Variability in the Southern Annular Mode due to decadal variations in tropical heating

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The Southern Annular Mode (SAM) is the dominant pattern of variability in monthly anomalies of atmospheric circulation in the Southern Hemisphere. While the SAM captures temporal variations in the meridional mass distribution, its shape is far from fixed. The Melbourne University General Circulation Model is used to determine the dependence of the SAM on spatial variations in tropical heating. The model is configured at T42 spectral resolution, and forced with four sets of SST anomalies, each formed as 12-month climatologies for both El Niño and La Niña conditions, during first the epoch 1944-1973 when the PDO was in the negative phase, and second during the epoch 1974-2003 when the PDO was in the positive phase. This choice, which produces SST anomalies that differ spatially, is motivated by the study of Lachlan-Cope and Connolley (2006) who showed that differences in the location of tropical heating give rise to substantial differences in the high southern latitude time-mean circulation due to changes in location and strength of Rossby wave generation and subsequent propagation.

Figure 1 shows the leading EOF of simulated surface pressure from the four simulations. The SAM is a transient feature, and thus arises from changes to the transient flow. While the differences in the time-mean circulation between the four experiments largely confirm Lachlan-Cope and Conelley's findings, here we show that changes in the mean flow alter the transient circulation. Changes in vertically integrated transient meridional momentum flux explain the differences in gradients (and geostrophic flow) between experiments. Indeed, Figure 2 shows that baroclinic growth rates tend to be larger slightly upstream of increased momentum fluxes, and that local ridges in the SAM pattern are coincident with reduced instability. The influence of the tropical SST variability is explained as follows. Tropical sources of Rossby waves produce enhancement of the mid-latitudes westerly jet in locations controlled by the trajectory of the wave propagation. A stronger jet increases the likelihood of baroclinic instability and thus preconditions the flow to transient eddy generation. The generation of baroclinic eddies yields a poleward momentum flux, and consequently modifies the structure of the SAM. This mechanism is strongest in wintertime when the baroclinicity is generally stronger, however, the mechanism also occurs in summertime. Indeed, Figure 1 suggests that the variation in the structure of the SAM is greatest in the summertime, when the mean shape of the SAM is less robust.

These experiments provide some insight to the reason behind the apparently large difference in model simulations of the SAM. Specifically, coupled climate models are unlikely to reproduce the observed SAM unless the temporal and spatial variations in tropical SSTs, and thus teleconnection patterns, are also reproduced reliably. On the other hand, it is likely that models capture the mechanism well since it is fundamental to the development of mid-latitude storms.

References

Lachlan-Cope T., and W. Connolley, 2006: Teleconnections between the tropical Pacific and the Amundsen-Bellinghausen Sea: Role of the El Niño/Southern Oscillation. *Journal of Geophysical Research*, **111**, D23101, doi:10.1029/2005JD006386.

