

SOUTHERN SLOPES



PROJECTIONS FOR AUSTRALIA'S NRM REGIONS



Australian Government
Department of the Environment
Bureau of Meteorology



CLIMATE CHANGE IN THE SOUTHERN SLOPES

THE INTERNATIONAL SCIENTIFIC COMMUNITY ACCEPTS THAT INCREASES IN GREENHOUSE GASES DUE TO HUMAN ACTIVITIES HAVE BEEN THE DOMINANT CAUSE OF OBSERVED WARMING SINCE THE MID-20TH CENTURY. CONTINUED EMISSIONS OF GREENHOUSE GASES WILL CAUSE FURTHER WARMING AND CHANGES IN ALL COMPONENTS OF THE CLIMATE SYSTEM.

Australia’s changing climate represents a significant challenge to individuals, communities, governments, businesses and the environment. Australia has already experienced increases in average temperatures over the past 60 years, with more frequent hot weather, fewer cold days, shifting rainfall patterns, and rising sea levels.

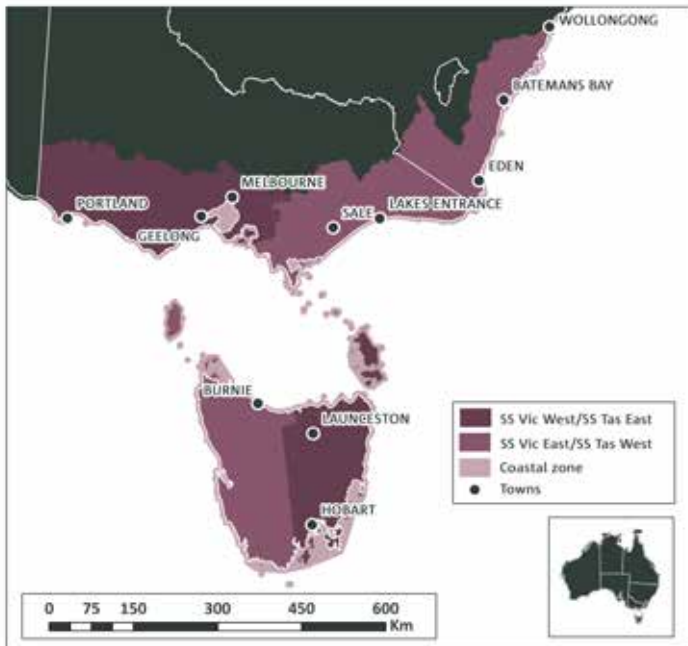
To assist the planning and management of Natural Resource Management (NRM) regions, CSIRO and the Australian Bureau of Meteorology have prepared climate change projections for eight regions of Australia, termed NRM clusters.

This brochure is for the Southern Slopes cluster (Figure 1), comprising nine NRM

regions in Tasmania, southern Victoria and south-east New South Wales. This cluster has an extensive coastal zone and a diversity of local climates across its relatively small area. Because of the climate differences, the cluster has been split into four sub-clusters for analysis and reporting. They are: 1) Western Victoria (SSVW), 2) Eastern Victoria and South-East NSW (SSVE), 3) Western Tasmania (SSTW) and 4) Eastern Tasmania (SSTE).

The Southern Slopes is within the ‘mid-latitudes’ of the global climate system, falling between the subtropical ridge of high pressure (at about 30 °S) and the so called ‘Roaring Forties’ (at 40-50 °S). The dominant rain-bearing weather systems are cold fronts and troughs coming from the west.

FIGURE 1: MAP OF THE SOUTHERN SLOPES CLUSTER



CLIMATE CHANGE PROJECTIONS

Projections for the Southern Slopes are based on the outputs of a set of 40 global climate models (GCMs) developed by Australian and international scientists. Climate models are based on established laws of physics and are rigorously tested for their ability to reproduce past climate. These projections draw on the full breadth of available data and peer-reviewed literature to provide a robust assessment of the potential future climate.

Projections for the Southern Slopes are based on four Representative Concentration Pathways (RCPs) underpinned by emission scenarios. More information on climate models and RCPs can be found inside this brochure.

► FOR MORE COMPREHENSIVE INFORMATION ABOUT THE SOUTHERN SLOPES READ THE CLUSTER REPORT AVAILABLE ON THE CLIMATE CHANGE IN AUSTRALIA WEBSITE: WWW.CLIMATECHANGEINAUSTRALIA.GOV.AU

PAST TEMPERATURE TRENDS

Temperatures have increased over the past century, with the rate of warming higher since 1960. Mean temperature increased between 1910 and 2013 by 0.8 to 1.0 °C across the sub-clusters.

