Climate Change
How real is it, the issues and implications?

Professor Bob Miles[1]

[1] *Executive Director, Institute for Sustainable Regional Development, Central Queensland University*

Abstract

The community's knowledge and understanding of climate change is fragmented and confused by a myriad of conflicting information and political posturing. This appears to be largely driven by commercial interests about climate change and its causes. What is needed is a readable objective synopsis of the available evidence to date and an evaluation of the likely impacts to the community, industry and the environment.

The reason why this information is now needed is that many parts of the eastern sea board of Australia have in the past 50 years recorded a significant and progressive decline in average rainfall e.g. Mackay 80mm per decade (25% reduction based on historical metrological records). Projected declines include a further 15% reduction by 2030 and a further 40% reduction by 2070. Annual average temperature has also risen at rates higher than previously recorded changes.

Implications of this decline in rainfall include risk and reliability in water supply, land use changes, health issues for the aged, energy use, agricultural productivity, industry restructuring, infrastructure planning, conservation and biodiversity, and pest and disease issues.

It is the purpose of this paper to provide a practical and objective overview of what is known about climate change in Australia (with specific reference to Queensland) and what it will mean for business, the community and the environment. This pragmatic approach deals with the actual changes that are being recorded and the implications of these trends.

Introduction

For many people confusion still exists about climate change, how real is it, what does it mean, what are the impacts and can we ameliorate them, and how do we adapt. These questions have encouraged Scientists and Governments throughout the world to allocate resources and effort to understand the complex interrelations and systems that influence our climate (IPCC 2001a). This collaborative effort has largely been directed at (a) the science of climate change (b) the implications and (c) adaptation strategies. Of primary interest is the concern about the impact that the changing climate will have on the global economy. One of the major products to emerge from this effort has been the establishment of the International Panel on Climate Change (IPCC) (IPCC 2001a).

This international co-operative body was formed to assess the state of knowledge on climate change in terms of observation, theory and modeling. Three working groups of leading edge, internationally recognized scientists, from countries throughout the world were brought together to undertake this task. The groups focused on:

1. The science behind understanding climate change and the cause,
2. The impacts of the change in climate and possible adaptation strategies, and
3. The mitigation of the impacts (IPCC 2001a).

In 2001 the IPCC released the third assessment report of the working groups. While now four years on, the work by the IPCC is still recognized by Governments throughout the world as the benchmark information on climate change.

These IPCC reports included findings which on the surface, seemed of no concern; statements such as *"The global average surface temperature has increased over the 20th Century by 0.6^{o} C"* (IPCC 2001b).

While seemly insignificant to many, the impact is on the length of the freeze-free season in the mid latitudes and high latitudes and the number of days in summer above 35^{o}C in countries like Australia. The implications of this at a regional level include the impacts on pests and disease, frosting on crops, health care for the aged and the level of energy demand for cooling (IPCC 2001c). For example, in Australia the CSIRO have predicted that the average number of days in summer over 35^{o}C in Brisbane is expected to rise from an average of three to thirty by 2070 (CSIRO 2003).

Translating the IPCC findings to the Australian context and assessing the implications and adaptation strategies required is now a priority. For the past decade scientists within the Queensland Government (Queensland Centre for Climate Applications (QCCA)), the CSIRO and the Australian Bureau of Meteorology and others have been working toward this goal and have publicly expressed their concern over the significant and emerging trends in climate for Australia (BoM 2003; CSIRO 2003). A summary of these concerns and findings follow.

