

# Climate research: opportunities and challenges

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On decadal to century timescales, climate prediction is influenced by internal climate variability and external drivers such as increasing greenhouse gas concentrations and changes in aerosols (fine particles in the atmosphere). Over these time scales, trends may be detected, such as the global average surface warming of 0.6°C since 1900 (IPCC, 2001). Most of the warming over the last 50 years is attributable to human-induced changes in greenhouse gases and aerosols. There has also been a warming of the lowest 8 km of the atmosphere, a decrease in global snow cover and sea-ice extent, a rise in global average sea level of 0.1-0.2 metres since 1900, and warming of the deep ocean. Since at least 1946 there has been an almost global increase in extreme maximum temperatures, a decrease in extreme minimum temperatures, and an increase in extreme precipitation (Frich et al., 2002). In some regions, there has been an increase in continental drying and associated risk of drought (IPCC, 2001). Australian droughts have become hotter since 1973 (Nicholls, 2003). The drought of 2002-2003, and the associated impacts on agriculture, water resources and fire, were probably made more severe than past droughts due to greenhouse warming (Karoly et al., 2003).

Prediction of future climate change in the coming decades has become an important global issue. Rather than simply extrapolating observed trends, we use computer models of the climate system driven by scenarios of greenhouse gas and aerosol emissions. The scenarios for the 21st century are based on various assumptions about demographic, economic and technological change. The climate models are based on our understanding of the Earth's physics and dynamics, and they include the land surface (soil and plants), ocean, atmosphere and polar ice. Calculations are made on a set of grid points that are spaced regularly in the horizontal direction, over a number of layers in the vertical direction. Due to the complexity of the models and the cost of running super computers, the spacing between data points is about 200 km, which limits regional detail. Nevertheless, global climate models

reproduce most aspects of the present climate with sufficient accuracy to give us confidence in broad-scale climate projections. Finer-resolution climate models (data points 50 km apart) or statistical down scaling techniques can be used over small regions to provide better regional projections.

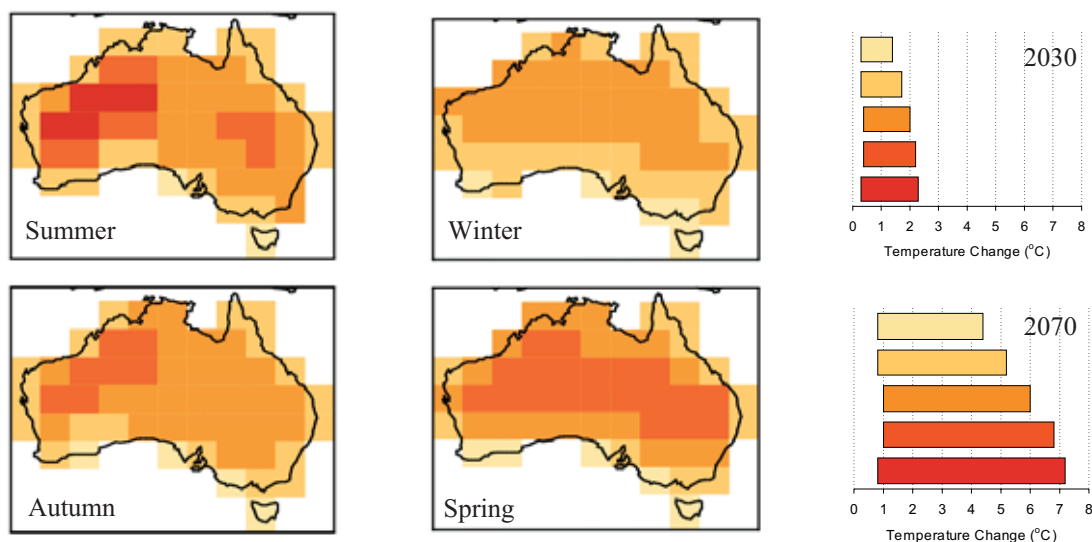
The models indicate that global average temperatures will rise by 1.4-5.8°C between 1990 and 2100, with land areas warming faster than the oceans, and the polar regions warming faster than the tropics (IPCC, 2001). This large range of uncertainty is due to two factors: (i) the range of emission scenarios (behavioural uncertainty) and (ii) the range of climate sensitivity to a given emission scenario due to differences between climate models (scientific uncertainty). The trend toward more hot days and fewer cold days will continue. A more El-Niño-like pattern of ocean temperatures is projected in many models. Global average precipitation and surface evaporation are likely to increase, with a tendency for decreased precipitation in some mid-latitude regions, including Australia. Heavier precipitation events are likely, and wind-speeds of tropical cyclone peak may strengthen in some regions. Glaciers will continue their widespread retreat and the Greenland ice sheet is likely to lose mass, but the Antarctic ice sheet is likely to gain mass. Global-average sea level may rise 0.09-0.88 metres between 1990 and 2100. Changes in smaller-scale phenomena such as thunderstorms, tornadoes, hail and lightning are not simulated in coarse-resolution global climate models, so projections have not been made.

