

Water and climate

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Key messages

- * Floods, droughts, and climate change are the three most important influences of climate on Australia's water resources.
- * Water resources are vulnerable to both climate variability and change; for example, runoff into Perth's reservoirs has declined by 55% since the 1970s and the 1997 to 2009 drought resulted in unprecedented decline in runoff and water use in the southern Murray–Darling Basin.
- * Climate change has played a part in recent reductions in rainfall and water resources, however its specific contribution is difficult to quantify.
- * Climate change by 2030 is likely to reduce average river flows by 10% to 25% in some regions of southern Australia but further climate change could produce even more profound reductions of water resources in southern Australia.
- * The relationships between climate and runoff are now being used to provide more accurate seasonal forecasts of water resources useful for irrigators, dam operators, and environmental managers.

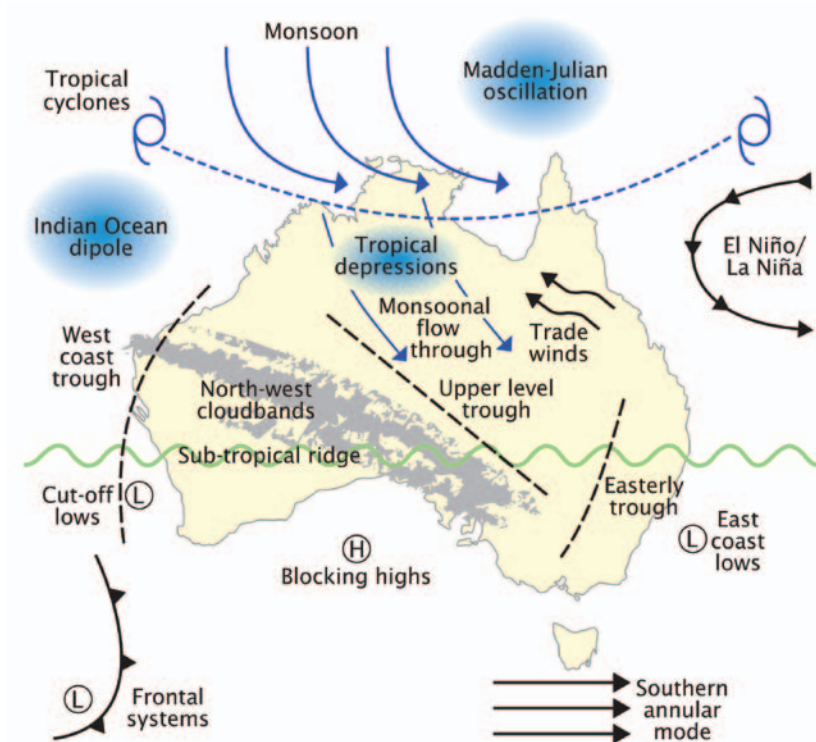
Weather and climate are the primary influences on Australia's water resources. Extreme storms and cyclones produce floods that can rise and fall within hours or that can last for months, while yearly variability in rainfall can produce droughts that may last for a decade or longer. Longer-term climate change increases or decreases average rainfall and evaporation, fundamentally changing the amount of water resources available. This chapter describes the influences of climatic events, variability, and change on water resources through their influence on floods, droughts, and water resources.

'Weather' is the brief, rapidly changing daily and seasonal conditions in the atmosphere, while 'climate' is the average weather experienced over years to decades. 'Climate variability' is the year to year and decade to decade noise or variability around the average climate, while 'climate change' is the longer term change in average conditions over several decades to centuries. The noise of weather and climate variability can occur around a changing average climate, making it difficult to detect long-term trends, especially for rainfall, which, in Australia, is highly variable from year to year.

Yearly variations in rainfall, or changes between centuries are amplified as even greater changes to runoff and river flows, making impacts on water resources one of the greatest concerns about climate change. Annual variations in rainfall are typically amplified as two- to three-times larger variations to annual runoff. So a 10% reduction in rainfall typically leads to a 20 to 30% reduction in runoff.¹ This amplification applies to climate change as well, so small reductions in average rainfall as a result of climate change will lead to two- to three-times larger reductions in water resources.

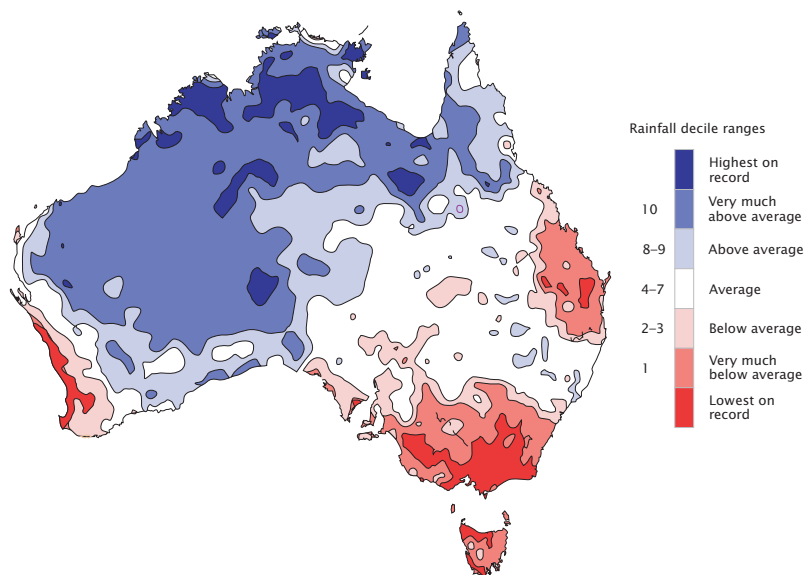
Weather and climate drivers

Floods, drought, and climate change are all driven by a number of processes in the atmosphere and oceans (Figure 3.1), but the changes are driven at different timescales. The drivers shown in Figure 3.1 interact with each other and influence different parts of the continent to bring local weather and climate. The drivers include circulation patterns in the Pacific Ocean that bring El Niño conditions associated with drought in eastern Australia and La Niña conditions that are associated with floods. The Indian Ocean Dipole is a similar pattern in the Indian Ocean that can bring drought to south-west and south-east Australia, and the Southern Annular Mode is a



◀ **Figure 3.1:** The major influences on rainfall (and thus runoff) in Australia.² (Reproduced with permission from Australian Bureau of Meteorology. © Commonwealth of Australia.)

