

# Climate Change: Snapshot for Australia 2008 – with reference to Water Resources

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## The Climate Change Challenge

With the release in 2007 of the Fourth Assessment Report from the International Panel on Climate Change (IPCC AR4), there is now scientific and international consensus that climate change is occurring, and that impacts of this change can already be observed. The term *climate change* refers to a directional change in climate, beyond natural bounds of variability, that is attributed to human activity and alters the composition of the atmosphere. Over the past 100 years or so, the levels of carbon dioxide (CO<sub>2</sub>) and other greenhouse gases have increased dramatically in the Earth's atmosphere – primarily from the burning of fossil fuels and land clearing. The current concentration of CO<sub>2</sub> in the atmosphere (ca. 380 ppm) is already about 100 ppm higher than preindustrial times and the levels associated with interglacial states (Steffen 2006). Emissions of CO<sub>2</sub> continue to accelerate on a global scale, with their growth rate increasing from 1.1%/yr for 1990-1999 to >3%/yr for 2000-2004 (Raupack *et al.* 2007).

The main concern with climate change is the projected rapidity of change, with current projections suggesting a global average warming in the range of 1.1 °C to 6.4 °C in a mere 100 years (IPCC AR4; with best estimates in the range 1.8 °C to 4.0 °C), compared with thousands of years for similar changes historically. It appears likely that a substantial proportion of organisms and many natural systems may not have time to adapt to this rapid change given the evolutionary timescales at which they normally adapt to change. Another key factor adding to the vulnerability of natural systems to climate change is the unprecedented levels of landscape fragmentation. Fragmentation leads to isolation and discontinuity of ecosystems and creates artificial barriers – each of which limits dispersal, migration and resilience. In addition, experts have identified a decline in the efficiency of natural CO<sub>2</sub> sinks on land and in the world's oceans to absorb anthropogenic emissions (Canadell *et al.* 2007) – weakening of these natural carbon sequestering capacities in the Earth system is likely to further accelerate climate change.

The recent (October 2007) report by Australia's CSIRO, *Climate Change in Australia: Observed Changes and Projections*, concurs that warming of the global climate system over the past century is beyond doubt - as evidenced by increasing atmospheric and oceanic temperatures, sea level rise (from thermal expansion of seawater and melting ice masses), increasing ocean acidity, and accelerated melting of snow and ice. Importantly, the report stresses that while global warming can be slowed through reductions in greenhouse gas emissions, we are now locked into a period of unavoidable change. Warming of the atmosphere and oceans will continue – the rate and duration depending on prevailing greenhouse gas concentrations; sea level rise has substantial inertia and will continue beyond 2100 for many centuries, as will changes to ocean acidity and ice cover. Many experts consider that climate change and its impacts may be the dominant driver of biodiversity loss and change in ecosystem services globally. This has significant implications for the quantity, quality, accessibility, and usability of Australia's water resources.

## Observed Changes and Climate Change Projections

### *Temperature*

Since 1950, average temperatures have increased over most of Australia by 0.9 °C, with significant regional variations. The frequency of hot days and nights has increased and the frequency of cold days and nights has declined (CSIRO 2007AA). The CSIRO (2007a) report also predicts substantial increases in the frequency of days over 35 °C, and less extreme cold days with fewer frosts likely. The best estimate of annual warming over Australia by 2030 relative to 1990 is about 1.0 °C under a scenario of mid-range greenhouse gas emissions

(CSIRO 2007a). The range of uncertainty is about 0.6 °C to 1.5 °C, with warming less in coastal areas compared to inland. While the pattern of warming varies little seasonally, projections suggest less warming in winter, particularly in the south (CSIRO 2007a).

Later in the century, the level of predicted warming is more dependent upon the assumed greenhouse gas emission scenario, however temperatures of up to 5 °C are predicted for some parts of Australia by 2070 under a high emissions case, particularly in the north. For the high emissions case there is around a 30% chance of exceeding 3 °C in southern and eastern coastal areas, with a much greater chance inland. The IPCC 4AR process determined for the Australia/New Zealand region that water security and natural ecosystems shift from the realm of adaptive capacity into a high vulnerability status at about a 2 °C increase in temperature (see Hennessy *et al.* 2007). Scientists estimate that the maximum degree of climate change that can be tolerated without significant loss of biodiversity is a temperature rise of about 1.5 °C compared to preindustrial levels (see Steffen 2006).