TEMPERATURE PROJECTIONS



Average temperatures will continue to increase in all seasons (*very high confidence*).

There is *very high confidence* in continued substantial increases in projected mean, maximum and minimum temperatures projected in line with our understanding of the effect of further increases in greenhouse gas concentrations.

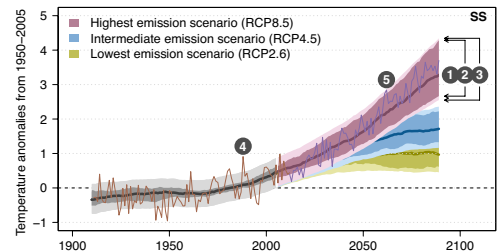
For the near future (2030), the annually averaged warming across all emission scenarios is projected to be around 0.4 to 1.1 °C above the climate of 1986–2005. By late in the century (2090), for a high emission

scenario (RCP8.5) the projected range of warming is 2.5 to 4.0°C (Table 1 and Figure 2). Under an intermediate scenario (RCP4.5) the projected warming is 1.1 to 2.0 °C.

TABLE 1: PROJECTED TEMPERATURE CHANGE (°C), COMPARED TO 1986–2005, FOR 20-YEAR PERIODS (CENTRED ON 2030 AND 2090) AND THREE RCPs. THE MEDIAN PROJECTION ACROSS THE MODELS IS SHOWN, WITH THE 10TH TO 90TH PERCENTILE RANGE OF MODEL RESULTS IN BRACKETS.

	RCP2.6 Low emissions	RCP4.5 Intermediate emissions	RCP8.5 High emissions
2030	0.7 (0.4 to 0.9)	0.6 (0.5 to 0.9)	0.8 (0.5 to 1.1)
2090	0.8 (0.4 to 1.3)	1.5 (1.1 to 2.0)	3.1 (2.5 to 4.0)

FIGURE 2: SIMULATED HISTORICAL AND PROJECTED TEMPERATURE (°C) TIME-SERIES FOR THE SOUTHERN SLOPES CLUSTER, SHOWN AS DIFFERENCES FROM THE 1950–2005 AVERAGE. (SEE EXPLANATION BELOW).



EXPLANATION OF THE TEMPERATURE TIME-SERIES:

1. The projected multi-model median temperature. Half the models have projections above, and half below, this line.
2. 10th to 90th percentile of projected 20-year average climate. 80 per cent of model results lie in this range.
3. 10th to 90th percentile of individual years (taking into account year to year variability). 80 per cent of years lie in this range.
4. The observed time-series for 1910–2013 is overlaid on the simulated climate for the corresponding period (grey line and shading as per 1–3).
5. One climate model is shown to illustrate how the warming future may unfold. Note that models simulate realistic variability in annual temperature.

PAST RAINFALL TRENDS

The Southern Slopes experienced wet and dry decades through the 20th century, and shows a drying trend since 1960, especially in autumn. The wet decades of the 1950s and 1970s were followed by a very significant period of drought, known as the Millennium Drought (1996 to 2009).

RAINFALL PROJECTIONS

In the near future (2030) natural variability is projected to predominate over trends due to greenhouse gas emissions. Understanding of physical rainfall processes (southward shift of winter storm systems), supported by climate model results, indicate rainfall decreases for winter and spring (*high confidence*), except for Tasmania in winter, where increases are projected (*medium confidence*). The winter decreases over Victoria are up to 30 per cent in 2090 under high emissions. By the middle of the century, and under high emissions, winter

changes are projected to be evident against natural variability. Changes to summer and autumn rainfall are possible but not clear, although there is a tendency for decrease in Tasmania, particularly western Tasmania in summer and decrease in western Victoria in autumn. Available fine-scale modelling provides further detail on possible spatial variation in rainfall response.



Generally less rainfall in winter and spring is projected with *high confidence*, but with strong regional differences. Changes to summer and autumn rainfall are possible but less clear. For the near future, natural variability is projected to dominate any projected changes.

