6

THE AUSTRALIAN CONTEXT TO CLIMATE CHANGE

Key points

Australia's dry and variable climate has been a challenge for the continent's inhabitants since human settlement.

Temperatures in Australia rose slightly more than the global average in the second half of the 20th century. Streamflow has reduced significantly in the water catchment areas of the southern regions of Australia. Some of these changes are attributed by the mainstream science to human-induced global warming.

Effects of future warming on rainfall patterns are difficult to predict because of interactions with complex regional climate systems. Average expectations are for significant drying in southern Australia, with risk of much greater drying. The mainstream Australian science estimates that there may be a 10 per cent chance of a small increase in average rainfall, accompanied by much higher temperatures and greater variability in weather patterns.

Australia is a vast continent that is accustomed to regional and seasonal climate variability. It has a wide range of ecosystems within its borders, from tropical to alpine, and Mediterranean to arid desert. There are multiple influences on Australia's climate, ranging from the global, the regional, such as the El Niño – Southern Oscillation, to the local, such as the Great Dividing Range. Understanding the Australian climate is a complicated task.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Bureau of Meteorology (2007) have undertaken major work projecting Australia's future climate. The Review has commissioned the CSIRO to extend its projections further for a number of variables out to 2100 on the basis of the Review's projections of emissions under no mitigation, ad hoc mitigation, and the specified global mitigation cases.

6.1 Attributing observed and projected climate change to humans

Changes in climate variables that exhibit only a small range of natural variability, such as global mean temperature, are attributed to human factors with some confidence, as small deviations can be significant. Changes in climate variables such as rainfall, which can exhibit high interannual and interseasonal variability, are much harder to attribute to climate change. It is difficult to distinguish the human-induced element from natural variability. Climate variables that manifest themselves over longer scales, such as decades or centuries, are harder still to attribute to human activity (CSIRO & BoM 2007).

Single events, such as an intense tropical cyclone or an intense or long-lived heatwave, cannot be directly attributable to climate change. Climate change may, however, affect the factors that lead to such events and make certain events, like the heatwave that occurred in Adelaide during the summer of 2007–08, much more likely (CSIRO & BoM 2007). In this sense, global warming can make events like Adelaide's heatwave or the prolonged dry conditions seen in Southern Australia in recent years, seem less extraordinary (Power & Nicholls 2007).

Despite these caveats, some changes in the Australian climate system have been attributed to human-induced climate change. Examples include the increase in average temperatures since the middle of the 20th century, the reduction in rainfall in south-west Western Australia, and the decline in snow cover (CSIRO & BoM 2007; Cai & Cowan 2006).

Rainfall declines in parts of the country, such as south-east Australia, have not been definitively attributed to climate change. By contrast, the higher temperatures that have accompanied and exacerbated the drought conditions have been so attributed (see section 6.2.2).

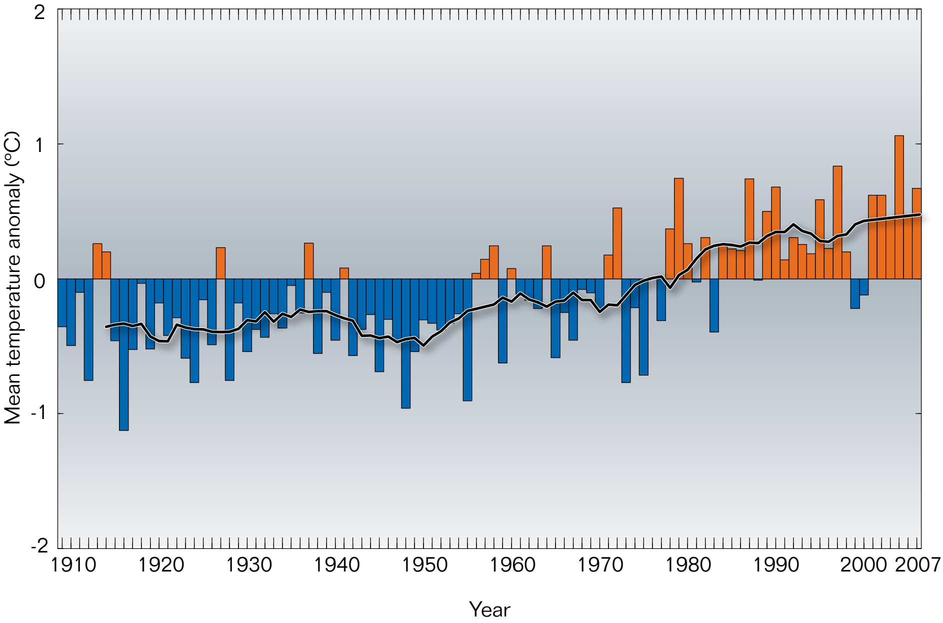
6.2 Historical climate change in Australia

Observations over the last century, and the last 50 years in particular, have shown marked changes in a number of key climate variables.

