2. National overview

2.1 Introduction

This chapter of the Australian Water Resources Assessment 2010 presents an assessment of climatic conditions and water flows and stores in the Australian landscape in 2009–10 at the national scale and discusses their variation between the regions (see Figure 2-1). The assessment contains national landscape water balance model outputs for the year including: rainfall, evapotranspiration, landscape water yield, change in soil moisture and consideration of changes in surface water storage in each region.

The important drivers of climatic conditions in Australia are examined and their impact on rainfall over the year evaluated. Information on nationally significant weather and water events experienced in 2009–10 focuses on abnormally heavy rainfall and flood events.

2.1.1 Australian landscape water balance modelling

Long-term average annual rainfall across Australia varies from less than 300 mm per year in the majority of central Australia to over 4,000 mm per year in parts of far northern Queensland.

Of this rainfall, about 85–95 per cent evaporates directly or is transpired by plants into the atmosphere. These two processes are collectively referred to as evapotranspiration. The remaining water finds its way into streams and other surface water features like dams and wetlands, or drains below the root zone into groundwater aquifers, which may subsequently discharge to surface water features.

The proportion of rainfall used by plants depends on soil type and depth, plant type and condition and the stage of plant growth. Annual crops and pasture use less water than perennial vegetation, such as trees, primarily because of their shorter growing seasons and shallower root systems.

The processes mentioned above are conceptually represented in the landscape water balance models that were used in this report (see Chapter 1 for a description of the AWRA-L and WaterDyn models). A conceptual representation means that simplifications and assumptions were used so that the models only estimate the dominant water balance components.

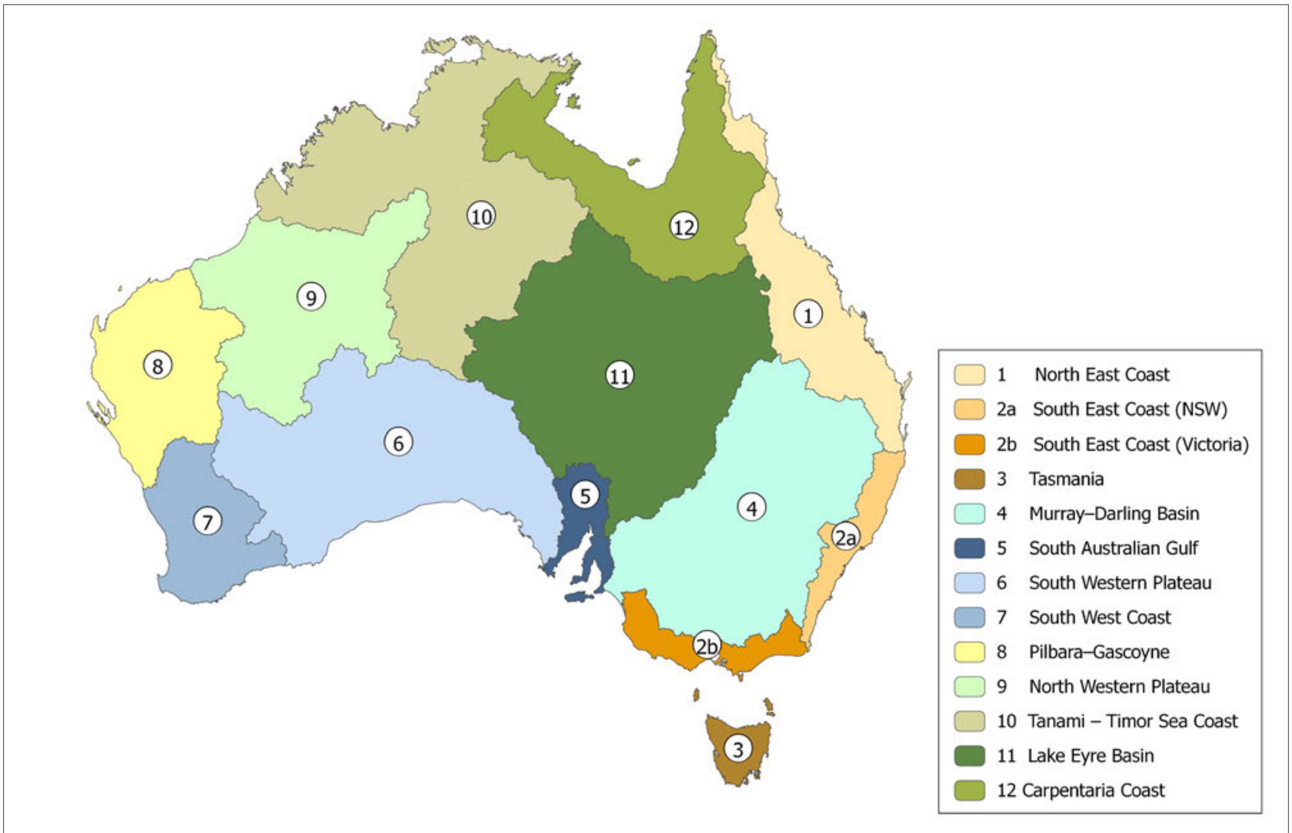


Figure 2-1. 2010 Assessment reporting regions

2.2 Key findings

The Australian climatic condition in 2009–10 was characterised by an El Niño event in the Pacific Ocean, which broke down in early 2010 and was followed by a rapid switch to La Niña conditions[1]. The development of this significant La Niña event heralded the beginning of at least 12 months of very much above average rainfall in most parts of Australia. For more information see: www.bom.gov.au/climate/annual_sum/annsum.shtml.

It was relatively wet in the centre and north of the country from December 2009 onwards, resulting in above average evapotranspiration and landscape water yield for the year. Soil moisture stores increased for all of the North East Coast, Carpentaria Coast, Tanami – Timor Sea Coast, Lake Eyre Basin, Murray–Darling Basin and South Australian Gulf regions. However, total surface water storage in the Carpentaria Coast and Tanami – Timor Sea Coast regions decreased, which was largely due to significant releases in the few major storages in these regions.

In contrast to the centre and north of the country, 2009–10 was relatively dry in the west, particularly in the Pilbara–Gascoyne and South West Coast regions, where rainfall, evapotranspiration and landscape water yield were below average. This was also reflected in a decrease in soil moisture for these regions as well as for the North and South Western Plateau regions. Despite this, the total accessible volume of water held in surface water storages in the South West Coast region increased as a result of water restrictions and a number of significant coastal rainfall and run-off events in July, September and November 2009.

Rainfall conditions were around average in the South East Coast (Victoria), South Western Plateau, Tasmania and North Western Plateau regions.

Key information regarding the climatic conditions and water outcomes for Australia over 2009–10 is provided in Table 2-1. Some highlights were:

- Australian rainfall in 2009–10 was 13 per cent above the long-term (July 1911 to June 2010) average; evapotranspiration was four per cent above the long-term average and landscape water yield was 40 per cent above the long-term average.
- Deep soil moisture stores increased in the northeast and southeast of the country, but decreased in the west.
- The total water stored in major reservoirs in Australia increased from 46 per cent to 52 per cent of accessible volume, driven primarily by increases in the Murray–Darling Basin, Tasmania and North East Coast regions.
- Urban water use in the urban centres considered in this report decreased from 1,719 GL in 2005–06 to 1,497 GL in 2009–10. Residential water consumption accounted for 68 per cent of urban use in 2009–10.
- Annual agricultural irrigation water use in Australia in 2009–10 was approximately 6,600 GL, up one per cent on 2008–09.
- Widespread heavy rainfall was experienced in the Northern Territory and Queensland between 22 February and 3 March 2010 and caused significant flooding in the Lake Eyre Basin region, in the south of the North East Coast region and in the far north of the Murray–Darling Basin region.

1. See Box 2-1 for explanations of El Niño and La Niña

Table 2-1. Key information on the water flows, stores, use and climatic condition in Australia for 2009–10[2]

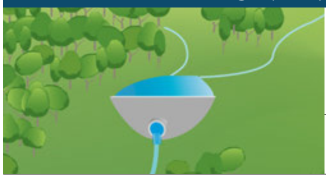
Landscape water balance in 2009–10

	Australian average	Difference from long-term mean	Rank (out of 99)*
Rainfall	536 mm	+13%	80
Evapotranspiration	415 mm	+4%	71
Landscape water yield	96 mm	+40%	86

Soil moisture in 2009–10

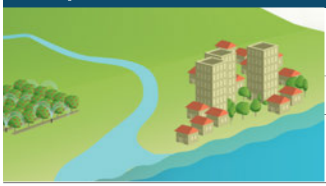
Regions that became drier	Regions that became wetter
North Western Plateau, Pilbara–Gascoyne, South West Coast, South Western Plateau, South East Coast (NSW) and Tasmania	Carpentaria Coast, Lake Eyre Basin, Murray–Darling Basin, North East Coast, South Australian Gulf, South East Coast (Victoria) and Tanami – Timor Sea Coast

Surface water storage (comprising approximately 94% of Australia's total surface water storage)



Total accessible capacity	July 2009		June 2010		% Change
	Accessible volume	% of accessible capacity	Accessible volume	% of accessible capacity	
78,500 GL	36,000 GL	46%	40,500 GL	52%	+6%

Comparison of water use between 2008–09 and 2009–10



Urban water use		Agricultural irrigation water use (natural resource management regions)	
Volume	Change	Volume	Change
1,568 GL in 2008–09 1,497 GL in 2009–10	-4.5%	6,530 GL in 2008–09 6,600 GL in 2009–10	+1%

Drivers of climatic condition in 2009–10

El Niño-Southern Oscillation	Central and eastern equatorial Pacific Ocean was warm (El Niño conditions) until February 2010 then cooled to La Niña conditions by April 2010. As a result the Southern Oscillation Index was negative until March 2010 then strongly positive
Indian Ocean Dipole	Positive during 2009 and negative during 2010

Major rainfall events in 2009–10

Timing	Location	Characteristics
22 February – 3 March 2010	Northern Territory, Queensland and far northern New South Wales	Monsoon low triggered very widespread heavy rainfall: 28 February – wettest day on record for the Northern Territory, 2 March – wettest day on record for Queensland

Major flood events in 2009–10

Timing	Location	Characteristics
February– March 2010	Gulf of Carpentaria, Lake Eyre Basin, North East Coast, Murray–Darling Basin	Short but large flood peaks in the major tributaries of the Darling River, with an estimate of only 15% reaching Menindee Lakes in western New South Wales

*A rank of 1 indicates the lowest annual result on record, 99 the highest on record

2. See Section 1.4.3 of Chapter 1–Introduction for the definition of these terms.

2.2 Key findings (continued)

Table 2-2 gives an overview of the region totals and rankings for the three water balance components (rainfall, evapotranspiration and landscape water yield) in comparison to the 99-year record. The values on the left side of the table show how the regions relate to each other in absolute terms for the year 2009–10. Values to the right show how 2009–10 compares to the historical model data for the 99 years of record.

High landscape water yield was associated with high rainfall in all but two regions. In the North Western Plateau region the rainfall was ranked close to median and evapotranspiration was higher than median, but still enough water was available for the generation of relatively high landscape water yield. The South East Coast (Victoria) region shows the opposite, where rainfall was ranked higher than median and evapotranspiration was lower than median, but landscape water yield was low. These discrepancies are explained by the intra-annual temporal and spatial variability of these flows and the soil moisture conditions at the start of the year (this is further discussed in the regional chapters).

Table 2-2. Region average rainfall, evapotranspiration and landscape water yield in 2009–10 by region (left), and 2009–10 ranking in the 1911–2010 record (right). The highest (blue) and lowest (red) values in each component (column) are highlighted

	Region average in 2009–10 (mm)			Rank (out of 99)*		
Region	Rainfall	Evapo-transpiration	Landscape water yield	Rainfall	Evapo-transpiration	Landscape water yield
North East Coast	866	675	172	64	42	73
South East Coast (NSW)	913	**840**	140	39	55	53
South East Coast (Victoria)	773	603	59	69	33	**11**
Tasmania	**1,481**	631	**769**	69	53	74
Murray–Darling Basin	533	428	45	81	55	78
South Australian Gulf	367	291	24	85	78	66
South Western Plateau	220	222	**6**	48	55	29
South West Coast	346	373	24	11	**15**	20
Pilbara–Gascoyne	**132**	**195**	9	**5**	19	12
North Western Plateau	311	297	48	52	65	76
Tanami – Timor Sea Coast	775	602	157	82	76	85
Lake Eyre Basin	387	220	74	**92**	81	**96**
Carpentaria Coast	976	679	268	89	**82**	94

* Indicates the lowest annual result on record, 99 the highest on record

2.3 Landscape water flows in 2009–10

2.3.1 Rainfall

Australian rainfall was 13 per cent above average in 2009–10

Average Australian rainfall for 2009–10 was estimated to be 536 mm, which is 13 per cent above the estimated national long-term average of 473 mm (calculated from July 1911 to June 2010). The year was wetter than average throughout much of the country, with the Lake Eyre Basin and Carpentaria Coast regions receiving well above average rainfall (Figure 2-2). In contrast, conditions were relatively dry in parts of the southern South East Coast (NSW) and northeast Murray–Darling Basin regions. In Western Australia, the South West Coast and Pilbara–Gascoyne regions received well below average annual rainfall.

The 2009–10 year began with hot and dry conditions prevailing between July and October 2009, particularly in the east of the country (Figure 2-3 and Figure 2-4) with August being Australia's warmest on record. Very much below average rainfall totals were experienced over large areas of the North East Coast, Murray–Darling Basin and South East Coast (NSW) regions, consistent with the El Niño event which was in place during this time (see Section 2.9 for a description of the drivers of the climatic condition).

