EXECUTIVE SUMMARY

This report updates some of the chapters of a previous CSIRO report on climate change and impacts on South Australia (McInnes *et al*., 2003b) focussing on temperature and rainfall. It presents results of a project undertaken by CSIRO for the South Australian Government to assess observed and projected climate change in South Australia using a new set of climate change simulations conducted for the Fourth Assessment of the Intergovernmental Panel on Climate Change (IPCC), which will be published in 2007. It provides results for SA's eight Natural Resource Management (NRM) regions. This project does not update information about changes in extreme weather, nor does it update potential impacts.

Global climate change

The Third Assessment Report of the IPCC (2001) indicates:

- There has been a warming of the lower atmosphere and upper ocean.
- Global-average precipitation over land has increased by about 2% since the beginning of the 20th century, but there have been significant regional and seasonal increases and decreases.
- Most of the global warming observed over the last 50 years is attributable to human activities.
- By the year 2100, global average temperatures may rise 1.4 to 5.8°C and global sea level may rise 9 to 88 cm, relative to 1990, if there are no explicit policies to limit greenhouse gas emissions.
- Projected changes in climate extremes could have major consequences.

New evidence (Steffen, 2006) since the Third Assessment Report of the IPCC (2001) shows:

- Most of the IPCC conclusions have been confirmed or strengthened in recent years.
- The global average surface temperature has increased by about 0.7°C during the last century.
- Heatwaves and heavy rainfall have increased in many regions, while glaciers, ice-sheets and frosts have decreased.
- Oceans are becoming more acidic.
- The global average sea level has risen 1.7 mm per year since 1900.
- There have been shifts in plant and animal locations and seasonal behaviour consistent with global warming.
- The unusual nature of the warming of the past 50 years relative to the past 1000-2000 years, based on the so-called Hockey Stick graph, has been supported by many other independent studies.
- The influence of human activities has been detected in land-ocean temperature contrasts, the annual cycle of surface temperature over land, the hemispheric temperature contrast, regional (not just global) warming, the height of the tropopause (between the troposphere and stratosphere) and the heating of the oceans.
- New information about climate feedbacks indicates a greater likelihood of warming at the higher end of the uncertainty range.

Observed climate trends in Australia and South Australia

From 1910 to 2005, Australia's average temperature increased by 0.89ºC (0.09ºC per decade), with the minimum temperature increasing by 1.14ºC (0.12ºC per decade) and maximum temperature by 0.65ºC (0.07ºC per decade). The rate of increase has accelerated since 1950 - Australia's average temperature increased by 0.95ºC (0.17ºC per decade), while the minimum increased by 1.04ºC (0.18 per decade) and maximum increased by 0.86ºC (0.15ºC per decade).

From 1910 to 2005, South Australia's average temperature increased by 0.96ºC (0.10ºC per decade), with the minimum temperature increasing by 1.13 (0.12ºC per decade) and maximum temperature by 0.79ºC (0.08ºC per decade). Since 1950, South Australia's average maximum temperature has increased by 1.2ºC (0.21ºC per decade), the minimum by 1.01ºC (0.18ºC per decade) and the average temperature by 1.1ºC (0.20ºC per decade). Thus, compared to national trends, South Australian maximum temperature indicates a faster rate of increase, while minimum temperature shows a slower rate.

Sea surface temperatures in Spencer Gulf and the Bight have risen at about half the rate of the land-based temperatures (0.05ºC per decade from 1900 to 2005 and 0.11ºC per decade from 1950 to 2005).

Australian rainfall records from 1900 to 2005 show an increasing trend over many parts of the country, except for south-western Western Australia and some parts of coastal Queensland, Tasmania and southern South Australia. However, during the second half of the century, there is a stronger tendency for decreased rainfall in south-western Australia and eastern Australia and an increase over the northwest.

Trends in South Australian annual rainfall since 1900 are generally weaker than other parts of the continent. Much of the northern half of South Australia became wetter while southern coastal regions became drier. These tendencies were strengthened during last the 55 years.

Annual and seasonal rainfall shows fluctuations on multi-decadal time scales. In South Australia, the 1920s and 1960s were dry decades while the 1970s was a wet period. Decadal fluctuations in annual rainfall are dominated by summer and spring rainfall fluctuations. Winter rainfall shows no trend with weak year-to-year variability. Rainfall in autumn shows year-to-year variability which is greater in the second half of the century.

Among three South Australian stations, two coastal stations show a decreasing trend in pan evaporation, while an inland station shows an increasing trend.