6.2.1 Temperature

Annual mean temperature in Australia has increased by 0.9°C since 1910 (CSIRO & BoM 2007). Figure 6.1 shows Australian annual mean temperature anomalies from 1900 to 2007.

Figure 6.1 Australian annual mean temperature anomalies, 1900–2007



Note: The data shows temperature difference from the 1961–90 mean. The black line shows the 10-year trailing average.
Source: Bureau of Meteorology.

The warming tendency since the middle of the 20th century has not been uniform across the country. The greatest warming has occurred in central Australia (Murphy & Timbal 2008). In south-eastern Australia, mean maximum temperatures have increased. As a result, droughts have become hotter (Nicholls 2004).

Ocean temperature has changed at a slower pace, due to the ocean's large heat content and enhanced evaporative cooling. Nevertheless, substantial warming has occurred in the three oceans surrounding Australia. The Indian Ocean is warming faster than all other oceans with significant warming off the coast of Western Australia (CSIRO & BoM 2007).

6.2.2 Rainfall

There has been a major change in rainfall patterns since the 1950s, with large geographic variation. Across New South Wales and Queensland, the difference partly reflects a wet period around the 1950s. North-west Australia has seen a significant increase, whereas most of the eastern seaboard and south-west Australia have seen a significant decrease in annual rainfall (CSIRO & BoM 2007). Rainfall changes over the longer period from 1900 to 2007 are generally positive and are largest in the north-west. Drying tendencies over this longer period are evident in south-west Australia, some other parts of southern Australia, including much of Tasmania, and over much of north-east Australia.[1]

Change can occur to both the mean and distribution of variables (Chapter 3). In Australia, the rate of change in the frequency and intensity of rainfall and temperature extremes is greater than the rate of change for the equivalent means (Alexander et al. 2007). For example, maximum temperatures are increasing at a greater rate than mean temperature.

The attribution of changes in rainfall patterns in Australia to climate change is difficult due to naturally high interannual variability. Attribution has been possible in the south-west of Western Australia, where up to 50 per cent of the rainfall decline has been attributed to human-induced climate change (Cai & Cowan 2006). This rainfall decline has been observed since the 1970s, and as such has been the subject of research over many years. The rainfall decline observed in the 1990s in south-east Australia shares many characteristics with the decline in the south-west, but has only recently become the subject of extensive research (CSIRO & BoM 2007). The factors affecting rainfall decline in the south-east appear more complex, however, as this region is affected to a greater extent by major systems such as the El Niño – Southern Oscillation and the subtropical ridge (Murphy & Timbal 2008). This is discussed further in Box 6.1.

Rainfall can be affected by anthropogenic emissions other than greenhouse gases. It has been suggested that the increased rainfall in the north-west of Australia could be affected by aerosols drifting south from Asia. Aerosols can create a localised cooling effect, which in turn affects convection and rainfall patterns, often at long distances (Rostatyn et al. 2007).

Streamflows

A reduction in rainfall results in a proportionately larger fall in streamflows. Generally, a decrease in rainfall can result in a two- to threefold decrease in streamflow (Chiew 2006). In the Murray-Darling Basin, a 10 per cent change in rainfall seems to result in a 35 per cent change in streamflow (Jones et al. 2001).

Low streamflows have been recorded in the rivers supplying most major urban water storage systems over the last decade (Water Services Association of Australia 2007). For Melbourne, Sydney, Brisbane, Adelaide and Canberra,[2] average streamflows over the period 1997–2007 are notably below the long-term average (the period of the long-term average is between 84 and 108 years depending when measurements began). Recent streamflows supplying Canberra are 43 per cent of the long-term average, in Melbourne 65 per cent, Adelaide 62 per cent, Sydney 40 per cent and Brisbane 42 per cent.

The greatest, and earliest, decline in streamflows of rivers supplying major urban water storages has been observed in Perth (Figure 6.2). There has been a marked decline since the 1970s, which has continued and appears to have intensified over the last decade. Annual streamflows over recent years (2001–07) are only 25 per cent of the long-term average up to this observed

Box 6.1 Drought in Australia

Drought can be defined in many ways. The main contributing factors for all definitions, however, are rainfall, temperature and evaporation. Due to the strong connection between anthropogenic emissions and warming in Australia, the CSIRO and the Bureau of Meteorology (2007) conclude that the drought in many parts of the country is linked to, or at least exacerbated by, global warming.