► **Figure 3.2:** Rainfall conditions across Australia from 1 January 1997 to 31 December 2009 relative to the 1900–2009 climate, showing the extreme dry conditions across the south-east, the far south-west of Australia, and south-east Queensland.³



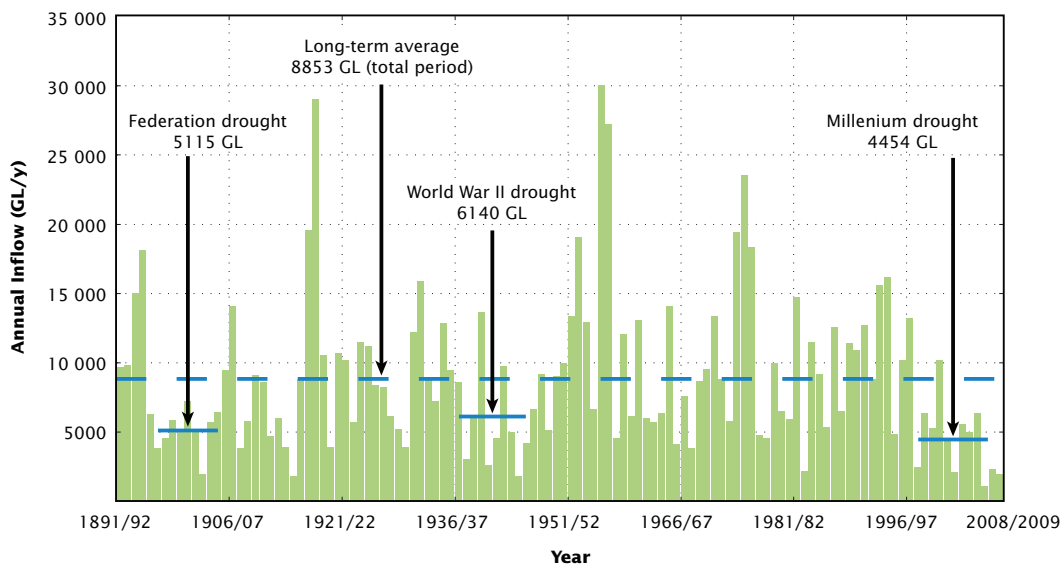
feature of the Southern Ocean that affects weather and climate in southern Australia. Atmospheric patterns such as the monsoon winds and southern ocean frontal systems bring rain, whereas southerly tracks of blocking highs and the subtropical ridge tend to bring dry weather.

Recent drought in southern Australia

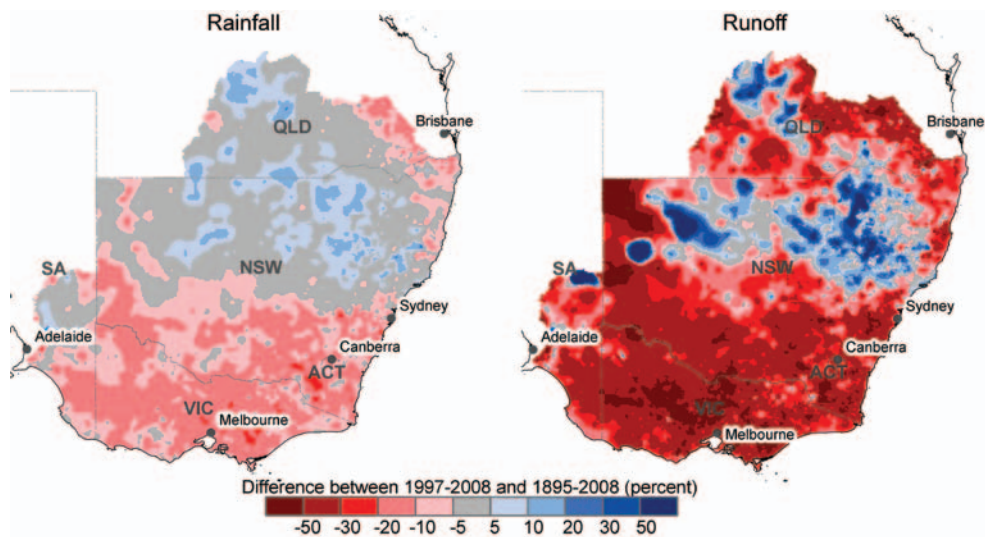
From 1997 to 2009, large areas of southern Australia, in particular the southern Murray–Darling Basin, Victoria, south-west Australia, and South East Queensland experienced prolonged drought, often referred to as the millennium drought (Figure 3.2, Figure 3.3).

The millennium drought in the southern Murray–Darling Basin was unprecedented in the 110 years of reliable rainfall records.⁴ It resulted in declining storage levels in reservoirs, several years of severe water restrictions in cities, and years of low water allocations to irrigators in the southern Murray–Darling Basin and elsewhere in Victoria. Water sharing arrangements for the Murray, Murrumbidgee, and Lachlan Rivers were suspended because they were not designed for such extreme conditions.

