Wet and wild summers during the middle Miocene?

Nicholas Herold (nicholas.herold@geosci.usyd.edu.au), John You, Dietmar Müller, Maria Sdrolias

Introduction

The Australian summer monsoon forms the southern extent of the greater Southeast Asian monsoon. A lack of sufficient fossil flora and sedimentary data has left the Australian monsoon's pre-Quaternary history (>1.6 Ma) largely unconstrained. **Monsoons are commonly thought to be driven by land-sea temperature gradients, so would the more southerly location of Australia during the middle Miocene (15.9 - 11.6 Ma) preclude the existence of the Australian monsoon?** Testing this relationship through palaeo-climate simulations and ground truthing will help us understand future evolutions of the monsoon.

The middle Miocene is the last time in geological history where Australia lay significantly south of its modern day location while maintaining a warm, humid climate (Martin, 2006). This makes it an ideal period for testing the existence of a pre-Quaternary monsoon.

Results

To assess the relative strength of the Miocene Australian monsoon system **two climate simulations were run; one configured at year 2005 conditions (Forster et al., 2007) and the other at middle Miocene conditions (see Methods).**

Compared to our present day simulation, precipitation in our Miocene simulation over northern Australia is lower, however is higher over the monsoon trough (Fig. 1). December-January-February (DJF) precipitation over the monsoon trough reaches 1,405 mm in the Miocene, compared to 1,147 mm at present. Lower precipitation over northern Australia in the Miocene (520 mm) compared to present (667 mm) is due to the continent's more southerly location, not to migration of precipitation (Fig. 3).

Intensity of the monsoon trough (indicated by precipitation, wind strength and sea-level pressure) is greater in the Miocene compared to present. This is a result of increased evaporation and precipitation due to larger and warmer seas north of Australia (Fig. 3).

The monsoon trough does not transect northern Australia during the Miocene, as opposed to the modern (Fig. 2b), however its greater extent ensures that northern Australia receives significant seasonal rainfall. The relatively static location of the monsoon trough supports the hypothesis that the monsoon is driven primarily by migration of the Inter Tropical Convergence Zone (ITCZ) (Chao and Chen, 2001), and not the land-sea temperature gradient.