The causes of drought can be many. For example, the drought in south-west Western Australia has been attributed to a combination of natural variability, an increase in greenhouse gas concentrations, and land-use change (Timbal et al. 2006).

In south-east Queensland, the drought appears to have been caused by changes in two key climate variables: the El Niño – Southern Oscillation (see section 6.2.3) and tropical cyclones (Department of Natural Resources and Water 2007). Since 1950, there has been a strong decline in rainfall across eastern Australia and since 1977 there has been an increase in the frequency of El Niño events (Power & Smith 2007). Related to this shift in the system's El Niño behaviour has been a reduction in the region of the number of tropical cyclones, which contribute a large amount to total rainfall.

Since 1997, south-east Australia has recorded a number of changes in relation to rainfall mean (Murphy & Timbal 2008; B. Timbal, pers. comm.):

- From 1997 to 2007 only one year has had rainfall above the 1961–90 annual average.
- Only one autumn from 1990 had rainfall above the 1961–90 autumn average.
- Melbourne streamflows have been below the long-term average every year since 1996 (Timbal & Jones 2008).

Changes in autumn rainfall and temperature are important for a number of reasons. First, April to June is a critical rainfall period for the establishment of crops. Second, while most rainfall in the region falls in winter and spring, autumn rainfall acts as a soil-wetting mechanism affecting streamflows in preceding months. Without this preparation, winter and spring streamflows can be negatively affected, even if rainfall is not (Cai & Cowan 2008a). Finally, it has recently been suggested that increased temperature has a very large impact on streamflow. After accounting for interdependencies, such as the effect of rainfall and clouds on minimum temperatures, Cai and Cowan (2008b) concluded that a 1°C increase in maximum temperature results in a 15 per cent decrease in streamflow in the Murray-Darling Basin.

A similar decline in annual mean rainfall in south-east Australia has occurred once before in historical records. Between 1936 and 1945 mean annual rainfall was 493.8 mm compared with the 1997–2007 mean of 515.1 mm (Murphy & Timbal 2008; B. Timbal, pers. comm.)

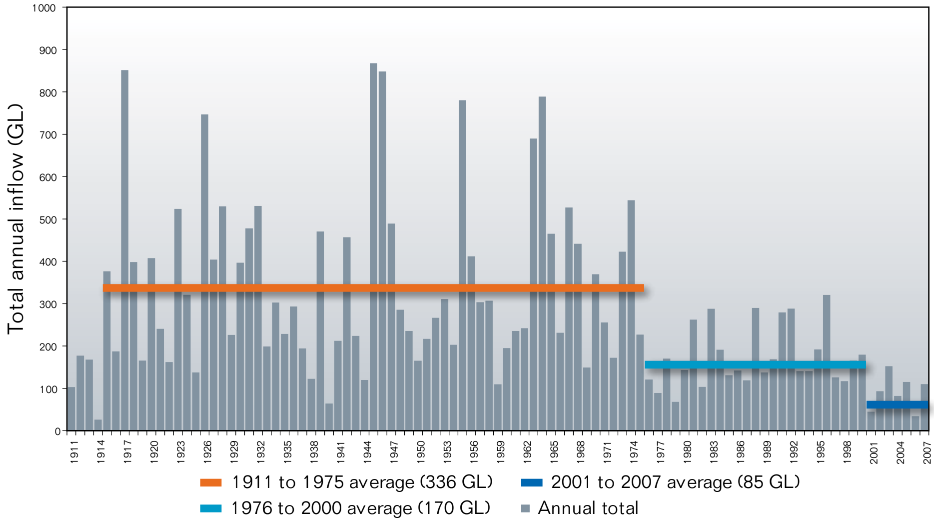
Box 6.1 Drought in Australia *(continued)*

The current drought is marked by an increase in mean maximum temperatures, further affecting evaporation and streamflows and reduced interannual variability.[3]

The decline in autumn rainfall in south-east Australia has strong qualitative similarities with the decline observed in the 1970s in Perth (Murphy & Timbal 2008). However, it has occurred much later. Unlike south-west Western Australia, however, the south-east of Australia is affected by a multitude of climate systems including the El Niño – Southern Oscillation and the Southern Annular Mode, subtropical ridges, and the Indian Ocean Dipole.[4] Although there is currently no consensus on the magnitude of influence of these systems, or on how they will respond to global warming (Murphy & Timbal 2008; Timbal & Murphy 2008; Cai & Cowan 2008a; Hendon et al. 2007), one estimate is that the El Niño system and the Southern Annular Mode account for around 15 per cent of the observed rainfall decline in the south-west and south-east of the country (Hendon et al. 2007).

decline. The decline in rainfall in the region, which occurred at approximately the same time, has been partly attributed to human-induced climage change (Cai & Cowan 2006).