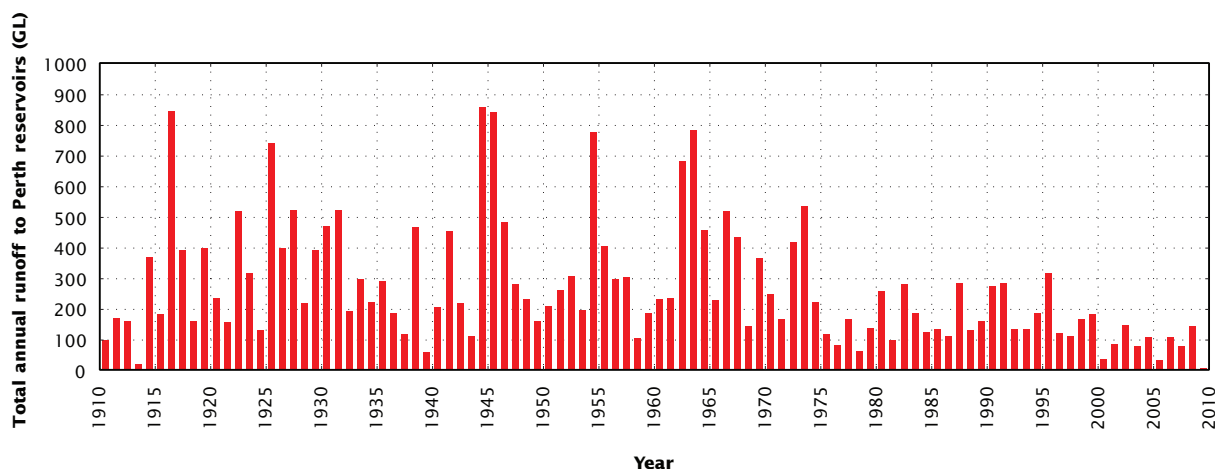
The drought had major environmental impacts.⁵ For example, the Lower Lakes of the Murray River fell more than 1 m below previously record low levels, exposing potentially toxic acidic sediments and increasing salinity in the lakes. Across the Murray–Darling Basin, there was either extensive death or stress to river red gums on floodplains, and low river flows led to the isolation of fish communities and a decline in fish breeding. Water use for irrigation fell by 64%⁶ and it was the first time that drought had caused a major fall in use for an extended period (see Chapter 8). Most of Australia's water use is in southern Australia, so the drought had a substantial economic, environmental, and social impact.



▲ **Figure 3.3:** Annual total inflows into the Murray River showing the high year to year and decade to decade variability and the low inflows from 1997 to 2009 and during earlier droughts. (Data provided by the Murray–Darling Basin Authority.)



▲ **Figure 3.4:** Percentage difference between recent (1997–2008) rainfall and runoff in south-eastern Australia and the long-term (1895–2008) averages.^s Although rainfall in Victoria and southern NSW was only 10–30% below average, runoff was 30–60% below average.



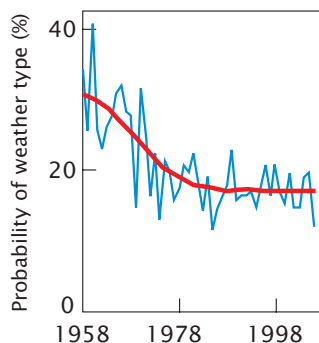
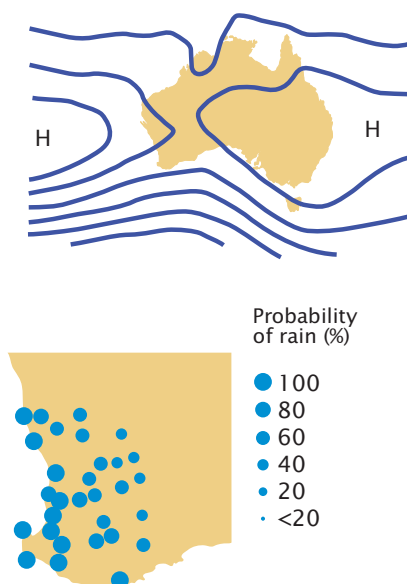
▲ **Figure 3.5:** Annual series of runoff into Perth reservoirs showing a persistent decline in inflows since the mid-1970s.¹⁰

There had been earlier multi-year droughts in the southern Murray–Darling Basin such as the Federation drought of 1895 to 1903 and the depression drought of the late 1930s and early 1940s (Figure 3.3), but none were as severe in terms of reduced runoff as the millennium drought. In places, runoff was less than half of the long-term average, even though average rainfall had decreased by less than 20% (Figure 3.4).⁷ The amplification of change from rainfall to runoff was greater than expected from previous droughts. Possible reasons include: a disproportionate rainfall decline in autumn resulting in dry soil at the start of the runoff season; rainfall decline in winter when most of the runoff occurs; the lack of any high rainfall years, which produce disproportionately high runoff; and higher temperatures driving greater evaporation.³

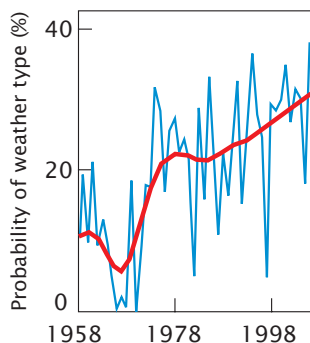
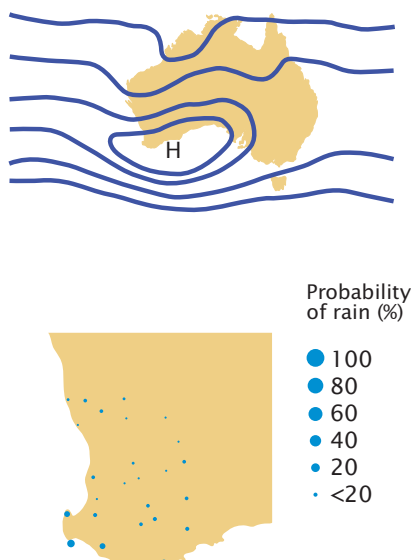
In the South West region of Western Australia, the very low rainfall from 1997 to 2009 has been part of a longer 35-year trend of gradually declining rainfall.⁹ The average runoff to Perth reservoirs was 338 GL/year before 1975 but from 1975 to 2009 it was only 181 GL/year, or 55% lower than before, as a result of a 16% fall in average annual rainfall (Figure 3.5). The higher runoff years are now nowhere near as high as previously (i.e. since 1975, no annual runoff to Perth reservoirs was above the pre-1975 average). This persistently low runoff led the Western Australian Government to secure additional water supplies for Perth, leading to a greater reliance on groundwater and the opening of Australia’s first desalination plant for supply of water to major city (see Chapter 7). Whether the change since the 1970s is a result of global warming or whether it reflects long-term natural variation in climate is discussed below.

The decline in rainfall around Perth has been attributed to changes in weather patterns across south-west Australia (Figure 3.6). Since the 1970s, high pressure systems and associated cold fronts have moved south bringing less rainfall than their previous more northerly track across southern Australia.¹¹ These changes most strongly affect autumn and winter rainfall and are the same sort of changes predicted to intensify with increasing global temperatures in future.