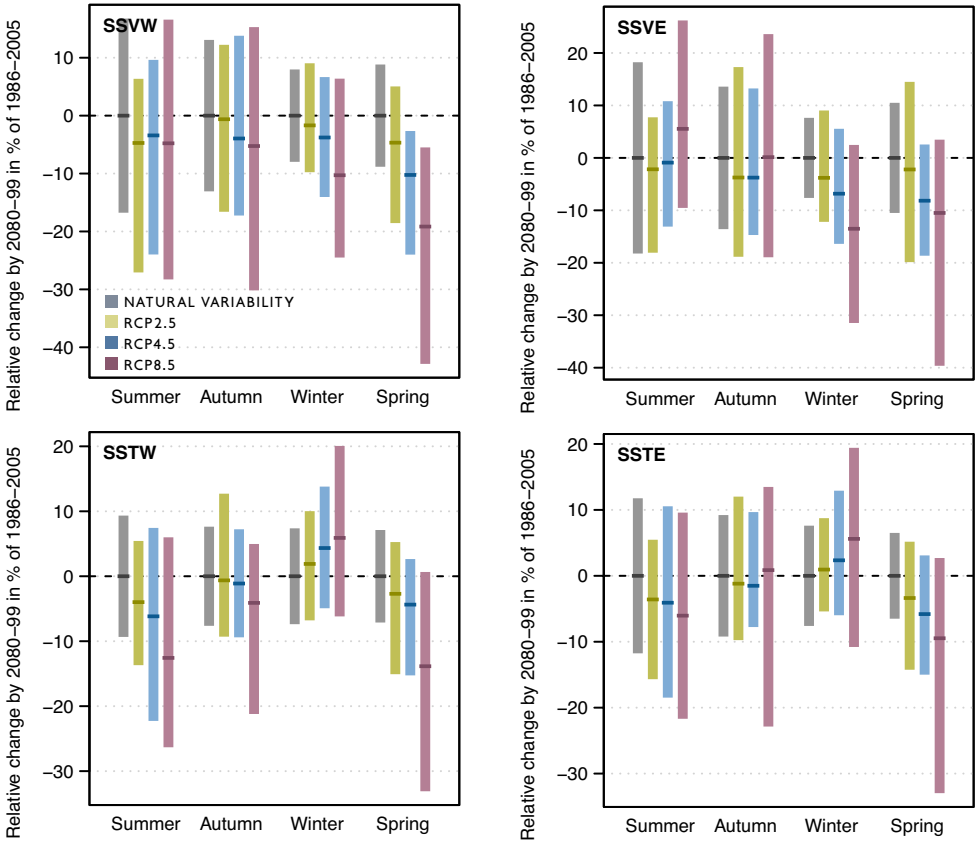
► **CONSULT THE SOUTHERN SLOPES CLUSTER REPORT FOR MORE DETAILED DESCRIPTIONS OF THE RESULTS USING DIFFERENT MODELLING METHODS (E.G. DOWNSCALING).**

TABLE 2: PROJECTED RAINFALL DIFFERENCES (PER CENT), COMPARED TO 1986–2005. FOR 20-YEAR PERIODS (CENTRED ON 2030 AND 2090) AND THREE RCPs. THE 10TH TO 90TH PERCENTILE RANGE OF MODEL RESULTS IS SHOWN. FOR 2030, RESULTS FOR ALL RCPs ARE SIMILAR SO ONLY RCP4.5 VALUES ARE SHOWN.

	RCP4.5 2030	RCP2.6 2090	RCP4.5 2090	RCP8.5 2090
ANNUAL	-7 to +4	-8 to +2	-10 to +3	-19 to +5
SUMMER	-16 to +8	-18 to +5	-17 to +7	-19 to +13
AUTUMN	-11 to +9	-12 to +8	-11 to +8	-19 to +13
WINTER (Vic West)	-10 to +7	-10 to +9	-14 to +7	-25 to +6
WINTER (Vic East)	-11 to +6	-12 to +9	-16 to +6	-31 to +2
WINTER (Tas West)	-5 to +10	-7 to +10	-5 to +14	-6 to +20
WINTER (Tas East)	-6 to +10	-5 to +9	-6 to +13	-11 to +19
SPRING	-11 to +5	-14 to +4	-17 to +1	-34 to -1

MEDIAN RESULTS ARE NOT SHOWN HERE BECAUSE MODELS DO NOT ALWAYS AGREE ON THE DIRECTION OF CHANGE.

FIGURE 3: PROJECTED RAINFALL DIFFERENCES (PER CENT) FOR THREE RCPs FOR THE SOUTHERN SLOPES SUB-CLUSTERS FOR 20 YEARS CENTRED ON 2090 (2080–2099 PERIOD) COMPARED TO 1986–2005. BARS INDICATE THE 10TH TO 90TH PERCENTILE RANGE OF MODEL RESULTS. THE HORIZONTAL LINE INDICATES THE MEDIAN.