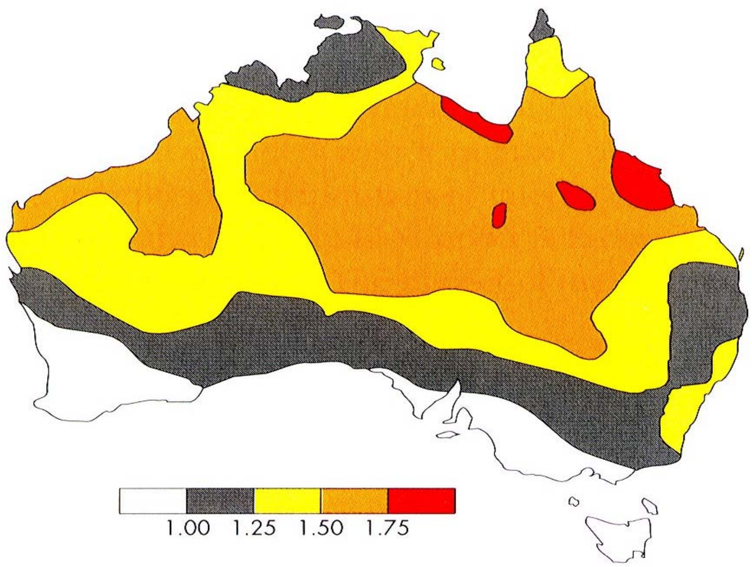
Australia's average temperature varies by up to one degree Celsius from year to year, however Australia has experienced a warming trend of about 0.8°C since 1910, most of this since 1950. Averaged over Australia, maximum temperatures have risen 0.56°C since 1910 and minimum temperatures have risen 0.96°C, with the largest warming since about 1950 (BoM 2003). According to CSIRO projections released in mid-2001, which use as their reference point the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC a 2001), annual average temperatures over most of the continent could be up to 2°C higher than 1990 by 2030. By 2070, average temperatures are projected to increase by up to 6°C. Warmer conditions will produce more extremely hot days and fewer cold days and frosts. Greatest warming is to be expected in spring and winter will warm the least.

Australia's current rainfall averaged over the whole continent is about 450mm a year, varying between 300-800mm in any one year (with the variability much larger in specific regions). According to the CSIRO projections, rainfall decreases are projected for the southwest of Western Australia and for parts of the southeast of the continent and Queensland. Most other locations have an even chance of wetter or drier conditions. Decreases are projected to be most pronounced in winter and spring. Some inland and eastern coastal areas are projected to become wetter in summer, and some inland areas to become wetter in autumn. These projections include the effect of simulated changes in El Niño and La Niña events.

Over the past two years scientists have been voicing the emerging need to start including the risk factors into the decision making framework of policy makers and regional planners. This paper collates the current understanding of the trends already being recorded and discusses the implications in this real-time data for regional planning and policy makers. The following are largely drawn from information available through the IPCC, the Australian Bureau of Meteorology, the Australian Academy of Science, CSIRO and the Australian Greenhouse Office. A detailed review of Climate activities in Australia is provided by Australian Bureau of Meteorology (2003) and a detail treatise is also provided by the Australian Greenhouse Office BoM 2003).

Key drivers and historical trends in Australia's climate

Australia is recognised as one of the driest continents on earth and parts of Queensland have the highest recorded climate variability in the world (figure 1(a) and (b)) (Nicholls et al 2003 unpublished Love 2005). What is of particular note is the very high degree of variability concentrated on the eastern seaboard around the tropic of Capricorn and the generally high level of climatic variability in the Australian regions in the mid latitude, particularly Queensland.



Source: Nicholls, Drosdowsky and Lavery, Bureau of Meteorology Research Centre, from a paper 'Australian rainfall variability and change', yet to be published.

Figure 1 (a) Climate variability expressed as the order of magnitude of variability.

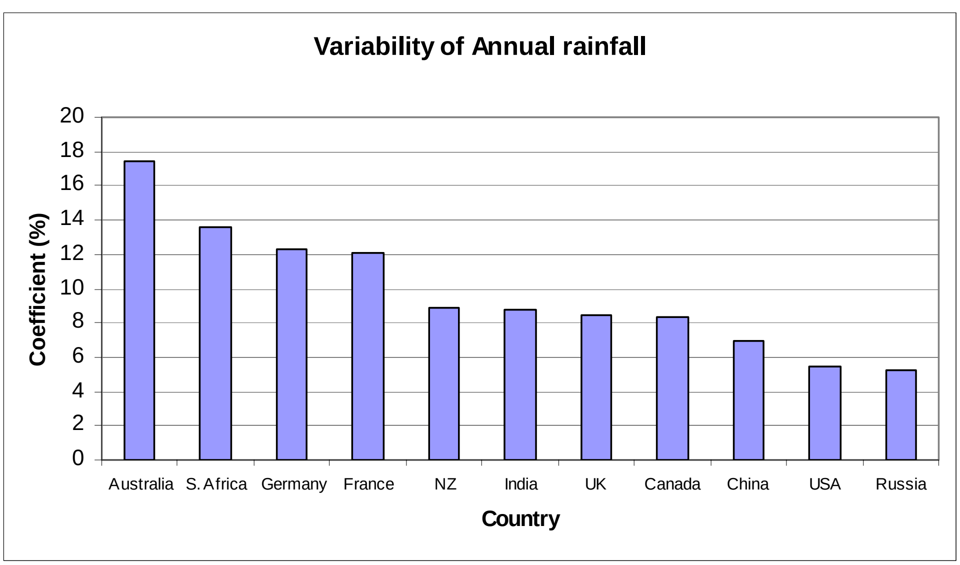


Figure 1 (b) Climate variability expressed as the coefficient of variability (Love 2005).