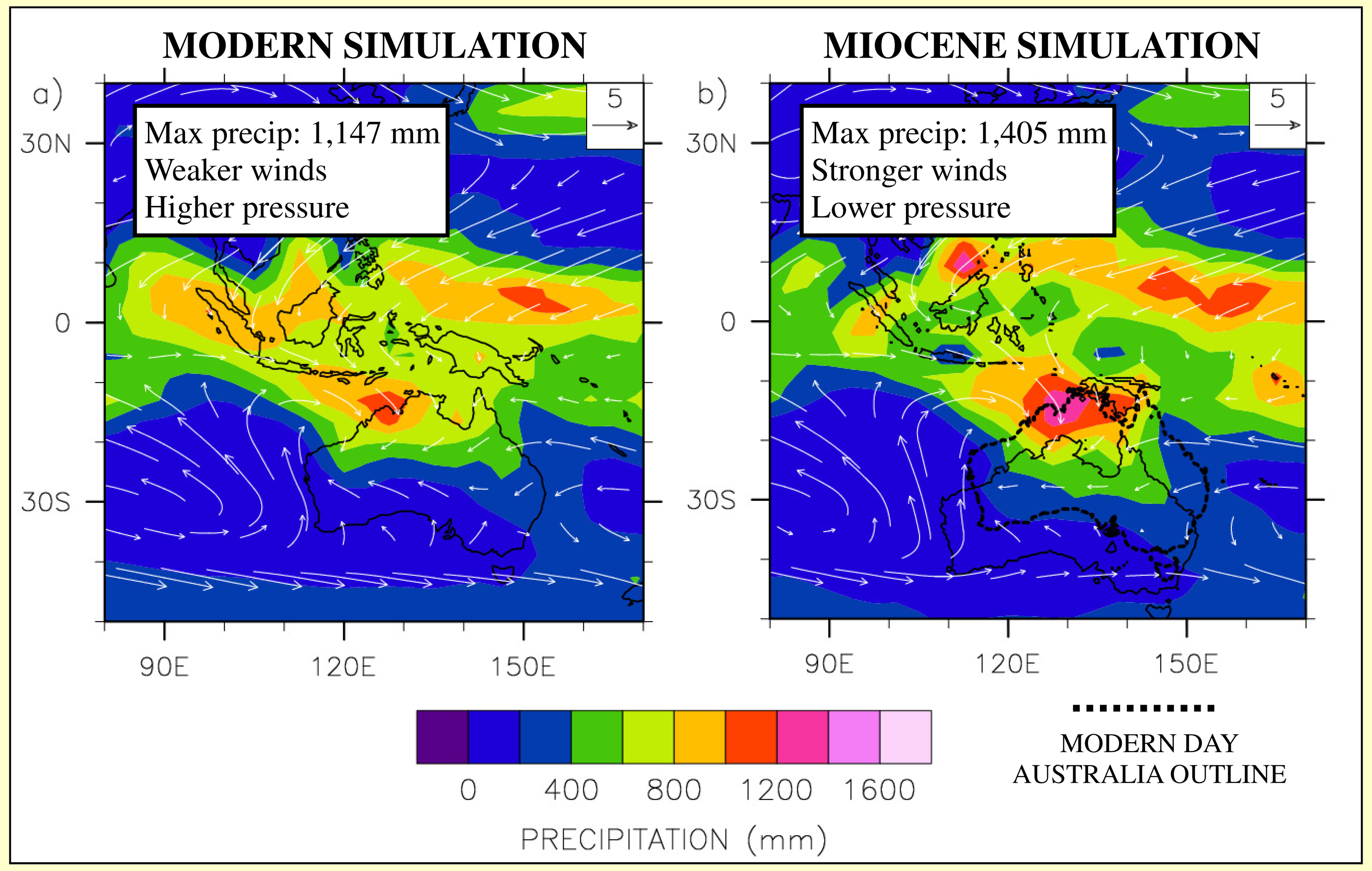

Figure 1. December-January-February precipitation and surface wind vectors for Modern (left) and Miocene (right).

