Proceedings of 8 ICSHMO, Foz do Iguaçu, Brazil, April 24-28, 2006, INPE, p. 311-313.

ASSOCIATION BETWEEN SEASONAL AUSTRALIAN RAINFALL AND THE SOUTHERN ANNULAR MODE

Belinda Meneghini[1,*], Ian Simmonds[1] and Ian N. Smith[2]
[1]The University of Melbourne, Victoria, Australia
[2]Commonwealth Scientific and Industrial Research Organisation, Victoria, Australia

1. INTRODUCTION

The Southern Annular Mode (SAM) is the leading mode of atmospheric variability in the Southern Hemisphere extratropics. The SAM exhibits two extreme phases, the positive phase and the negative phase. The positive (negative) phase may be characterised by higher (lower) pressures in the mid-latitudes and lower (higher) pressures in the high-latitudes. Variability in the SAM leads among other things to latitudinal shifts in the atmospheric jets, and mid- and high-latitude anomalies of opposite sign in a wide range of fields such as temperature, geopotential height and zonal wind. Furthermore, there is known to be a link between the SAM and synoptic activity (Rashid and Simmonds 2004, 2005). From such an association one may also anticipate a link between the SAM and rainfall.

Previous studies have investigated the relationship between seasonal rainfall and the SAM in southwest Western Australia (Cai and Watterson 2002), southeast South America (Silvestri and Vera 2003) and western South Africa (Reason and Rouault 2005). In this study we explore the relationships between seasonal Australian rainfall and the SAM. Since El Niño-Southern Oscillation (ENSO) has a large affect on Australian rainfall (McBride and Nicholls 1983, Simmonds and Hope 1997), we should also compare any SAM-rainfall relationship to the ENSO-rainfall relationship.

2. DATA AND METHODS

The Antarctic Oscillation Index (AOI) describes the strength and phase of the SAM, and in this study we calculated a seasonal AOI using the Gong and Wang (1999) definition (see equation 1) and the European Centre for Medium Range Weather Forecasts ERA-40 monthly mean sea level pressure (MSLP) dataset (Uppala et al. 2005).

$$AOI(t) = \frac{MSLP_{40°S}(t) - \overline{MSLP_{40°S}(season)}}{\sigma_{MSLP40°S}(season)} - \frac{MSLP_{65°S}(t) - \overline{MSLP_{65°S}(season)}}{\sigma_{MSLP65°S}(season)} \quad (1)$$

where $MSLP_{40°S}(t)$, $\overline{MSLP_{40°S}(season)}$ and $\sigma_{MSLP40°S}(season)$ are the seasonal MSLP, mean of the seasonal MSLP for the season in question and standard deviation of the seasonal MSLP for the season in question at 40°S, respectively. Similar expressions apply for 65°S.

We also constructed a seasonal ENSO index (the SOI) using the Troup (1965) definition and Darwin and Tahiti monthly MSLP data from the Australian Bureau of Meteorology. The rainfall dataset we used was that of the Australian Bureau of Meteorology, which contains Australian monthly rainfall on a 0.25° × 0.25° grid (Jones and Beard 1998).

We used correlations to explore the relationships between Australian rainfall and the SAM, and performed correlations using raw and detrended data so as to observe the relationships on interannual to interdecadal and interannual timescales, respectively (Li et al. 2005). In this study autocorrelation was accounted for by determining the effective degrees of freedom, and the significance of the correlations was evaluated at the 95% confidence level.

3. RESULTS

For 1958-2002 there are significant positive correlations in western Australia in summer using raw data (not shown). These correlations can be explained by anticyclones and

*Corresponding author address: Belinda Meneghini, School of Earth Sciences, The University of Melbourne, Victoria 3010, Australia; e-mail: b.meneghini@pgrad.unimelb.edu.au

surface heating, which affect the likelihood and intensity of convection occurring in this region. By detrending the data the number of significant correlations in northern and central western Australia is reduced, thus in these regions the SAM contributes to interannual to interdecadal summer rainfall variability. However, detrending has little effect on the correlations in southern western Australia so the SAM contributes to interannual summer rainfall variability there. In winter there are significant positive correlations in parts of eastern Australia (Fig 1). Such correlations may be accounted for by anticyclones and easterlies, which influence the effectiveness of orographic uplift (along the east coast of Australia) in producing rainfall. Furthermore, the correlations using raw and detrended data are very similar in winter so the SAM contributes to interannual winter rainfall variability in eastern Australia.