Climate is influenced by many factors but one which is emerging as a key driver of climate in Australia is referred to as the Walker Circulation or more commonly known as the Southern Oscillation. Simply, as the sea surface temperatures on the eastern coast of Australia rise, with a concurrent cooling in the eastern equatorial and eastern pacific, Australia experiences La Nina type conditions. This translates to generally above average rainfall (figure 2). When the western pacific cools, the eastern coast of Australia experiences El Nino like conditions or, generally lower than average rainfall (figure 3).

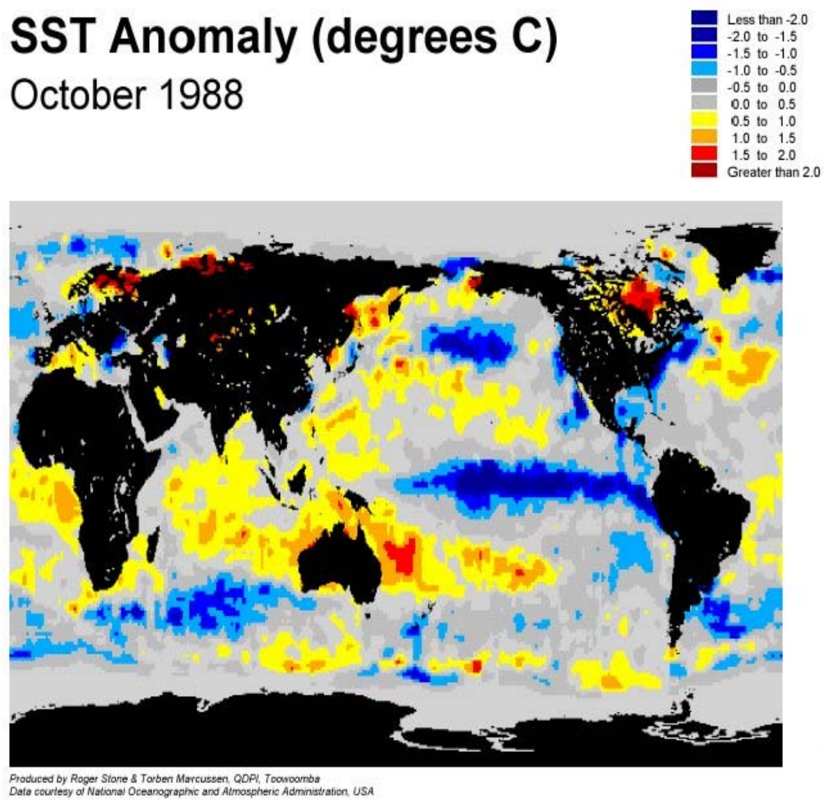


Figure 2 A classic La Nina where higher than above average rainfalls would be generally experienced along the eastern seaboard of Australia. Ocean temperatures are expressed in degrees Celsius variation from the mean.

