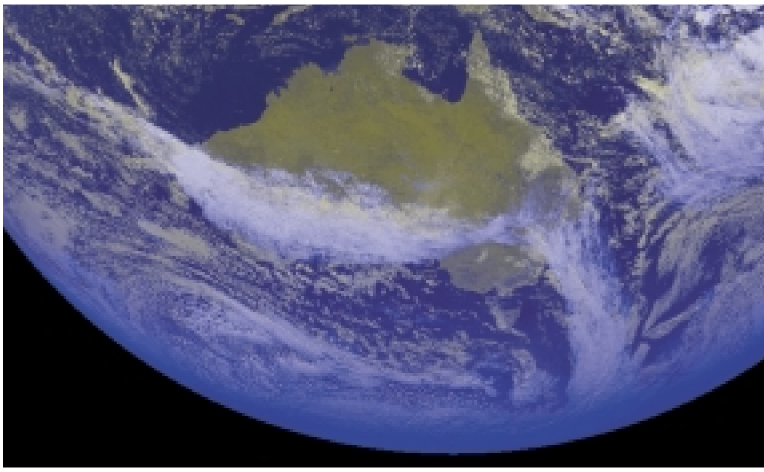
Climate Change

Projections for Australia



Cloud imagery obtained with the Geostationary Meteorological Satellite of the Japan Meteorological Agency, and processed by the Bureau of Meteorology, Australia.

Introduction

Some human-induced changes in future climate are inevitable. While international efforts to reduce emissions in greenhouse gases will limit the changes, adaptation strategies based on assessment of potential changes in regional climate and their impacts are also necessary.

This brochure summarizes current understanding of enhanced greenhouse changes to Australia's climate over the 21st century. Uncertainty in projections[1] of future climate change is addressed and quantified where possible.

Observed climate change

The Earth has warmed by 0.6 ± 0.2°C on average since 1900. Australia's continental-average temperature has risen by about 0.7°C from 1910–1999. Most of this increase occurred after 1950. Minima have generally increased more than maxima. While Australian rainfall has varied substantially over time and space, there has been no significant continental-average trend since 1910[2].

Future trends in greenhouse gases

The Intergovernmental Panel on Climate Change (IPCC) produced forty future world scenarios[3] resulting in a range of greenhouse gas and sulfate aerosol emissions (IPCC 2000). The carbon dioxide concentrations that result from a number of these scenarios, which cover the full range of possibilities explored by IPCC, are shown in Figure 1. Increases in sulfate aerosols (particles) are much less in the revised IPCC scenarios than in the 1996 IPCC assessment.

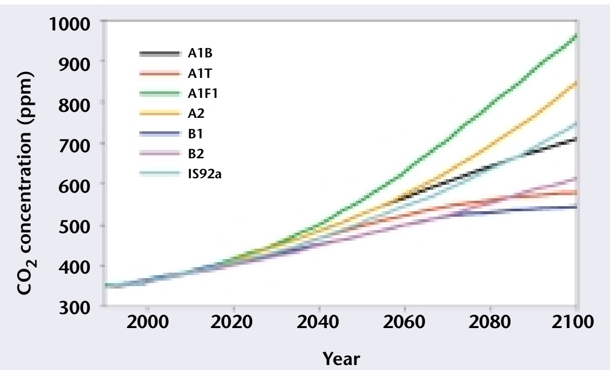


Figure 1: Atmospheric carbon dioxide (CO_2) concentrations based on various SRES emission scenarios. The IS92a mid-case scenario used by the IPCC in 1996 is also shown. From IPCC (2001a).

Global warming and global sea-level rise

From the SRES emission scenarios, the IPCC projects a globally averaged warming of 1.4 to 5.8°C by 2100 relative to 1990 (Figure 2). This range includes the uncertainty in the climate system response to enhanced greenhouse gases as well as the uncertainty in the amount of emissions. The projected rate of warming is 0.1 to 0.5°C per decade.

[1] Ranges of future climate change derived from climate models are described here as 'projections'. The term 'scenarios' is now usually applied to the climate information used in impact assessment. Our terminology has changed from that used in CSIRO (1996) to be consistent with that of IPCC (2001a).