## **Rainfall**

Since 1950, most of eastern and south-western Australia has experienced substantial rainfall declines, with the largest drying along the east coast exceeding 50 mm per decade (CSIRO 2007a). It is also recognised that the last 5 to 10 years mark one of the most severe droughts in Australia's history (BoM 2006 and 2007). Conversely, in north-western and central Australia extreme daily rainfall intensity and frequency has increased over the same period. An abrupt decline in rainfall occurred in south-west Western Australia (WA) in the mid-1970's. This region derives much of its winter rain from passing cold fronts and associated storms, and since the 1970's these have decreased or moved more southerly over the ocean. Importantly, the average winter rainfall decline of 10 - 15 % in south-west WA over the past 30 years has produced a corresponding reduction in average annual flows of up to 50% in some rivers and streams; this highlights the sensitivity of these aquatic systems to climate change. This case also highlights that one of the major impacts of the rainfall decline in southern and eastern Australia is the reduction in surface water available for storage.

Australian rainfall patterns naturally show considerable variability from year-to-year, partly in association with the El Niño - Southern Oscillation (ENSO). Notable dry years generally coincide with major El Niño events, while the very wet years coincide with La Niña events. Such high natural variability in rainfall patterns means that it is much harder to predict changes in rainfall for a particular region under future climate change than it is for temperature. Nevertheless, rainfall records show that there has already been a steady decrease in winter and spring rainfall in southern Australia, and this is predicted to continue (CSIRO 2007a). Decreases in rainfall are also likely in: southern areas for the annual average and in winter; southern and eastern areas in spring; and along the west coast in autumn (CSIRO 2007a). CSIRO projections for 2030 best estimates of annual rainfall change indicate a decrease of about 2 to 5 % (except in the north). In summer and autumn, decreases are smaller and there may be slight increases in New South Wales in summer. According to CSIRO (2007a), natural variability on a decadal-scale is comparable in magnitude to these projected changes in rainfall and may therefore mask, or significantly enhance, the greenhouse-induced changes.

## **Extreme Events**

There are some indications that climate change could alter the effects of the El Niño Southern Oscillations (ENSO), which have a strong influence on Australia's climate. In addition to changing rainfall patterns, this could increase the intensity and/or frequency of extreme weather events such as tropical cyclones, drought, fire, severe storms and floods in some regions. Of particular importance to Australia's agricultural sector is the finding of the CSIRO (2007a) report that due to projected changes in rainfall and increases in evaporation, soil moisture is likely to decline over much of southern Australia. The report also suggests that hail risk may increase over the south-east coast.

## Climate Change Impacts

For Australia, in addition to a general warming and drying trend, the frequency and intensity of extreme events will be a critical feature of climate change impacts. Overall, the impacts of climate change are likely to subject Australia's terrestrial, aquatic, coastal and oceanic environments to major change and potential damage. As the driest inhabited continent and an ancient land of low productivity soils and oceans, Australia is highly vulnerable to the compounding effects of a changing climate. For a range of likely impacts see Table 1; there is emerging evidence that a number of these changes may already be occurring. Also from an Australian perspective, abrupt shifts in the behaviour of known modes of climate variability such as ENSO and the Asian Monsoon system would have potentially very significant consequences (Steffen *et al.* 2006). The ENSO phenomenon exerts a strong influence on eastern Australia, and a strong El Niño event can cause a 1% decrease in Australia's GDP (Steffen *et al.* 2006).

**Table 1: Some likely impacts of climate change for Australia (sources: CSIRO Marine and Atmospheric Research; Bureau of Meteorology; Department of Climate Change).**