Figure 6.2 Annual streamflow into Perth's dams



Note: Values represent totals for May–April.

Source: Western Australia Water Corporation.

6.2.3 El Niño – Southern Oscillation and the Southern Annular Mode

El Niño – Southern Oscillation

The El Niño – Southern Oscillation is a naturally occurring phenomenon that temporarily disrupts climatic patterns in many countries in the Pacific and Asia, including Australia (Power et al. 2006; Ropelewski & Halpert 1984; Nicholls 1992; Allan et al. 1996). It is often monitored using the Southern Oscillation Index, which is a measure of the difference in mean sea-level pressure across the Pacific Ocean, between Darwin and Tahiti. A positive sustained index is associated with stronger trade winds, a cooler than normal eastern equatorial Pacific Ocean and warmer sea temperatures in the north of Australia. In Australia, it is associated with increased rainfall, flooding and decreased temperatures (Power et al. 1998). This is known as a La Niña episode. A negative index is associated with warmer than normal sea surface temperatures in the central to eastern equatorial Pacific Ocean, weaker trade winds, and a reduction in rainfall in eastern and northern Australia. This is known as an El Niño episode (BoM 2005; Power & Smith 2007).

Many major Australian droughts are associated with an El Niño event, though not all El Niño events trigger a drought. The effect of the El Niño – Southern Oscillation on climate varies across the country. South-west Western Australia, the west coast of Tasmania and coastal New South Wales are less affected than inland eastern Australia (BoM 2005).

A La Niña episode does not produce an exactly opposite effect to that of an El Niño and the pattern of influence is also different (Power et al. 2006). For example, parts of northern and central Australia are more affected by La Niña than El Niño.

The impact of the El Niño – Southern Oscillation on Australia also varies substantially from decade to decade and generation to generation. In fact the 1977–2006 average value of the Southern Oscillation Index was the lowest 30-year value on record. Moreover, the trend over this period was statistically significant at the 95 per cent level. This record-low value primarily arose from record high values in Darwin air pressure, and the changes coincided with very weak trade winds. This period also saw a record high number of El Niño events and a corresponding record low number of rain-bearing La Niña events, making it the most El Niño-dominated period on record (Power & Smith 2007).

The extent to which this decline in the Southern Oscillation Index is influenced by global warming is unknown. Nevertheless some climate models exhibit weakened trade winds in response to global warming (Vecchi et al. 2006), and so global warming might also be contributing to some of the observed changes evident in and around the tropical Pacific (Power & Smith 2007).

The relationship between the Southern Oscillation Index and temperature and rainfall in Australia has also changed over time: both temperature and rainfall values for the period 1973–2005 tended to be higher for any given value of the index than for the preceding period (1910–1972) (Nicholls et al. 1996; Power et al. 1998; CSIRO & BoM 2007).

Southern Annular Mode

Another dominant mode of variability at high southern latitudes is the Southern Annular Mode. When this mode is in its positive phase, unusually high pressure is observed over Antarctica and unusually low pressure around 40–55° South (CSIRO & BoM 2007).

Both the Southern Annular Mode and El Niño – Southern Oscillation are estimated to drive approximately 15 per cent of the variability in spring and summer rainfall in south-east Australia (CSIRO & BoM 2007).

Over recent decades, the Southern Annular Mode has spent increasingly more time in its positive phase (CSIRO & BoM 2007). There is an association between this positive phase and significant winter rainfall reduction in southern Australia as well as significant rainfall increases in the Murray-Darling Basin in summer (Hendon et al. 2007).

This shift has led to a decrease in the potential for storm formation over southern Australia. In south-west Australia, a reduction in winter rainfall is associated with a decrease in the number of rain-bearing synoptic systems and a deflection southward of some storms (CSIRO & BoM 2007).

6.2.4 Other climate variables

Cyclones and storms

It is difficult to determine trends in the frequency and intensity of tropical cyclones in the Australian region due to inherent multidecadal variability in tropical cyclone frequencies and intensities, and the varying quality of historical records (CSIRO & BoM 2007). Similarly, hailstorms are highly sensitive to small-scale variations in meteorological and oceanographic conditions as well as geographic features. Furthermore, accurate and consistent data collection methods, such as digital and microwave satellite imagery and comprehensive storm spotter networks, have been continually evolving, and hence comprehensive and homogeneous datasets are not yet of sufficient length for rigorous climate change analyses. As such, it is difficult to draw definitive conclusions on observed changes in hailstorm and tropical cyclones that can be attributed to climate change from the current historical datasets (B. Buckley, pers. comm.).