[2] For more information on observed changes in Australian temperature and rainfall, see *www.bom.gov.au/climate/change/auscc.shtml*

[3] The IPCC Special Report on Emissions Scenarios (SRES) is based on a range of assumptions about population, energy sources and regional or global approaches to development and socio-economic arrangements. The scenarios do not include any specific greenhouse gas mitigation activities.

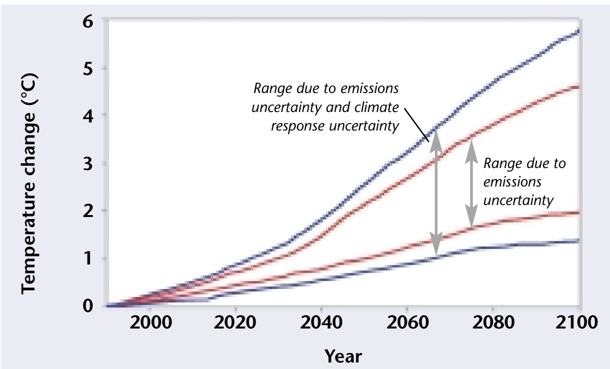


Figure 2: Ranges of global-average warming relative to 1990. From IPCC (2001a).

Since the 1970s, the observed rate of warming has been 0.15°C per decade.

Sea-level is projected to rise by 9 to 88 cm by 2100, or 0.8 to 8.0 cm per decade, associated with this warming. The observed rise over the 20th century has been 1 to 2 cm per decade.

Australian climate change

Changes in future Australian temperature and rainfall have been derived from simulations with climate models, in which the level of greenhouse gas concentrations was enhanced. Each of these models was found to have an acceptable simulation of Australia's climate under current conditions.

We present ranges of change that incorporate quantifiable uncertainties associated with the range of future emission scenarios, the range of global responses of climate models, and model to model differences in the regional pattern of climate change.

The ranges are based on:

- the global warming projections in Figure 2, which provide information on the magnitude of the global climate response over time
- the regional response in terms of local change (in degrees Celsius for temperature and in percentage for rainfall) per degree of global warming. A range of local values is derived from the differing results of nine recent climate model simulations (see Acknowledgements).

Spatial results are presented as colour-coded maps for the changes in average climate conditions by around 2030 and 2070 relative to 1990. These selected dates[4] illustrate both the changes that may be expected in the next few decades and the larger changes that may occur late in the century. The changes in climate given for these dates represent the change in average climatic conditions. The conditions of any individual year will continue to be strongly affected by natural climatic variability and cannot be predicted.

Temperature

Simulated ranges of warming for Australia are shown in Figure 3. By 2030, annual average temperatures are 0.4 to 2.0°C higher over most of Australia, with slightly less warming in some coastal areas and Tasmania, and the potential for greater warming in the north-west. By 2070, annual average temperatures are increased by 1.0 to 6.0°C over most of Australia with spatial variation similar to those for 2030. The range of warming is greatest in spring and least in winter. In the north-west, the greatest potential warming occurs in summer.

Model results indicate that future increases in daily maximum and minimum temperature will be similar to the changes in average temperature. This contrasts with the greater increase in minima than maxima observed over Australia in the 20th century.

Changes in daily temperature extremes can be influenced by changes in daily variability and changes in average maximum or minimum temperature. CSIRO modelling results for Australia indicate that future changes in variability are relatively small and the increases in average maximum and minimum temperature mainly determine the change in extremes. Changes in extreme temperatures, assuming no change in variability, are given in Tables 1 and 2.

[4] Previous CSIRO climate change statements (e.g. CSIRO 1996) also refer to these dates

Figure 3: Average seasonal and annual warming ranges (°C) for around 2030 and 2070 relative to 1990. The coloured bars show ranges of change for areas with corresponding colours in the maps.