Simulating South Australia's current climate

Twenty three global climate model (GCM) experiments, with the addition of the two regional climate models, were assessed for their ability to simulate observed average (1961-1990) patterns of mean sea level pressure, temperature and rainfall in the South Australian region. Thirteen models performed satisfactorily. Temperature and rainfall projections were made using the results from those 13 models.

Average regional temperature and rainfall projections

Annual and seasonal temperature projections were constructed using two types of greenhouse gas emission scenarios: (i) those from Special Report on Emission Scenarios (SRES, 2000) which exclude policies to reduce emissions, and (ii) emission reduction scenarios that stabilise CO_2 concentrations at 450 parts per million (ppm) by 2100 or 550 ppm by 2150. Temperature scenarios for 2030 and 2070 are given in Figure E.1. By 2030 under the SRES scenarios, areas within 200 km of the coast warm by 0.2 to 1.6ºC, the region 200 to 600 km from coast warms by 0.4 to 1.6ºC, and the region more than 600 km inland warms by 0.6 to 1.8ºC. By 2070, areas within 200 km of the coast warm by 0.5 to 4.7ºC, the region 200 and 600 km from coast warms by 1.0 to 5.5ºC and the region more than 600 km from coast warms by 1.2 to 5.5ºC. Spring and summer show greater warming than winter and autumn. If CO_2 concentrations are stabilised at 550 ppm by the year 2150, the upper limit of warming is reduced by 23% by 2030 and 38% by 2070. If CO_2 concentrations are stabilised at 450 ppm by the year 2100, the upper limit of warming is reduced by 25% by 2030 and 48% by 2070.

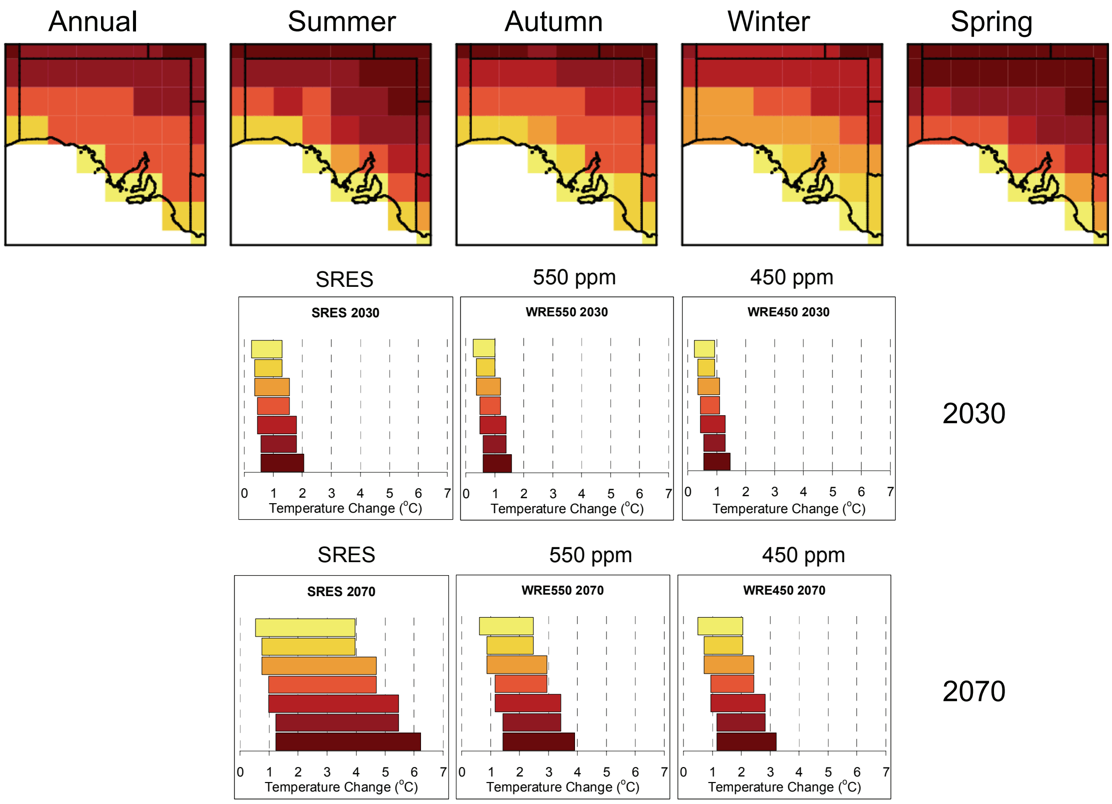

***Figure E.1:** (a) Average seasonal and annual warming ranges (°C) for around 2030 and 2070 relative to 1990 for SRES scenarios, and CO_2 concentrations stabilised at 450 ppm by 2100 and 550 ppm by 2150. The coloured bars show ranges of change for areas with corresponding colours in the maps.*