Limited observations have suggested that there was a substantial increase in tropical cyclone numbers on the east coast since the 1950s, followed by a reduction since the 1970s. This reduction appears to be linked to an increasing number of El Niño events since there tend to be fewer tropical cyclones in Australia during El Niño events (CSIRO & BoM 2007). On the west coast, there appears to have been an increase in the proportion of severe (category 3 and 4) cyclones (CSIRO & BoM 2007). During the period 1974–88, severe cyclones accounted for 29 per cent of the total. In the period 1989–98 they accounted for 41 per cent.

In general, there are fewer tropical cyclones in Australia during El Niño events than during La Niña (CSIRO & BoM 2007).

Bushfires

During the period 1973–2007, there has been a general increase in the Forest Fire Danger Index across the east and south-east of the country. A recent review of 23 measuring locations over this period analysed the three years with the highest index (Lucas et al. 2007). Fifty out of 69 of the selected years were after the year 2000, with the increasing trend statistically significant above the 95 per cent level for most inland locations.

Box 6.2 Heatwaves

The number of hot days and warm nights per year has increased since 1955 (CSIRO & BoM 2007) and heatwaves have become increasingly common (Lynch et al. 2008).

In February 2004, for example, maximum temperatures were 5–6°C above average throughout large areas, reaching 7°C above average in parts of New South Wales (National Climate Centre 2004). Adelaide had 17 successive days over 30°C (the previous record was 14 days). Sydney had 10 successive nights over 22°C (the previous record was six). Around two-thirds of the continent recorded maximum temperatures over 39°C and temperatures peaked at 48.5°C in western New South Wales (Lynch et al. 2008).

In May 2007, high mean temperatures were observed in large parts of eastern Australia and records were set over most of Victoria and Tasmania, most of New South Wales, parts of Southern Australia and most of Queensland. January to May 2007, in south-east Australia, was the warmest on record at 0.3–0.5°C higher than the previous record period (National Climate Centre 2007).

In March 2008, Adelaide had 15 consecutive days 35°C or above and 13 consecutive days of 37.8°C or above. Hobart matched its previous record high temperature of 37.3°C and Melbourne recorded a record high overnight minimum of 26.9°C (National Climate Centre 2008).

6.3 Projected climate change in Australia

Climate projections are based on emissions cases or scenarios. In assessing projections of climate change in Australia, the Review used a combination of the IPCC SRES scenarios, as used by the CSIRO and BoM (2007), and emissions cases based on strong and ambitious global mitigation. Emissions scenarios are based on, necessarily, simplified global models and the actual outcome is unlikely to exactly match a predicted scenario or case. There is significant uncertainty in the timing of particular temperature increases, as discussed in Chapter 3.

As discussed in Chapter 5, projections of global mean temperature across different emissions scenarios show little variation until the decade of the 2030s. Australian mean temperature responds in a similar fashion. After this point, projections of climate variables are increasingly dependent on emissions pathways.

The future climate is a function of both human-induced climate change projections and natural climate variability about these projections. In some decades the natural variability will reinforce the climate change signal, while in other decades it will offset the signal to some degree.

6.3.1 Temperature

Annual mean temperatures in Australia are expected to rise in parallel with rises in global mean temperature. Significant regional variation, however, is projected across Australia. In general, the north-west is expected to warm more quickly than the rest of the country.

By 2030, annual temperature over Australia will be around 1°C above 1990 levels (CSIRO & BoM 2007).[5] The range of uncertainty (10th to 90th percentiles) produces a national increase of between 0.4°C and 1.8°C for 2030. Coastal areas will experience slightly less warming in the range 0.7–0.9°C, whereas inland Australia will experience greater warming in the range 1.0–1.2°C.