In contrast, the 2009 winter had very much above average rainfall in Tasmania, ranking as the fourth-wettest on record (46 per cent above average). Winter rainfall in 2009 equalled or exceeded seasonal averages over areas of the South Australia Gulf region and much of the western half of the South East Coast (Victoria) region.

The summer of 2009–10 was relatively wet for most of Australia, particularly in the east. In the north, relatively dry conditions over winter and spring in 2009 gave way to a wetter than average summer and autumn 2010 (Figure 2-3 and Figure 2-4). Conversely, the average rainfall conditions that prevailed across much of Western Australia during the second half of 2009 gave way to dry conditions at the start of 2010, particularly across the South West Coast and Pilbara–Gascoyne regions.

Widespread dry conditions in Western Australia in the first half of 2010 were associated with very much below average rainfall in much of northern Western Australia. This was combined with persistent and abnormally high pressure over southern Western Australia. Autumn 2010 was characterised by an unusual absence of westerly winds and a very low number of cold fronts passing over southern Western Australia. This deprived the region of its main rain producing mechanism. The extremely dry conditions continued and exacerbated a sequence of abnormally low rainfall that the southwest of Western Australia has experienced since the mid-1970s. Serious or severe water deficiencies became established over much of the South West Coast and Pilbara–Gascoyne regions by the end of 2009–10.

Autumn 2010 was generally warm and wetter than average in Australia. The most significant rainfall was in early March (see Section 2.10 on notable rain events) causing widespread flooding in inland southern Queensland and northern New South Wales (see Section 2.11 on major flood events). Rainfall continued through the season in many areas, giving parts of south-eastern Australia the first above average autumn rainfall since 2000 and first above average July to June rainfall in the Murray–Darling Basin since 2001. Very high rainfall totals occurred in April and May 2010 across the Carpentaria Coast and Tanami – Timor Sea Coast regions; typically the start of the dry season for these areas. June 2010 was subsequently relatively dry over most parts of the continent.

Current and historical daily, monthly, seasonal and annual rainfall maps and data are available at: www.bom.gov.au/jsp/awap

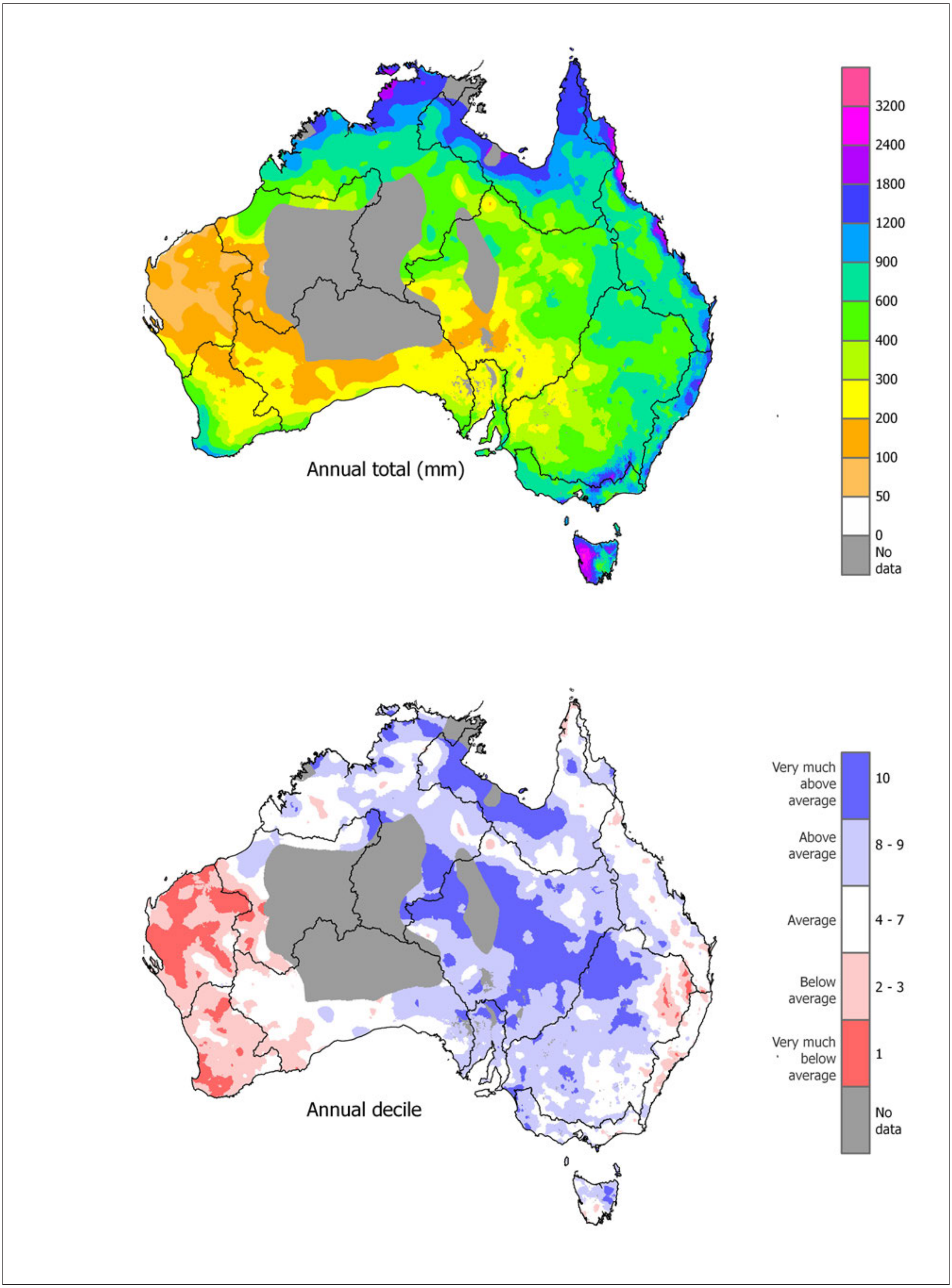


Figure 2-2. Annual total rainfall in 2009–10 (top) and its decile range with respect to the 1911–2010 record (bottom)

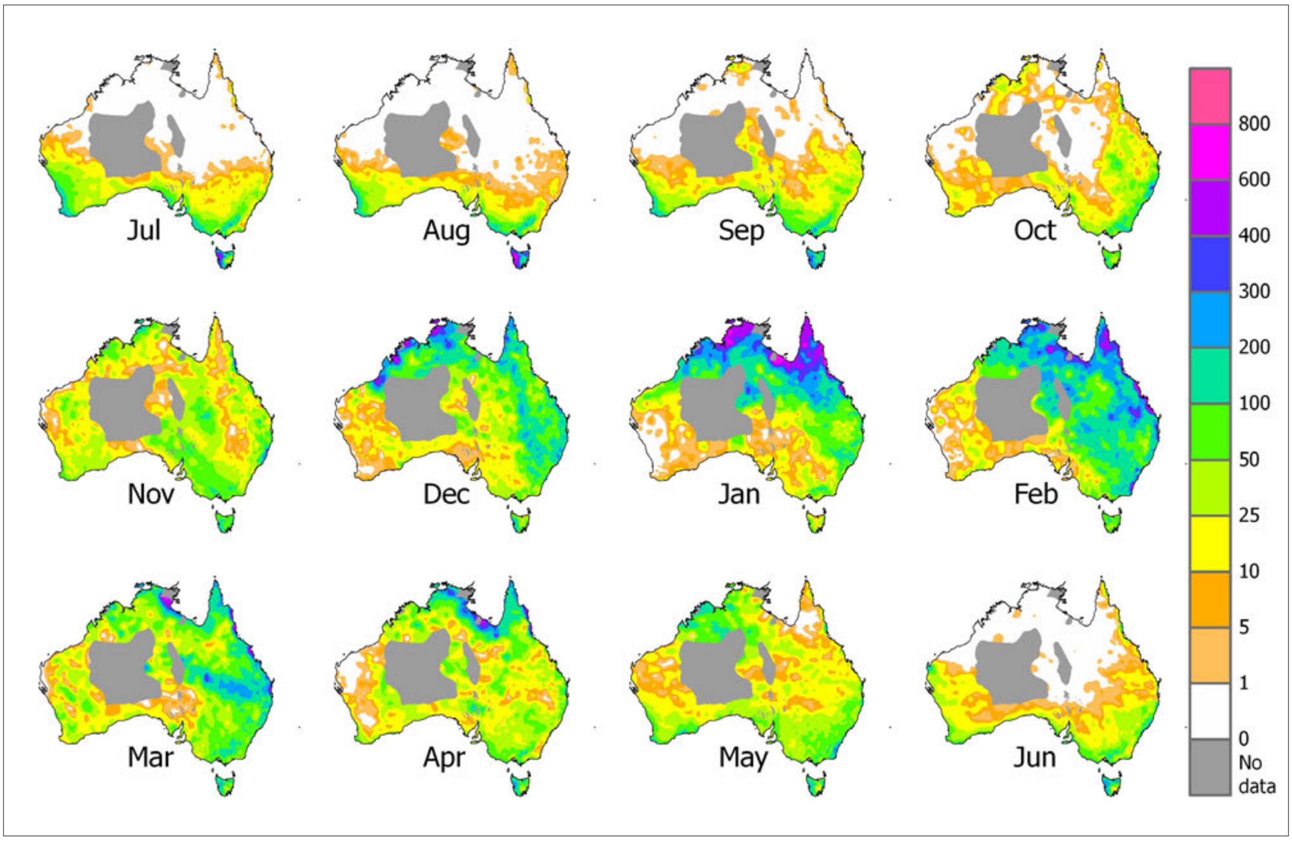


Figure 2-3. Monthly rainfall totals (mm) for 2009–10

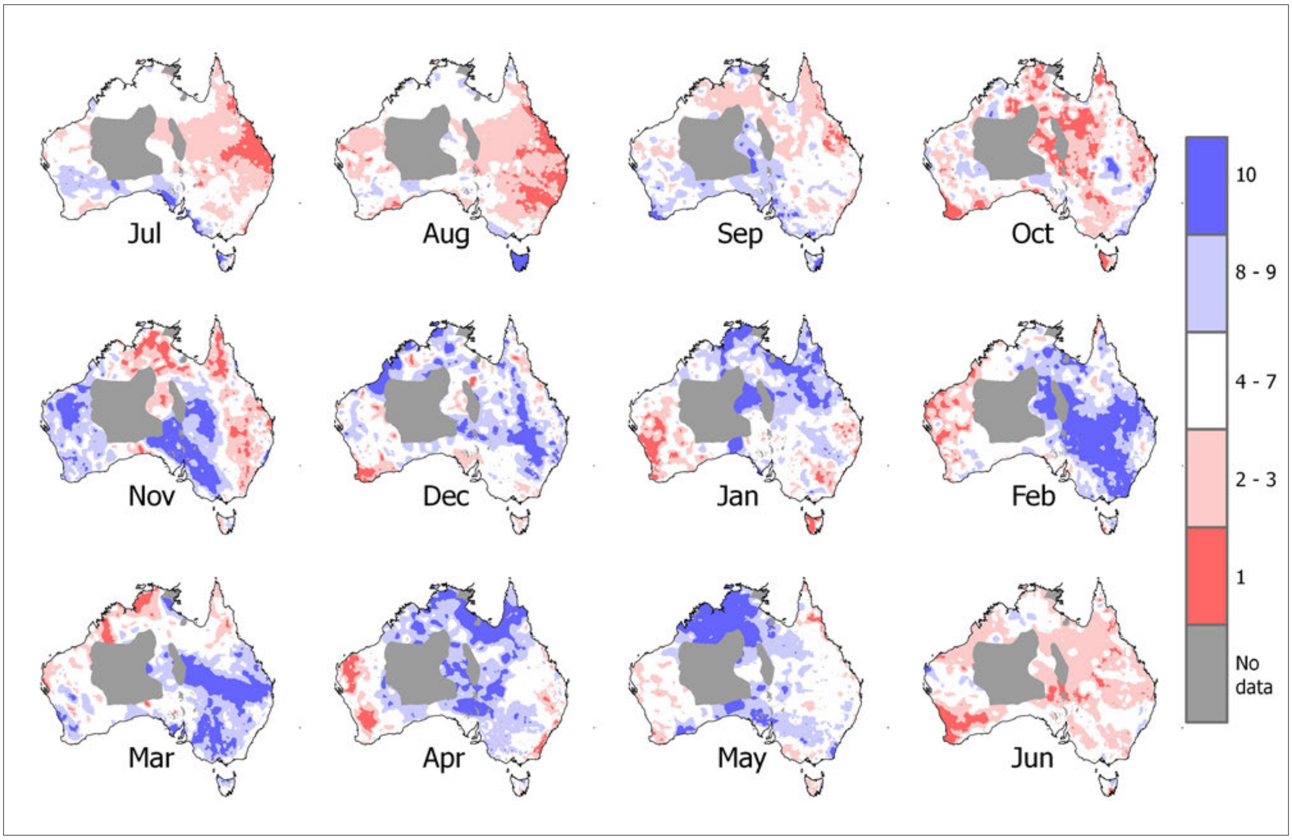


Figure 2-4. Monthly rainfall deciles for 2009–10 with respect to the 1911–2010 record

2.3.2 Evapotranspiration

Australian evapotranspiration was 4 per cent above average in 2009–10

Average Australian evapotranspiration for 2009–10 was estimated to be 415 mm, which is four per cent above the estimated national long-term (July 1911 to June 2010) average of 400 mm. Evapotranspiration for the year was generally higher than average across most inland areas, particularly in the Lake Eyre Basin region, as a result of above average rainfall. Below average levels of evapotranspiration occurred in the west and southwest of Western Australia (South West Coast and Pilbara–Gascoyne regions) and also across areas of the North East Coast, Murray–Darling Basin, South East Coast (Victoria) and Tasmania regions (Figure 2-5).

