Meteorological context

Drought

The Bureau of Meteorology defines drought as 'a prolonged abnormally dry period when there is not enough water for users' normal needs'. Australia has one of the most variable climates in the world, and drought is part of the landscape and the culture of its peoples. Because drought is insidious, it can be difficult to know or to define when a region passes into a drought. The Bureau of Meteorology maintains a Drought Watch system that helps identify the need for contingency or drought relief action.

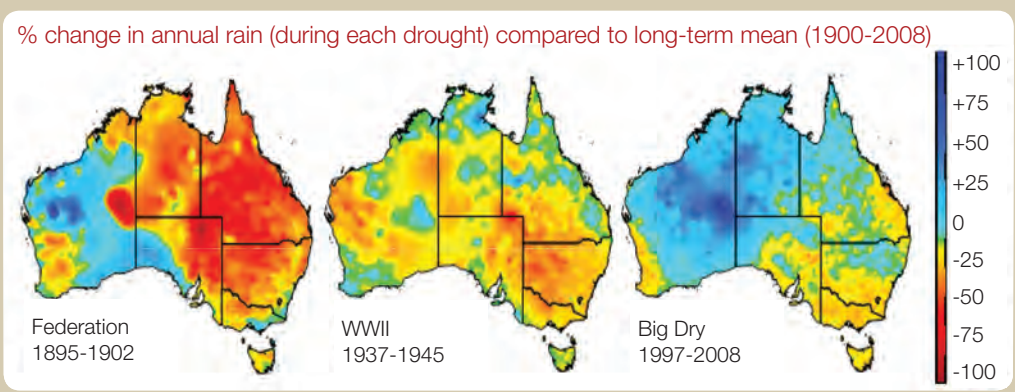

Figure 1. Annual average rainfall deficiency compared with long term (1870-2009) mean during the Federation, WWII and the Big Dry droughts for Wentworth (BoM station no. 047053) near Mildura.

Droughts may be short, intense and affect a small area. They may be widespread and persist for many years. On average, severe drought affects some part of Australia about once every 18 years, although the occurrence is highly variable and this is only an average figure.

The clearest and best understood cause of drought in Australia is the Southern Oscillation: a major air pressure shift between the west and east Pacific regions. The El Niño phase of the Southern Oscillation occurs when the ocean warms in the eastern Pacific, accompanied by the development of high surface air pressure over the western Pacific. This in turn is associated with drought over the eastern half of Australia, especially northern and eastern Queensland. Another large-scale air pressure fluctuation, the Indian Ocean Dipole, has been linked to drought occurrence in southern Australia. The current drought in south-western Australia has been linked to global warming.

Over the twentieth and twenty-first centuries, the three most significant droughts, in terms of spatial extent, magnitude and duration of impact, are:

- The Federation Drought, 1895 – 1902;
- The World War II Drought, 1937 – 1945;
- The Big Dry (or Millennium Drought), 1997 – 2010.

Fig. 1 provides information on the extent of the droughts.

East Coast Lows

East Cold Lows (ECLs) are intense, relatively small, low-pressure systems that occur along the east coast of Australia between southern Queensland and Tasmania in autumn or winter, most commonly in June. They derive their energy from the thermal gradient between warm air over the sea and cold air over the land. Typically, there will be one or two in each year that make landfall, but there have been years in which as many as six have occurred.

ECLs are associated with high wind speeds (but typically lower than those in a tropical cyclone), high seas and large amounts of very intense rainfall (snow over higher ground). The heaviest rain falls on the poleward side of the system. ECLs intensify very rapidly, making them difficult to forecast precisely, and last only a few (2-3) days, generally tracking along the coast.

Heatwaves

A heatwave is a prolonged period of excessive and unusual heat. Thus, temperatures over 40°C in western Queensland in January do not constitute a heatwave, because these temperatures are usual and expected. The same conditions in Adelaide and Melbourne most certainly do represent a heatwave.

Hot air over central Australia in summer may extend southwards under certain meteorological conditions. When a high pressure system lies to the east of the continent, and a cold front is advancing from the west, hot air from the centre will be channelled southwards.

Over south-western Australia, the same situation arises when a low pressure system lies over the mid-west coast, channelling hot air eastwards. Normally, as these meteorological systems progress eastwards, the atmospheric circulation will change and cooler air from the oceans or higher latitudes will return. However, sometimes these systems will stagnate, leading to a heatwave: very high temperatures, in the high 30s or low 40s, for days over coastal regions, and for weeks in inland areas.

Queensland floods

The case study examples considered by NCCARF are both examples of riverine flooding. The type and severity of floods depend on the characteristics of the rainfall - the amount, the intensity and the prior conditions e.g., is the

ground already saturated by earlier rainfall events? and on the morphology of the river and its catchment – is it a large, open catchment prone to slowly developing floods, or is it a small enclosed catchment in which flash floods may develop? The NCCARF studies looked at the January 2008 flood at Charleville, and the February 2008 flood in Mackay.