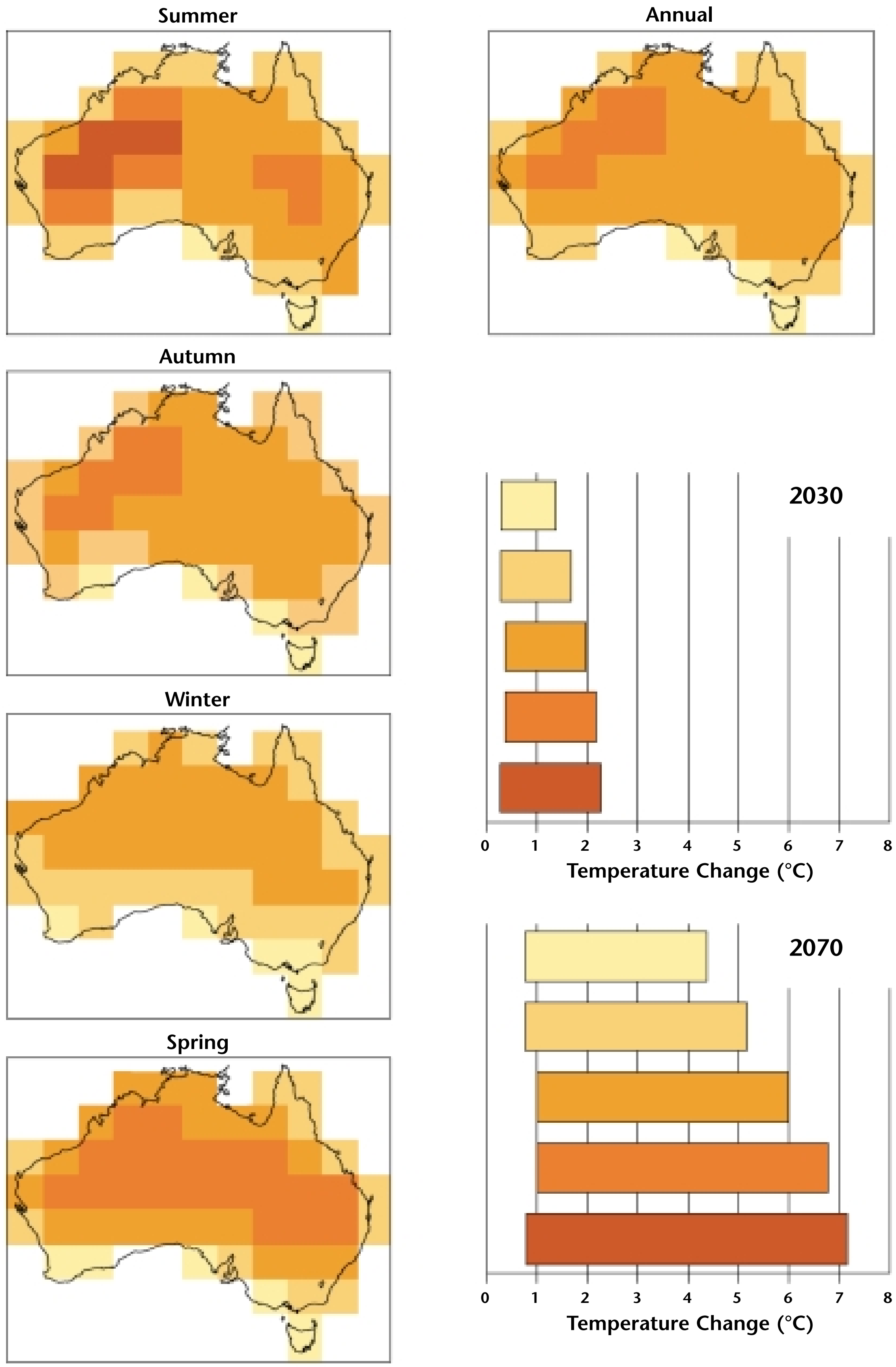


Table 1: The average number of summer days over 35°C at capital cities (excluding Darwin) for present conditions, 2030 and 2070.

Number of summer days over 35°C

	Present	*2030*	*2070*
Hobart	1	1–2	1–4
Sydney	2	2–4	3–11
Brisbane	3	3–6	4–35
Canberra	4	6–10	7–30
Melbourne	8	9–12	10–20
Adelaide	10	11–16	13–28
Perth	15	16–22	18–39

Table 2: The average number of winter days below 0°C at selected sites for present conditions, 2030 and 2070.

