The evolution of the Southern Hemisphere climate within transient simulations of the Holocene

Steven J. Phipps[1,2], Maisa Rojas[3,4] and Duncan Ackerley[5]

[1]Climate Change Research Centre, University of New South Wales, Sydney, Australia (s.phipps@unsw.edu.au).
[2]ARC Centre of Excellence for Climate System Science, University of New South Wales, Sydney, Australia.
[3]Department of Geophysics, University of Chile, Santiago, Chile. [4]Millennium Nucleus on Paleoclimate of the Southern Hemisphere.
[5]Monash Weather and Climate, Monash University, Melbourne, Australia.

SHAPE

Southern Hemisphere Assessment of PalaeoEnvironments

1. Introduction

- The SHAPE project aims to reconstruct and understand past changes in the atmospheric and oceanic circulation of the Southern Hemisphere.
- Within this context, climate modelling plays a critical role in testing the interpretation of the proxy data and exploring the underlying dynamical mechanisms.
- Here, we analyse a suite of simulations of the Holocene climate. These are generated using state-of-the-art climate system models, and include simulations conducted by Phase Three of the Paleoclimate Modelling Intercomparison Project (PMIP3).

2. Model simulations

- We analyse four transient simulations of the period from 8ka BP to present (Table 1). Different combinations of forcings are applied; some of the models accelerate the rate of change of the external forcings so as to reduce the time taken to complete each simulation.

Model	Atmospheric resolution		Forcings			Acceleration	Reference
	Horizontal	Levels	O	G	IS		
CCSM3	3.75° × 3.75°	26	Y	-	-	10x	Varma et al. (2012)
CSIRO Mk3L	5.625° × 3.18°	18	Y	Y	-	10x	Phipps et al. (2013)
FAMOUS	7.5° × 5°	11	Y	Y	-	-	Bakker et al. (2013)
TRACE (CCSM3)	3.75° × 3.75°	26	Y	Y	Y	-	Liu et al. (2009)

Table 1. The simulations presented here: the model, the resolution of the atmosphere, the forcings applied (O = orbital, G = greenhouse gases, IS = ice sheets), the rate of acceleration, and the reference.

- We also examine the PMIP2 and PMIP3 time slice simulations of the mid-Holocene climate (6ka BP).

3. Westerly Winds

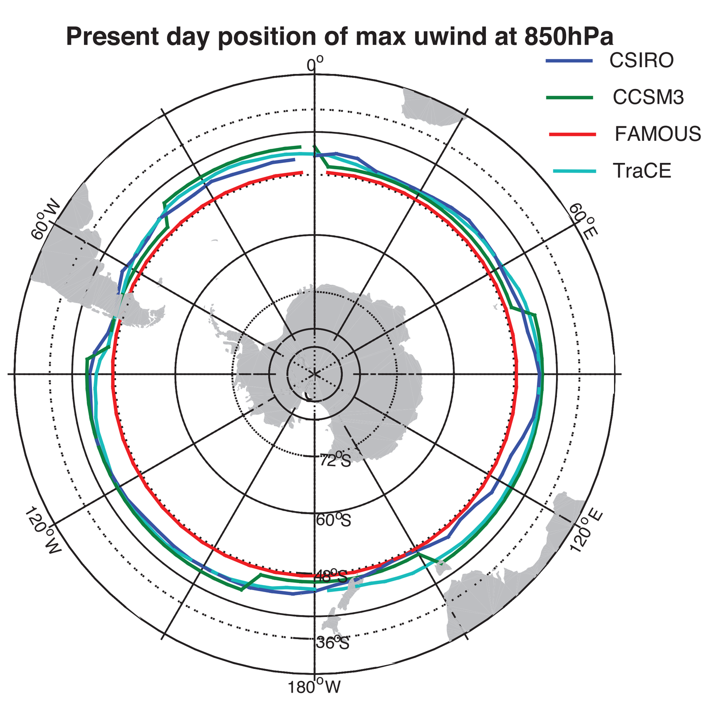

Figure 1. The present-day position of the SH westerly winds within each transient simulation.

- A Gaussian fit to the zonal wind at 850 hPa is used to characterise the strength, position and width of the Southern Hemisphere (SH) westerly wind belt.
- The present-day position of the westerly winds is simulated well by each model, although FAMOUS exhibits excessive zonal symmetry (Figure 1).

- All four models exhibit weak variability in the strength of the westerly winds throughout the Holocene (Figure 2a).
- CSIRO Mk3L and CCSM3, and to a lesser extent TRACE, show a progressive poleward shift in the latitude of the maximum wind speed (Figure 2b).
- CSIRO Mk3L and TRACE exhibit variability in the width of the westerly wind belt, with CSIRO Mk3L also simulating a trend towards a wider belt (Figure 2c).
- The coarse-resolution FAMOUS model simulates no changes in the location or width of the wind belt.