Type 3: Wet west & central



Type 5: Dry everywhere



▲ **Figure 3.6:** The relationship between two weather patterns and winter rainfall in the South West of Western Australia, showing the changed frequency of the weather patterns as an explanation for why rainfall has declined in the region since the 1970s. In Type 3 weather, high pressure systems and the subtropical ridge occur over the centre of Australia. This weather produces rain over south-west Australia as shown by the blue circles. During Type 5 weather, the high pressure systems occur further south and produce weather that brings very little rainfall to the region. The graphs at the bottom show that since the 1970s the frequency of Type 3 weather has declined and Type 5 weather has increased, explaining the decline in rainfall since that time.

Floods

At the opposite end of the range of climate variability are floods such as those experienced in 2010 and 2011 across eastern Australia. These were associated with one of the strongest La Niña events on record, the opposite to the El Niño conditions that were associated with drought. During La Niña conditions, the eastern Pacific Ocean is unusually cool as a result of upwelling of deep ocean water, strengthening the easterly trade winds coming to Australia from the western Pacific Ocean. This brings warm moist air over eastern Australia, causing widespread above-average rainfall.

Floods are the most costly natural disaster in Australia. The average direct annual cost of flooding between 1967 and 1999 has been estimated at \$314 million.¹² Costs vary widely between flood events (depending on flood volumes and infrastructure affected); for example, the Brisbane floods of 1974 caused \$700 million damage at that time, while the damage from the 2011 floods is likely to be in the vicinity of \$10 billion in current value. Moderate floods also have several benefits – they infill reservoirs, recharge groundwater, and replenish natural environments (see Chapter 9). These benefits can accrue for several years after the flood has subsided.

The Bureau of Meteorology issues flood warnings based on continuous monitoring and reporting of rainfall and river levels, rainfall forecasts, and hydrological modelling. Floods on small rivers generally have warning periods lasting from several hours to a couple of days. Large regional floods on lowland rivers occur with warning periods of days or weeks as they flow gradually downstream from runoff that is generated in tributaries. The most unpredictable form of flooding is local flash flooding in creeks and small rivers. This type of flooding is caused by locally intense storms that can cause a creek to rise to a major torrent in less than an hour. Flooding in Toowoomba and the Lockyer Valley in January 2011 were examples of flash flooding with tragic consequences.

Statistical analysis of historical floods shows that decades of higher than average rainfall, such as the 1950s to 1970s, can have higher magnitude floods than under average climatic conditions. A flood expected once every 100 years or so on average can be twice as large in these wetter decades than in drier decades.¹³ The same could happen with global warming. The warmer ocean temperatures will produce stronger convection and the ability of the air to hold more moisture, which could increase the intensity of storms and cyclones.¹⁴ Climate modelling also shows that extreme rainfall events such as cyclones are likely to be more intense in future, although less frequent,¹⁵ resulting in bigger floods and greater costs from flooding.

Many large dams, such as the Wivenhoe Dam in Brisbane, are managed to store water supplies and to retain some empty storage capacity to absorb and mitigate floodwaters, protecting downstream communities. These two functions may appear in conflict but the level of water to be stored is determined well in advance. Better seasonal forecasts of inflows (see below) offer the prospect of increasing the flood storage volume in dams when the forecasts predict a high probability of flooding.



Brisbane floods, January 2011. Photo: Glenn Walker.

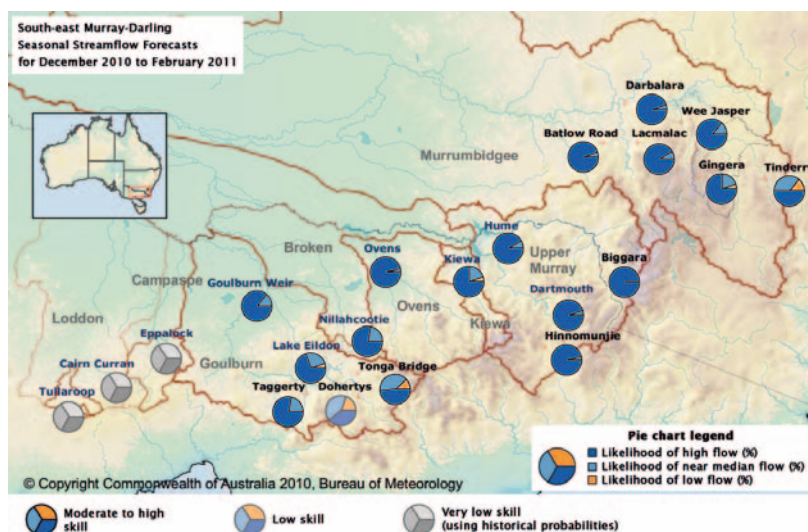
Short-term and seasonal forecasting of river flow

A paradox of Australia's highly variable rainfall and runoff is that it can be predicted several months in advance from the signals of global circulation such as El Niño and La Niña and other indicators. River flows can be forecast several months or seasons ahead using information on the soil moisture in the catchment, and the state of the ocean and atmosphere (e.g. droughts in eastern Australia are often linked to El Niño events in the equatorial Pacific Ocean).¹⁶ Seasonal rainfall and runoff forecasts can help irrigators plan, support trade of water, and make water use more efficient, and help decide when to release water from reservoirs.

The Bureau of Meteorology has been issuing seasonal weather outlooks since the 1990s, and in 2010 it launched a new service on seasonal river flow forecasting.¹⁷ This forecasting system is based on models developed by CSIRO¹⁸ that give probabilistic forecasts of river flow several months ahead, in particular flows to major water storages (e.g. Hume and Dartmouth Dams in the upper Murray; Figure 3.7).

The Bureau of Meteorology is also responsible for issuing flood warnings and is planning to extend its current flood warning service to forecast river flows continuously up to 10 days ahead. The Bureau of Meteorology and CSIRO are jointly developing and testing a modelling system for this purpose combining hydrological and weather prediction models that use real-time data from climate stations, river flow gauging sites, and satellite data.

- **Figure 3.7:** Seasonal forecast of runoff into the upper catchments of the Murrumbidgee and Murray Rivers issued in December 2010 for the 3-month period from December 2010 to February 2011.¹⁹ Dark blue indicates the probability of markedly above average runoff; light blue indicates the probability of average runoff, and orange indicates the probability of markedly below average runoff. The prediction was for high flow across the region as a result of wet catchment conditions and the forecast for continuing La Niña conditions. High flows did persist through the summer.