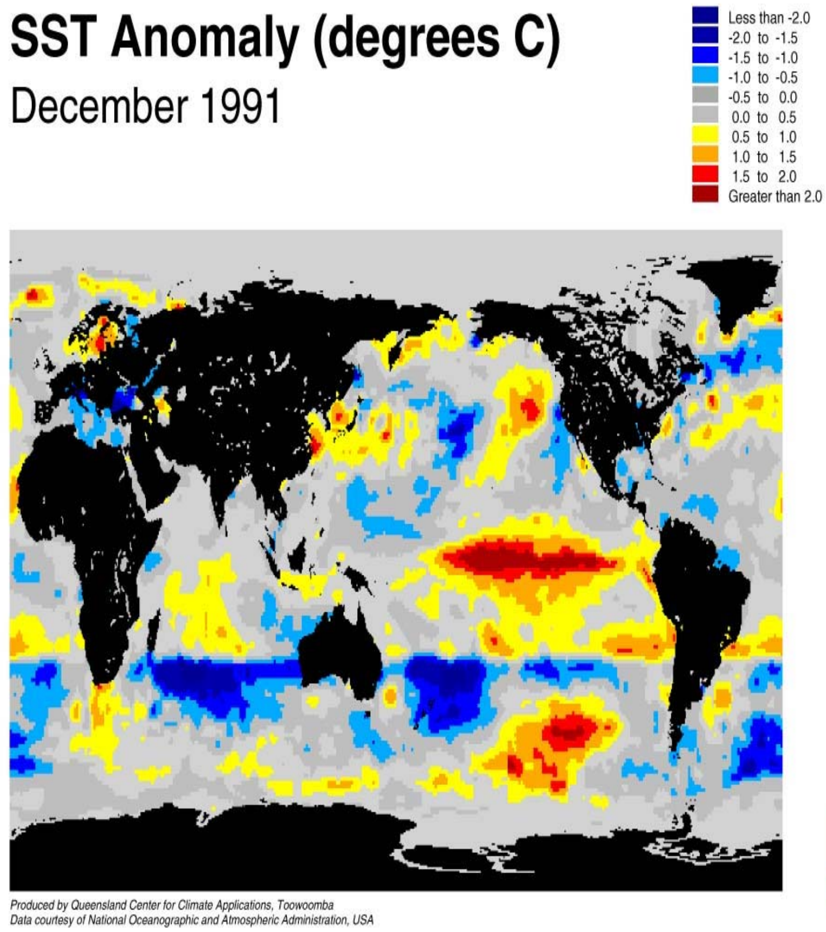


Figure 3 A classic El Nino where lower than average rainfalls would be generally experienced along the eastern seaboard of Australia. Ocean temperatures are expressed in degrees Celsius variation from the mean.

The measure of these changes is often expressed to as changes in the Southern Oscillation Index (SOI). This index, which is based on the barometric pressure differential between Tahiti and Darwin, provides a useful data set to detect and assess any changes to this pattern over time. The IPCC reported that El Nino events (which have a major impact on Queensland rainfall and river systems) "*have become more frequent, persistent and drying during the past 20 to 30 years compared to the previous 100 years*". The IPCC went on to say that many world climate models predict more El Nino like mean conditions to prevail. The projected changes expected during the 21st Century include increased summer drying over most continental interiors of the world with decreased crop yield, decreased water resource quantity and quality and increased risk of forest fires (IPCC 2001a).

The changes in this index over the past 30 years and the impact on eastern Australian rainfall are graphically presented in figure 4. The graph shows the significant number of El Nino conditions occurring in the past 30 years. These changes in the SOI correlate with the wetter periods experienced in the seventies and the late eighties with very dry conditions prevailing in the intervening periods and over the past decade.