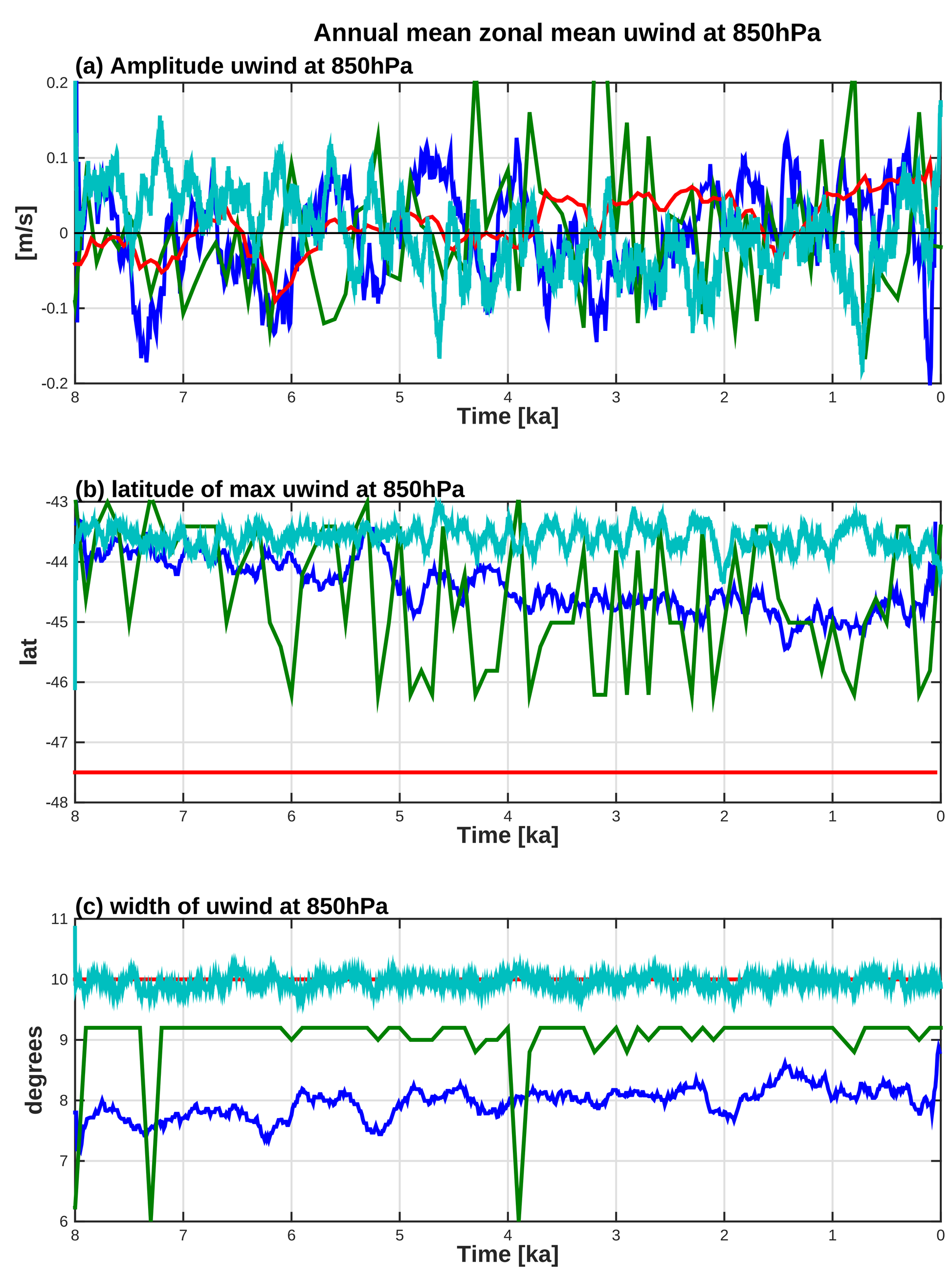

Figure 2. The evolution of the SH westerly winds within each transient simulation: (a) the strength, shown relative to the mean, (b) the latitude of maximum zonal wind speed, and (c) the width of the westerly wind belt.

