The 95% confidence interval for Mann et al. (2009) is indicated by grey shading. All values are expressed as anomalies relative to the 1500–1850 CE mean.

3. Mediaeval Climate Anomaly and Little Ice Age

The simulated temperature anomalies associated with the Mediaeval Climate Anomaly (MCA) and the Little Ice Age (LIA) are shown in Figure 3.

Solar and volcanic forcing both contribute to the relative warmth during the MCA, as well as to the relatively cool conditions during the LIA. The model fails to capture the La Niña-like pattern of temperature anomalies that appears to have prevailed during the MCA (Mann et al., 2009).

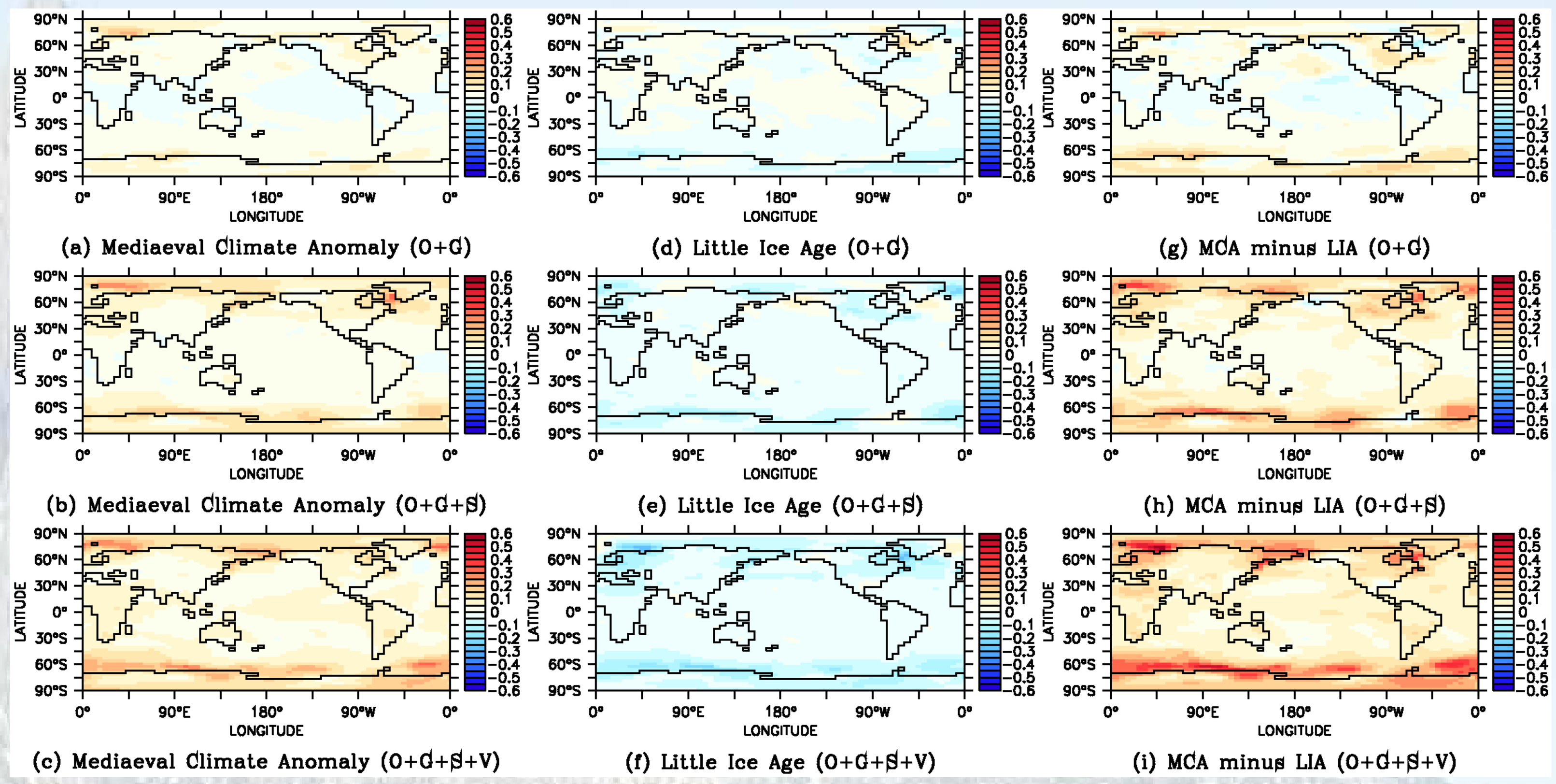

Figure 3. The simulated annual-mean temperature anomalies according to each ensemble of climate model simulations for the Mediaeval Climate Anomaly (MCA; 950–1250 CE) and the Little Ice Age (LIA; 1400–1700 CE): **a, b, c** the MCA, expressed as anomalies relative to the 850–1850 CE mean, **d, e, f** the LIA, expressed as anomalies relative to the 850–1850 CE mean, and **g, h, i** the MCA minus the LIA.

4. Australasia

The simulated SONDJF (September-February) surface air temperature for the Australasian region is shown in Figure 4, and is compared with a new multiproxy reconstruction developed by the PAGES Aus2k network (see the poster in this session by Gergis, Neukom and Aus2k working group members).