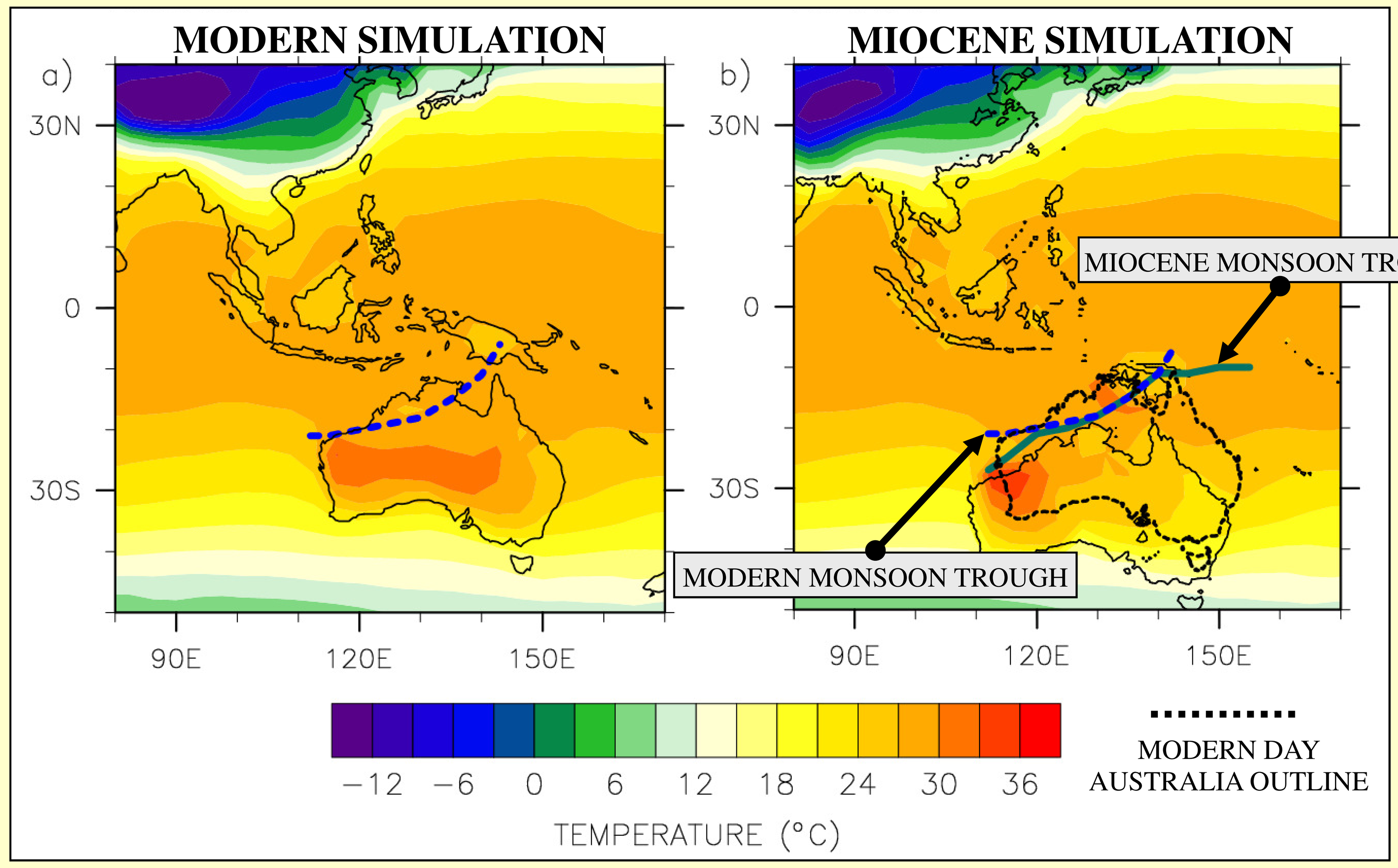

Figure 2. December-January-February surface temperature for Modern (left) and Miocene (right).