Number of winter days below 0°C

	Present	*2030*	*2070*
Canberra (ACT)	44	31–42	6–38
Orange (NSW)	38	18–32	1–27
Launceston (TAS)	21	10–18	0–14
Tatura (VIC)	15	6–13	0–9
Wandering (WA)	14	5–11	0–9
Dalby (QLD)	10	3–7	0–6
Nuriootpa (SA)	9	2–7	0–5

Rainfall

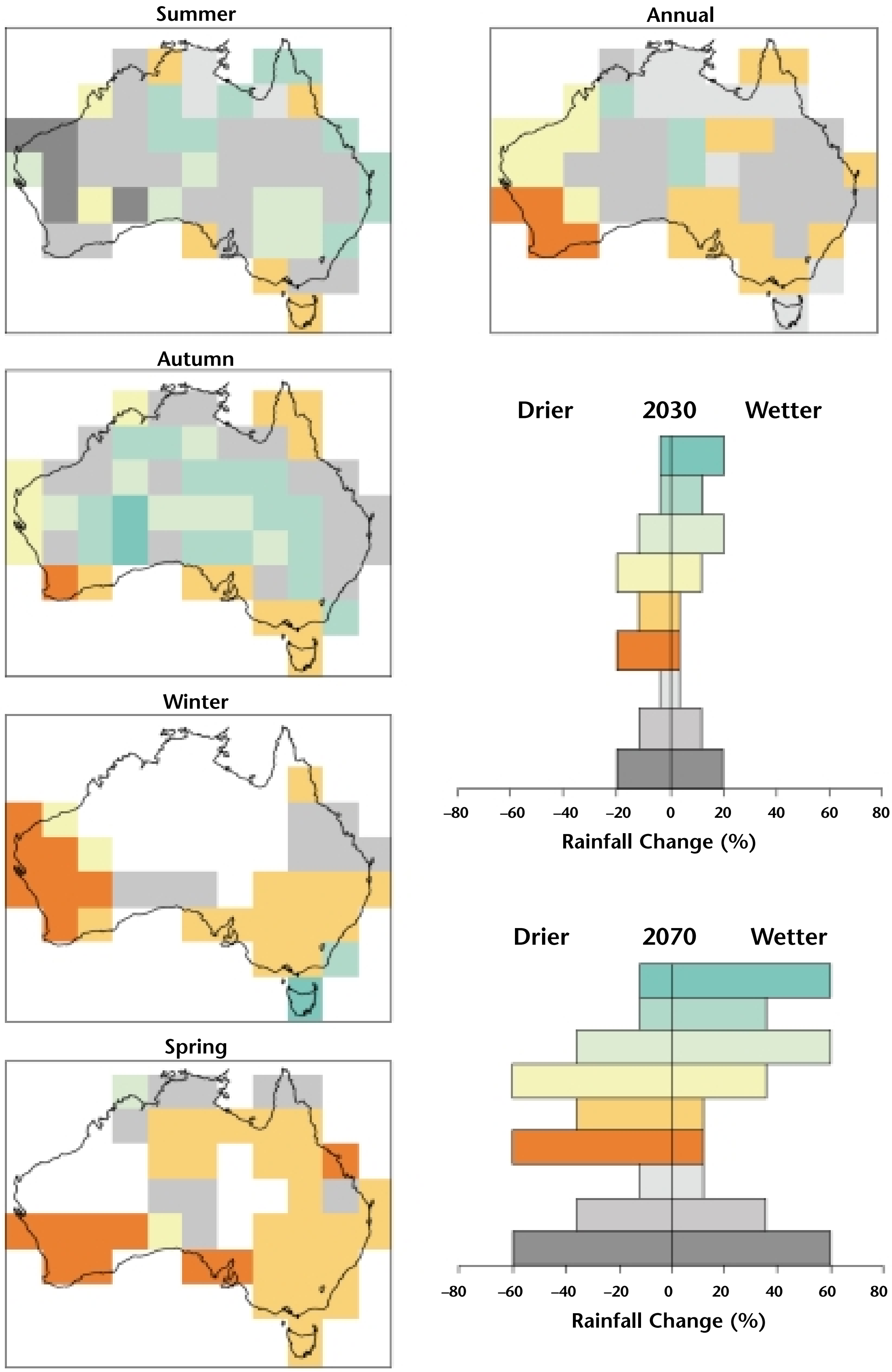
Figure 4 shows ranges of change in Australian rainfall for around 2030 and 2070. Projected annual average ranges tend towards decrease in the south-west (–20% to +5% by 2030 and –60% to +10% by 2070, rounded to the nearest 5%), and in parts of the south-east and Queensland (–10% to +5% by 2030 and –35% to +10% by 2070). In some other areas, including much of eastern Australia, projected ranges are –10% to +10% by 2030 and –35% to +35% by 2070. The ranges for the tropical north (–5% to +5% by 2030 and –10% to +10% by 2070) represent little change from current conditions.