Impacts of climate change on river flows

Global temperatures of both the atmosphere and the oceans have been rising since the 1950s, and rising more rapidly than has been recorded in the geological past.²⁰ Many studies have linked most of the global warming to increasing greenhouse gas emissions.^{20,21} There is less certainty whether human-induced increases in temperature are the cause of the decline in rainfall in south-west Australia since the 1970s and the historically unprecedented conditions of the recent millennium drought in south-east Australia. This is because the huge natural variability (or noise) in rainfall from year to year makes it difficult to detect an overall trend. Rainfall is also controlled by regional weather and climate patterns (Figure 3.1), which have a complex relationship with global temperatures.

Climate modelling indicates that the persistent dry conditions in the far south-west and the millennium drought in south-east of Australia are at least in part a result of climate change.^{3,11,22} The dry conditions are associated with the shift of storm tracks towards the southern ocean. Climate models indicate that such changes are likely to intensify and become more persistent in future, so the dry conditions experienced are consistent with the trajectories of future climate for those regions.

Extended droughts and decades of wetter conditions are also a natural feature of southern Australia's climate. With only a little over a century of measurements, it is hard to establish patterns that span several decades so proxy records from tree rings, corals, and caves are used to describe longer term climate patterns. These proxies are correlated for recent times with the

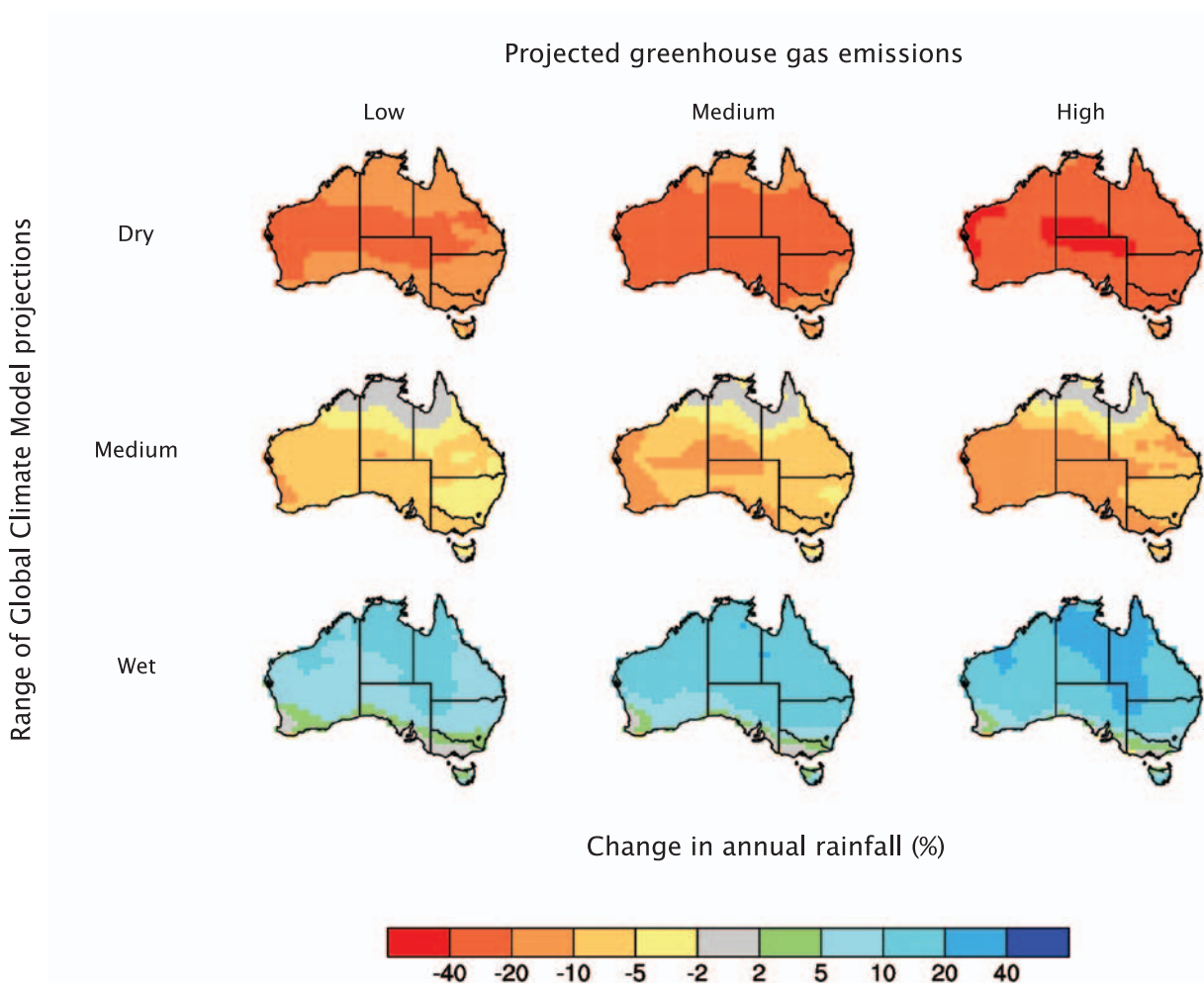
historical measurements of the oceans and atmosphere and then used to extend those records further back in time. At shorter time scales, we know that El Niño and La Niña influence rainfall and runoff²³ and now additional longer decade cycles are being found of increased frequency of El Niño events followed by decades of increased frequency of La Niña events. Decades of high frequency of El Niño events are associated with extended periods of drier-than-average conditions in eastern Australia, such as in the last few decades, and vice versa for wetter than average conditions, such as in the 1950s and 1970s.²⁴

It is possible that the millennium drought was a combination of natural variability and climate change and it is only through continued observations in coming years that any long-term trend in rainfall can be confirmed or not, and then, if the connection is evident, be attributed unequivocally to human-induced climate change. Regardless of the cause, though, a decade or more of drier conditions is enough to put water users, including ecosystems, under considerable stress and has tested whether water management is well adapted to such harsh conditions.