Projected rainfall changes are more complex than the temperature projections, as rainfall projections show stronger spatial and temporal variations as well as large variations between models. A tendency for decreases is dominant (Figure E.2). Under the SRES scenarios for 2030, the region within 200 km of the coast shows annual rainfall changes between -15 and 0%, while regions further inland show changes between -15 and +7%. By 2070, the region within 200 km of the coast shows annual rainfall changes between -45 and 0%, while regions further inland show changes between -45 and +25%. There are significant differences in projected changes among the seasons. Summer and autumn show increases and decreases, but decreases dominate winter and spring. As for temperature, the magnitudes of projected rainfall changes are significantly smaller for the stabilisation scenarios.

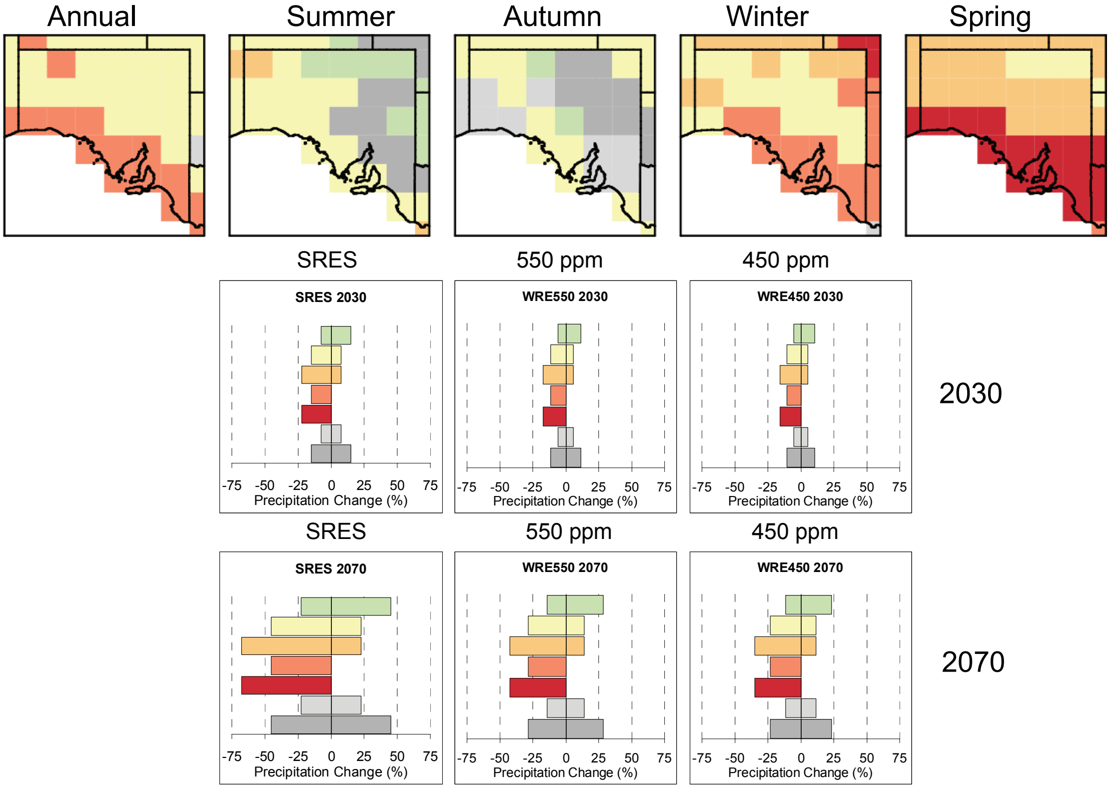

***Figure E.2:** Average seasonal and annual rainfall change (%) for 2030 and 2070 relative to 1990 for SRES scenarios, and CO_2 concentrations stabilised at 450 ppm by 2100 and 550 ppm by 2150. The coloured bars show ranges of change for areas with corresponding colours in the maps.*

Projections for eight NRM regions

Inland or northern regions such as Alinytjara Wilurara and South Australian Arid Lands show annual warming between 0.5 and 1.5°C by 2030 and between 1.2 and 4.7°C by 2070, while coastal or southern regions (Adelaide and Mt. Lofty Ranges, Eyre Peninsula, Kangaroo Island, Northern and Yorke, SA Murray Darling Region and South East) show warming between 0.3 and 1.3°C by 2030 and between 0.6 and 3.8°C by 2070. Significantly reduced warming is projected for CO_2 stabilisation scenarios.