Likely bio-physical change from climate change drivers	
Sea level rise and storms	<ul style="list-style-type: none"> <li>sea level rise from thermal expansion of the ocean and glacial melt, and increased frequency or intensity of extreme storms - leading to higher risk of inundation and flooding.</li> <li>shoreline erosion and realignment - leading to loss of amenity or damage to assets (natural and human).</li> </ul>
Warmer ocean temperatures	<ul style="list-style-type: none"> <li>increased frequency of coral bleaching events (present models project the Great Barrier Reef will warm by 2 to 5° C by 2100).</li> <li>potential impacts on biodiversity, affecting the distribution and reproductive patterns of marine organisms, and consequently productivity).</li> </ul>
Ocean acidification	<ul style="list-style-type: none"> <li>increased CO<sub>2</sub> concentration in sea water is altering ocean chemistry and impacting on calcitic organisms, such as planktonic coccolithophores, corals, and molluscs.</li> </ul>
Tropical cyclones and storm surges	<ul style="list-style-type: none"> <li>combined with higher sea levels, the projected increase in intensity, and possibly frequency, of tropical cyclones would cause more intense (and frequent) coastal flooding.</li> <li>tropical cyclones may occur further south.</li> <li>there are likely to be shifts in prevailing wind and wave climates.</li> </ul>
Decreased rainfall and drought	<ul style="list-style-type: none"> <li>warmer temperatures will cause greater evaporation, increasing the severity of drought for a given decrease in rainfall.</li> </ul>
Run-off changes	<ul style="list-style-type: none"> <li>changes in climate over land will cause changes in run-off reaching coastal and marine systems, altering the availability and quality of freshwater – this has implications for productivity and ecosystem function of coastal and estuarine environments.</li> <li>related changes in riverine flooding frequency and intensity.</li> </ul>
Ocean stability and currents	<ul style="list-style-type: none"> <li>changes to wind and water temperature affect water-column stratification and stability – leading to changes in upwelling of nutrient-rich deeper waters and productivity of surface waters.</li> <li>changes to ocean currents may affect dispersal, recruitment and distribution patterns of marine organisms, and therefore biodiversity.</li> </ul>
ENSO	<ul style="list-style-type: none"> <li>some models suggest global warming may lead to an increase in the frequency or intensity of El Niño events – if so, Australia may have more intense droughts and La Niña floods, particularly in the eastern part of the country.</li> </ul>
Increased fire and wind	<ul style="list-style-type: none"> <li>increased frequency and/or intensity of aeolian dust and fire-born particulates can affect coastal productivity and promote blooms.</li> </ul>
Snow, frost and hail	<ul style="list-style-type: none"> <li>decrease in snow cover, average season lengths and peak snow depths, and a tendency for maximum snow depth to occur earlier in the season.</li> <li>fewer frosts are likely</li> <li>likely to be an increased hail risk along south-eastern coastline, with a decreased risk along southern coastline.</li> </ul>

For natural environments, the threat of climate change is also compounded by other pressures such as pollution, invasive species, or extractive activities. In particular, Australia's coastal zone is highly vulnerable to the impacts of climate change due to the large proportion of the population living on the coast (ca. 85%), the large number of assets in the region (human and natural), and the extent of likely biophysical change at the land-sea interface (Newton 2007). The coast is also the conduit to Australia's export economy, with over 70 onshore and offshore trading ports, and one-third of ship losses are already linked to weather-related problems

(Newton 2007). Importantly, as a result of reduced precipitation and increased evaporation, water security problems are projected to intensify by 2030 in southern and eastern Australia (Hennessy *et al.* 2007). Risks to major infrastructure are also likely to increase. By 2030, it is expected that design criteria for extreme events are very likely to be exceeded more frequently (Hennessy *et al.* 2007). Risks include failure of floodplain protection and urban drainage/sewerage, increased storm and fire damage, and more heatwaves and blackouts.

## **Water Resources and Climate Change**

Australia is the driest inhabited continent and rainfall and stream flow are naturally highly variable. Most lowland rivers experience periods of dry and flood, and often have large floodplains with connected wetlands. Southern rivers have been extensively dammed to provide a reliable water supply for agriculture and urban use; in contrast rivers in the northern tropical regions are largely unmodified but they carry two thirds of Australia's surface water (Beeton *et al.* 2006). The often conflicting demands of irrigated agriculture, conservation of ecosystem services and biodiversity, and urban supply are placing Australia's scarce water resources under increasing pressure. This situation is exacerbated by drought and growing dependence on groundwater (Beeton *et al.* 2006).

Climate is a fundamental driver of the water cycle. Climate change projections of future warming and associated rainfall decreases are likely to increase water demand and reduce supply, further increasing the pressure on this key resource (Steffen *et al.* 2006). In addition, increases in the intensity of daily rainfall are likely to place increased pressure on urban drainage capacity and catchment management. However, at present little quantitative information is available about potential changes in flood risk in Australia. Changes in the water supply of the city of Perth over the past few decades exemplify the risks Australian cities are facing from climate change, and apart from Darwin, all major Australian cities have been on water restrictions during recent years. The Murray-Darling Basin, Australia's largest river basin, accounting for some 70% of irrigated crops and pastures – is expected to experience a fall in annual streamflow of 10 – 25% by 2050, with projections of up to 48% by 2100 (see Hennessey *et al.* 2007). There is also a 50% chance by 2020 of the average salinity of the lower Murray River exceeding the 800 EC threshold set for desirable drinking and irrigation water (MDBMC 1999). It is expected that toxic algal blooms are likely to become more frequent and last longer with climate change. However, at present there are no integrated assessments of the impacts of climate change on runoff quantity and quality, salt interception and revegetation policies, and water pricing and trading policies (Hennessy *et al.* 2007). Little is known about future impacts on groundwater in Australia.