Predicting climate change impact on river flows involves three main components. Firstly, global climate models are used to project future climate change. Secondly, the results from these global climate models are 'downscaled' to the region of interest and its weather patterns, and finally, these regional weather patterns are used to run hydrological models to predict future river flows. Global climate models simulate complex global and regional climate systems. The Bureau of Meteorology and CSIRO have combined climate process understanding with global climate model simulations from the Intergovernmental Panel on Climate Change (IPCC)²⁰ to provide climate projections for Australia.²⁵ Figure 3.8 is an example of the range of projected changes in average annual rainfall by 2070 relative to 20th century rainfall.

There is a considerable difference in the projected rainfall in each of the maps in Figure 3.8. This is because of two key uncertainties about future climate. The first is the future level of greenhouse gas emissions, which will be determined by future industrial development and mitigation of emissions. The world is currently tracking toward the high end of emissions shown on the right hand column of Figure 3.8. The second uncertainty is how future rainfall in Australia will respond to changes in global temperature. Future rainfall is predicted from global climate models, through changes to conditions in the atmosphere and ocean, such as those shown in Figure 3.1. Figure 3.8 shows the range in projections from the various global climate models used by the IPCC.

Most climate models indicate that southern Australia, where most water is consumed, is on average likely to be drier in the future. The model projections are consistent with the patterns observed during the last decade or so, with a shift of autumn and winter storm tracks towards the South Pole. In northern Australia, the direction of change in average rainfall is uncertain, with as many models predicting a wetter future as a drier future.



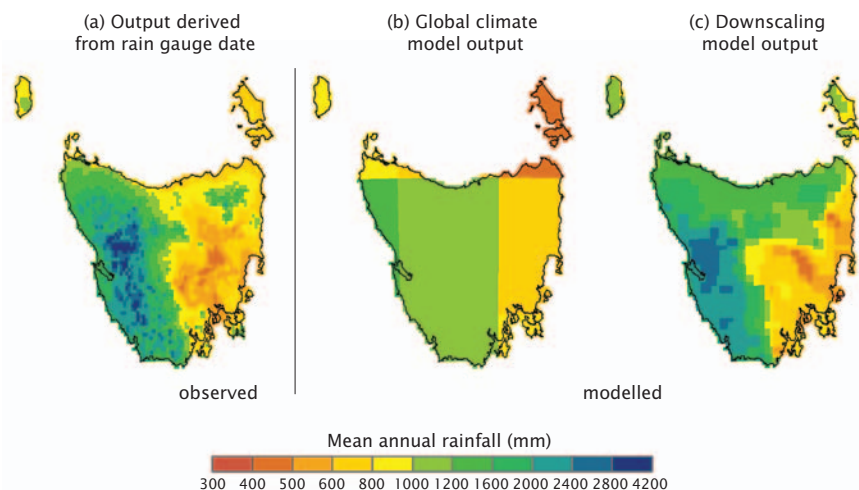
▲ **Figure 3.8:** Projections for percentage change in average annual rainfall in Australia by 2070 relative to 20th century rainfall. Nine projections are shown. The columns of maps show projections for low, medium, and high future greenhouse gas emissions, showing the effects of different amounts of global warming. The rows of maps show the range of projections from different global climate models. The top row shows the drier model results, the middle row is the mid-range of results and the bottom row shows the wetter projections of average annual rainfall from the models.²⁶

Global climate models produce results at a very coarse spatial resolution. Victoria is typically represented by less than five grid cells in a global climate model and Tasmania is equivalent in area to a single grid cell. Although driven by global circulation patterns, rainfall and river flows are regional phenomena influenced by local topography, proximity to the coast, and local weather patterns. For regional and catchment hydrological modelling, the global climate model simulations need to be scaled down to catchment-scale rainfall and other climate variables.²⁷

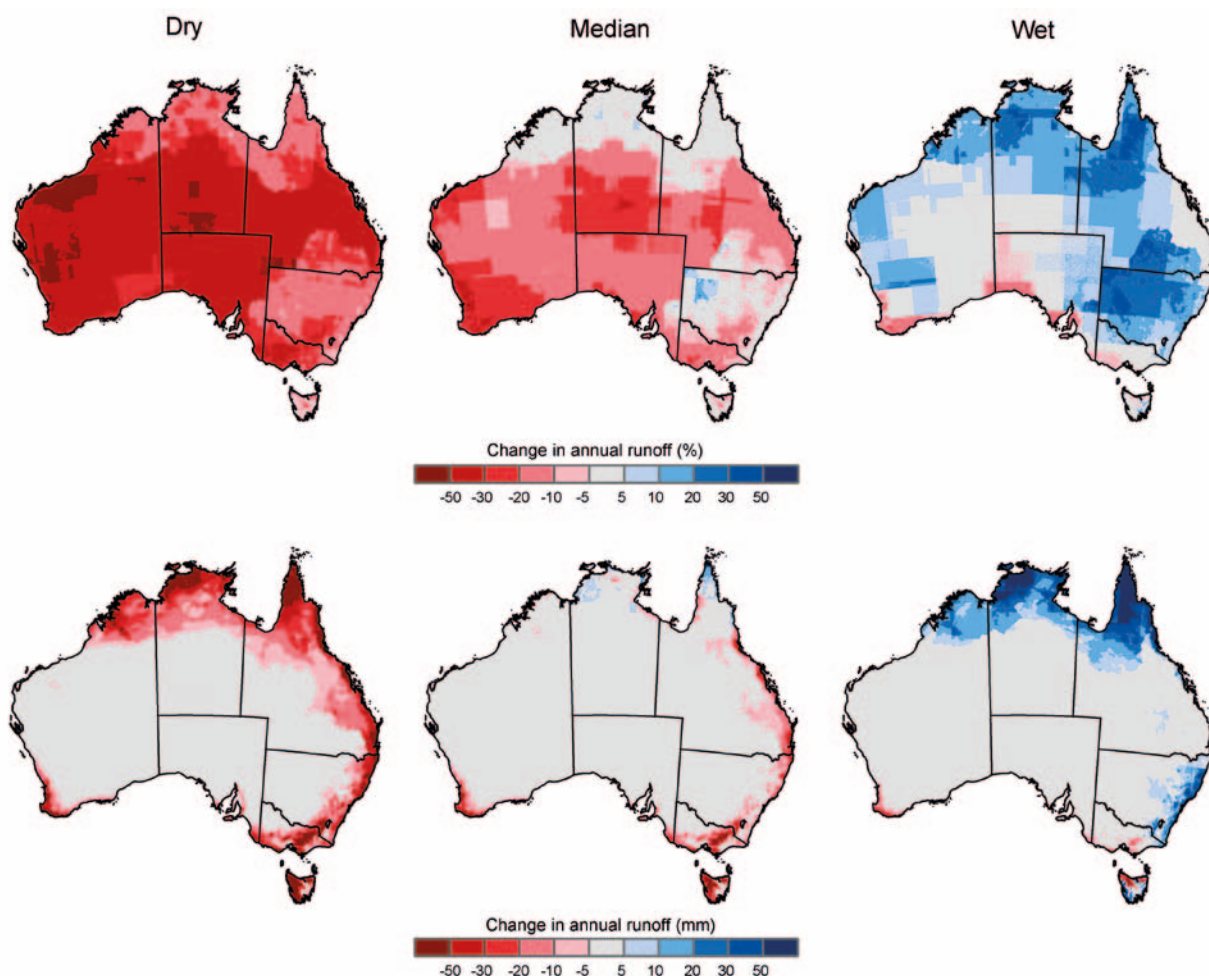
Dynamic downscaling models are fine-scale climate models nested inside the coarse-scale global climate models. They are able to represent fine-scale topography, vegetation, and weather patterns to produce more detailed patterns of rainfall and other climate variables. Figure 3.9 shows a dynamic downscaling example used for hydrological modelling in the CSIRO Tasmania Sustainable Yields project.