4. Holocene trends

- We now use the CSIRO Mk3L simulations to examine the linear trends in a number of climatic variables during the Holocene (Figure 3).
- Surface air temperature decreases over Antarctica and the Southern Ocean, but generally increases at lower latitudes. There is a deepening and poleward contraction of the circumpolar trough, accompanied by a strengthening and poleward contraction of the westerly winds. These changes are associated with increasing sea ice cover.
- The simulated cooling trend over the Southern Ocean is consistent with reconstructions, but is not generally captured by other models driven with similar forcings (Bakker et al., 2014). Otherwise, the trends are comparable with previous multi-model analyses of transient Holocene simulations (Varma et al., 2012; Bakker et al., 2014).

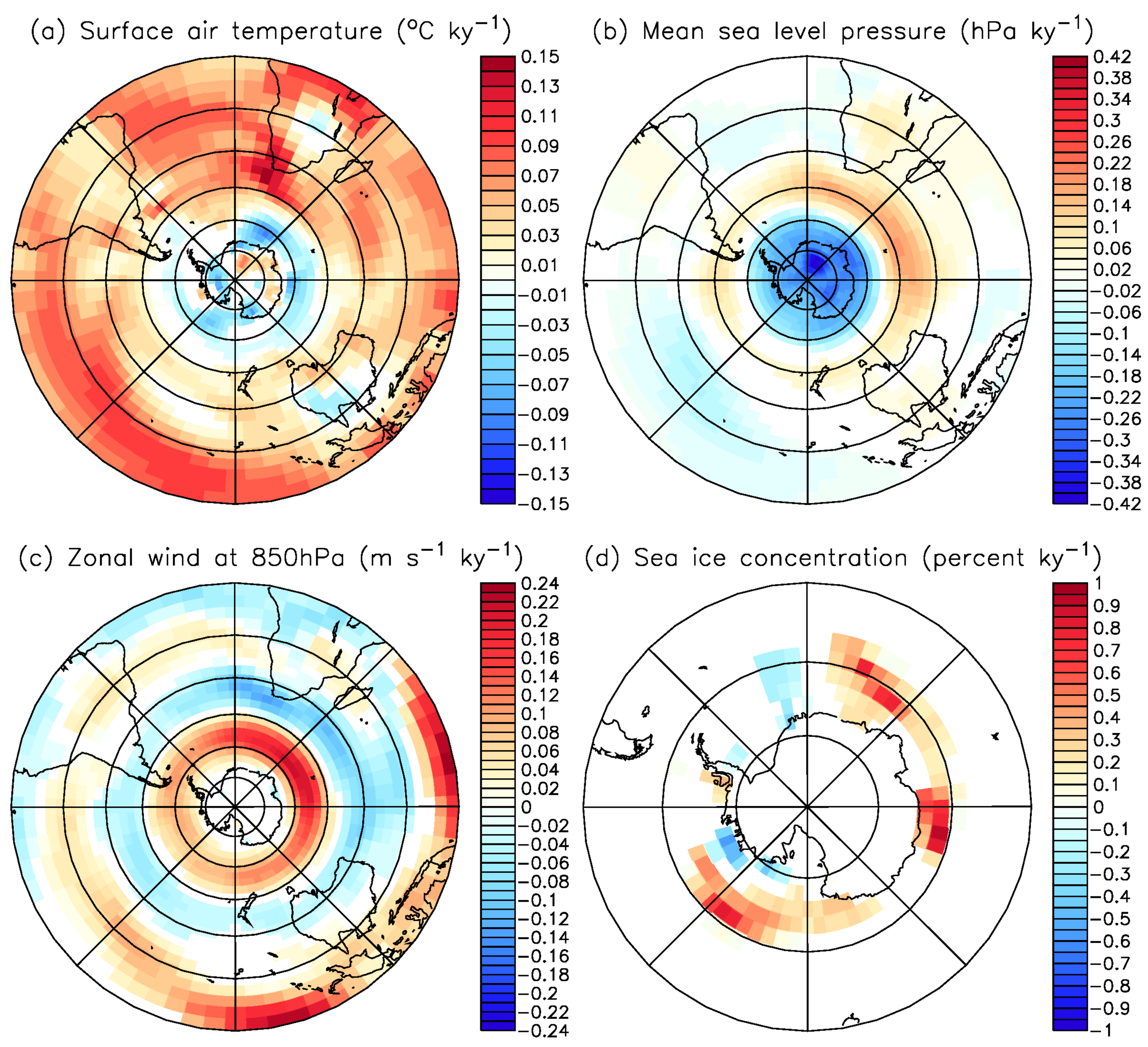

Figure 3. The simulated linear trends in various annual-mean variables over the period 8–0ka BP, according to CSIRO Mk3L. Only values that are significant at the 5% probability level are shown.

