19.4 MECHANISMS DRIVING MERIDIONAL SHIFTS IN THE SOUTHERN HEMISPHERE WESTERLIES IN EXTREME CLIMATES

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1. INTRODUCTION

Recent trends across Australia are to drier conditions, with some regions, such as western Victoria and southwest Western Australia showing consistent dry conditions over the last few years. Meteorological records in Australia extend back only about 100 years, and thus it is of interest to investigate the mechanisms driving earlier dry periods. Proxy evidence from the last glacial maximum (LGM), about 20,000 years ago, indicates a drier environment than today, (Hunt and Barrows, 1999). Although this dry period was linked with extended ice sheets at high latitudes, it provides a test for possible causes of dryness across Australia.

To test the mechanisms driving LGM dryness observed across Australia the Melbourne University Atmospheric General Circulation Model (MUGCM) is forced with LGM boundary conditions, and each of these is tested for their influence on possible precipitation mechanisms.

2. MODEL

The version of MUGCM used here is a spectral model, rhomboidally truncated at 21 waves, with 9 vertical levels. It produces a good representation of the climate in the sub tropics and midlatitudes, (Simmonds et al., 1988). The boundary conditions for the LGM include changes to carbon dioxide concentrations, ice sheets, sea level, orbital parameters and sea surface temperatures (SSTs). These are as specified in the paleo climate modelling intercomparison project (PMIP), Joussaume and Taylor (1999).

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3. RESULTS

The simulated precipitation for the LGM is reduced in the north in summer and in the south in winter compared to the present day. Here we will concentrate on the reductions over southern Australia in winter.

Due to decreases in the total column moisture at this latitude, some reduction of precipitation would be expected. The rainfall distribution has also changed, with the number of extreme rain events (events with rainfall greater than 10mm/day) greatly reduced.

Trajectories to the top 2% of rainfall events in Melbourne, southeast Australia, for the present day, as shown in Figure 1 display a strong zonal character – implying that the rainfall is most often from fronts embedded in the westerly flow. The paths are more varied in the LGM simulation, shown in Figure 2, indicating a shift in the structure of the westerlies.

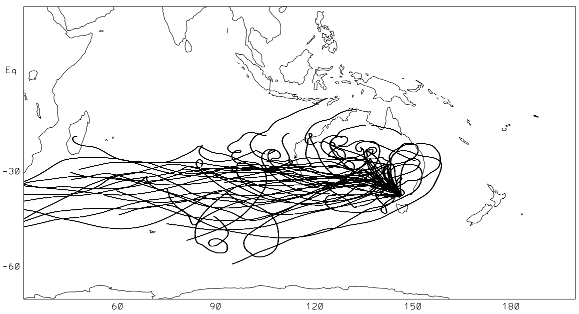

Figure 1. Trajectories to intense rainfall events in Melbourne in winter. Present day MUGCM simulation

Hemispheric maps of the zonal wind at 850hPa show a strong southward shift between the present day and LGM in the Australian region. This is not evident in other regions.

Wyrwoll et al. (2000) undertook a similar analysis of the shift in the southern hemisphere

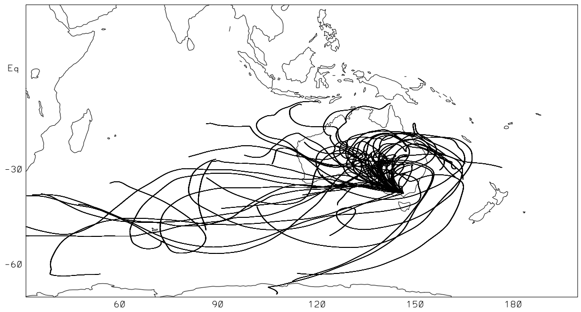

Figure 2. MUGCM LGM trajectories to intense rainfall events in Melbourne in winter

westerlies between the present and LGM and found similar regional differences.

To assess which of the PMIP boundary conditions is driving this southward shift in the Australian region each of them were implemented individually into the present day simulation. Figure 3 shows the zonal average over the Australian region of the 850hPa zonal wind for four of the experiments – the present day simulation, the LGM, the present day with LGM sea ice and present day with LGM SSTs. The other boundary conditions produced little change in winter. The latitude of the westerly maxima and the cross-over point to easterly winds in the LGM simulation is about 5 degrees to the south of the present day.

The LGM sea ice imposed in a present day simulation push the westerlies north, particularly in summer, when there is a large difference in sea ice extent between the present day and the LGM reconstruction. The present day simulation with LGM SSTs produces a zonal structure very similar to the full LGM conditions.

4. CONCLUDING REMARKS

The factor driving the southward displacement of the winter westerlies at the LGM is the change in SSTs. Yin and Battisti (2001) found that the tropical SSTs are most important. This is perhaps linked to a strengthened Hadley circulation at these longitudes.

The reduction in precipitation seen over southern Australia is a combination of the generally depressed level of water vapour in the air and the shift in the trajectories to rainfall events.

5. REFERENCES

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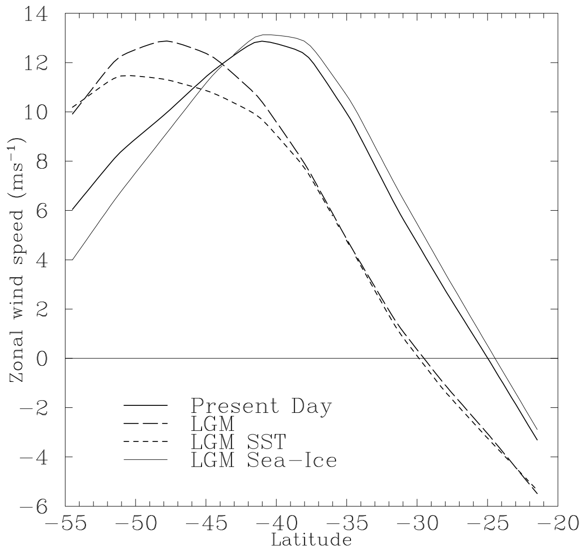

Figure 3. Zonally averaged 850hPa zonal wind in the Australian region. Simulations of the present day, full LGM, and present day with LGM sea-ice or SSTs