The above average Australian evapotranspiration for 2009–10 was due in particular to higher than average evapotranspiration in central Australia. Evapotranspiration across central Australia was well above average in both the Carpentaria Coast and Lake Eyre Basin regions. This was largely a consequence of heavy rainfall across northern and central Australia in the first four months of 2010, flooding large areas and filling lakes and wetlands (see Section 2.11).

Water flow from the land surface to the atmosphere via evapotranspiration can be limited by either available soil moisture or incident solar energy. In Australia evapotranspiration is mostly limited by available soil moisture therefore spatial patterns of evapotranspiration, both annual and seasonal, are generally closely related to patterns of rainfall (see Figure 2-3 and Figure 2-4). The most notable exceptions to this occur in winter in the south of the country, particularly in Tasmania, where evapotranspiration can often be energy limited.

Generally low rainfall across the south of the country during winter 2009 resulted in low evapotranspiration rates in these regions (Figure 2.6 and Figure 2.7). October 2009 saw above average evapotranspiration across much of Tasmania, western South East Coast (Victoria) and the South Australian Gulf following above average rainfall in these regions during the preceding months of August and September. Low rainfall over much of Queensland and New South Wales in winter and spring 2009 resulted in decreased evapotranspiration throughout spring, particularly in the south of the North East Coast region and the northeast of the Murray–Darling Basin.

Above average rainfall over the 2009–10 summer resulted in average or above average levels of evapotranspiration over much of the country except in Western Australia where levels were low in line with low rainfall conditions. Evapotranspiration in the north, east and centre of the country, especially across the Lake Eyre Basin and Murray–Darling Basin regions, reached very high levels during autumn and early winter as high rainfall continued. In the Western Australian regions of the Pilbara–Gascoyne and South West Coast, evapotranspiration levels remained relatively low over this period and were constrained to very much below average levels by June 2010. Below average early winter rainfall in the Tasmania and South East Coast (Victoria) regions also constrained evapotranspiration to below average levels towards the end of 2009–10.

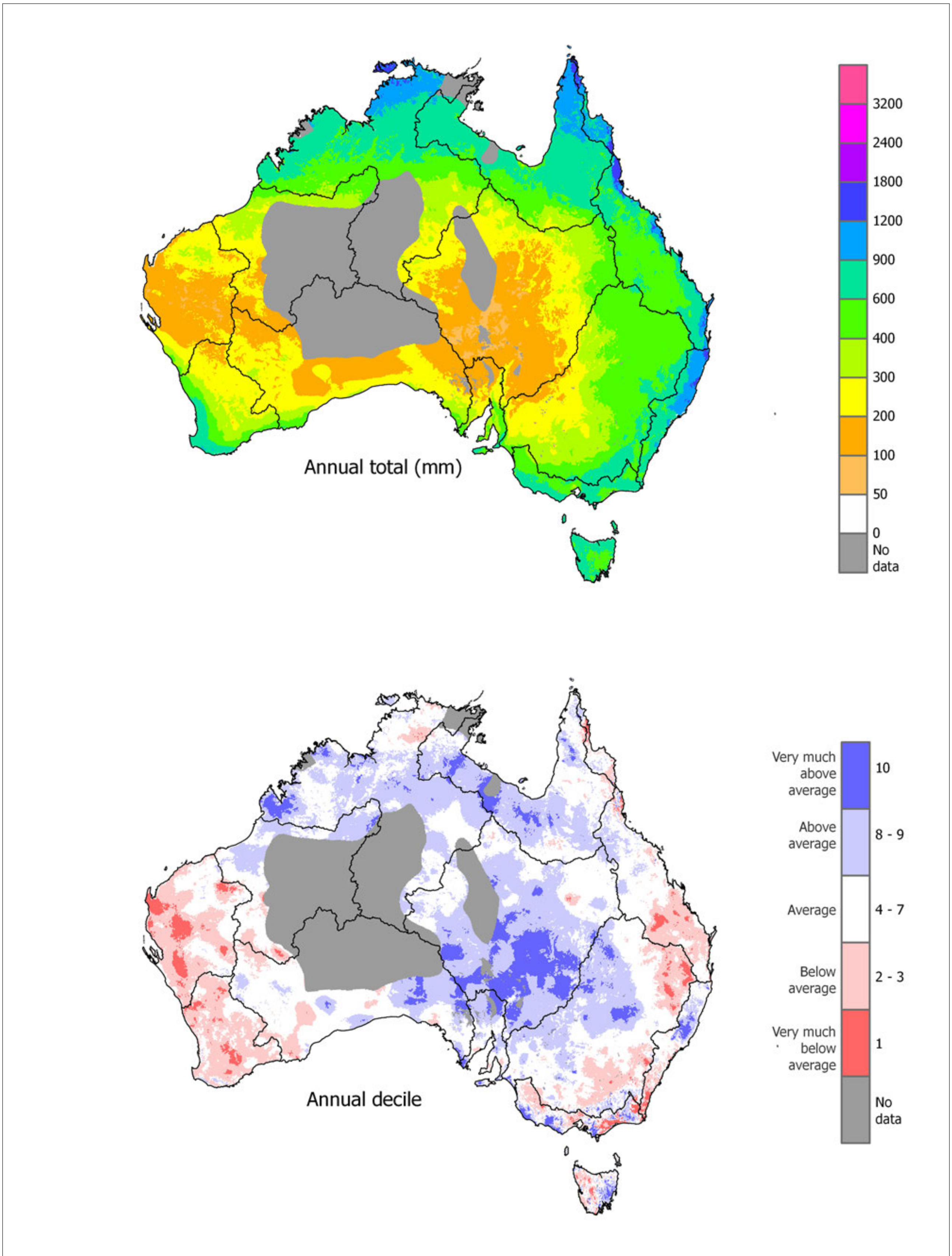


Figure 2-5. Modelled annual total evapotranspiration in 2009–10 (top) and its decile range with respect to the 1911–2010 record (bottom)

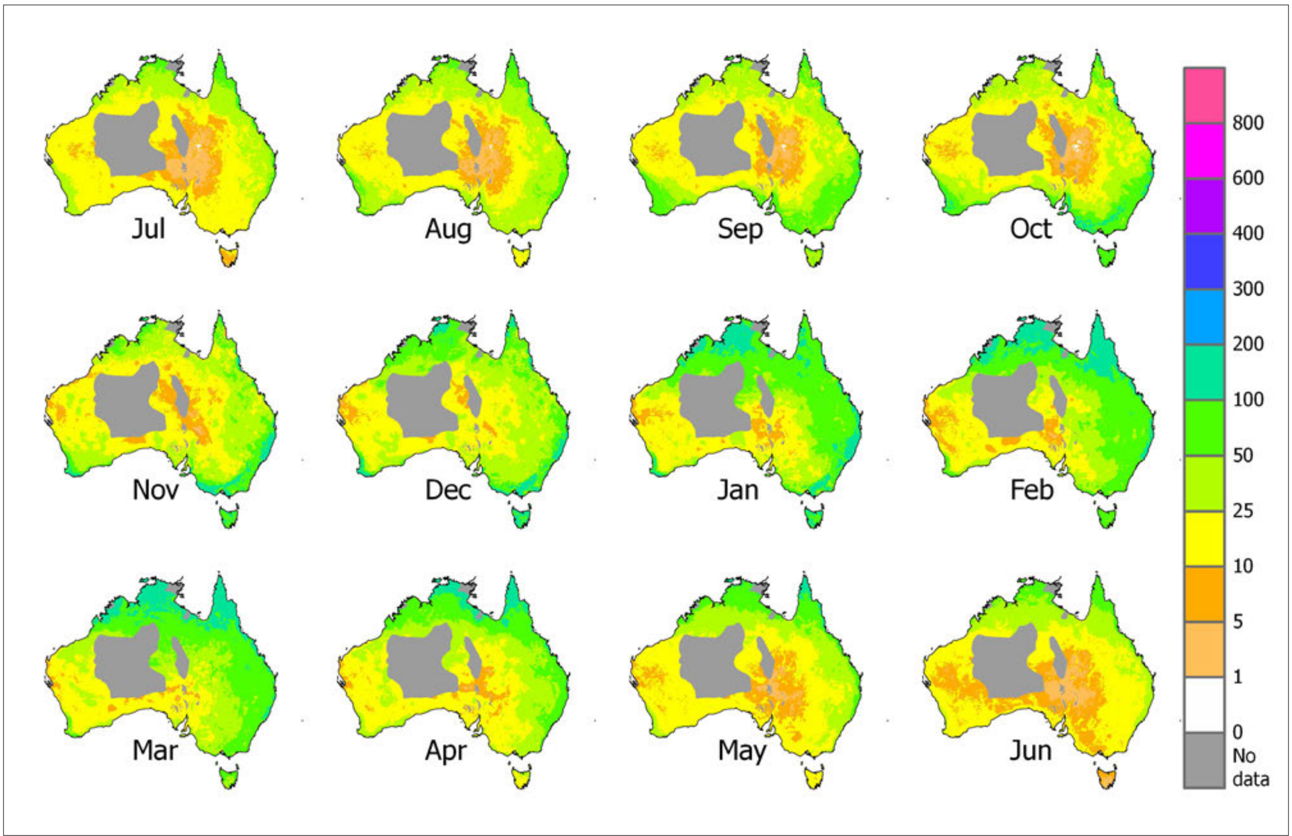


Figure 2-6. Modelled monthly evapotranspiration totals (mm) for 2009–10

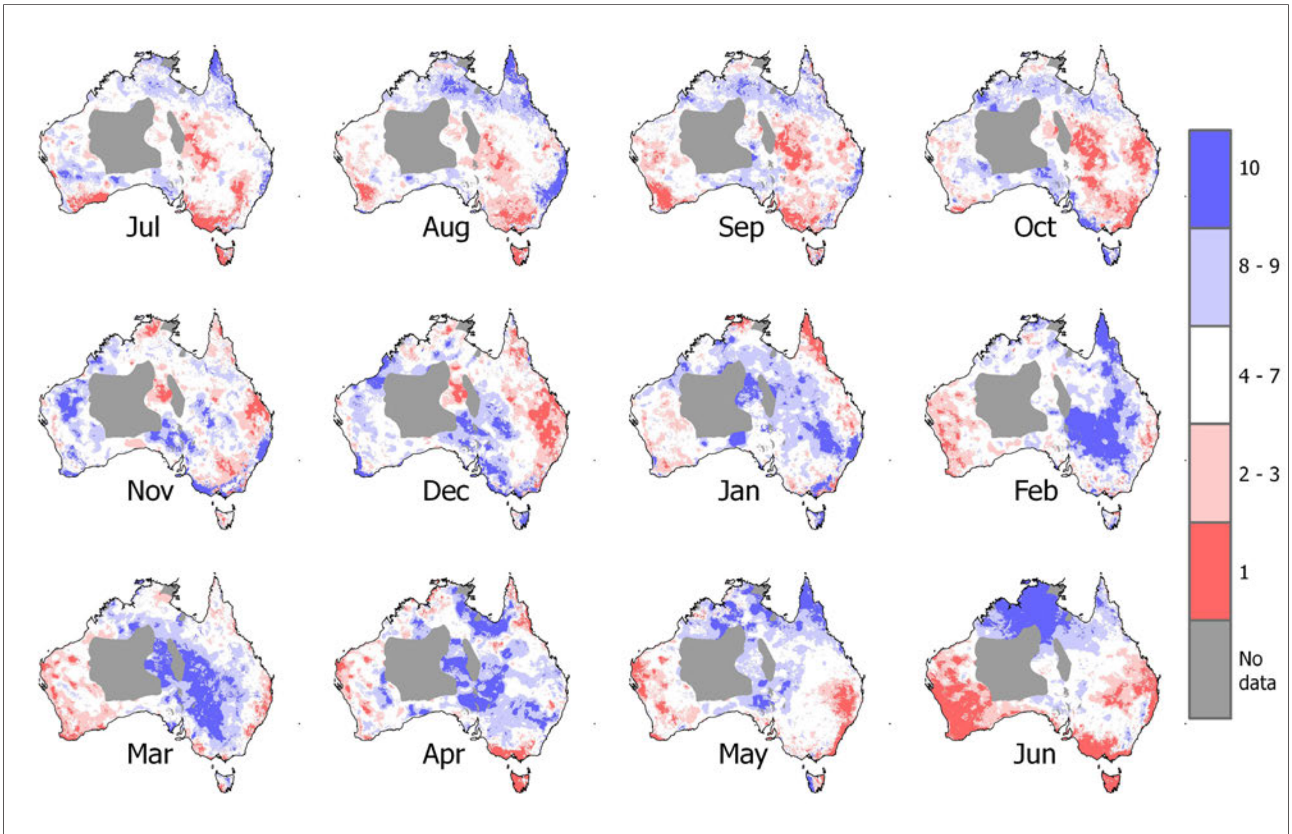


Figure 2-7. Modelled monthly evapotranspiration decile ranges for 2009–10 with respect to the 1911–2010 record

2.3.3 Landscape water yield

Australian landscape water yield was 40 per cent above average in 2009–10

Average Australian landscape water yield for 2009–10 was estimated to be 96 mm, which is 40 per cent above the estimated national long-term (July 1911 to June 2010) average of 68 mm. Landscape water yield for the year was above average in most parts of the country including the majority of the Murray–Darling Basin (Figure 2-8). Below average levels of landscape water yield occurred across much of the South West Coast, Pilbara–Gascoyne and South East Coast (Victoria) regions and also for southern areas of the South East Coast (NSW).