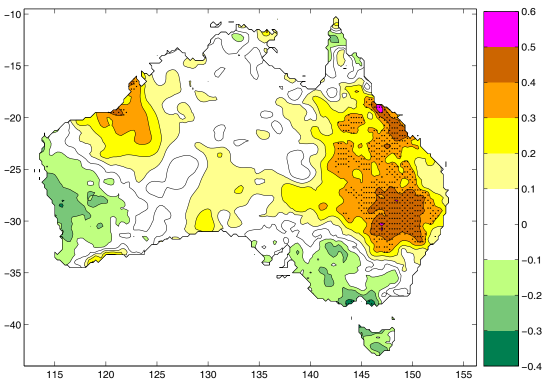

Figure 1 Correlation between total winter rainfall and the AOI for 1958-2002 using raw data. Contour interval is 0.1 and stippling indicates the correlations that are significant at the 95% confidence level.

The fact that the SAM has considerable zonal asymmetry (Simmonds and King 2004) motivated us to construct an AOI for the Australian region (AOIR). This was done using (1) but only utilising data from 90-180°E. The above correlations were then repeated using the AOIR and the results are as follows. In summer (not shown) the situation is similar to what we saw before with the correlation between the AOI and rainfall. This may not be all that surprising because the AOI and AOIR have a high correlation in summer (not shown). In winter we now see widespread significant correlations in southern Australia (Fig 2). These correlations can be explained by extratropical cyclones and cold fronts, which tend to move north during the negative phase of the SAM and south during the positive phase. The correlations in western Tasmania can also be explained by the mid-latitude westerlies which vary with the phase of the SAM. The correlations using raw and detrended data are very similar in winter so the SAM contributes to interannual winter rainfall variability in southern Australia. Over the past decade there has been a significant decline in winter rainfall in parts of southeast Australia. On the basis of our findings the SAM may have played a role.

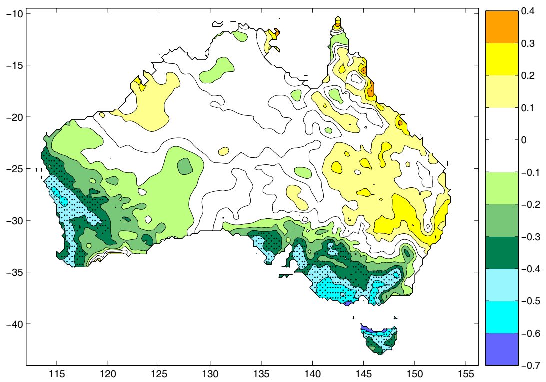

Figure 2 As in Figure 1, but the correlation between total winter rainfall and the AOIR for 1958-2002 using raw data

Based on previous studies the significant correlations in southern Australia in winter (Fig 2) are perhaps the most expected. Therefore, the SAM-rainfall relationships suggested in the correlations using the AOIR may be more accurate than those suggested in the correlations using the AOI.

Lastly, we look at how the SAM-rainfall relationships compare to the ENSO-rainfall relationships. We do this by finding the difference between the magnitude of the correlation between the AOIR and rainfall and the magnitude of the correlation between the SOI and rainfall. The results for summer and winter using raw data are shown in Figure 3, where the regions shaded in green (blue) are the regions where the SAM (ENSO) explains more of the rainfall variability than ENSO (the SAM) does. We can see that ENSO accounts for more of the seasonal rainfall variability than the SAM does across most of the continent, and this is true for autumn and spring as well (not shown). Although, the SAM does play a bigger role in seasonal rainfall variability than ENSO does in much of western Australia and western Tasmania in summer (Fig 3 top), and in far southwest Australia and the southern regions of southeast Australia in winter (Fig 3 bottom).