In summer and autumn, projected rainfall ranges for most locations are –10% to +10% by 2030 and –35% to +35% by 2070 or tend towards increase (–10% to +20% by 2030 and –35% to +60% by 2070). The latter occur mainly in parts of southern inland Australia in summer and inland areas in autumn. In some parts of northern and eastern Australia in summer and inland Australia in autumn the tendency for wetter conditions is –5% to +10% by 2030 and –10% to +35% by 2070. However, for the far south-east of the continent and Tasmania, projected rainfall tends to decrease in both seasons (–10% to +5% by 2030 and –35% to +10% by 2070).

In winter and spring most locations tend towards decreased rainfall (or are seasonally dry). Ranges are typically –10% to +5% by 2030 and –35% to +10% by 2070. Projected decreases are stronger in the south-west (–20% to +5% by 2030 and –60% to +10% by 2070) while Tasmania tends toward increases in winter (–5% to +20% by 2030 and –10% to +60% by 2070).

Individual locations within a classification may show significantly narrower ranges of change. Where scenarios are required for a location-specific application, we suggest that more detailed information obtainable from the Climate Impact Group is used.

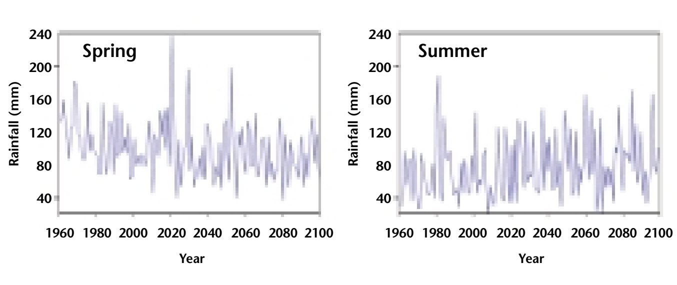
Figure 4: Ranges of average seasonal and annual rainfall change (%) for around 2030 and 2070 relative to 1990. The coloured bars show ranges of change for areas with corresponding colours in the maps. Ranges are not given for areas with seasonally low rainfall because percentage changes in rainfall cannot be as reliably calculated or applied in such regions.



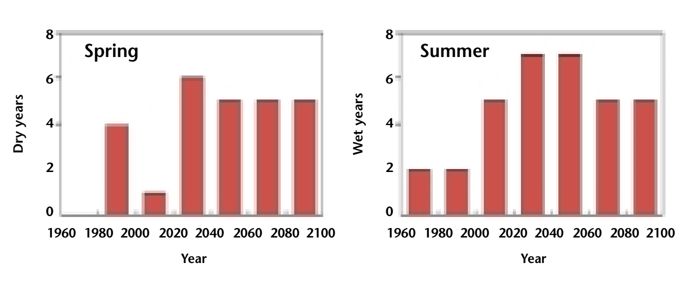
Changes in rainfall extremes: An example

Changes in average rainfall can affect the frequency of wet and dry seasons. To illustrate this effect, results from the CSIRO regional model for south-west New South Wales are considered. In this case, summers become about 15% wetter and springs become about 10% drier by 2030 *(Figure a)*. The number of extremely dry springs more than doubles after 2020, as does the number of extremely wet summers *(Figure b)*.

a



b



Regional climate model simulation for south-west NSW for (a) spring and summer total rainfall, and (b) the number of extremely dry springs (below the 4th driest year from 1961–2000) or extremely wet summers (above the 4th wettest year from 1961–2000) each 20 years. Results are based on the IPCC IS92a scenario (see Figure 1).