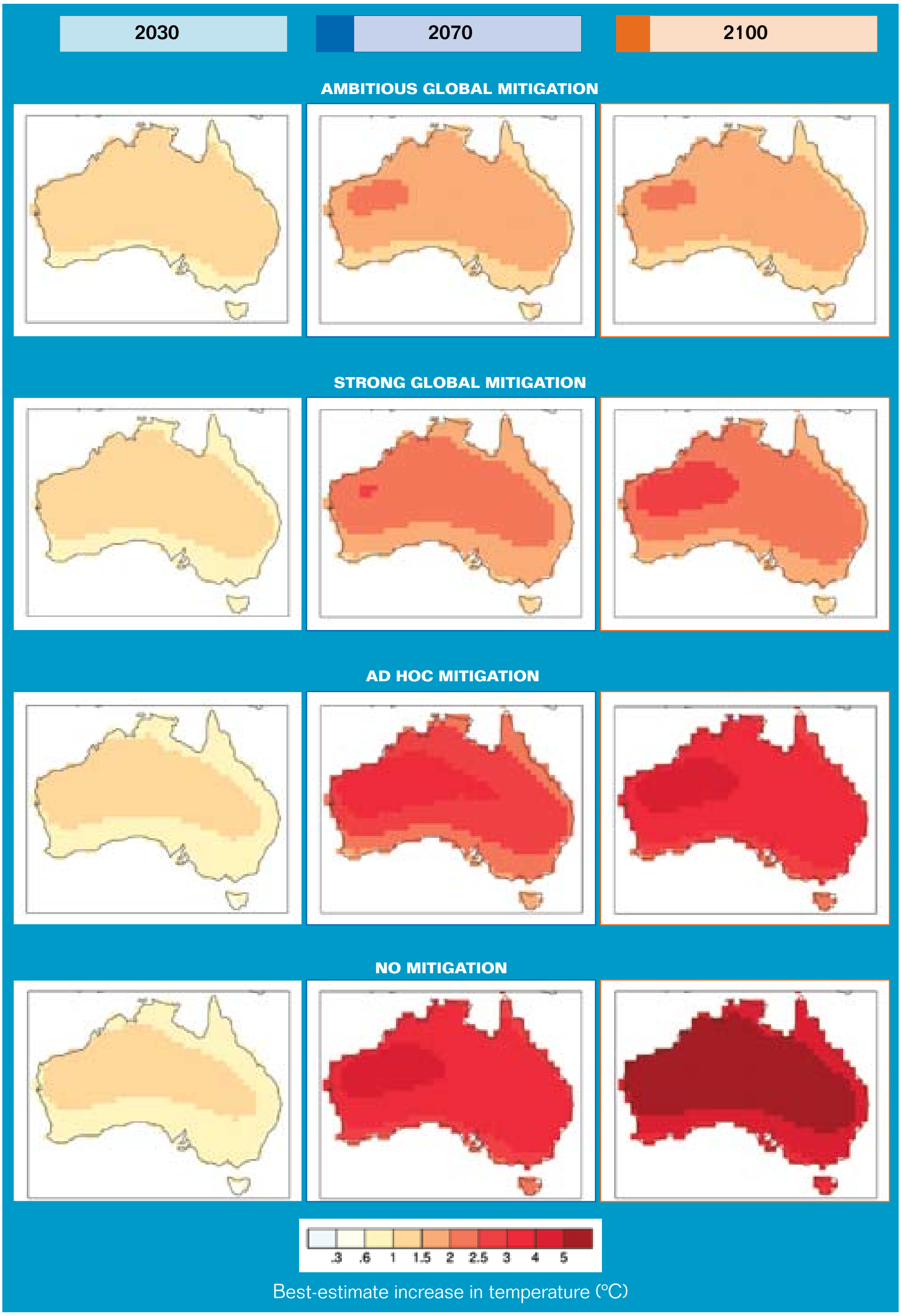
From 2030 to the end of the century there are marked differences between cases, as shown in Figure 6.3.

At both the 10th and 90th percentile outcomes there are noticeable temperature increases across the country. The 90th percentile of outcomes in a no-mitigation case includes an increase of more than 7°C in some areas. The 10th percentile of outcomes shows an increase of more than 3°C for most of the country, increasing to 4.85°C over an extensive area in north-west Australia.

6.3.2 Rainfall

The relationship between local precipitation and atmospheric temperature is complex. Local rainfall patterns are highly sensitive to the amount of water available for evaporation, the local topography and land cover, and atmospheric and ocean circulation patterns. At the global level a decrease in precipitation is indicated as the 'best estimate' outcome for Australia (see Chapter 5). However, because of the localised nature of influences on precipitation, there is considerable regional variation in precipitation change within Australia, so that some areas are expected to experience an increase in rainfall. The complexities also lead to disagreement between climate models regarding the potential extent, and even direction, of the change.

Figure 6.3 Best estimate (50th percentile) of Australian annual temperature change at 2030, 2070 and 2100 under four emissions cases



Notes: Four cases are shown: ambitious global mitigation (450 ppm stabilisation), strong global mitigation (550 ppm stabilisation), ad hoc mitigation (based on the SRES A1B scenario), no mitigation (based on the SRES A1FI scenario). Values greater than or equal to 5 are represented with the same colour.

Source: CSIRO.

Best-estimate annual average change in rainfall

Table 6.1 shows the best-estimate (50th percentile) annual average rainfall outcomes for Australia in a no-mitigation case in 2030, 2070 and 2100.[6] The best-estimate outcomes of change in annual average rainfall in 2030 are minimally different between the different emissions cases due to climate change commitments (Chapter 5), but later in the century the rainfall outcomes are more dependent on the level of mitigation action. The changes under the ad hoc and strong and ambitious global mitigation cases follow the same patterns of change but the reductions are considerably more subdued. The extent of rainfall change under the ambitious mitigation case in 2100 is less than that experienced under the no-mitigation case in 2070.