Rainfall changes show increases and decreases, but decreases dominate. Annual rainfall changes in Alinytjara Wilurara and South Australian Arid Lands are between -9 and +1% by 2030 and between -25 and +4% by 2070. In coastal or southern regions, annual rainfall changes are between -10 and 0% by 2030 and between -30 and -3% by 2070. Large decreases occur in spring with moderate decreases in other seasons. Significantly reduced warming and rainfall changes are projected for CO_2 stabilisation scenarios.

The enhanced greenhouse signal in temperature emerges from the natural variability around the year 2000 and simulations show it becomes stronger in the second-half of the 21st century. For rainfall, large natural variability and differences between model simulations indicates that it will be difficult to detect an enhanced greenhouse signal in annual rainfall before 2050 in South Australia. However, an enhanced greenhouse signal appears to emerge from natural variability around 2000 for Kangaroo Island and the Eyre Peninsula. More rigorous attribution studies are needed to separate the natural and anthropogenic trends.

Downscaling

There is a strong demand for appropriate downscaling methods to obtain fine resolution climate information from coarse resolution climate model simulations. This is critical where topography and extreme weather phenomena are important, such as southern part of South Australia. Fine resolution climate change information can be derived through statistical and dynamical downscaling methods. However, as this addresses only one of a range of uncertainties associated with projecting regional climate change, the expense involved in this approach needs to be considered. Fine resolution climatic information for use in impact assessment can also be prepared using simple interpolation simulated changes to a fine-resolution observed climate database. This can be done using CSIRO's OzClim scenario generator. However, not all risk assessment and management practices require fine resolution information.

Risk management

Strategies for addressing climate change and its potential consequences are increasingly being viewed by both public and private institutions in a risk management context. Risk-based tools have been applied to better understand different magnitudes of impacts on agriculture, water resources, and coastal infrastructure. There is a growing interest in using such information in current planning decisions.

Despite public concern about climate change, effective communication of climate change science, impacts and adaptation remains challenging. Novel tools for fostering discussions about climate change with different audiences are emerging at an ever-growing rate, but they must compete for the public's attention with a range of other priority issues.

Scientists and public and private institutions must work collectively to build upon recent advances in assessing and communicating climate risk. Access to resources – human, financial, and technical – for risk assessment and adaptation remains limited, particularly for local governments, which are likely to be the focal points for climate change impacts and adaptive responses.

Recommendations for further research and planning

A significant degree of climate change across South Australia now seems inevitable, and is likely to become increasingly apparent during the second half the 21st century as carbon dioxide concentrations in the atmosphere exceed twice the pre-industrial level. Changes are to be expected in both the average values and in the magnitude and frequency of extremes. This means that long-term planning should not be predicated on the assumption that future climate statistics and resources will be as they were over the last century. Significant adaptation to a changing climate will be necessary.

Climate change will have significant impacts on water supply, floods, sea level and storm surges. This has strong implications for coastal ecosystems and sustainable development of planned infrastructure including coastal development, ports, bridges and urban centres.

Higher temperatures and lower rainfall would lead to an increase in drought and fire that could have increasing impacts on biodiversity, agriculture and forestry. Significant changes in management may be required to minimise costs, maximise benefits and ensure environmental sustainability.

Decadal scale climate change is expected to affect the present functional capacity of ecosystems in South Australia. Some animal and plant species are likely to come under increasing stress, causing long-term change in species composition.

Coastal ecosystems will also be affected by sea level rise and changes in runoff. Globally sea level is expected to rise faster in the future due to thermal expansion of the oceans and melting of mid and low-latitude glaciers. An increase in temperature in the Antarctic region would initially lead to an increased accumulation of ice, but to increased meltwater contributing to sea level rise beyond the twenty-first century.

Significant uncertainties remain in relation to the estimation of future climate. These can be reduced by:

- Developing climate change scenarios based on improved and much finer resolution GCMs and regional climate model simulations.
- Improving the ability of GCMs to simulate climatic processes that influence South Australia as well as the whole of Australia.
- Improving climate change scenarios using new statistical and dynamical down scaling methods.

Climate impact and adaptation assessment should be done through a range of approaches including:

- Risk assessment using a bottom up approach, i.e. participation of key stakeholders in project design, workshops and communication.
- Development of versatile climate impact models and methodologies for a number of key sectors and activities. These models should be developed and tested as soon as possible. Priorities should be on the basis of potential sensitivity, impact model availability and stakeholder interest, and should include a wide range of sectors, such as agriculture, forestry, fisheries, water resources, coastal impacts, health, indigenous communities, biodiversity, transport, land planning, energy sector, urban infrastructure, emergency services and tourism.
- The impact assessment work will need to be done through close collaboration between scientists and stakeholders. Where appropriate integrated impact and adaptation assessment should be carried out.