Where average rainfall increases, there would be more extremely wet years, and where average rainfall decreases there would be more dry spells (see example above).

Most models simulate an increase in extreme daily rainfall leading to more frequent heavy rainfall events. This can occur even where average rainfall decreases. Reductions in extreme rainfall occur where average rainfall declines significantly. Increases in extreme daily rainfall are likely to be associated with increased flooding.

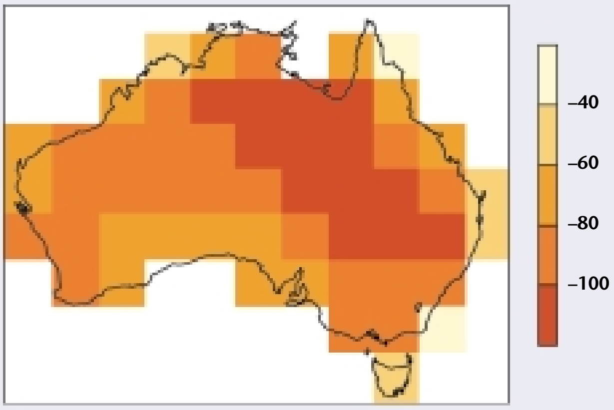


Figure 5: Average annual change (mm) in moisture balance for a 1°C global-average warming. The map is based on the average of eight climate model simulations. All regions experience increased moisture stress.

Evaporation and moisture balance

Higher temperatures are likely to increase evaporation. CSIRO has calculated projections of change in potential evaporation (atmospheric water demand) from eight climate models. The results show that increases occur in all seasons and, annually averaged, range from 0 to 8% per degree of global warming over most of Australia, and up to 12% over the eastern highlands and Tasmania. The increases tend to be larger where there is a corresponding decrease in rainfall.

The difference between potential evaporation and rainfall gives a net atmospheric moisture balance. In general, Australia has an annual net moisture balance deficit, and our environment is largely moisture-limited. When the simulated increases in potential evaporation are considered in combination with simulated rainfall change, the overall pattern shows decreases in moisture balance on a national basis. The eight-model-average is shown in Figure 5. Average decreases in annual water balance range from about 40 to 120 mm per degree of global warming. This represents decreases of 15 to 160 mm by 2030 and 40 to 500 mm by 2070. These decreases in moisture balance mean greater moisture stress for Australia.

The simulated changes show the greatest consistency in spring. Decreases in spring are greatest over eastern Australia and generally range between 20 and 100 mm per degree of global warming in individual models. Decreases in the western half of Australia range between 0 and 60 mm. Other seasons show less consistency.

Tropical cyclones

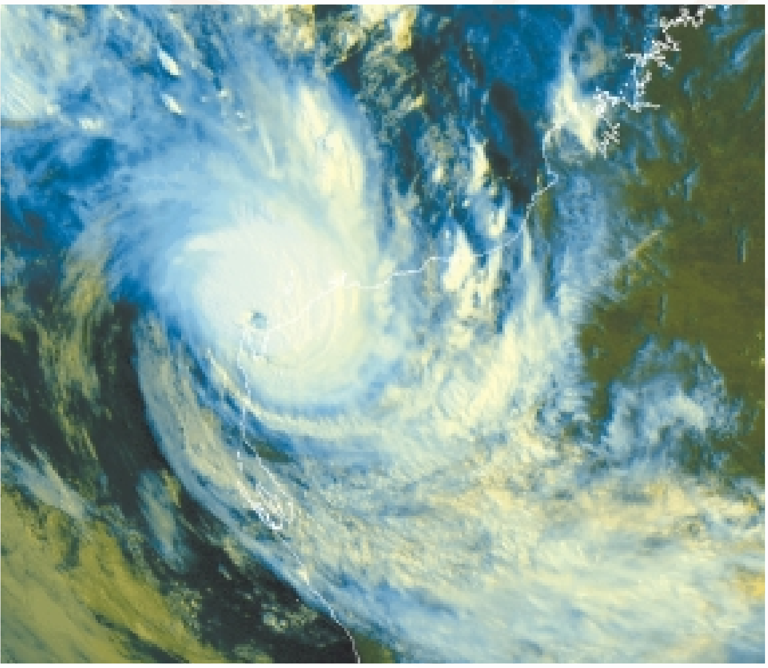
While regional and decadal variations in the frequency of tropical cyclones have been observed worldwide, no significant global trends have been detected. Projections are difficult since tropical cyclones are not well resolved by global or regional climate models. Present indications are:

- regions of origin are likely to remain unchanged
- maximum wind-speeds may increase by 5–20% in some parts of the globe by the end of the century
- preferred paths and poleward extent may alter, but changes remain uncertain
- future changes in frequency will be modulated by changes in the El Niño Southern Oscillation.

Tropical cyclones are associated with the occurrence of oceanic storm surges, gales and flooding rains in northern Australia. The frequency of these events would rise if the intensity of tropical cyclones increases. Projected rises in average sea-level will also contribute to more extreme storm surges.

El Niño Southern Oscillation

The El Niño Southern Oscillation has a strong influence on climate variability in many parts of Australia, and this will continue. Climate models do not give a consistent indication of future changes. However it is likely that global warming will enhance the drying associated with El Niño events.



Satellite image processed by the Bureau of Meteorology, originally obtained from the Geostationary Meteorological Satellite (GMS-5) of the Japan Meteorological Agency.

Uncertainties

Uncertainties about future human behaviour and shortcomings in climate modelling limit our climate change projections to ranges of change for some variables, and qualified statements on possible changes for others. Uncertainties have been quantified where possible, accounting for future greenhouse gas emissions and model to model differences in simulating both global and regional climate responses.

Greenhouse gas emissions are subject to uncertainties concerning population growth, technological change and social and political behaviour. Climate model responses are most uncertain in how they represent feedback effects, particularly those dealing with changes to cloud regimes, biological effects and ocean-atmosphere interactions. The coarse spatial resolution of climate models also remains a limitation on their ability to simulate the details of regional climate change. Future climate change will also be influenced by other, largely unpredictable, factors such as changes in solar radiation, volcanic eruptions and chaotic variations within the climate system itself. Rapid climate change, or a step-like climate response to the enhanced greenhouse effect, is possible but its likelihood cannot be defined. Because changes outside the ranges given here cannot be ruled out, these projections should be considered with caution (see Disclaimer overleaf).

Further information

This document is intended to provide a brief summary of regional climate projections for Australia. The ranges provide broadscale information. Further information relating to the production of these regional climate projections, including comparisons with previous Australia climate change statements, may be found at *www.dar.csiro.au/res/cm/projections.htm.* If scenarios are required for impact and adaptation assessment, relevant information can be obtained from the Climate Impact Group.

Impacts and adaptation are discussed in a companion brochure prepared by the CSIRO Impacts and Adaptation Working Group (IAWG, 2001). For a summary of Australian impact assessments also see IPCC (2001b).

The CSIRO Climate Impact Group has several other initiatives supporting impacts research. OzClim, a regional scenario generator and impacts software package for Australia, is available as are data from a number of global and regional climate models. Information can be obtained on a wider range of variables than summarised here, as well as high-resolution data on a 60–km or 125–km grid. Projections for the south Pacific and parts of Asia are also available.

World Wide Web

This brochure
www.dar.csiro.au/publications/projections2001.pdf

The greenhouse effect
www.dar.csiro.au/cc/default.htm

IPCC 2001 Summaries for Policymakers
www.unep.ch/ipcc

CSIRO Climate Change Research Program
www.dar.csiro.au/div/CCRP/default.htm

CSIRO Impacts and Adaptation Working Group
www.marine.csiro.au/iawg

CSIRO summary of climate change impacts
www.marine.csiro.au/iawg/impacts2001.pdf

CSIRO climate model output
www.dar.csiro.au/res/cm/data.htm

OzClim
www.dar.csiro.au/publications/ozclim.htm

References and further reading

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Most data were downloaded from the IPCC Data Distribution Centre web site at *http://ipcc-ddc.cru.uea.ac.uk.*

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