The model is broadly consistent with the reconstruction throughout the pre-industrial period. The best agreement is obtained, particularly on decadal timescales, when all forcings are applied. During the industrial period, the model over-estimates the magnitude of the warming trend.

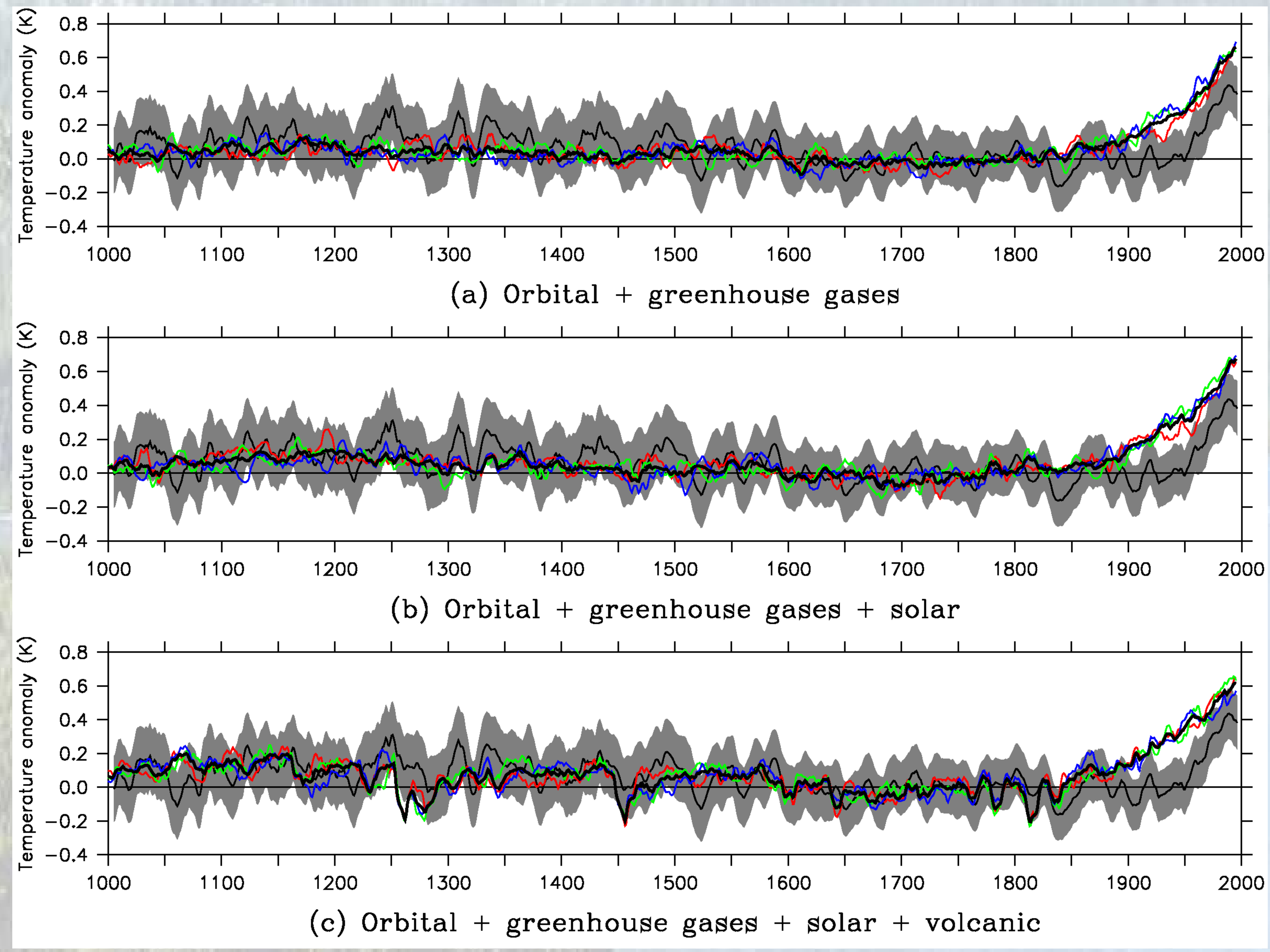

Figure 4. The simulated SONDJF surface air temperature for the Australasian region (100°–180°E, 50°–0°S), compared with the PAGES Aus2k reconstruction. The red, blue and green lines show the ten-year running means for individual climate model simulations, and the thick black lines show the ensemble mean. The 95% confidence interval for the reconstruction is indicated by grey shading. All values are expressed as anomalies relative to the 1500–1850 CE mean.

5. Conclusions

The CSIRO Mk3L climate system model is broadly capable of reproducing changes in surface temperature for the Northern Hemisphere and the Australasian region over the last millennium. Prior to 1100 CE, however, the simulated Northern Hemisphere temperature becomes increasingly divergent from the reconstruction, suggesting deficiencies in either the model or the forcing datasets.

The best agreement between the model and the reconstructions is obtained when all forcings are applied. On centennial timescales, both solar and volcanic forcing contribute to the global-scale temperature changes associated with the Mediaeval Climate Anomaly and the Little Ice Age. On decadal timescales, volcanoes appear to be the dominant driver of forced variability.

References

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