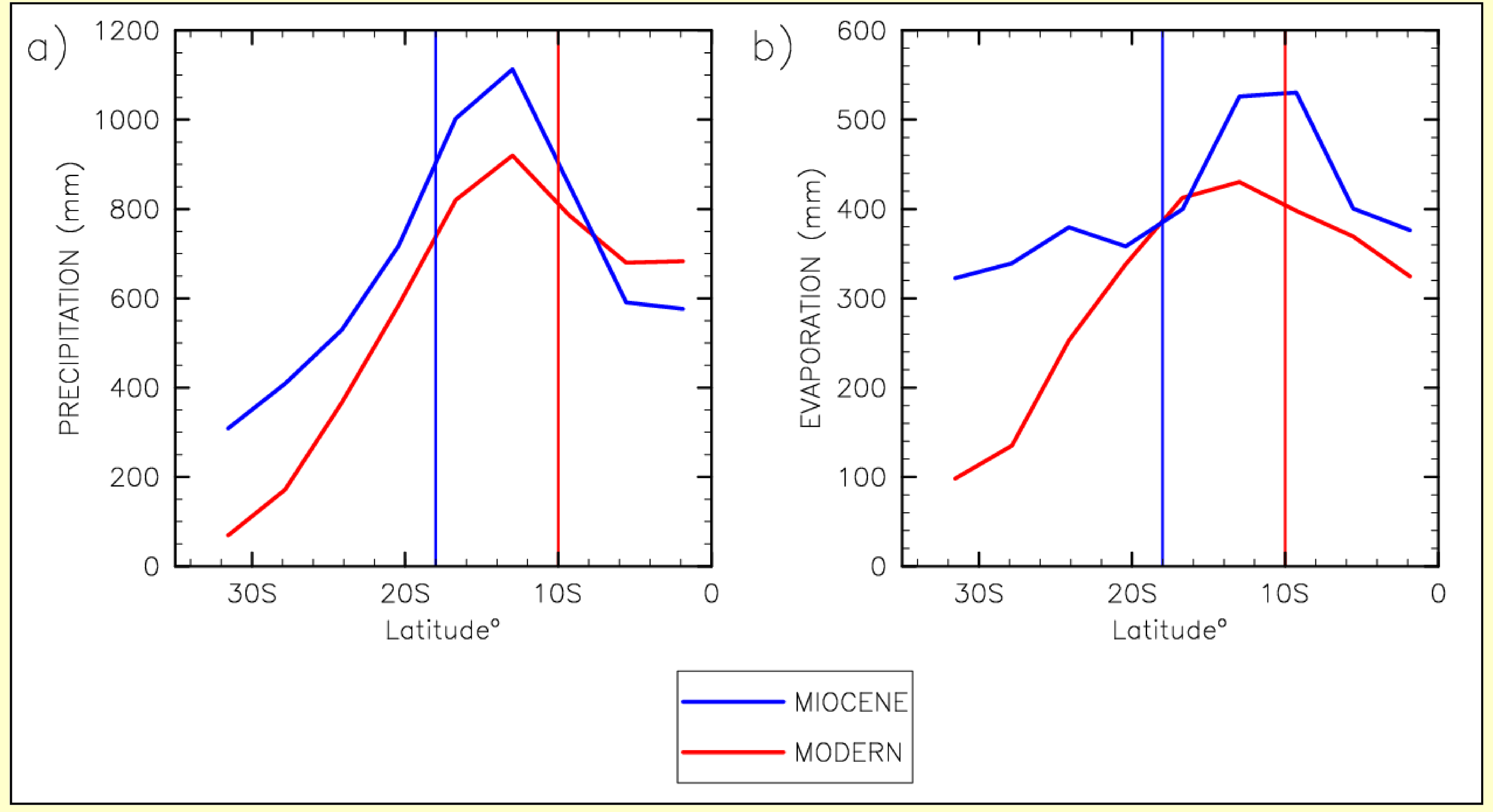

Figure 3. December-January-February precipitation (left) and evaporation (right) from the equator to 35°S over Australia. Vertical lines represent northern extent of Australia.

Evolution of the Australian monsoon

Independent model results (Cane and Molnar, 2001) suggest that the northward displacement of Papua New Guinea at ~5 Ma switched the source of Indonesian throughflow from warm South Pacific waters to cool North Pacific waters.

It is possible that after Australia reached a mid-latitude location during the late Paleogene a semi-constricted and warm South Pacific – Indian Ocean throughflow provided a greater moisture source for the monsoon. Following the middle Miocene, further shrinking and cooling (Cane and Molnar, 2001) of this moisture source led to a decrease in precipitation and wind strength, offset however by the increasing proximity of Australia to the monsoon trough (Fig. 2).

Conclusions

Location of the monsoon trough is similar between the Miocene and present simulations suggesting that the land-sea temperature gradient is not the primary driver of the monsoon.

Precipitation over the monsoon trough was more intense in the Miocene than present however due to Australia's more southerly location continental precipitation was lower. Therefore **a weaker than modern monsoon climate existed in Australia during the middle Miocene.**

Methods

We used the National Center for Atmospheric Research (NCAR) Community Atmosphere Model coupled to the NCAR Community Land Model and a slab ocean model. Model resolution corresponds to ~3.75° x 3.75° in the horizontal and 26 levels through the atmosphere.

Our Miocene simulation was configured with an amended vegetation map from Wolfe (1985), modified topography based on published elevation proxies, an atmospheric CO_2 of 355 ppmv (consistent with Berner and Kothavala, 2001; Pagani et al., 1999; Royer et al., 2001) and a sea-level rise of 50 m.

Acknowledgements

This work was funded by the Australian Research Council and the University of Sydney Faculty of Science.

Simulations were conducted at the National Facility of the Australian Partnership for Advanced Computing (APAC). The authors would like to thank the technical staff at APAC, particularly Margaret Kahn, for quick and consistent support.

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