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Changes and Projections in the Annual Cycle of the Southern Hemisphere Circulation, Storm Tracks and Australian Rainfall

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Large changes in the seasonal cycle of the Southern Hemisphere circulation over the last sixty years are shown to have impacted on the properties of weather systems associated with mid-latitude storms and consequently reductions in rainfall particularly in the southern Australian region. In particular, there have been significant negative trends in the baroclinic instability of the mid-latitude atmospheric circulation resulting in a reduction in storm formation at these latitudes, while increases in baroclinicity further poleward has led to increased storm development. These effects have become more pronounced with time and are likely to worsen under future climate change scenarios.

We consider the observed changes in the baroclinicity of the Southern Hemisphere circulation in all months and examine the corresponding changes in the growth rate and structure of dynamical modes of variability with emphasis on the mid-latitude storm track modes, in the four seasons. We focus on the periods 1949-1968, 1975-1994 and 1997-2006, and relate the reduction in the rainfall in the southwest of Western Australia since the mid-1970s and in South-eastern Australia since the mid-1990s to changes in growth rate and structures of the leading storm track modes.

Southwest of Western Australia get most of it's rainfall in autumn and winter. We find that in winter there are considerable reductions in the growth rates (by around 30%) of the leading storm track modes that cross southern Australia between the periods 1969-68 and 1975-94 and that these reductions continue into the period 1997-2007. In autumn growth rates of leading cyclogenesis modes with peak amplitudes across southern Australia decrease by between 10% and 20% between 1949-68 and the latter periods. Importantly, during the more recent periods, storm activity increasingly moves from the latitudes of the subtropical jet to the latitudes of the polar jet. These changes in storm activity are consistent with and provide an explanation of the reduced rainfall over southwest of Western Australia since the mid 1970s.

In southeastern Australia the rainfall is spread more evenly throughout the year. We find that in spring there is only a very modest reduction (of around 5%) in growth rates of the leading storm track modes that cross southern Australia between 1949-68 and 1975-94. However during the period 1997-2006 of drought the leading modes of storm activity tracked south of the Australian continent. Again, in summer there is a modest reduction (of around 10%), between 1949-68 and 1975-94, in growth rates of the leading cyclogenesis modes that influence southeastern Australia. However, for the period 1997-2006 the storm activity largely misses southeastern Australia as the storm track has moved poleward. Again these changes in storm activity during 1997-2006 provide an explanation for the causes of the recent prolonged drought in southeastern Australia.

Future projections using CMIP3 and CMIP5 models under different climate change scenarios show similar trend patterns in baroclinicity and associated reductions in southern Australian rainfall, and hemispheric reductions in rainfall in a zonal band north of 40S and increases further south.