Table 6.1 Projected changes to state-wide average rainfall, best-estimate outcome in a no-mitigation case (per cent change relative to 1990)

	NSW	Vic.	Qld	SA	WA	Tas.	NT	ACT
2030	-2.5	-3.5	-2.4	-4.2	-4.1	-1.4	-2.5	-2.8
2070	-9.3	-12.9	-8.6	-15.5	-14.9	-5.1	-9.0	-10.3
2100	-13.7	-19.0	-12.7	-22.8	-21.9	-7.6	-13.3	-15.2

Source: CSIRO.

The ‘dry’ and ‘wet’ ends of precipitation projections

The best-estimate outcomes do not reflect the extent of the uncertainty in potential rainfall outcomes for Australia under climate change. Rainfall projections are highly sensitive to small changes in model assumptions and inputs, and the range of precipitation outcomes predicted by various climate models for Australia is large.

Table 6.2 shows the average annual changes for rainfall in Australia for the no mitigation case for ‘dry’ (10th percentile) and ‘wet’ (90th percentile) end of projections in 2030, 2070 and 2100.

Table 6.2 Projected changes to state-wide average rainfall, ‘dry’ and ‘wet’ outcomes in a no-mitigation case (per cent change relative to 1990)

Dry outcome (10th percentile)

	NSW	Vic.	Qld	SA	WA	Tas.	NT	ACT
2030	-10.1	-8.3	-11.5	-13.1	-12.7	-5.2	-11.4	-8.2
2070	-37.0	-30.3	-42.0	-48.0	-46.5	-19.2	-41.8	-30.1
2100	-54.6	-44.7	-61.8	-70.8	-68.5	-28.3	-61.6	-44.4

Wet outcome (90th percentile)

	NSW	Vic.	Qld	SA	WA	Tas.	NT	ACT
2030	4.2	0.9	6.0	4.0	4.2	2.6	6.0	2.0
2070	15.5	3.4	22.0	14.8	15.5	9.5	22.0	7.4
2100	22.8	5.1	32.5	21.9	22.8	14.0	32.4	10.9

Source: CSIRO. The methodology for the preparation of these distributions is described in CSIRO & BoM (2007).

The uncertainty in projections of change in annual Australian rainfall has been taken into consideration in the determination of impacts in Chapter 7.

Temporal variation in rainfall

Changes in annual rainfall often mask significant inter-seasonal variation. Similarly, mean annual rainfall may mask changes in rainfall patterns, rainfall intensity and the number of rain events. For example, it is possible for mean annual rainfall to remain the same, while rain intensity increases and the number of rain days decreases.

In summer and autumn, decreases are more limited and some areas experience slight increases. Larger decreases in rainfall are experienced in winter and spring (CSIRO & BoM 2007).

As well as changes to annual average rainfall, the character of daily rainfall may change. There is expected to be an increase in the intensity of rainfall events in some areas, and the number of days without rainfall are also expected to increase. This suggests that the future precipitation regime may have longer dry spells broken by heavier rainfall events (CSIRO & BoM 2007).

Consideration of a progressive change in annual average rainfall does not reflect the considerable interannual and decadal variation in Australian rainfall. In terms of precipitation, observed decadal variability in the 20th century and models run with a 'no climate change assumption' show natural variability in rainfall of between 10 and 20 per cent (CSIRO & BoM 2007). Natural variability may therefore mask, or enhance, changes due to high concentrations of greenhouse gases.

Variation in the intensity and temporal pattern of daily rainfall, differences in seasonal change, and the influence of natural decadal variability could have considerable impact on sectors such as agriculture and infrastructure.

6.3.3 El Niño – Southern Oscillation and the Southern Annular Mode

There is no consensus among models as to how climate change will affect the El Niño – Southern Oscillation (see IPCC 2007: 779–80; CSIRO & BoM 2007; Lenton et al. 2008)—in some models it intensifies, while in other models it weakens.

The Southern Annular Mode is likely to shift towards its positive phase, which will result in weaker westerly winds in southern Australia and stronger westerly winds at higher latitudes. Such a movement would be associated with lower rainfall.

6.3.4 Other climate variables

Cyclones and storms

As stated above, tropical cyclone frequency and intensity display high variability across seasonal, annual, decadal and multi-decadal timescales (CSIRO & BoM 2007). The El Niño – Southern Oscillation also has a strong effect on tropical cyclone numbers (Abbs et al. 2006). As it is as yet unknown what effect climate change will have on the El Niño – Southern Oscillation, it is difficult to project changes in the frequency and intensity of tropical cyclones.