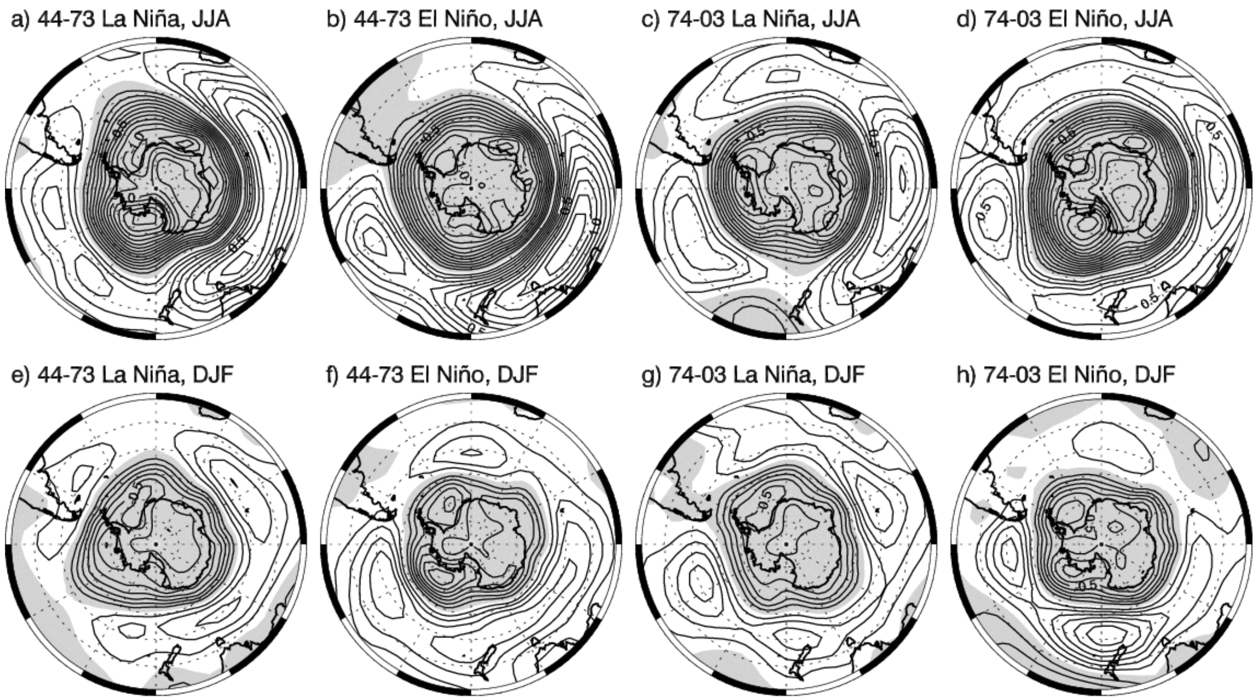

Figure 1: First EOF of monthly anomaly surface pressure for each season DJF (upper panels) and JJA (lower panels). The contour interval is 1 hPa. Negative values are shaded and the zero contour has been omitted. Results are from the final 30 years of 40-year simulations.

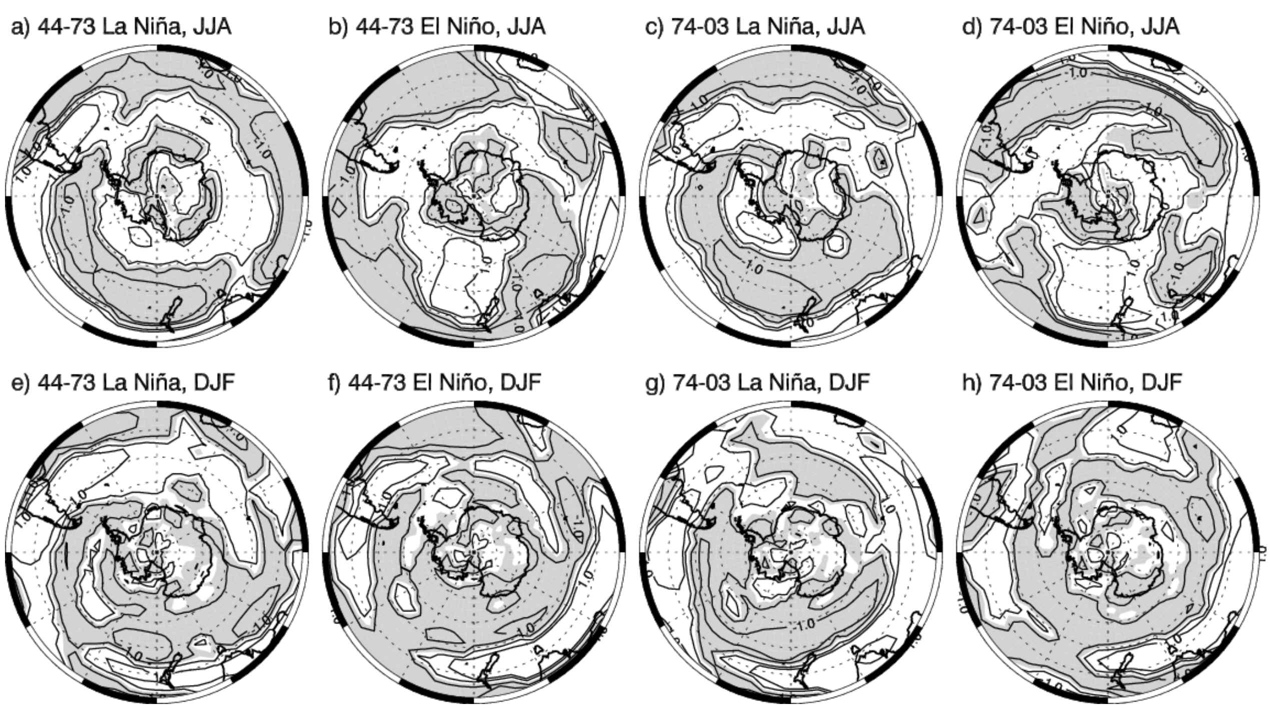

Figure 2: Experiment minus control difference in baroclinic growth rate (e-folding time) for the locally most unstable 2-layer baroclinic wave. Negative values indicate faster growth (shaded), positive indicates slower growth. Contour interval is 0.5 days. The zero contour has been omitted.