Indian Ocean Climate Initiative

Informed Adaptation

GOVERNMENT OF WESTERN AUSTRALIA

How our winter atmospheric circulation has changed

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Climate Note 4/05 (August) in a series outlining observed climate changes or variations over recent decades in south-west Western Australia.

Summary

South-west WA derives much of its annual rainfall from passing cold fronts and associated storms. These are a typical feature of the winter synoptic situation and form part of the atmospheric circulation. Since the mid 1970s, not only has the number of storms decreased, but they generally bring less rainfall. In fact, the preferred region for storm development has moved away from south-west WA, and the likelihood of storm development has decreased. At the same time the average sea level pressure over south-west WA has increased. There are many possible causes for these large-scale changes but it is believed that the underlying drivers include increased atmospheric greenhouse gases and the fact that the climate system undergoes natural fluctuations on the scale of several decades. Climate model simulations suggest that the influence from greenhouse gases will become more dominant in the future and that the tendency to higher pressures and fewer storms may continue.

The atmospheric circulation

The term ‘atmospheric circulation’ refers to the movement of air masses. Fronts, low pressure troughs and high pressure systems form part of the atmospheric circulation. Figure 1 depicts a typical synoptic situation just prior to a rain event in south-west WA. Note the low pressure trough and frontal system approaching the south-west coast.

Long-term averages of the winter atmospheric circulation reveal the persistent features of the circulation. The flow pattern in Figure 1 is similar to the average situation in the Australian region. The dominant features include a region of high pressure over the continent and in the southern Indian Ocean to the west of Australia. A region of low pressure off the coast of WA is also seen. This pattern is one of the most persistent features in the Southern Hemisphere. The average conditions high above south-west WA show features favourable to storm development. The surface region of low pressure is made up of frequent rain-bearing troughs and fronts in the westerly flow, conducive to south-west WA rainfall.

Observed changes

The change from a wetter to a drier regime over south-west WA in the mid-1970s has been accompanied by large-scale changes in atmospheric circulation patterns. The past few decades have been characterised by an increase in average winter sea-level pressure in Australian latitudes, with decreases in pressure further south (Figure 2). Some of the largest increases are over south-west WA. These pressure increases are associated with a decline in south-west WA rainfall.

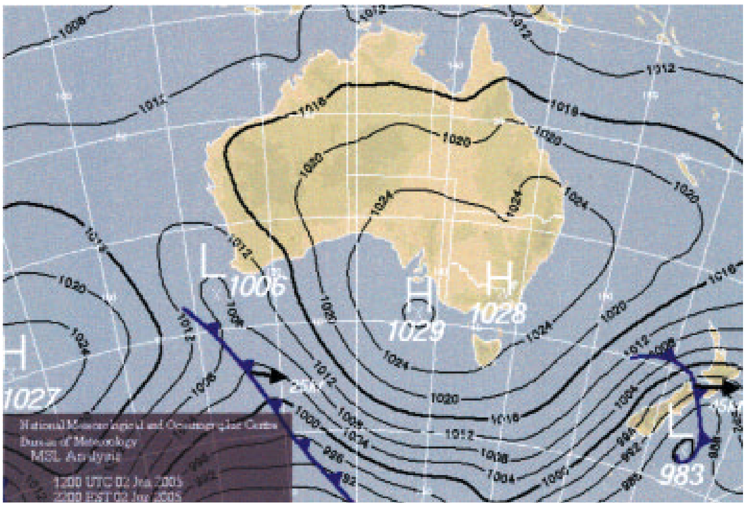

Figure 1: A representative winter situation prior to rainfall in the south-west. The lines are of equal pressure at sea level. (hPa = hecto Pascal – a measure of pressure)

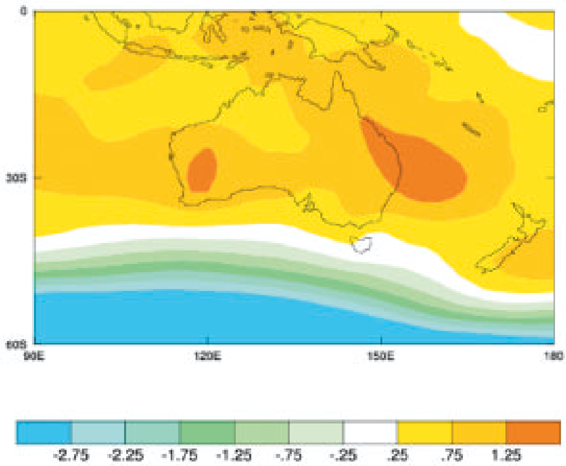

Figure 2: The difference (in hPa) between average winter (June to August) mean sea level pressure for the period 1976–2004 compared to the period 1948–1975. Data source: NCEP/NCAR reanalyses.