Statistical downscaling models statistically relate regional patterns of rainfall and other climate variables to its large-scale drivers in the atmosphere or oceans. Statistical relationships are built between regional rainfall observations and the larger scale properties of the atmosphere. These are then used to predict future regional rainfall under the changed atmospheric conditions of human-induced climate change. Figure 3.6 is an example of statistical downscaling, showing how rainfall across south-west Australia is related to larger scale patterns of atmospheric circulation.

The results from climate downscaling are used to run hydrological models to predict future catchment runoff and river flows.^{29,30} Changes to the average annual runoff (and hence river flow) for a 1°C global warming (median warming by 2030 relative to 1990) across Australia have been modelled (Figure 3.10, Table 3.1). The considerable range in runoff projections is mainly because of uncertainty of future rainfall under a changed climate. In the far south-west and south-east, a large majority of the climate models project a drier future and this translates to runoff declines of 25% in the south-west and 10% in southern Murray–Darling Basin and Victoria for a 1°C global warming in the median projection. The hydrological models also simulate changes to other flow characteristics, such as the variability of reservoir inflows and floods and low flows. The low flows and loss of connectivity in the more frequent long dry periods in the future will affect aquatic ecosystems⁵ and may exacerbate water quality problems. Larger changes than those shown are predicted to occur beyond 2030 as climate change continues (Figure 3.11); for example, if there is 2°C or more of global warming, which now seems highly likely.^{20,21}



◀ **Figure 3.9:** An example of the need to downscale rainfall from global climate models. (a) The observed patterns of rainfall across Tasmania. (b) A global climate model prediction of rainfall that portrays only the coarsest patterns. (c) Rainfall downscaled from the global climate model using a regional climate model that represents the topography and other influences on regional rainfall, producing patterns similar to those observed across Tasmania.²⁸



▲ **Figure 3.10:** Change in average annual runoff for 1°C of global warming (~2030 relative to ~1990) across Australia. The top row shows percentage change in runoff and the bottom row shows change in runoff depth (mm). The median, dry and wet extremes of the range of climate projections are shown.^{28,29,31,32}

Table 3.1: Projected changes to average annual runoff for a 1°C global warming from Figure 3.10.

Region	Modelled changes in average annual runoff (%)		
	Dry extreme	Median projection	Wet extreme
North-east Australia	-15	-1	+20
North-west Australia	-18	0	+16
South West of Western Australia	-37	-25	-12
Tasmania	-6	-3	0
Northern Murray–Darling Basin	-15	-5	+12
Southern Murray–Darling Basin and Victoria	-20	-10	+1

Although climate change is likely to reduce average rainfall and runoff in southern Australia, the climate will still be experienced largely as floods and droughts. The interactions between climate change, floods, and droughts are illustrated in Figure 3.11 for the southern Murray–Darling Basin and Victoria. A useful indicator for the use of water resources is the 10-year average of runoff. Large dams are able to buffer water supplies against the year to year variations in runoff and provide reliable supplies. However, they are unable to maintain supplies if there is a long drought with low runoff, as was seen in the millennium drought. Similarly, ecosystems have evolved to cope with floods and droughts, but a decade of drought in addition to other pressures can place them under stress.

Figure 3.11 shows that the impact of climate change on runoff by 2030 is small relative to the year to year and decadal variability in runoff, where flood years can have 10 times the runoff of drought years. The climate in 2030 will still be one that produces floods and droughts, but with a lower average annual runoff: the droughts may be more intense and the floods less frequent. Projecting out to 2050 and 2070, more profound changes to average runoff are possible, with the prospect that the average runoff could be similar to that experienced in the decade of the millennium drought. Floods and droughts would still be superimposed on that, giving periods of very severe droughts in future. The experience of the millennium drought suggest that such a large reduction in average runoff and more severe droughts on top of that would have severe impacts on water use and on river ecosystems.