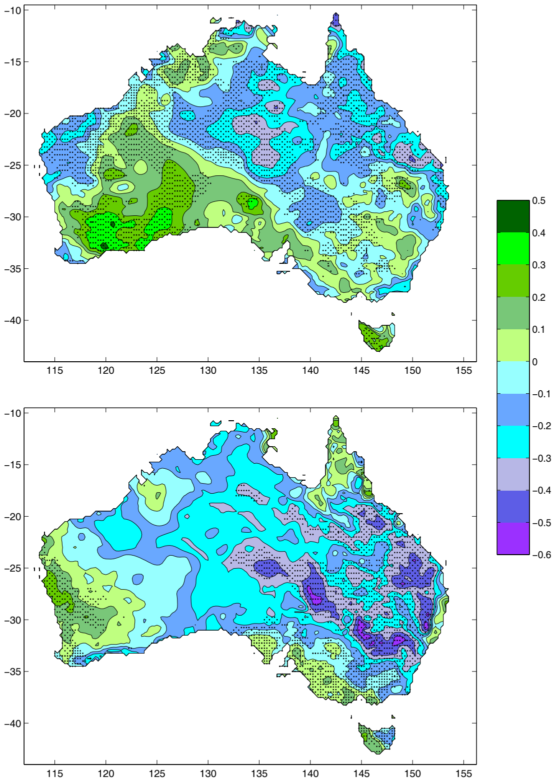

Figure 3 Difference between the magnitude of the correlation between the AOIR and rainfall and the magnitude of the correlation between the SOI and rainfall for 1958-2002 using raw data in summer (top) and winter (bottom). Contour interval is 0.1 and stippling indicates the correlations that are significant at the 95% confidence level.

4. SUMMARY

The correlations between the SAM and rainfall are generally positive (negative) in the northern half of Australia (southern Australia). The strongest links between the SAM and Australian rainfall are in winter in the southern regions of southeast Australia and in spring in western Tasmania, where the SAM accounts for as much as 49% of the rainfall variability. Correlations performed using raw and detrended data were generally very similar, indicating that the SAM contributes mainly to interannual rainfall variability and the SAM-rainfall relationships are mostly genuine and are not due to trends in either of the time series. The region where the SAM consistently has a greater effect on seasonal rainfall than ENSO does is western Tasmania.

5. REFERENCES

Cai, W., and I. G. Watterson, 2002: Modes of interannual variability of the Southern Hemisphere circulation simulated by the CSIRO climate model. *J. Climate*, **15**, 1159-1174.

Gong, D., and S. Wang, 1999: Definition of Antarctic Oscillation Index. *Geophys. Res. Lett.*, **26**, 459-462.

Jones, D. A., and G. Beard, 1998: Verification of Australian monthly district rainfall totals using high resolution gridded analyses. *Aust. Meteor. Mag.*, **47**, 41-54.

Li, F., L. E. Chambers, and N. Nicholls, 2005: Relationships between rainfall in the southwest of Western Australia and near-global patterns of sea-surface temperature and mean sea-level pressure variability. *Aust. Meteor. Mag.*, **54**, 23-33.

McBride, J. L., and N. Nicholls, 1983: Seasonal relationships between Australian rainfall and the Southern Oscillation. *Mon. Wea. Rev.*, **111**, 1998-2004.

Rashid, H. A., and I. Simmonds, 2004: Eddy-zonal flow interactions associated with the Southern Hemisphere annular mode: Results from NCEP-DOE reanalysis and a quasi-linear model. *J. Atmos. Sci.*, **61**, 873-888.

Rashid, H. A., and I. Simmonds, 2005: Southern Hemisphere annular mode variability and the role of optimal nonmodal growth. *J. Atmos. Sci.*, **62**, 1947-1961.

Reason, C. J. C., and M. Rouault, 2005: Links between the Antarctic Oscillation and winter rainfall over western South Africa. *Geophys. Res. Lett.*, **32**, L07705, doi:10.1029/2005GL022419.

Silvestri, G. E., and C. S. Vera, 2003: Antarctic Oscillation signal on precipitation anomalies over southeastern South America. *Geophys. Res. Lett.*, **30**, 2115, doi:10.1029/2003GL018277.

Simmonds, I., and P. Hope, 1997: Persistence characteristics of Australian rainfall anomalies. *Int. J. Climatol.*, **17**, 597-613.

Simmonds, I., and J. C. King, 2004: Global and hemispheric climate variations affecting the Southern Ocean. *Antarct. Sci.*, **16**, 401-413.

Troup, A. J., 1965: Southern Oscillation. *Quart. J. Roy. Meteor. Soc.*, **91**, 490-506.

Uppala, S. M., and Coauthors, 2005: The ERA-40 re-analysis. *Quart. J. Roy. Meteor. Soc.*, **131**, 2961-3012.