Landscape water yield in the context discussed here relates to flow entering river systems and aquifers from surface run-off and leaching from the sub-surface soil layer. Landscape water yield represents annual rainfall minus evapotranspiration plus, or minus, any change in soil moisture storage over 2009–10. As a result, landscape water yield patterns tend to follow those of rainfall (see Figure 2-2), albeit moderated by evapotranspiration, and may be affected by initial soil moisture levels.

Despite a generally drier than average start to the 2009–10 year, significant rainfall in the north of the country during the summer months contributed to above average run-off and drainage to rivers and aquifers across northern Australia (Figure 2-9 and Figure 2-10). Lake Eyre Basin and the Carpentaria Coast experienced very much above average landscape water yield totals for the 2009–10 year.

Given the rainfall received, landscape water yield was relatively low in the South Australian Gulf, South East Coast (Victoria) and Murray–Darling Basin regions. The initial dryness of these areas (see Section 2.4), resulting from preceding dry years contributed to lower landscape water yield for the year than would otherwise be expected, as water was retained in the landscape as increased soil moisture storage (see Table 2-3).

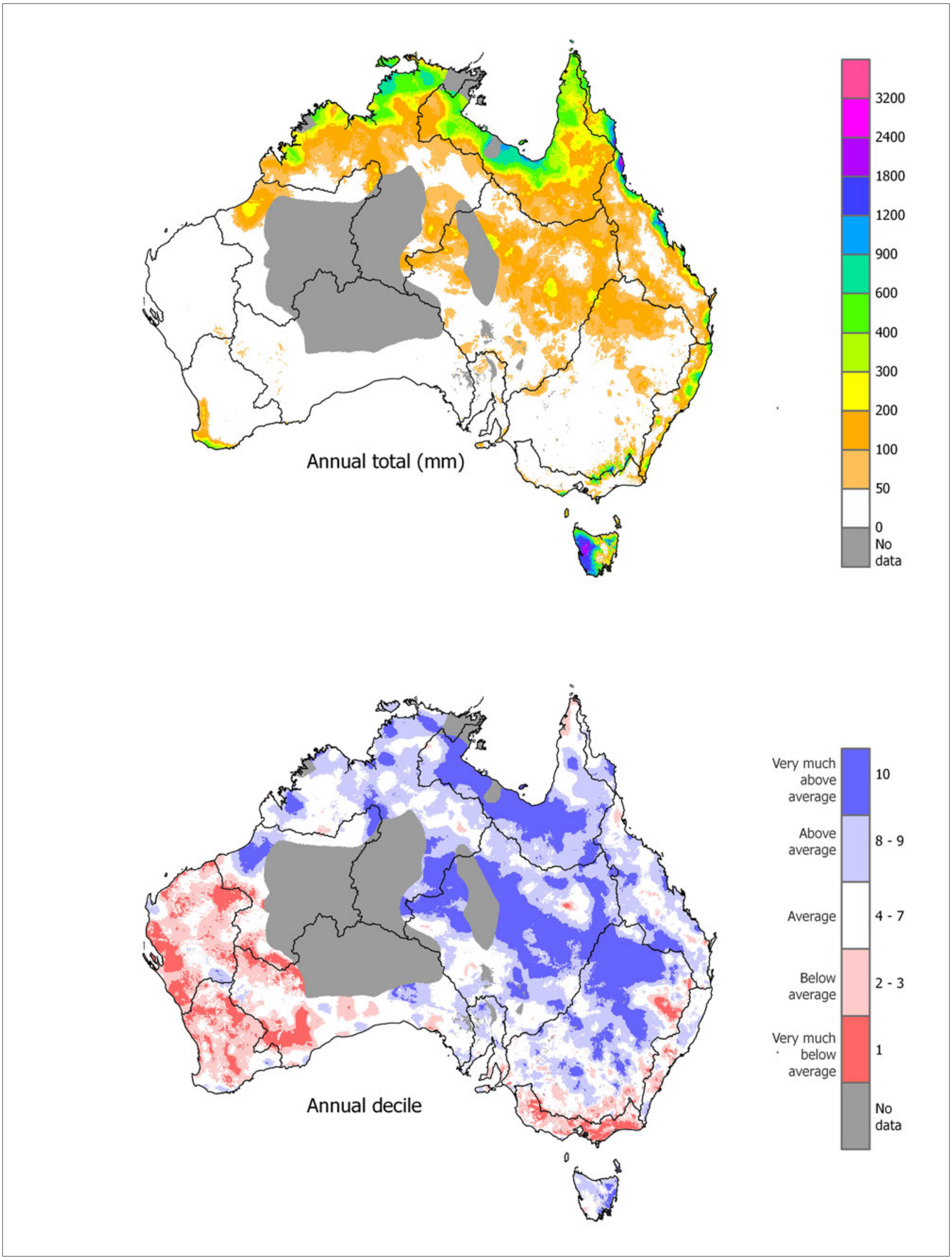


Figure 2-8. Modelled annual total landscape water yield in 2009–10 (top) and its decile range with respect to the 1911–2010 record (bottom)

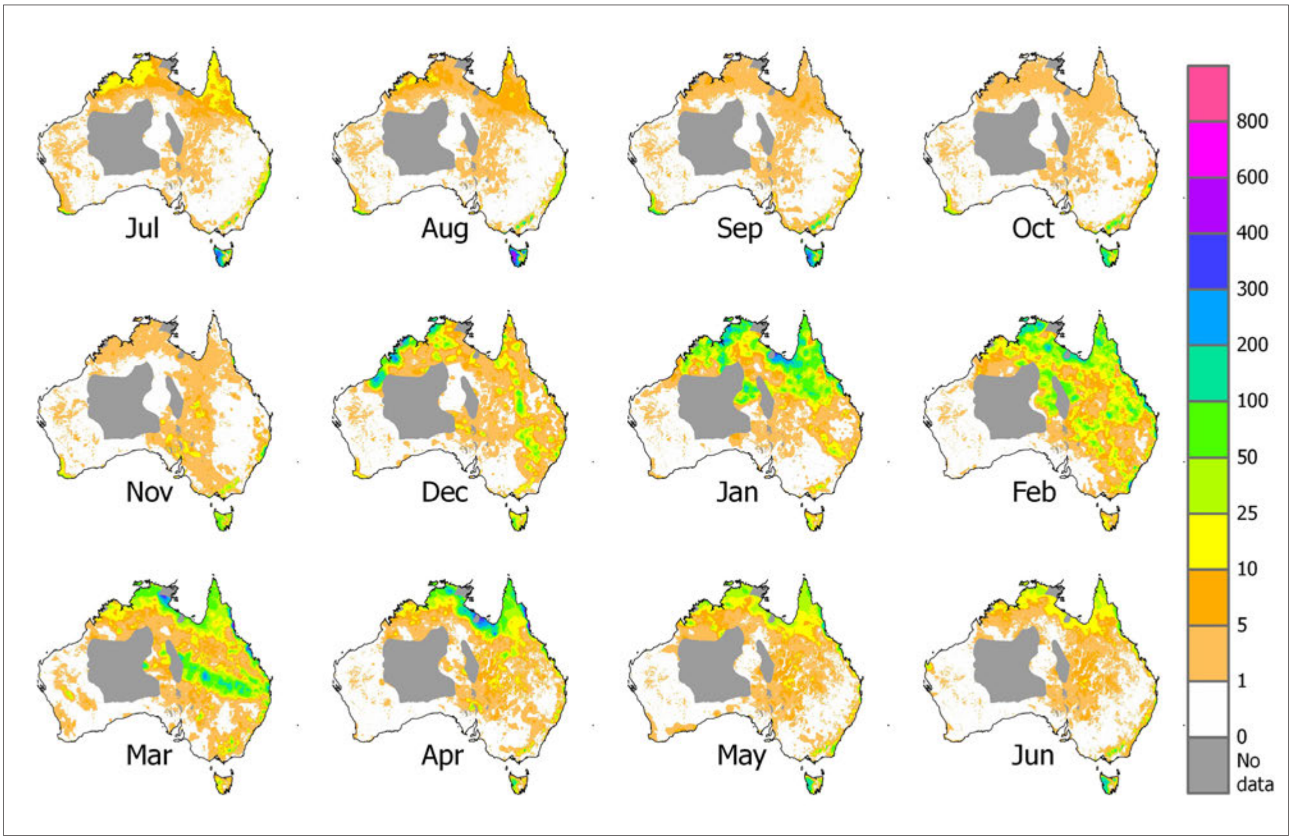


Figure 2-9. Modelled monthly landscape water yield totals (mm) for 2009–10

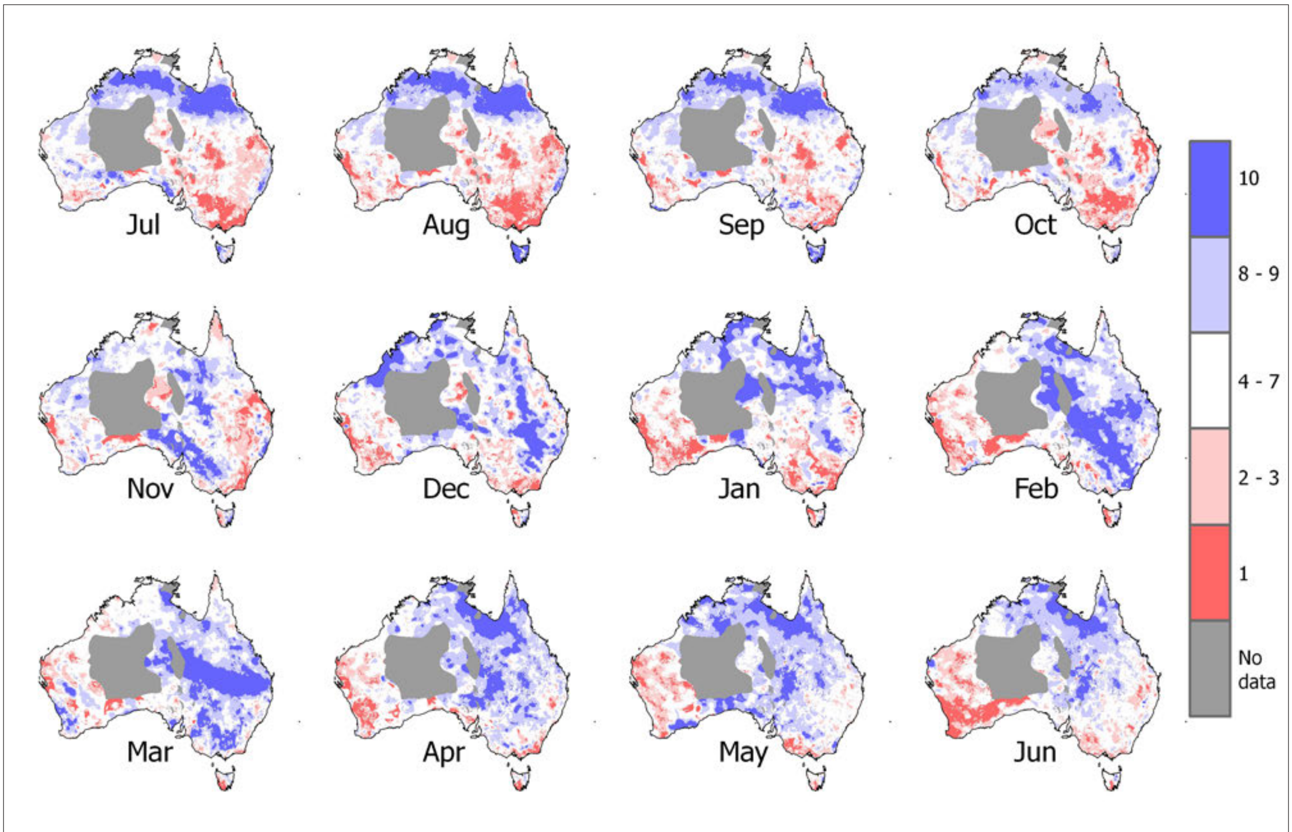


Figure 2-10. Modelled monthly landscape water yield deciles for 2009–10 with respect to the 1911–2010 record

2.4 Soil moisture store in 2009–10

Deep soil moisture stores increased in the north, centre and south of the country over 2009–10 but decreased over most of Western Australia and along the New South Wales coast

Deep soil moisture stores are estimated to have generally increased across the country in 2009–10 indicating more favourable conditions for drainage of soil moisture below the root zone and potentially groundwater recharge.

The most notable increases were in the Carpentaria Coast, North East Coast, Lake Eyre Basin and Murray–Darling Basin regions. The South Australian Gulf, South East Coast (Victoria) and Tanami – Timor Sea Coast regions also experienced increases in deep soil moisture storage (Table 2-3). The values shown in Table 2-3 provide a measure of deep soil moisture storage, ranging from completely dry (zero per cent) to saturated (100 per cent).

The Murray–Darling Basin region was relatively dry at the start of 2009–10, particularly in the south (Figure 2-11). Above average rainfall conditions resulted in deep soil moisture content increasing from 33–43 per cent over 2009–10 (Table 2-3). Deep soil moisture conditions were estimated to be average to very much above average over much of the centre and north of the Murray–Darling Basin region by the end of the year. In the far south of the region, including the major run-off generating areas in the New South Wales and Victorian Alps, soil moisture conditions had improved from very much below average to around average by the end of 2009–10 (Figure 2-11).