## **Need to Act and Adapt**

The period through to 2030, and to a lesser extent 2050, is one that is most relevant today for decisions about adaptation strategies (Allen Consulting Group, 2005). As yet knowledge is limited as to what extent Australia will be impacted by climate change and what form the flow-on socio-economic ramifications may take. Natural disasters already cost the Australian community billions of dollars per year, and it is expected that climate change will reduce the return period or increase the intensity of some climate-driven weather extremes (eg. winds, floods, fire, etc). Poleward shifts in distribution and changes to phenology (eg. breeding, flowering, migration times, etc) have already been observed within some Australian terrestrial and marine ecosystems which has implications for conservation and natural resource management.

Recent observations suggest that, globally, we have been tracking the upper limits of climate change projection models (eg. sea level rise) – so greater change than first thought may be in order. There is clearly an urgent need to:

- improve knowledge and mechanisms to help better understand, predict and prepare for the likely challenges of climate change,

- continue abatement of greenhouse gases, and
- mainstream and integrate climate change considerations into policy development, planning and management.

Experts (eg. Stern report; CSIRO Energy Futures Forum) recognise that the global benefits of taking early action to avoid climate change, will far exceed the costs of not acting. Decision makers from government, industry and the community need to consider options for reducing their vulnerability to climate change.

Climate change is occurring now, and despite the uncertainties there is a window of opportunity to act and adapt now, before critical thresholds are breached (some experts consider this window may be as narrow as 5 - 10 years). However, the non-climate factors affecting vulnerability and resilience remain poorly studied, including the social, economic, institutional, technological and governance conditions. Sensitivities, thresholds and 'tipping points' of human and natural systems need to be determined to facilitate avoiding damage and irreversible change from climate impacts.

Evaluation of past adaptation by communities would be valuable in identifying cost-effective options. For example, the story of the south-western WA wheat farmers represents a positive demonstration of adaptation, with wheat yields increasing over the 30 year period of abrupt rainfall decline. Capacity is required by the community to understand climate change information and make informed decisions on adaptation responses. However currently, decision-makers are hampered by a general lack of long-term data series and monitoring across a range of sectors and disciplines. People will need to understand that historical experience and past trends may no longer be a reliable predictor of the future. Therefore there is a need for national benchmarking to enhance confidence and consistency of decision-making, combined with effective education and extension programs to raise community awareness of climate change and likely impacts.

Climate change has important implications for Australia's water resources and aquatic systems, including the ecosystem services they deliver. Significant proportions of Australia's wetland areas of international and national importance occur in regions likely to be highly vulnerable to climate change. For example, recent work by CSIRO reported that Lake Albacutya in the Wimmera region of western Victoria, a Ramsar listed wetland, would be unlikely to ever fill under best estimate climate predictions for 2030 (CSIRO 2007b).

The inherent capacity for Australia's aquatic systems to adapt to climate change varies but is probably limited for most - therefore, other stressors will need to be reduced to increase resilience to the likely impacts of climate change. Some examples of options for increasing resilience include:

- maintaining riparian forests and vegetation
- restoring/maintaining ecological flows
- reducing nutrient loading
- minimising spread of pests
- minimising groundwater withdrawal
- minimising the threat of acid sulphate soils
- assisting dispersal/migration corridors/buffers, and
- strategic placement of new reservoirs.

Important water reforms such as the National Water Initiative, the recent *Water Act 2007*, the national plan for water, and related COAG initiatives, such as the Murray-Darling Basin Reform MoU, are all essential tools to help develop the adaptive capacity required to adequately respond to climate change and its implications for Australia's water resources. However, there remains a critical need for data on water needs, where the water is, its condition, and who is using it. The recent expansion of the Bureau of Meteorology's role to significantly enhance the

quality and utility of Australia's water information (ie. via its new Water Division) as mandated by the *Water Act 2007*, should address much of this critical need.

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