The Charleville flood was caused by rainfall from a tropical low pressure which was the remnant of Tropical Cyclone Helen. It tracked south across Queensland from Townsville on the 14th January to Cunnamulla on the 18th, passing to the west of Charleville. Charleville received 258 mm rainfall from this system, but it is the very large area affected by heavy rainfall that contributed to the flooding rather than the large amounts. The Warrego peak flood at Charleville reached 6 m, and Bradley's Gully, which was responsible for the damage, reached 3 m.

The flash flood at Mackay in the early hours of 15th February 2008 was caused by a convergence zone in the lower atmosphere combined with the passage of an upper trough. This produced very intense rainfall in just a few hours: Mackay received 268 mm in 2 hours and the highest total was in Mackay East – 625 mm in two hours. The Pioneer River is just 120 km in length, with a catchment of 1500 km^2 which is steeply sloped in the upper reaches. This combination of intense rainfall on a small catchment inevitably led to a flash flood which reached 7 m.

Storm tides

A storm tide occurs when a storm surge coincides with the normal (astronomical) high tide.

A storm surge occurs along a shoreline when there are strong onshore winds and/or when an intense low pressure system crosses the coast. Storm surge is associated with landfall of tropical cyclones in northern Australia and, further south, of intense low-pressure systems such as East Coast Lows. The surge may extend several hundred kilometres along the coast. The surge height depends on:

- Wind speed - higher speeds lead to higher seas;
- The speed of passage of the low-pressure system – higher speeds lead to faster and more powerful storm surges;
- The angle at which the low-pressure system crosses the coast – generally if it crosses at right angles the impact will be greater;
- The topography of the coastal region and the sea bed.

Because the cycle of low tide to high tide and back to low tide is only around 12 hours long, and because cyclone tracks are erratic, storm tides are difficult to predict accurately. If a low pressure system crosses the coast at high tide the flood and wave damage will be much more extensive, extending to several kilometres inland in low-lying areas, than if it crosses at low tide. The damage caused by Cyclone Tracy would have been much greater if it had crossed the coast at high tide.

Tropical cyclones

A tropical cyclone is an intense low pressure system that forms over tropical or sub-tropical waters. It gains its energy from the warmth of those waters – surface water temperatures greater than 26.5ºC are required for a tropical cyclone to form. Once the system passes over the land, it is removed from its energy source and generally decays rapidly. Characteristic features of a tropical cyclone are:

- An annular structure of high wind speeds and cloud rotating in a circular path (clockwise in the Southern Hemisphere) which surrounds a cloud-free eye in which wind speeds are much lower;
- Occurring between November and April;
- An eye typically around 50 km across; the diameter of the whole system may be several hundred kilometres;
- Wind speeds greater than 63 km/h, gusting to over 90 km/h;
- Intense thunderstorm activity in the cloud wall;
- Persistence – they can last for around a week, following an erratic path that typically, over the lifetime of the system, has a generally east to west direction;
- As shown in Figure 2, tropical cyclones can affect north-eastern, northern and north-western Australia, but the area of greatest occurrence is along the northern coastline from Townsville to Port Hedland.

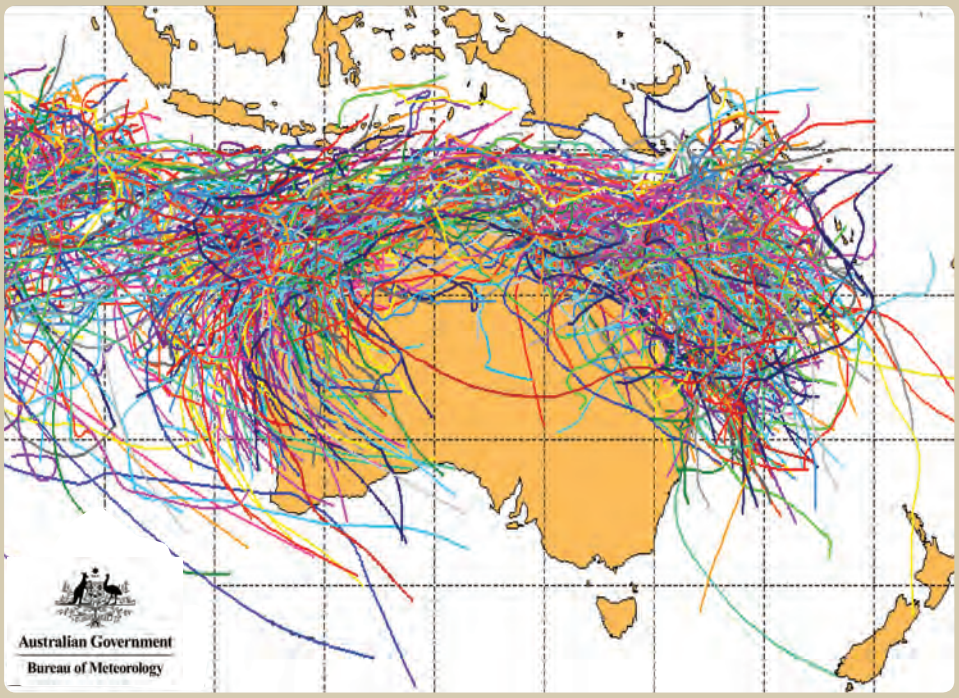

Figure 2: Tropical cyclones 1906-2006. Image: BoM

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