Table 2-3. Change in the modelled deep soil moisture store over 2009–10 by region

Region	Soil moisture storage		Change in deep soil moisture*
	July 2009	June 2010	
North East Coast	47%	58%	+11%
South East Coast (NSW)	73%	62%	–11%
South East Coast (Victoria)	38%	46%	+8%
Tasmania	91%	85%	–6%
Murray–Darling Basin	33%	43%	+10%
South Australian Gulf	45%	50%	+5%
South Western Plateau	33%	29%	–4%
South West Coast	38%	25%	–13%
Pilbara–Gascoyne	47%	34%	–13%
North Western Plateau	50%	43%	–7%
Tanami – Timor Sea Coast	51%	59%	+8%
Lake Eyre Basin	53%	66%	+13%
Carpentaria Coast	61%	75%	+14%

*As a percent of total deep soil water holding capacity

2.4 Soil moisture store in 2009–10 (continued)

There were also increases in soil moisture content over the course of the year in the Carpentaria Coast and North East Coast regions (Table 2-3). In the North East Coast region, some of the biggest increases in deep soil moisture were in the Fitzroy River basin which experienced major flooding in February and March 2010 (see Section 2.11). Deep soil moisture was very much above average over significant areas of the Carpentaria Coast region by June 2010 following significant rainfall during the summer of 2009–10 and subsequent flooding in the Nicholson, Flinders and Mitchell river basins (Figure 2-11).

In contrast, the deep soil profile dried in most parts of Western Australia, particularly in the South West Coast and Pilbara–Gascoyne regions. In the South West Coast region, deep soil moisture was average or below average for most of the region at the beginning of 2009–10. These conditions deteriorated over the year such that by June 2010 deep soil moisture was below average or very much below average across most of the region.

In the east of the country, there was also significant drying of the deep soil profile estimated for central and northern parts of the South East Coast (NSW) region over 2009–10 (Figure 2-11). This drying was largely the result of average levels of rainfall combined with relatively high levels of evapotranspiration estimated in these areas.

Deep soil moisture in the South East Coast (Victoria) region increased over 2009–10 in response to above average rainfall, particularly in November 2009 and February, March and April 2010. The region was exceptionally dry at the beginning of 2009–10. Although deep soil moisture was estimated to have increased across the region over the year, soil moisture stores at the end of the year were still below average in many areas. This retention of rainfall within the deep soil store contributed to the below average landscape water yield for the region in 2009–10, despite the generally average or better rainfall conditions.

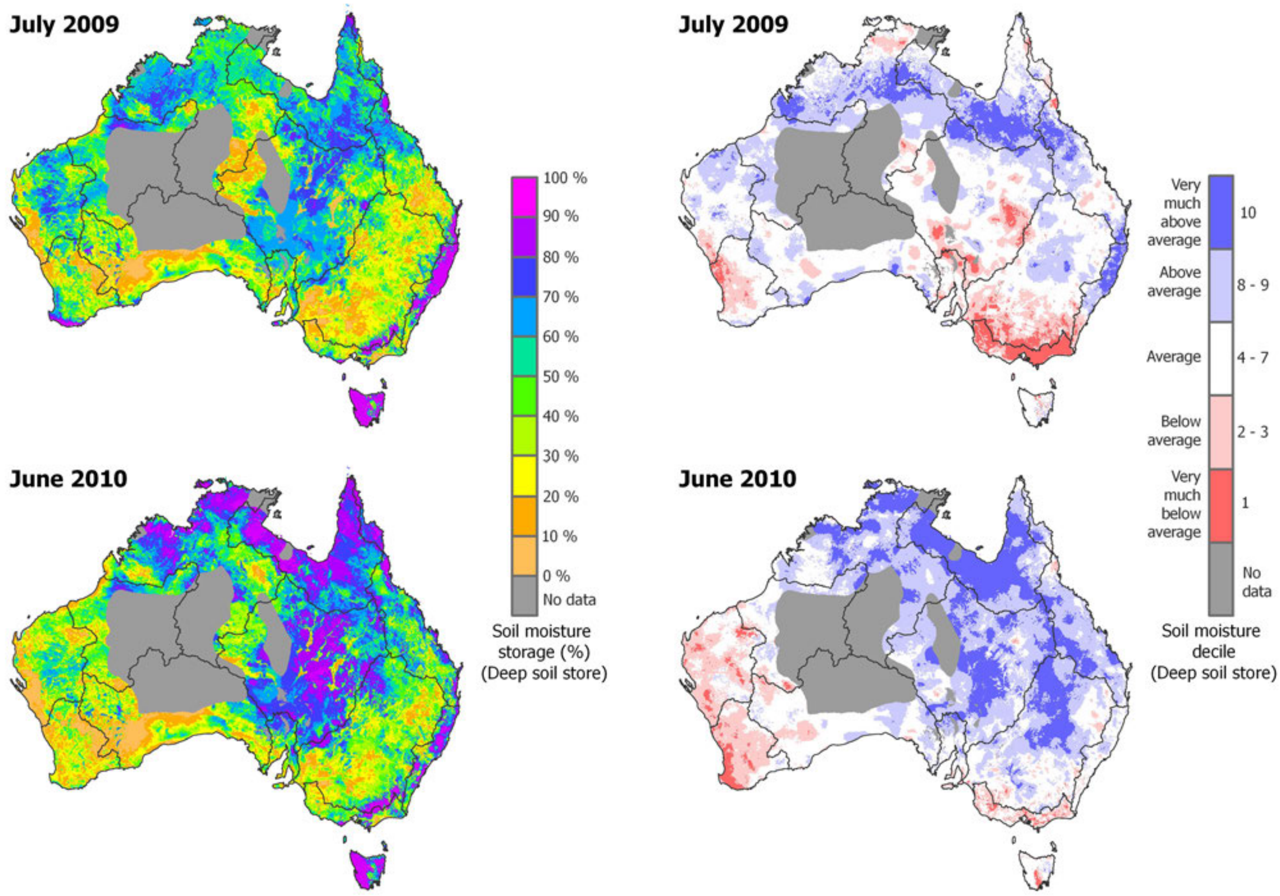


Figure 2-11. Modelled deep soil moisture index values for July 2009 and June 2010 (left) and their deciles with respect to the 1911–2010 record (right)

2.5 Surface water storage in 2009–10

Surface water storage in Australia increased from 46 per cent to 51.6 per cent of total accessible volume over 2009–10

The volume of water held in public water storages[3] listed in the Bureau's water storage database[4] on 1 July 2009 was 46 per cent of the total accessible volume of these storages. The total volume of water stored in major public water storages in Australia at the end of 2009–10 was at 51.6 per cent of their total accessible capacity which represented a 5.6 per cent increase compared with the previous year. Surface water storage in the South East Coast (NSW), Carpentaria Coast and Tanami – Timor Sea Coast regions decreased (Table 2-4). Regions absent from Table 2-4 have no significant surface water storages. As a percentage of total accessible volume, the biggest increase in storage was in the Murray–Darling Basin region (+12.4 per cent) and the biggest decrease was in the Tanami – Timor Sea Coast region (–17.1 per cent). These two regions also experienced the biggest volumetric increase of 3,143 GL and decrease of 1,827 GL in storage volume respectively.

Despite the increase in the volume of water in surface storages in the Murray–Darling Basin region, at 30 June 2010 the volume of water held was still only 32.5 per cent of total accessible volume (Table 2-4). The volume of water held in surface storages in the heavily populated South East Coast (Victoria) region had also not risen above 20 per cent of total accessible volume by 30 June 2010 (see Section 4.6 in Chapter 4 and Section 5.6 in Chapter 5 for more details).

While run-off for the year was below average in the South West Coast region, the volume of water in surface storage in this region increased from 35.3 per cent of accessible volume to 38.3 per cent of accessible volume. This was a result of a number of significant coastal rainfall and run-off events (in July, August, September and November 2009) and provision of other sources of water (such as groundwater) assisted by water restrictions in place in metropolitan areas. Conversely, despite above average run-off, the volume of water in surface storage in the Tanami – Timor Sea Coast region decreased from 97.3 per cent of accessible volume to 80.2 per cent of accessible volume. This was largely due to releases of water from Lake Argyle concurrent with average rainfall and run-off conditions in the Lake Argyle catchment.

Table 2-4. Change in surface water storage over 2009–10 by region

Region	Accessible volume in storage (GL)			Per cent of total accessible capacity		
	01 July 2009	30 June 2010	Difference	01 July 2009	30 June 2010	Difference
North East Coast	6,573	7,615	+1,042	77.1	89.4	+12.3
South East Coast (NSW)	2,402	2,237	-165	65.3	60.8	-4.5
South East Coast (Victoria)	891	1,288	+397	12.8	18.6	+5.8
Tasmania	10,209	11,969	+1,760	46.1	54.1	+8.0
Murray–Darling Basin	5,057	8,200	+3,143	20.1	32.5	+12.4
South Australian Gulf	107	109	+2	54.3	55.3	+1.0
South West Coast	339	367	+28	35.3	38.3	+3.0
Tanami – Timor Sea Coast	10,398	8,571	-1,827	97.3	80.2	-17.1
Carpentaria Coast	94	92	-2	94.9	92.9	-2.0

3. Refers to the accessible volume of water in the water storages.
4. Represents 94% of total accessible volume of public water storages in Australia (See http://water.bom.gov.au/waterstorage/awris/index.html).

2.6 Groundwater status

A truly national overview of groundwater status was not possible in this report due to the limited amount of quality-controlled data available in a suitable form. For example, the status of nationally-significant groundwater systems has not been assessed in Western Australia, Victoria, the Northern Territory, Tasmania and the Great Artesian Basin. Suitable groundwater data for these areas will be available in future.

The status of groundwater levels was evaluated in a number of aquifers in two regions where data were available. The data are presented in terms of linear trends for the period of 2005–10. The trends in groundwater levels in a subsystem are categorised for each 20-kilometre grid square (Murray–Darling Basin) or five-kilometre grid square (South Australian Gulf). The following categories are assigned when greater than or equal to 60 per cent of the bores in a grid square have a linear trend that is:

- lower than -0.1 m/year – decreasing
- between -0.1 m/year and 0.1 m/year – stable
- higher than 0.1 m/year – increasing
- has no dominant tendency – variable

As indicated above, the analysis was constrained by the limited amount of quality controlled data available in a suitable form. The available results are summarised in the tables below.

Table 2-5. Groundwater status for aquifers in the Murray–Darling Basin region

Groundwater subsystem	Change in groundwater levels
Condamine	decreasing or variable
Narrabri and Gunnedah	decreasing or variable
Cowra and Lachlan	decreasing
Shepparton	decreasing
Calivil	decreasing
Murray Group	decreasing or stable
Renmark	decreasing

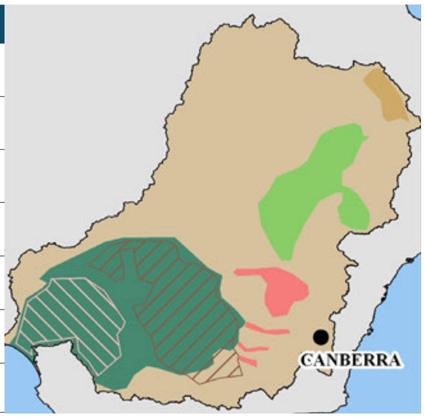


Table 2-6. Groundwater status for aquifers in the South Australian Gulf region

Groundwater subsystem	Change in groundwater levels
Adelaide Plains watertable aquifer (upper)	decreasing
Tertiary aquifer T1 (middle)	decreasing
Tertiary aquifer T2 (lower)	decreasing
McLaren Vale watertable (upper)	decreasing or stable
Port Willunga (middle)	decreasing
Maslin Sands (lower)	decreasing or stable

2.7 Urban water use in 2009–10

Urban water use in the urban centres considered in this report decreased from 1,719 GL in 2005–06 to 1,497 GL in 2009–10. Residential water consumption accounted for 68 per cent of urban use in 2009–10.

The past decade in Australia was characterised by low rainfall conditions in the south, east and west of the country that resulted in the implementation of water restrictions in most cities and towns. Water restrictions led to a reduction of total urban water consumption for the eight major urban centres considered in this report, from a total of approximately 1,719 GL in 2005–06 to 1,497 GL in 2009–10 (National Water Commission 2011a). In the residential sector however, consumption has increased from 2007–08 as a result of higher rainfall and expectation of water security projects being completed. In 2009–10 the residential consumption of the urban centres considered in this report increased by 3.2% compared to 2008–09 and accounted for approximately 68 per cent of use whilst commercial, municipal and industrial used 24 per cent, with the remainder to other uses.

In Sydney, the annual residential water supplied increased from 198 KL/property in 2008–09 to 205 KL/property in 2009–10 (National Water Commission 2011a). In Melbourne, however, water use continued to fall as restriction levels remained unchanged over 2009–10 and average rainfall conditions experienced across the metropolitan area reduced water demand, particularly over summer and autumn 2010.

In the northeast and east of the country, above average rainfall in early 2010 led to a rapid increase in water storage levels for many urban areas and enabled utilities to ease restrictions. This resulted in a six per cent increase in annual household use in Brisbane, up to 143 KL/property (National Water Commission 2011a).

In Western Australia, annual household water consumption for Perth remained stable in 2009–10 at 276 KL/property, only one KL less than in 2008–09. Typically 50 per cent of Perth's total water consumption comes from groundwater, 40 per cent from surface water and ten per cent from desalination (National Water Commission 2011a).