Studies suggest that the frequency of east coast cyclones will either remain the same or decrease by up to 44 per cent (see CSIRO & BoM 2007). Abbs et al. (2006) estimate that category 3–5 storms will increase in intensity by 60 per cent for 2030 and 140 per cent in 2070.

Projections also indicate that the regions of east Australian cyclone genesis could shift southward by 2° (approximately 200 km) by 2050 (Leslie et al. 2007), while the average decay location could be up to 300 km south of the current location (Abbs et al. in CSIRO & BoM 2007). Models also estimate that the number of strong cyclones reaching the Australian coastline will increase, and ‘super cyclones’, with an intensity hitherto unrecorded on the Australian east coast, may develop over the next 50 years (Leslie et al. 2007).

Future projections indicate an increase in the intensity and frequency of hailstorms in the Sydney basin region with only a 1–2°C rise in temperature (Leslie et al. 2008).

Heatwaves

There is projected to be a strong increase in the frequency of hot days and warm nights. The current projected number of days per year above 35°C for 2030, 2070, and 2100 in all capital cities is displayed in Table 6.3.

Most notable is the marked increase of hot days in Darwin. Under a no-mitigation case, there are 221 days over 35°C in 2070. By 2100, this increases to 312—or less than eight weeks in the year with days under 35°C.

Table 6.3 Projected increases in days over 35°C for all capital cities under a no-mitigation case

	Current	2030	2070	2100
Melbourne	9	12	21	27
Sydney	3.3	4.4	9	14
Brisbane	0.9	1.7	8	21
Adelaide	17	22	34	44
Perth	27	35	56	72
Canberra	5	8	21	32
Darwin	9	36	221	312
Hobart	1.4	1.7	2.5	3.4

Source: CSIRO.

Bushfires

The most recent projections of fire weather in a study by Lucas et al. (2007) suggest that fire seasons will start earlier, end slightly later, and generally be more intense in their duration. This effect increases over time, but should be directly observable by 2020.

Table 6.4 shows projections of the percentage increase in the number of days with very high and extreme fire weather.[7]

Table 6.4 Projected increases in the number of days with very high and extreme fire weather for selected increases in global mean temperature

	Approximate year		
	2013	2034	2067
Very high	+2–13	+10–30	+20–100
Extreme	+5–25	+15–65	+100–300

Note: This study was based on scenarios producing 0.4°C, 1.°C and 2.9°C temperature increases, which equate to the years in this table under a no-mitigation case.

Source: Lucas et al. (2007).

The Lucas study defined two new categories of fire weather: 'very extreme' and 'catastrophic'.[8] Of the 26 sites used in the study, only 12 have recorded catastrophic fire danger days since 1973. At a 0.4°C increase in temperature there is little or no change in the number of catastrophic fire weather days. At a 1.0°C increase, catastrophic days are occurring at 20 sites. For half of these sites, the return period is around 16 years or less. At a 2.9°C increase, 22 sites record catastrophic days. Nineteen of these have a return period of around eight years or less. Seven sites have return periods of three years or less.

Notes

1 See <www.bom.gov.au/climate/> for further details.

2 Hobart has not been included as normally only 40 per cent of supply is taken from storage facilities with the remainder being extracted from the Derwent River, whose catchment area is approximately 20 per cent of the area of the state. During scarce periods, larger quantities are drawn from the Derwent River, though on average this represents less than 1 per cent of the total streamflow. Darwin has not been included as streamflows in its catchment areas have been largely unaffected over the last decade (R. Young, pers. comm.).

3 The standard deviation for annual rainfall for the period 1936–45 was 105.5 mm, compared with 85.8 mm for the current drought (Murphy & Timbal 2007; B. Timbal, pers. comm.).

4 While geographically distant, Indian Ocean sea surface temperatures have been shown to be associated with south-eastern Australian rainfall (Murphy & Timbal 2008; Cai & Cowan 2008a).

5 All temperature increases are from a 1990 baseline.

6 Changes in precipitation are reported as percentage changes from a 1990 baseline.

7 'Very high' fire weather has a Forest Fire Danger Index (FFDI) of 25–50 and 'extreme' fire weather has an FFDI of 50+. Suppression of fires during 'extreme' fire weather is "virtually impossible on any part of the fire line due to the potential for extreme and sudden changes in fire behaviour. Any suppression actions such as burning out will only increase fire behaviour and the area burnt" (Vercoe in Lucas et al. 2007).

8 'Very extreme' fire weather has an FFDI of 75–100 and 'catastrophic' fire weather has an FFDI of over 100 (Lucas et al.).

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