REPRESENTATIVE CONCENTRATION PATHWAYS

- Future changes in greenhouse gases, aerosols (suspended particles in the atmosphere) and land use depend on human behaviour.
- The scientific community defined a set of four scenarios, called Representative Concentration Pathways (RCPs) for the *Fifth Assessment Report* of the Intergovernmental Panel on Climate Change.
- The RCPs reflect plausible trajectories of future greenhouse gas and aerosol concentrations to the year 2100 and represent a range of economic, technological, demographic, policy, and institutional futures.
- Climate projections are available from model simulations using four RCPs: RCP8.5 (high emissions), RCP6.0 and RCP4.5 (intermediate scenarios resulting from moderate emissions reduction, with differing timing of peak emissions) and RCP2.6 (low emissions; ambitious and sustained global emissions reduction). RCPs are named in accordance with the level of influence these gases have on the Earth’s energy balance.
- Not every combination of RCP and climate variable is available for all GCMs in the projections presented here.
- Projections for RCP6.0 are not presented in this brochure, but are available on the website.

EXTREME TEMPERATURE

Extreme temperatures are projected to increase at a similar rate to mean temperature, with a substantial increase in the temperature reached on hot days, the frequency of hot days, and the duration of warm spells (*very high confidence*).

As the century progresses frost-risk days (minimum temperatures under 2 °C) are expected to decrease across the cluster but with decadal variability and regional

exceptions (high confidence) (Table 3). Damaging frosts may still occur periodically.



More hot days and warm spells are projected with *very high confidence*. Fewer frosts are projected with *high confidence*.

► **CALCULATE THE FREQUENCY OF DAYS EXCEEDING SELECTED TEMPERATURE THRESHOLDS ON THE WEBSITE THRESHOLD CALCULATOR.**

TABLE 3: AVERAGE ANNUAL NUMBER OF DAYS ABOVE 35 °C AND BELOW 2 °C FOR HOBART (TAS EAST) AND MELBOURNE (VIC WEST) FOR THE 30-YEAR PERIOD CENTRED ON 1995 (1981–2010) AND FOR FUTURE 30-YEAR PERIODS (CENTRED ON 2030 AND 2090).

THRESHOLD	HOBART (Tas East)				MELBOURNE (Vic West)			
	1995	2030 RCP4.5	2090 RCP4.5	2090 RCP8.5	1995	2030 RCP4.5	2090 RCP4.5	2090 RCP8.5
OVER 35 °C	1.6	2.0 (1.9 to 2.1)	2.6 (2.0 to 3.1)	4.2 (3.2 to 6.3)	11	13 (12 to 15)	16 (15 to 20)	24 (19 to 32)
BELOW 2 °C	9.1	5.8 (6.9 to 3.7)	2.1 (4.1 to 1.1)	0.3 (0.6 to 0.1)	0.9	0.6 (0.8 to 0.4)	0.2 (0.3 to 0.1)	0.0 (0.0 to 0.0)

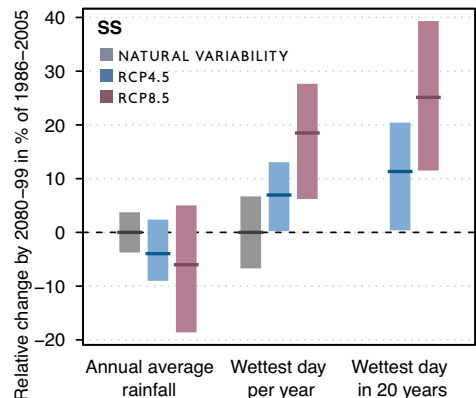
EXTREME RAINFALL & DROUGHT

Even though annual mean rainfall is projected to decrease in the region, understanding of the physical processes that cause extreme rainfall, coupled with modelled projections (Figure 4) indicate with *high confidence* a future increase in the intensity of extreme rainfall events. However, the magnitude of the increases cannot be confidently projected. Time spent in drought is projected, with *medium confidence*, to increase over the course of the century.



Increased intensity of extreme rainfall events is projected, with *high confidence*.

FIGURE 4: MODELLED DIFFERENCES (PER CENT) IN ANNUAL AVERAGE RAINFALL, RAINFALL ON THE WETTEST DAY PER YEAR, AND RAINFALL ON THE WETTEST DAY IN 20 YEARS FOR 2080–2099 COMPARED TO 1986–2005. (BARS AS PER FIGURE 3).