2.8 Agricultural water use (2005–06 to 2009–10)

Between 2005–06 and 2009–10, agricultural water use in Australia decreased from 11,688 GL to 7,359 GL

Annual agricultural water use in Australia was 8,369 GL on average between 2005–06 and 2009–10, based on annual surveys of water use on Australian farms by the Australian Bureau of Statistics. Water use by agriculture over this period was highest in 2005–06 (11,688 GL) and lowest in 2007–08 (6,989 GL). Annual water use for irrigation over the period was 7,551 GL on average, with a high of 10,737 GL in 2005–06 and a low of 6,285 GL in 2007–08.

The highest levels of irrigation water use during 2005–06 to 2009–10 occurred in New South Wales (2,003 GL in 2009–10), which also experienced the greatest reduction in irrigation water use over the five-year period. Victoria and Queensland also show notable decreases in total irrigation water use. The Northern Territory uses by far the lowest irrigation volume (18 GL in 2009–10).

Figure 2-12 clearly shows that water use for irrigation decreased dramatically in the Murray–Darling Basin after 2005–06. In 2005–06, irrigation water use in the Murray–Darling Basin was more than double that of the rest of the country. By 2007–08, water use in the Murray–Darling Basin was approximately equal to the rest of Australia and has not noticeably increased in 2009–10.

Table 2-7. Agricultural water use in Australia between 2005 and 2010 (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011)

Water use category	Total annual water use (GL)				
	2005–06	2006–07	2007–08	2008–09	2009–10
Irrigation*	10,737	7,636	6,285	6,501	6,596
Other agriculture^	951	885	704	785	763
Total agriculture	**11,688**	**8,521**	**6,989**	**7,286**	**7,359**

* Total volume applied
^ Including stock drinking, dairy and piggery cleaning

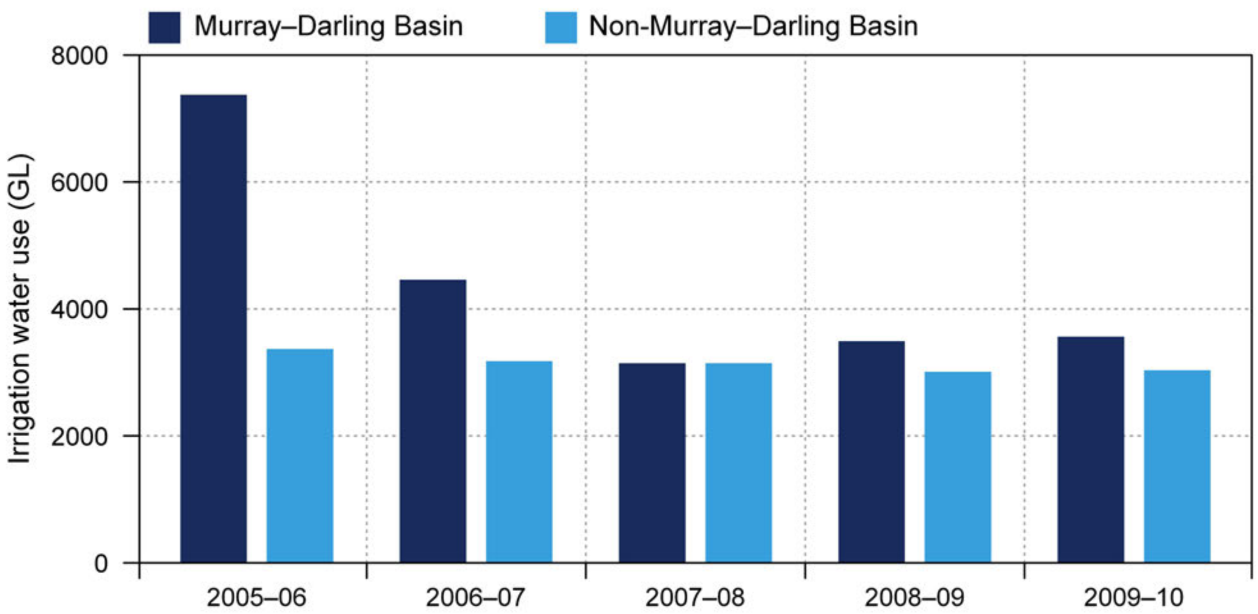


Figure 2-12. Changes in irrigation water use between 2005–06 and 2009–10 (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011)

2.9 Drivers of the Australian climatic condition in 2009–10

The central and eastern equatorial Pacific Ocean was warm (El Niño conditions) until February 2010 then cooled to La Niña conditions by April 2010

An El Niño event persisted in the Pacific Ocean region from July 2009 until February 2010. Trade winds in the tropics were weak from July to December as a result of the enhanced El Niño event, which peaked in late December 2009. The Southern Oscillation Index (SOI), which reflects the strength of the Pacific trade winds, remained negative and at levels typical of an El Niño event until early 2010.

With weak Pacific trade winds, surface water temperature conditions in the central and eastern tropical Pacific Ocean remained warm and cloudiness remained high. This pattern contributed to the drier than average conditions over northern and eastern parts of Australia during winter and spring 2009 and summer 2009–10. See Box 2-1 for more on the influence of Pacific Ocean temperatures on rainfall in Australia.

The shades of red in Figure 2-13 indicate uncharacteristically warm sea temperatures and the shades of blue indicate uncharacteristically cool sea temperatures when averaged over the top 150 metres of the ocean (approximating the well mixed surface layers). The first two four-month sequences in Figure 2-13 show the unusually warm sea surface temperatures across the central and eastern tropical Pacific Ocean, typical of an El Niño event, remaining until February 2010. However, as shown in the last four-month sequence (March to June 2010) in Figure 2-13, a steady cooling occurred in each successive month from February onwards, with a large volume of cooler than normal water extending across most of the tropical Pacific by the end of June. In some regions the sub-surface water was more than 3°C cooler than average by June 2010 and the SOI was consistent with the early stages of a La Niña event (Figure 2-14).

The breakdown of the El Niño event and establishment of a La Niña in 2010 was associated with strong Pacific trade winds and well above average rainfall in the north and east of the country. While rainfall in these areas was generally below average to very much below average to December 2009, rainfall in the north and east was generally average to very much above average for all subsequent months in 2009–10, except for June 2010. As a consequence of this marked reversal in rainfall conditions, total rainfall for 2009–10 over northern and eastern Australia was only below average in relatively small parts of the South East Coast (NSW) and North East Coast regions, and in the northeast corner of the Murray–Darling Basin region.

To the west of the continent, however, the Indian Ocean Dipole index was positive from October 2009 to June 2010, peaking at 0.8°C in late April 2010 (Figure 2-15). These ocean temperature conditions are likely to have contributed to below average rainfall experienced in the Pilbara–Gascoyne and South West Coast regions in 2009–10. See Box 2-2 for more on the influence of Indian Ocean temperatures on rainfall in Australia.

More information on the drivers of climatic conditions in Australia can be found on the Bureau's website at: www.bom.gov.au/lam/climate/levelthree/analclim/analclim.htm.

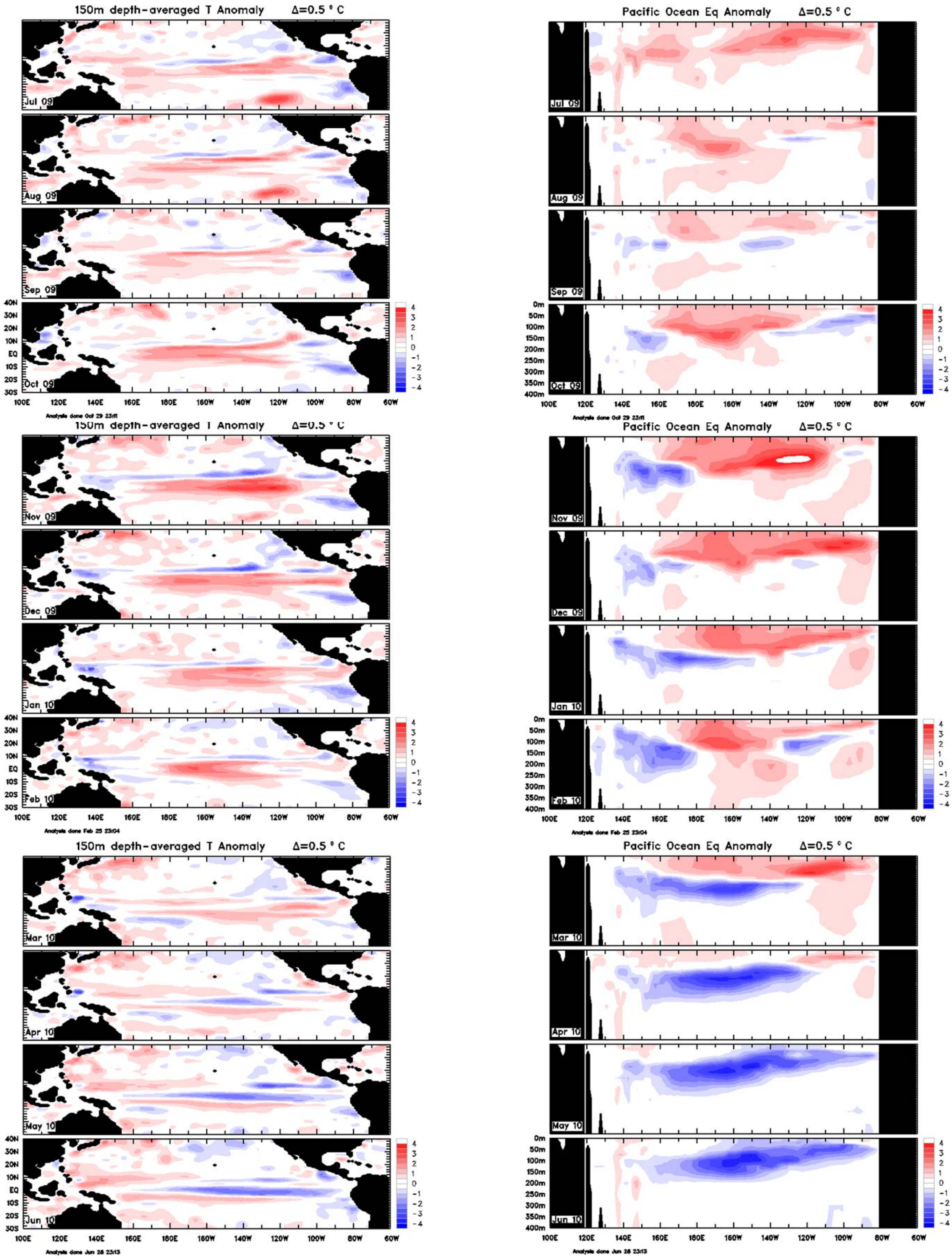


Figure 2-13. Pacific Ocean temperature profiles driving the Walker Circulation (see Box 2-1) in 2009–10. Monthly sequences of 150 m depth-averaged temperature anomalies (left) and vertical temperature anomaly sections at the equator (right). The historic archive of sub-surface temperature charts can be found at www.bom.gov.au/oceanography/oceantemp/pastanal.shtml

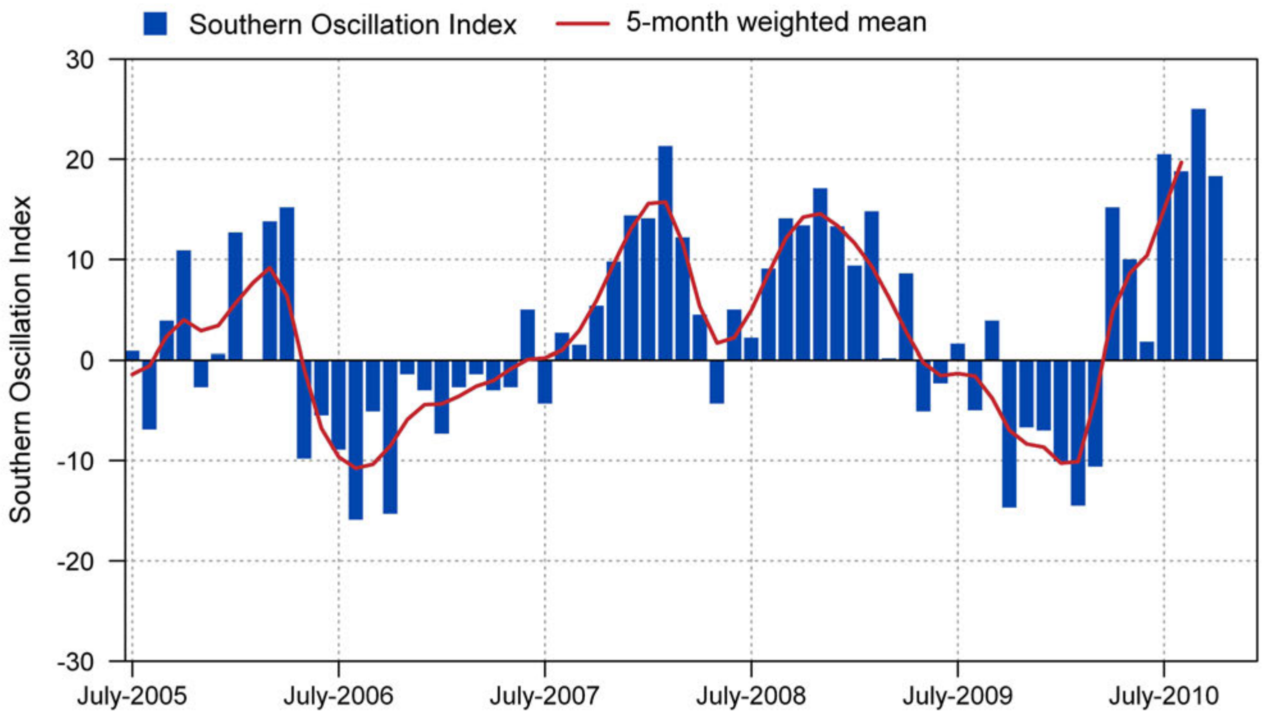


Figure 2-14. Southern Oscillation Index time-series (data available at: www.bom.gov.au/climate/enso/indices.shtml)