Based on analysis of climate change patterns simulated by nine climate models, most of Australia is expected to warm 0.4-2.0°C by 2030 and 1-6°C by 2070 (CSIRO, 2001), which is slightly faster than the global average. Warming is expected to be slightly higher inland than near the coast and less in winter than in summer (Figure 1). By 2030, a 10-50% increase in the number of summer days over 35°C is expected in many cities, with a 10-80% decrease in frosty

winter days (Table 1). A tendency for more summer rainfall on the east coast and more autumn rainfall inland is simulated. A tendency for less rainfall is expected over most of southern and eastern Australia, particularly in winter and spring (Figure 1). The models indicate that declining average rainfall is associated with increases in the frequency of serious rainfall deficiency (3-month total rainfall in the lowest 10% on record). For example, comparing 30-year periods centred on 1980 and 2080 in Victoria, the number of serious rainfall deficiencies doubles in spring and summer in three of the nine models analysed (Whetton and Suppiah, 2003). In general, extreme daily rainfall increases, except in areas and seasons with large decreases in average rainfall such as south-western Australia.

Annually averaged from 1961-1990, most of Australia has 500-2000 mm more potential evaporation than rainfall. This can be considered an atmospheric moisture deficit, an extreme example of which occurred in the 2002-2003 drought. The combined effect of projected changes in precipitation, temperature and potential evaporation over Australia will enhance the existing moisture deficit. For example, in south-eastern Australia, including the Murray-Darling Basin, the scenario for 2030 is an annual-average decrease in atmospheric moisture of 20-130 mm, relative to 1990 (Figure 2).

### Temperature



### Rainfall

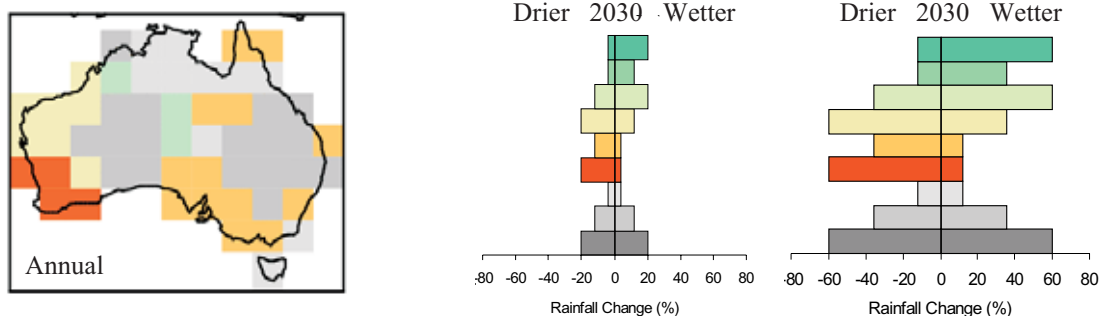


Figure 1: CSIRO projections of changes in seasonal temperature and rainfall by 2030 (upper scale) and 2070 (lower scale). The colours in the map correspond to the coloured bars. The length of each bar represents a range of warming relative to 1990, e.g. Tasmania warms 0.3 to 1.4°C by 2030.

Table 1: CSIRO projections of the average number of winter days below 0°C and summer days over 35°C at selected sites for present conditions and for years 2030 and 2070.