5. Australia during the mid-Holocene

- We also examine the anomalies in Australian temperature and precipitation within the PMIP2/PMIP3 mid-Holocene simulations (Figure 4).
- These anomalies are calculated on a regional basis, to enable comparison with the OZ-INTIMATE synthesis (Reeves et al., 2013).
- The regions where there is strong (>80%) multi-model agreement indicate cooler conditions in the tropics, and warmer and drier conditions over the Southern Ocean. There is poorer agreement elsewhere.

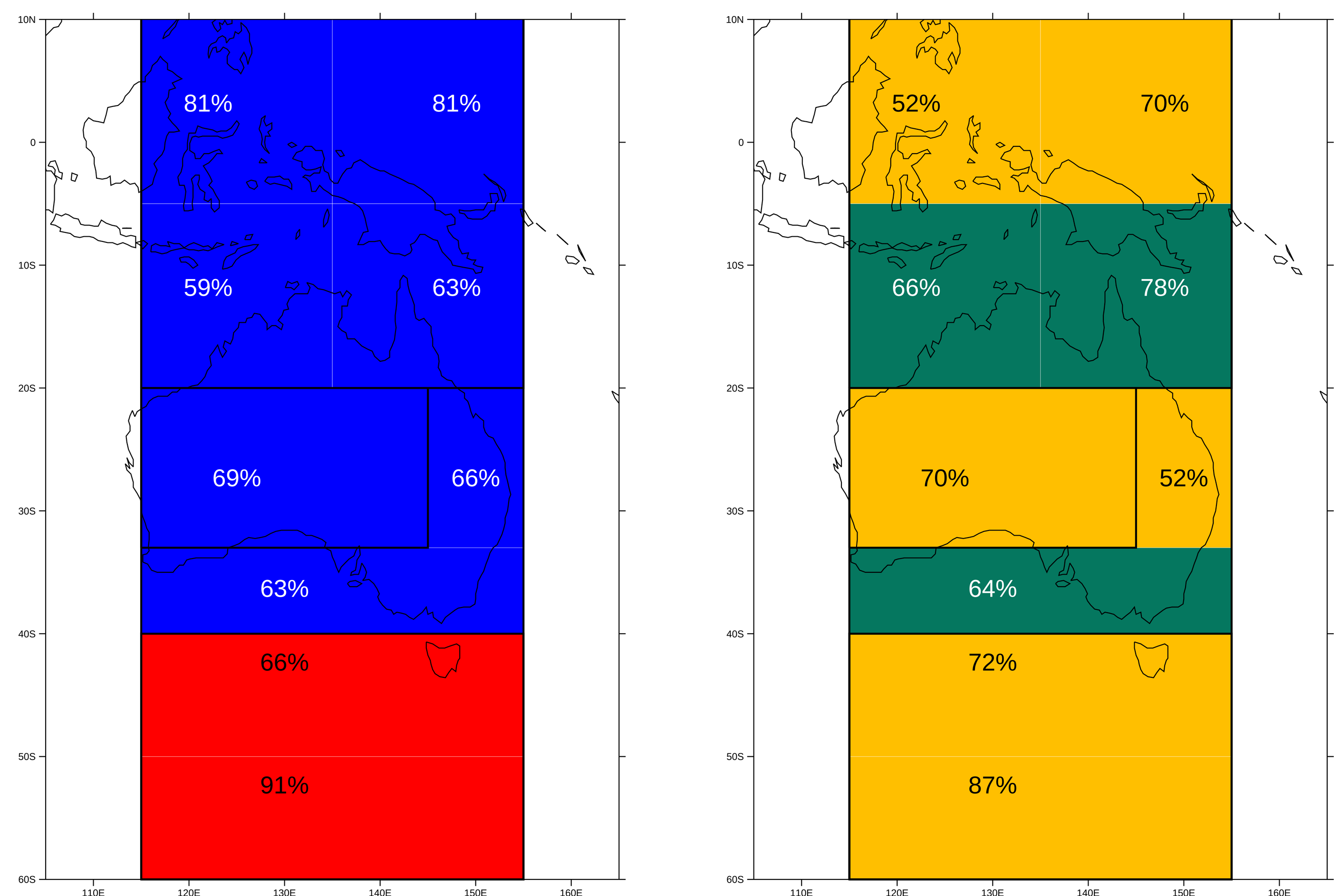

Figure 4. The annual-mean anomalies in temperature (left) and precipitation (right) at 6ka BP according to the PMIP2/PMIP3 multi-model ensemble. Red/blue indicates warmer/colder; green/amber indicates wetter/drier. The percentage of simulations that agree on the sign of each anomaly is shown.

References

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