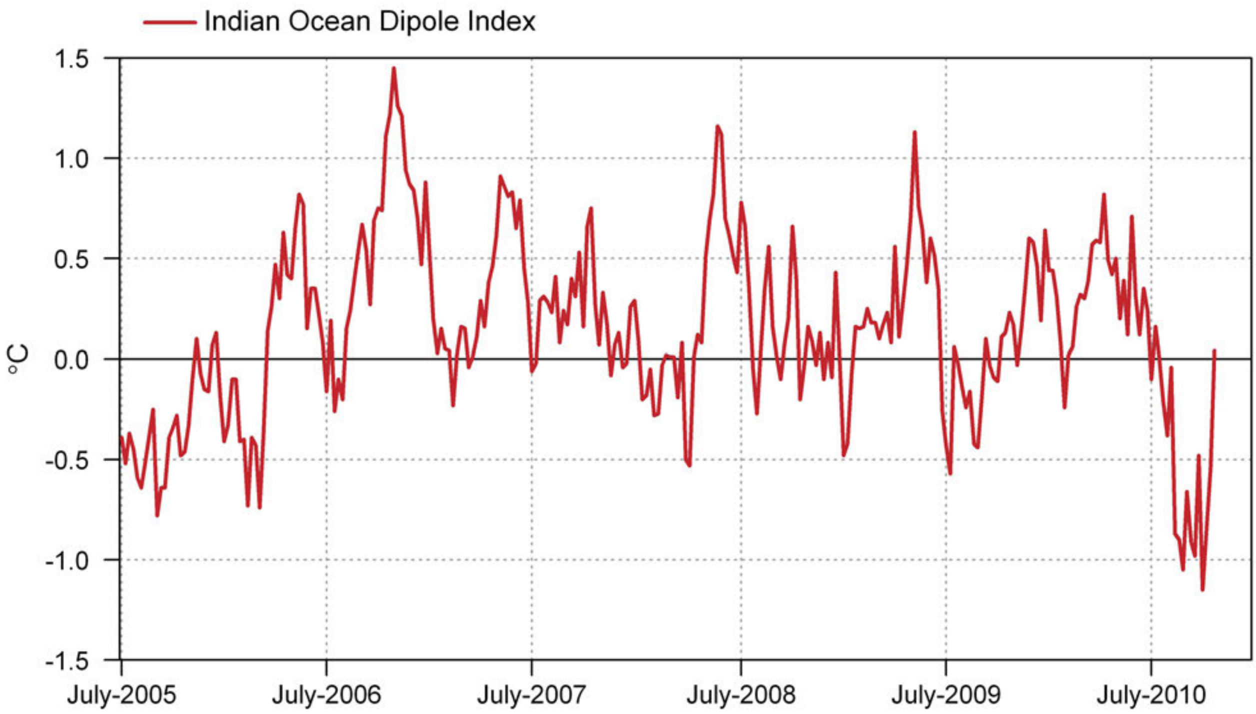


Figure 2-15. Indian Ocean Dipole time series (data available at: www.bom.gov.au/climate/enso/indices.shtml)

BOX 2-1: THE SOUTHERN OSCILLATION AND EL NIÑO/LA NIÑA

Much of the variability in Australia's climatic condition is connected with the atmospheric phenomenon called the Southern Oscillation, a major see-saw of air pressure and rainfall patterns between the Australian/Indonesian region and the eastern tropical Pacific. The Southern Oscillation Index (SOI) is calculated from the monthly mean air pressure difference between Tahiti and Darwin and provides a simple measure of the strength and phase of the Southern Oscillation and Walker Circulation.

The 'typical' Walker Circulation pattern shown in the top panel of the schematic below has an SOI close to zero (i.e. the Southern Oscillation is close to the long-term average or neutral state). Positive values of the SOI are associated with stronger than average Pacific trade winds blowing from east to west and warmer sea temperatures to the north of Australia. Together these give a high probability that eastern and northern Australia will be wetter than normal.

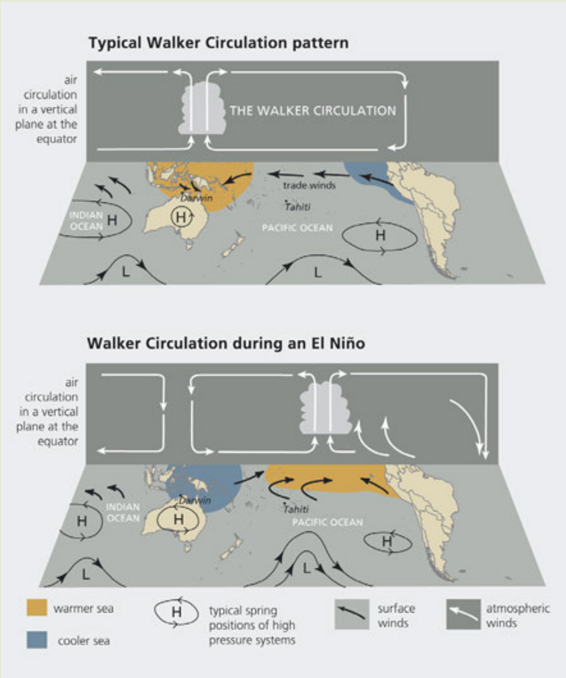
During El Niño episodes, the Walker Circulation weakens, seas around Australia cool, and slackened trade winds feed less moisture into the Australian/southeast Asian region (bottom panel of schematic). Air pressure is higher over Australia and lower over the central Pacific in line with this shift in the Walker Circulation, and the SOI becomes persistently negative (for example, below -7). Under these conditions, there is a high probability that eastern and northern Australia will be drier than normal.

In addition to its effect on rainfall, the El Niño phenomenon also has a strong influence on temperatures over Australia. During winter/spring, El Niño events tend to be associated with warmer than normal daytime temperatures. Conversely, reduced cloudiness means that temperatures tend to cool very rapidly at night, often leading to widespread and severe frosts.

When the Pacific trade winds and Walker Circulation are stronger than average, the eastern Pacific Ocean is cooler than normal and the SOI is usually persistently positive (e.g. above +7). This enhancement of the Walker Circulation, also called La Niña, often brings widespread rain and flooding to Australia.

The effect of La Niña on Australian rainfall patterns is generally more widespread than that of El Niño. During La Niña phases, temperatures tend to be below normal, particularly over northern and eastern parts of Australia. The cooling is strongest during the October to March period.

For more information see:
www.bom.gov.au/info/leaflets/nino-nina.pdf



Walker Circulation in neutral (top) and El Niño (bottom) conditions

BOX 2-2: THE INDIAN OCEAN DIPOLE

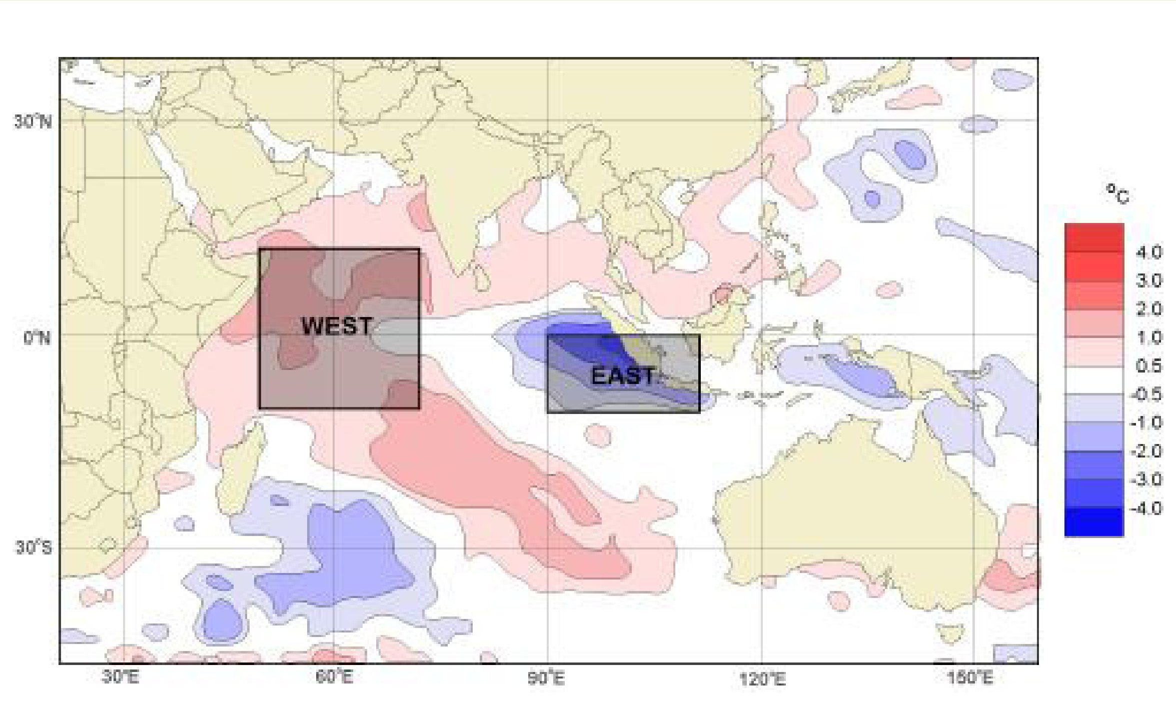
The Indian Ocean Dipole (IOD) is a coupled ocean and atmosphere phenomenon in the equatorial Indian Ocean that affects the climatic conditions in Australia and other countries that surround the Indian Ocean basin.

The IOD is commonly measured by an index that is the difference in sea surface temperature (SST) between the western (50°E to 70°E and 10°S to 10°N) and eastern (90°E to 110°E and 10°S to 0°S) equatorial Indian Ocean. The boxes on the map below show the east and west poles of the IOD.

A positive IOD period is characterised by cooler than normal water in the tropical eastern Indian Ocean and warmer than normal water in the tropical western Indian Ocean (see map below for an example of a typical positive IOD SST pattern). A positive IOD SST pattern can be associated with a decrease in rainfall over parts of central and southern Australia.

Conversely, a negative IOD period is characterised by warmer than normal water in the tropical eastern Indian Ocean and cooler than normal water in the tropical western Indian Ocean. A negative IOD SST pattern can be associated with an increase in rainfall over parts of southern Australia.

For more information see:
www.bom.gov.au/climate/IOD/about_IOD.shtml



Departures from average ocean surface temperatures in November 1997 at the height of the 1997 positive IOD event.

2.10 Notable rainfall events in 2009–10

Widespread heavy rainfall occurred in the Northern Territory and Queensland between 22 February and 3 March 2010

An exceptional rain event affected the Lake Eyre Basin, northern Murray–Darling Basin and North East Coast regions during the last week of February and first week of March 2010. The event began on 22 February when a strong low pressure system developed over the Northern Territory within a monsoon trough. Over the following days the monsoon low tracked south, triggering heavy falls through central and southern parts of the Northern Territory.

From 28 February, the monsoon low moved eastwards into southwest Queensland, bringing widespread heavy rain on 28 February and 1 March, then spread further east into the southern interior on 1 March and 2 March (see Figure 2-16). Moist easterly flow, combined with a second low pressure system which formed off the coast near Fraser Island, also brought heavy rain to coastal regions of southeast Queensland and northeast New South Wales. The main low weakened and drifted south after 2 March. Rainfall amounts were smaller from this point, but remnant moisture from the system continued to provide substantial rain over eastern Australia for the next few days, particularly in Victoria and southern New South Wales over the period 6–8 March. The moisture also contributed to severe thunderstorms which affected parts of the region.

The most remarkable aspect of this event was the area covered by the heavy rainfall and the total volume of rainfall. Daily totals exceeded 100 mm over 1.7 per cent of Australia on 1 March and 1.9 per cent on 2 March (Figure 2-16). The latter is the largest area of 100 mm plus daily totals on a single day in the Australian meteorological record, breaking the previous record of 1.7 per cent set on 22 December 1956. In the Northern Territory, 28 February 2010 was the wettest day recorded, with a Territory-wide average of 29.23 mm, while 2 March set a new record for Queensland with a state-wide average of 31.74 mm.

Over the ten-day period ending 3 March 2010, an estimated 403,000 GL of rain fell across the Northern Territory and Queensland. This resulted in major flooding in most of the northern catchments of the Lake Eyre Basin and Murray–Darling Basin regions. Compared with a notable previous flooding event in the region in April 1990, peak rainfall amounts were smaller, but heavy rains (ten-day totals exceeding 200 mm) covered a much larger area.

The event of February–March 2010 occurred during the declining phase of an El Niño which was in place since mid-2009. While El Niño is typically associated with dry conditions in eastern Australia in winter and spring, it is not unusual for major rain events to occur during late summer or early autumn during its declining phase. Notable historical examples include those of February 1973, March 1983, January 1995 and January 2007.