**Winter days below 0°C**

**Summer days over 35°C**

	Present	2030	2070		Present	2030	2070
Canberra (ACT)	44	31-42	6-38	Hobart	1	1-2	1-4
Orange (NSW)	38	18-32	1-27	Sydney	2	2-4	3-11
Launceston (Tas)	21	10-18	0-14	Brisbane	3	2-6	4-35
Tatura (Vic)	15	6-13	0-9	Canberra	4	6-10	7-30
Wandering (WA)	14	5-11	0-9	Melbourne	8	9-12	10-20
Dalby (Qld)	10	3-7	0-6	Adelaide	10	11-16	13-28
Nuriootpa (SA)	9	2-7	0-5	Perth	15	16-22	18-39

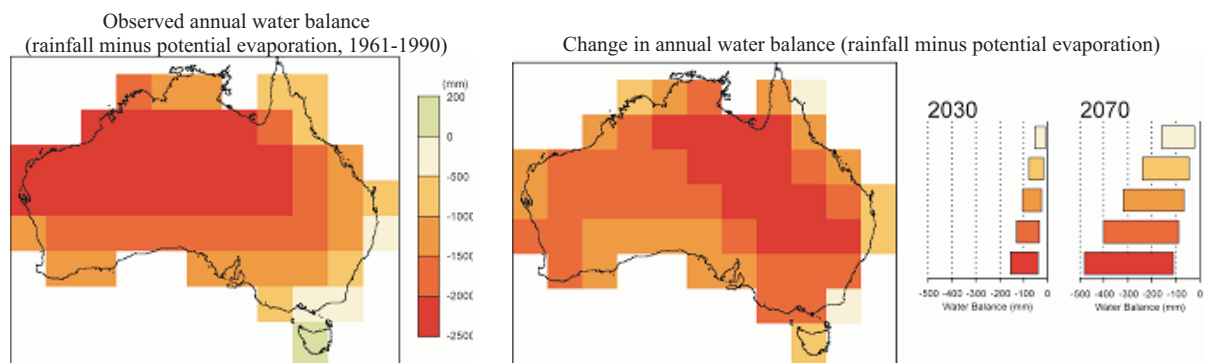


Figure 2: Annual average Australian moisture balance (rainfall minus potential evaporation) for (a) 1961 to 1990 and (b) changes projected by eight climate models for 2030 and 2070 relative to 1990. For example, in south-west NSW, the average moisture balance is –1000 to –1500 mm (net moisture deficit) and the change by 2030 is –20 to –130 mm (greater moisture deficit).

During the 2002-2003 drought, a number of communication issues arose. CSIRO formed a Drought Communication Network to ensure that the latest information was shared, that responses to queries were directed to relevant contacts, and that public statements were coordinated. The Network covered five CSIRO Divisions, with greenhouse issues being referred to CSIRO Atmospheric Research. The main communication issues were:

- keeping abreast of the latest developments in the drought status and forecasts by maintaining a close working relationship with the National Climate Centre (NCC), attending monthly NCC Climate Outlook briefings, accessing

Australian rainfall forecasts from NCC, Queensland Department of Primary Industries and CSIRO, and attending relevant drought workshops, e.g. National Drought Forum in Brisbane in April 2003;

- responding to questions raised by the media, sceptics and government about the role of greenhouse warming in intensifying the drought;
- improving community awareness of past and projected climate change, e.g. through briefings, distribution of reports/brochures, media interviews;

- building partnerships with regional land and water resource managers to quantify future risks associated with drought and climate change;
- emphasizing the need for risk management through planned adaptation to anticipated climate change, in addition to reducing greenhouse gas emissions.

Opportunities for climate prediction, using existing capabilities, include:

- applying techniques for regional detection and attribution of observed climate change, e.g. explaining the cause of the drying since 1970 in south-western Australia;
- providing more detailed regional climate change information for Australia using fine-resolution regional climate models and/or statistical down scaling;
- providing better projections for extreme events, e.g. tropical cyclones, storms, hail, drought;
- working with decision-makers to assess the effectiveness of current climate risk management strategies, use model predictions to quantify future climate-related risks, and identify enhanced adaptation strategies.

Challenges for climate prediction, requiring development of capabilities, include:

- narrowing the range of uncertainty in emission scenarios and providing probabilities for each scenario;
- narrowing the range of uncertainty in climate sensitivity, which is significantly affected by the representation of clouds, aerosols, oceans, vegetation dynamics and ice in models;
- deriving projections of regional sea-level rise rather than global-average sea level;
- improving the realism of ENSO in global climate models.

## References

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