MARINE AND COASTAL PROJECTIONS

For 1966 to 2009, the average rate of relative sea-level rise for Australia, from observations along the coast, was 1.4 mm/year.

There is *very high confidence* in future sea-level rise. By 2030 the projected range of sea-level rise for the cluster coastline is 0.07 to 0.19 m above the 1986–2005 level, with only minor differences between emission scenarios. As the century progresses, projections are sensitive to concentration pathways. By 2090, the intermediate emissions case (RCP4.5) is associated with a rise of 0.27 to 0.66 m and the high case (RCP8.5) a rise of 0.38 to 0.89 m.

Under certain circumstances, sea-level rises higher than these may occur (see Table 4 caption).

Late in the century warming of the Southern Slopes coastal waters poses a significant threat to the marine environment through biological changes in marine species, including local abundance, community structure, and enhanced coral bleaching risk. Sea surface temperature is projected to increase in the range of 1.6 to 5.1 °C by 2090 under high emissions (RCP8.5). The sea will also become more acidic, with acidification proportional to emissions growth.



Mean sea level will continue to rise and height of extreme sea-level events will also increase (*very high confidence*).

TABLE 4: PROJECTED SEA-LEVEL CHANGE (METRES) FOR TWO SOUTHERN SLOPES SITES. COMPARED TO 1986–2005, FOR 20-YEAR PERIODS (CENTRED ON 2030 AND 2090) AND THREE RCPs. THE MEDIAN PROJECTION ACROSS THE MODELS IS SHOWN, WITH THE RANGE OF MODEL RESULTS IN BRACKETS. THESE RANGES OF SEA-LEVEL RISE ARE CONSIDERED 'LIKELY'. HOWEVER, IF A COLLAPSE IN THE MARINE BASED SECTORS OF THE ANTARCTIC ICE SHEET WERE INITIATED, THESE PROJECTIONS COULD BE SEVERAL TENTHS OF A METRE HIGHER BY LATE IN THE CENTURY.

SEA-LEVEL CHANGE	BURNIE (Tas West)		PORTLAND (Vic West)	
	2030	2090	2030	2090
RCP2.6	0.12 (0.08 to 0.17)	0.38 (0.23 to 0.54)	0.12 (0.08 to 0.17)	0.39 (0.23 to 0.55)
RCP4.5	0.12 (0.08 to 0.16)	0.46 (0.29 to 0.63)	0.12 (0.08 to 0.16)	0.46 (0.29 to 0.64)
RCP8.5	0.13 (0.08 to 0.18)	0.61 (0.41 to 0.83)	0.13 (0.08 to 0.18)	0.61 (0.39 to 0.84)

OTHER VARIABLES

HUMIDITY AND SOLAR RADIATION:

An increase in solar radiation and a decrease in relative humidity is projected in the cool season through the century (*high confidence*). This will be influenced by changes in rainfall (and associated changes to cloudiness) and temperature in the cluster. Changes in summer and autumn are less clear.

EVAPORATION: Potential evapotranspiration is projected to increase in all seasons as warming progresses (*high confidence*).

FIRE WEATHER

There is *high confidence* that climate change will result in a harsher fire-weather climate in the future. However, there is *low confidence* in the magnitude of the change to fire weather. This depends on the rainfall projection and its seasonal variation. Relative changes are comparable across all four sub-clusters.



A harsher fire-weather climate in the future.

WWW.CLIMATECHANGEINAUSTRALIA.GOV.AU

This website provides comprehensive information about the future climate and its impacts, and how communities, in particular the NRM sector, can adapt to these projected changes.

A number of interactive tools allow exploration of a range of climate variables up to late in the 21st century.

A full report for the cluster can be found on the site, as well as specific impacts and adaptation information.

KEY MESSAGES FOR THE SOUTHERN SLOPES



Average temperatures will continue to increase in all seasons.



More hot days and warm spells, and fewer frosts.



Generally less rainfall in the cool season (winter and spring) is projected but with strong regional differences. Changes to summer rainfall are possible but less clear.



Increased intensity of extreme daily rainfall events.



Mean sea level will continue to rise. Height of extreme sea-level events will also increase.



A harsher fire-weather climate in the future.



On annual and decadal basis, natural variability in the climate system can act to either mask or enhance any long-term human induced trend, particularly in the next 20 years and for rainfall.