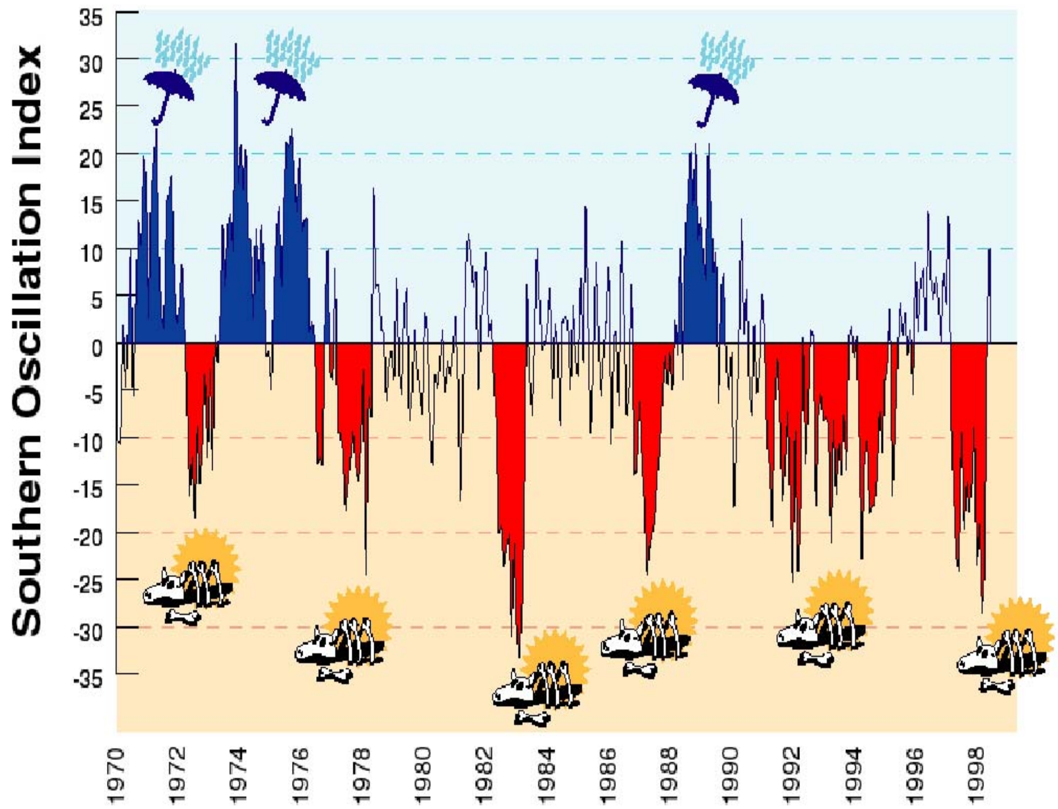


Figure 4 The relationship between positive and negative Southern Oscillation Index values and wet and drought conditions in Queensland

Given the difficulty in identifying trends within the high levels of variability experienced in Australia's climate, techniques referred to as smoothing are used to assist in identifying trends. Smoothing is simply, mathematically creating a moving average. This suppresses normal variability and highlights any longer term trends. The change in the long term SOI is clearly evident as the SOI reached some threshold in the mid 1970's (figure 5). What is not known from this data is - will this trend continue and if so for how long. However as indicated above, the IPCC believe that "*El Nino like mean conditions will prevail*".

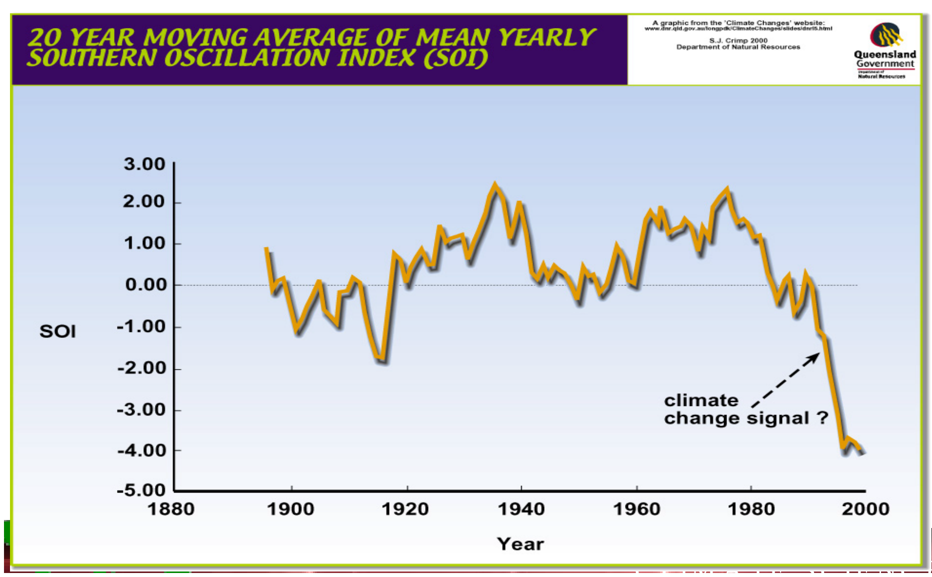


Figure 5 Long term 20 year moving average of the Southern Oscillation Index (SOI) since 1880 (by courtesy of Steven Crimp Department on Natural Resources and Mines, Queensland)

The changes in the SOI are also reflected in significant changes in cyclonic activity/movement. During El Nino conditions, cyclones form in the equatorial areas and track south then east, moving off the coast of Queensland with very little consequent rain (figure 6). In La Nino type conditions the cyclones form in the equatorial areas and then track south and west bringing rain to the eastern sea board of Australia. The reverse rainfall pattern also applies to the western coast of Australia and will be discussed later.