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Changes in storminess

Over south-west WA there have been fewer troughs, each generally bringing less rainfall, and more high pressure systems since 1975. Figure 3 shows the regions where storm development is favoured (in red). During early decades, south-west WA was the preferred region for storm development. More recently, storms are less likely to form and the favoured region of development has shifted east. This again reflects the fact that the rainfall decline in south-west WA is linked to changes in the large-scale circulation.

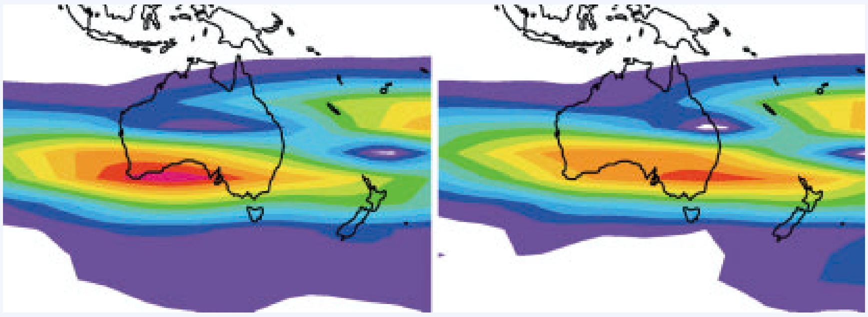

Figure 3: The left panel shows the preferred location of winter storm tracks (in red) over southern Australia 1949–1968. The right panel shows the preferred locations 1975–1994. Data source: NCEP/NCAR reanalyses.

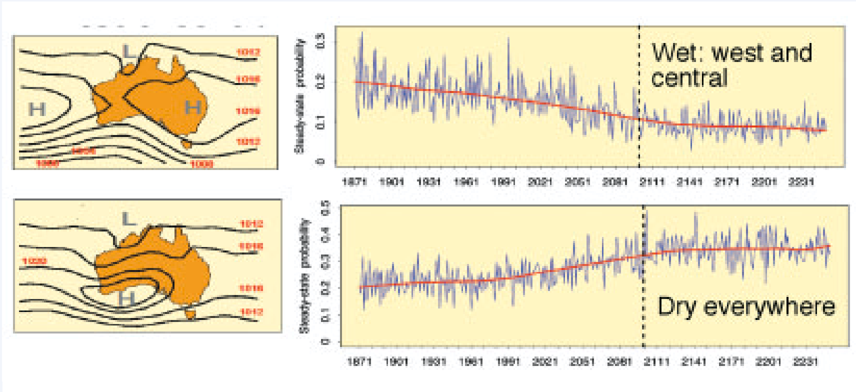

Figure 4: The top panel shows the pattern associated with wet conditions over the west and central regions and the time series shows how this becomes less frequent in a climate model simulation with increasing greenhouse gases into the future. The bottom panel shows the pattern associated with widespread dry conditions and the time series shows how this becomes more frequent in the simulation. The dashed line refers to the year 2099.

What caused the changes?

Observing, diagnosing and documenting changes to the large-scale atmospheric circulation over south-west WA is one thing. Determining the causes of these changes is more difficult.

Climate model experiments have shown that increases and decreases in mean sea level pressure over Australia can occur over several decades due to natural variability. However, the model results show a tendency towards higher pressures when forced by increased atmospheric greenhouse gases. IOCI believes that the increased pressure and reduced likelihood of storm development currently observed are most likely due to both factors.

Changes in the amount of ozone over Antarctica during spring and early summer also affect the atmospheric circulation. However, this effect is unlikely to have much impact during winter.

Clearing native vegetation for crops is unlikely to induce the large-scale changes to the circulation described here. However, modelling studies have shown that a decrease in surface roughness produced by vegetation change led to reduced rainfall totals, possibly through a decreased potential for precipitation from passing weather systems.

Observed changes in local sea surface temperatures are a possible candidate for affecting the atmospheric circulation, but analysis with climate models and data suggest that they have played a minor role.

New evidence proposes decreases in Antarctic sea-ice extent south of WA between 1950 and 1972. It is unclear if these reductions are due to the circulation changes or were themselves a driver.

At this stage, IOCI believes that the circulation changes over south-west WA were due to the natural variability of the climate system and the influence from increasing levels of greenhouse gases, however other factors may have played a role.

What can we say about the future?

Because the effect of increasing atmospheric greenhouse gases is expected to become more significant over time, the trend towards higher pressure values over south-west WA is likely to continue. This may mean fewer troughs and winter storms. Figure 4 provides an indication of how the frequency of pressure patterns corresponding to wet or dry south-west WA conditions as simulated by a climate model are expected to change into the future.

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