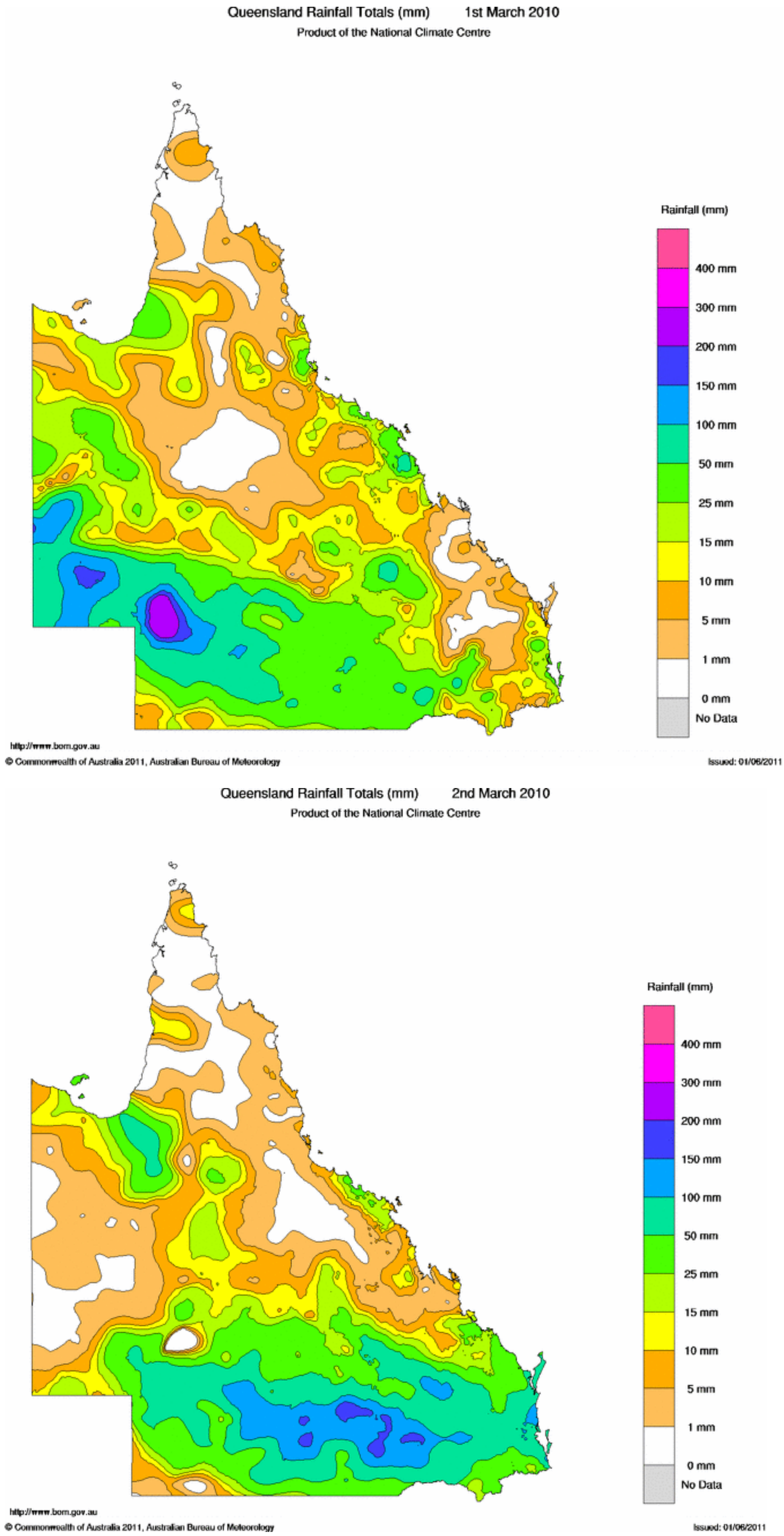


Figure 2-16. Rainfall that contributed to flooding in central Queensland in March 2010

2.11 Major flood events in 2009–10

The most significant flooding of 2009–10 occurred during February and March in the Lake Eyre Basin region, southeast Queensland and in the top of the Murray–Darling Basin region

Several short-term flood events occurred in eastern Australia in 2009. Parts of Tasmania were affected by repeated minor to moderate flooding during May to September. The calendar year ended with further flooding in parts of New South Wales and Queensland.

The most significant flooding of the reporting period occurred during February and March 2010 in the Carpentaria Coast, Lake Eyre Basin, North East Coast and Murray–Darling Basin regions as a consequence of the significant rainfall event described in Section 2-10. Locations where peak river heights exceeded 'major flood' thresholds (see Glossary for flood category definitions) during the year are shown in Figure 2-17.

The short but high flood peaks delivered an estimated 6,700 GL to the major tributaries of the Darling River and Lake Eyre, inundating floodplains and replenishing lakes and wetlands (Figure 2-18). The flows also increased the volume held in private storages by around 1,500 GL. However, the flows in the Darling River system were not sufficient to allow releases to the Murray mouth and Coorong or provide drought relief in the lower Murray–Darling Basin, with only about 1,100 GL reaching the Menindee Lakes in western New South Wales.

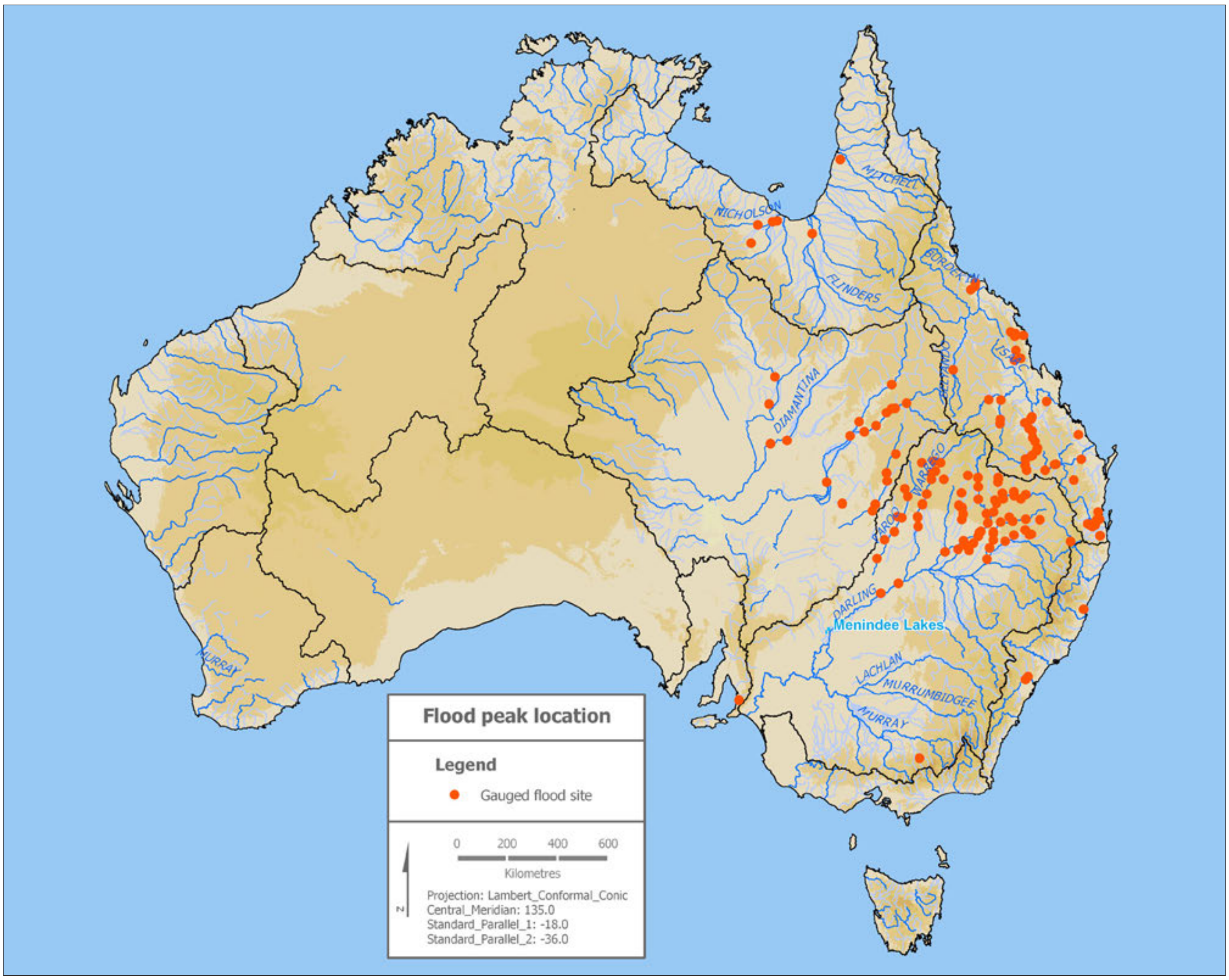
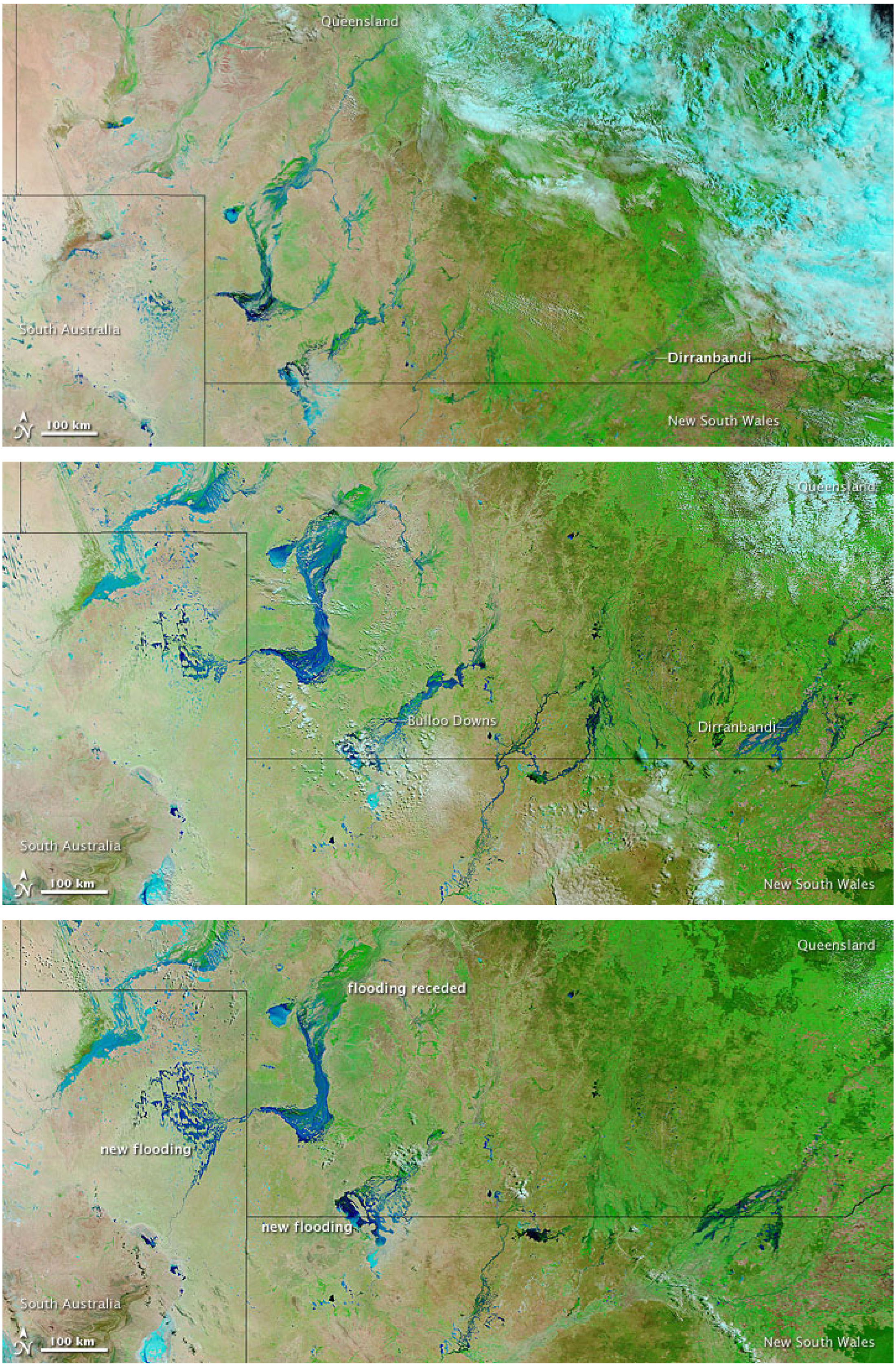


Figure 2-17. Location of flood peaks classified as 'major' in 2009–10



17 February 2009

14 March 2009

27 March 2009

Figure 2-18. Satellite derived images showing flood progression through the channel country in southwest Queensland, northwest New South Wales and northeast South Australia. Note that some cloud is apparent (coloured pale blue) particularly in the upper right of the first image (source: www.earthobservatory.nasa.gov)

2.12 Regional water resources assessments

Chapters 3 to 15 detail assessments of water availability and use at regional scales. Within each reporting region, patterns, variability and trends in water availability and use are considered. Topics addressed include the impacts of the climatic condition on water resources over 2009–10 and between 1980 and 2010. There is a focus on presentation of annual to decadal patterns and trends, and monthly and seasonal effects.

Particular consideration is given to describing the hydrological state of rivers within each region over 2009–10 and over recent years. Groundwater resources are also described where data was available. Water availability and use in selected cities and irrigation areas is also presented.

Information is conveyed in general descriptions of each region and the results of analysis are presented in graphs, tables and diagrams. Landscape water balance data provide a spatially explicit regional perspective, and data from selected monitoring sites give more detail at particular locations.