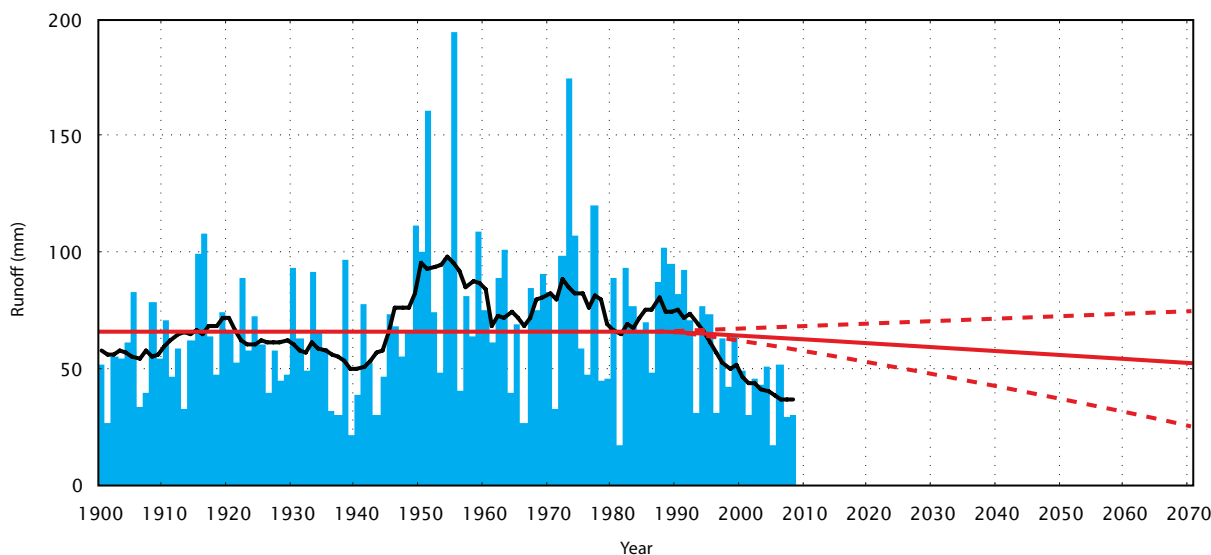
Water management and planning in a changing climate

As well as reducing runoff, a warmer climate could increase potential evaporation and hence increase the demand for water in irrigated agriculture, cities, and for use by wetlands and other water-dependent ecosystems. Evaporation though, like runoff, has a complex relationship with global warming and is influenced by other factors such as wind speeds and cloud cover. Thus climate change could not only reduce water availability in these regions but could further increase the gap between water supply and demand. Essentially, climate change intensifies the water scarcity challenge facing cities and rural catchments and intensifies the challenge of achieving environmentally sustainable levels of usage.

Water managers and policy makers in Australia are developing and updating plans to cope with a variable and changing water future. Most capital cities are investing in additional water supply infrastructure to meet the needs of growing populations. Some cities are moving away from their traditional reliance on catchment runoff and groundwater, because these sources are most sensitive to climate change and drought. Instead they are diversifying by investing in desalination plants and water reuse. Water demand per capita is reducing as a result of water use efficiencies, water-

sensitive urban design, and water conservation by communities (see Chapter 6). In rural areas, the increased use of water markets, improvements in irrigation efficiency (see Chapter 8), and return of water to degraded ecosystems (see Chapter 9) are all improvements in water management that will also make water management more adaptable to climate change and variability.

It should not be assumed that under conditions of climate change all users of water, including the environment, will bear the reductions in runoff equally. In the highly managed rivers of the Murray–Darling Basin, and city water supplies, flows in the river are largely determined by the operation of dams in accordance with water plans. These river operations and plans are designed to provide reliable supplies, buffering users against a drop in runoff during dry years and storing more water during wet years to compensate. The plans also tend to pass on impacts of reduced flows to regions downstream. They were not designed to deal with long-term reductions in runoff due to climate change. Under the plans, long-term reductions in runoff would be largely borne by the environment and downstream regions.³³ In the Murrumbidgee River system, the median climate projection for 2030 predicts a 9% reduction in runoff, which under the existing water sharing plan would reduce water supply to irrigation districts by only 2%, whereas outflows to the Murray River would reduce by 17% and water for the major wetlands would reduce by over 30%. New arrangements would be needed to share the impacts of climate change more evenly while still providing reliable supplies to water users.



▲ **Figure 3.11:** Annual runoff across the southern Murray–Darling Basin and Victoria (blue bars) and the moving average of the previous 10 years runoff (black line) showing large year to year and decade to decade variability in runoff. The long-term average runoff from 1895 to 2008 (red line), is projected forward using the median climate change projection for mean annual runoff (1990 to 2070). The two dashed lines are the dry and wet extremes of projected average runoff under climate change.³³ By 2030 the change in average annual runoff is small compared to the variability in runoff, but by 2070 the average runoff could be as low as that experienced in some of the worst historical droughts.



Dried-out lagoon on old station property at Big Bend, South Australia. Photo: Greg Rinder, CSIRO.

Advances in climate and hydrological sciences and modelling tools can be used to guide water management and planning in a changing climate. The predictions of future water availability are improving as more data become available and the science progresses, but the range of possible future runoff is likely to remain large. Water plans at present are almost exclusively based upon historical rainfall, runoff, and groundwater recharge measurements³⁴ because these data provide some confidence for assessing water resources and they encompass a range of historical conditions. However, the prospect of climate change and the experience of the millennium drought suggest that relying on history alone is insufficient. Formal risk management techniques can incorporate several future scenarios and the high uncertainties associated with them. These approaches can show how impacts from climate change would be shared among users and give certainty over how plans will be adapted to deal with new conditions if they emerge. Water planning can be made more effective by ongoing research to better understand climate, its relationship to water resources, and consequent impacts on water users and ecosystems.

Conclusions

Relatively small changes in rainfall are amplified to much larger changes in runoff and groundwater recharge, which make Australia's water resources the most variable in the world. Water management is highly adapted to this variability, but the millennium drought in south-east Australia and the sharp drop in runoff in the South West of Western Australia since 1975 have tested the effectiveness of these adaptations. New measures are being introduced such as urban water supplies that are less dependent on runoff and the return of water to the environment to make it more sustainable. Climate change is occurring on top of that variability and in southern Australia it is likely to further reduce water resources. For the moderate climate change predicted to occur by 2030, the adaptation to droughts and floods can be effective, because the worst consequences are likely to be more intense droughts and less frequent but more intense floods. For further climate change, projected to occur by 2050 or 2070, the conditions of the millennium drought might become the average future water availability, which would have profound consequences for the way water is used and for ecosystems. The understanding of how climate influences water can help make water management more adaptable, such as through improved seasonal forecasts, and it can help communities plan how they will respond to reduced water availability in future.

Further reading

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