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

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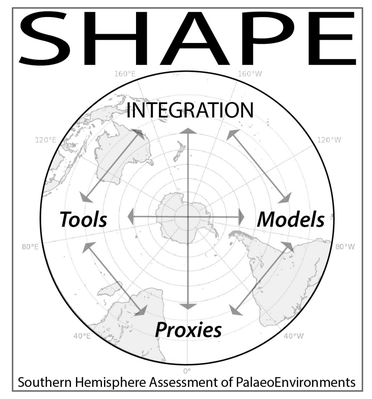


## 1. Introduction

- 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 also 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.

## 3. Westerly Winds

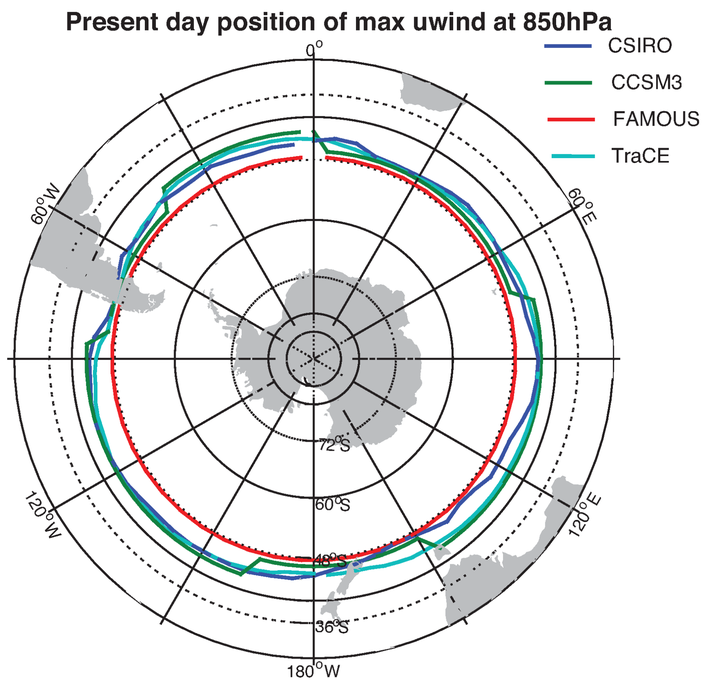


**Figure 1.** The present-day position of the SH westerly winds within each transient simulation.

- 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 (Fig. 1).
- All four models exhibit weak variability in the strength of the westerly winds throughout the Holocene (Fig. 2a).
- CSIRO Mk3L and CCSM3, and to a lesser extent TraCE, show a progressive poleward shift in the latitude of the maximum wind speed (Fig. 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 (Fig. 2c).
- The coarse-resolution FAMOUS model simulates no changes in the location or width of the wind belt.

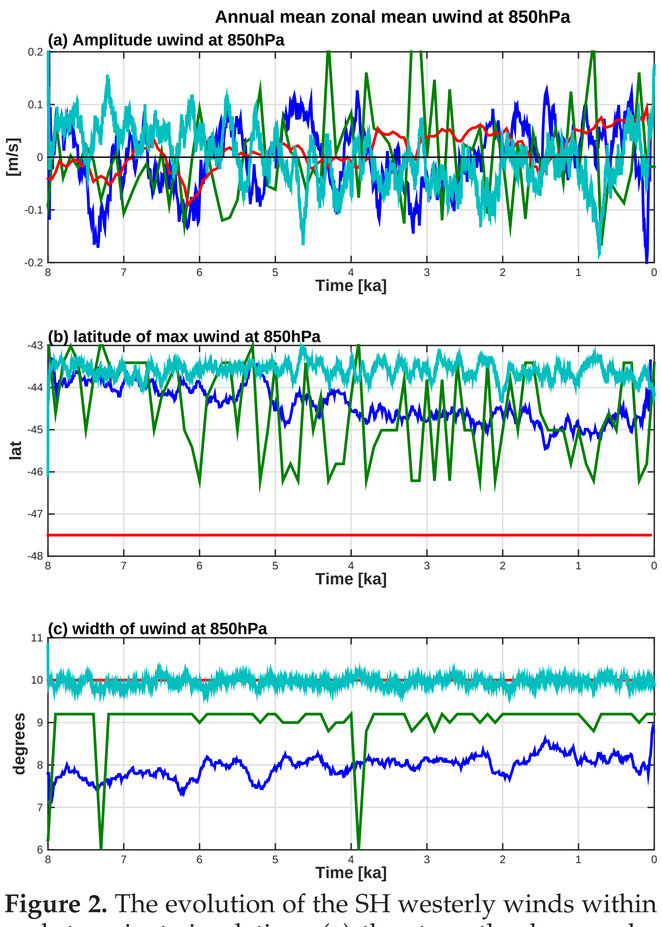


**Figure 2.** The evolution of the SH westerly winds within each transient simulation: (a) the strength, shown relative to the mean, (b) the latitude of maximum zonal wind speed, and (c) the width of the westerly wind belt.

## 4. Holocene trends

- We now use the CSIRO Mk3L simulations to examine the linear trends in a number of climatic variables during the Holocene (Fig. 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).

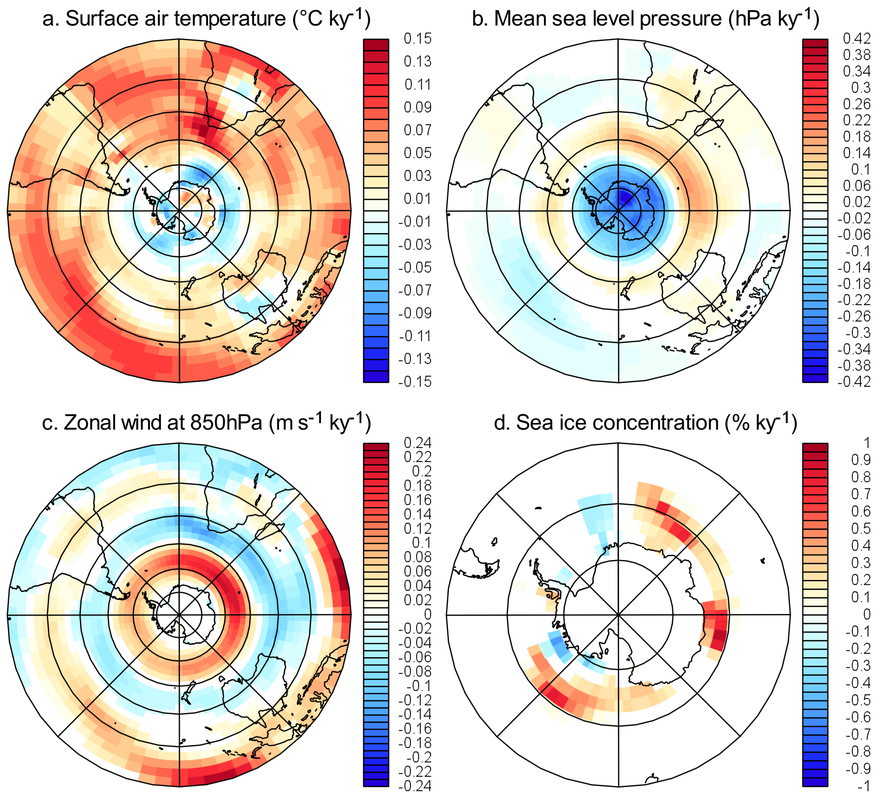


**Figure 3.** The linear trends in various annual-mean variables over the period 8–0ka BP, according to CSIRO Mk3L. Only values that are significant at the 5% probability level are shown.

## 5. Seasonality

- Within the CSIRO Mk3L simulations, the trends in the westerly winds can exhibit considerable seasonality (Fig. 4). This is particularly apparent in the Pacific sector: over New Zealand and southern Australia, for example, even the sign of the trend depends upon the season.
- Seasonality should therefore be considered when using proxies to reconstruct changes in the SH westerly winds over the Holocene.

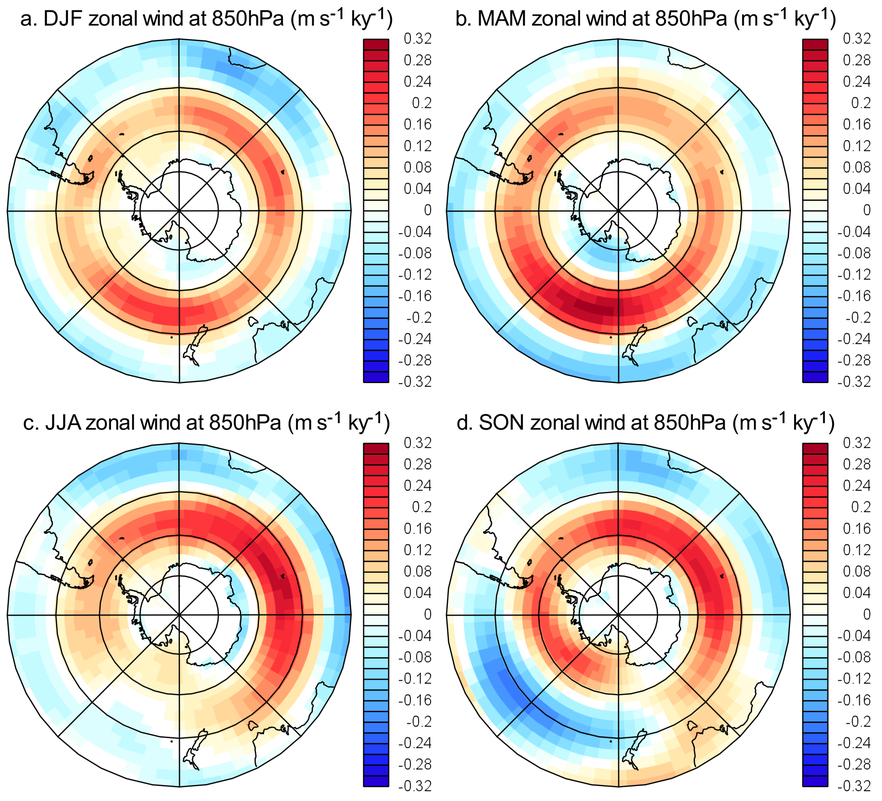


**Figure 4.** The linear trends in DJF (December-January-February), MAM (March-April-May), JJA (June-July-August) and SON (September-October-December) zonal wind at 850 hPa over the period 8–0ka BP, according to CSIRO Mk3L. Only values that are significant at the 5% probability level are shown.

## References

- Bakker et al. (2013), doi:10.5194/cp-9-605-2013.
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- Varma et al. (2012), doi:10.5194/cp-8-391-2012.