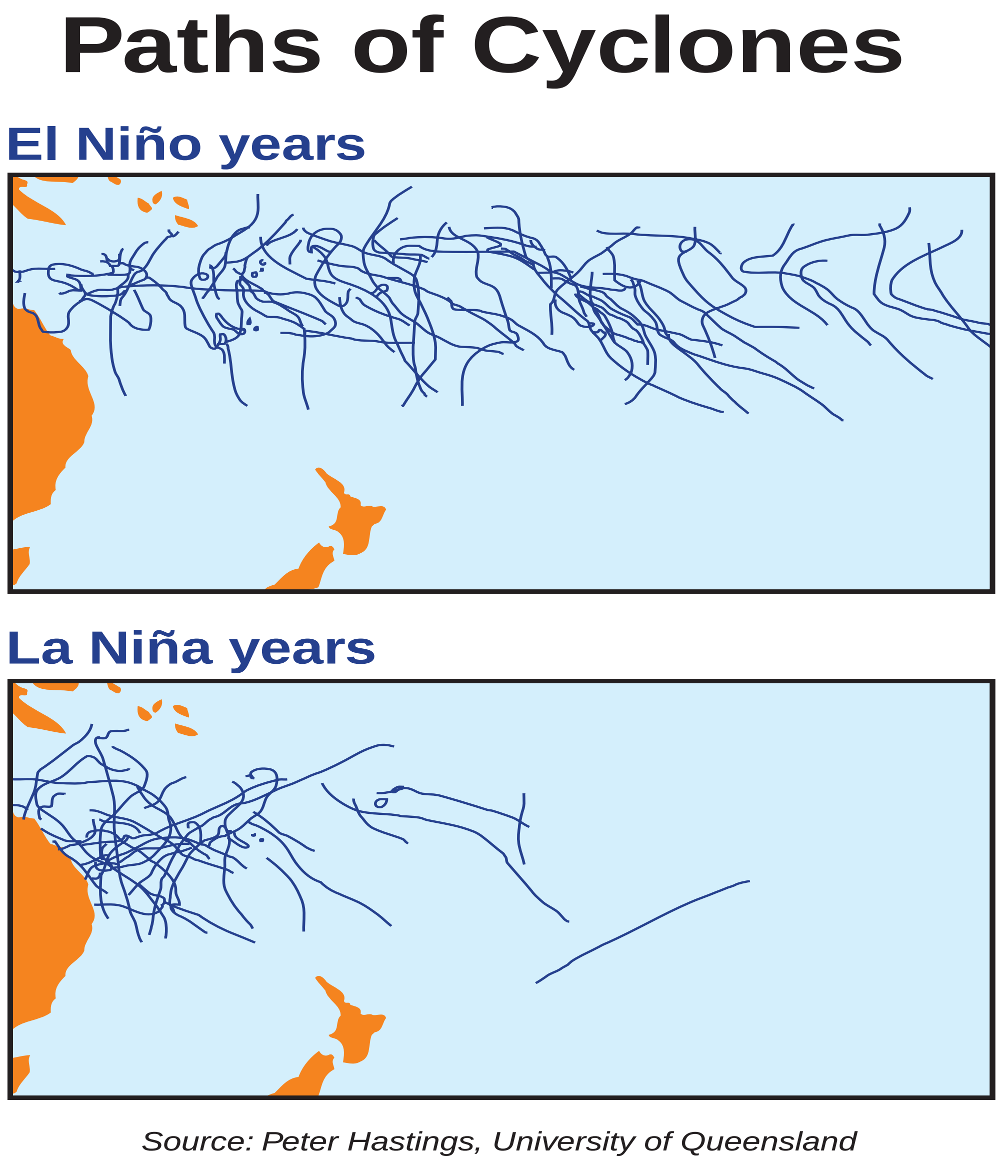


Figure 6 Patterns of cyclone movement in El Nino and La Nino years

The patterns referred to above have been recorded over a relatively small geological time frame. The world climate has been known to go into dry and wet phases over extended periods of time. By using parallel climate ensembles scientists have been able to look back through time and record the relativity of the current changes which correlates to climate in the past.

Carbon Dioxide (CO_2) accumulates in the polar ice caps and provides a useful record of CO_2 levels in the atmosphere in the past. By taking deep ice cores from the poles scientists have been able to go back 400,000 years to record changes in past levels of atmospheric CO_2. The levels of CO_2 have been shown to vary quiet considerably. However as can be seen in figure 7, in the past 100 years the atmospheric CO_2 levels have increased well beyond any scale recorded in the past 400,000 years.

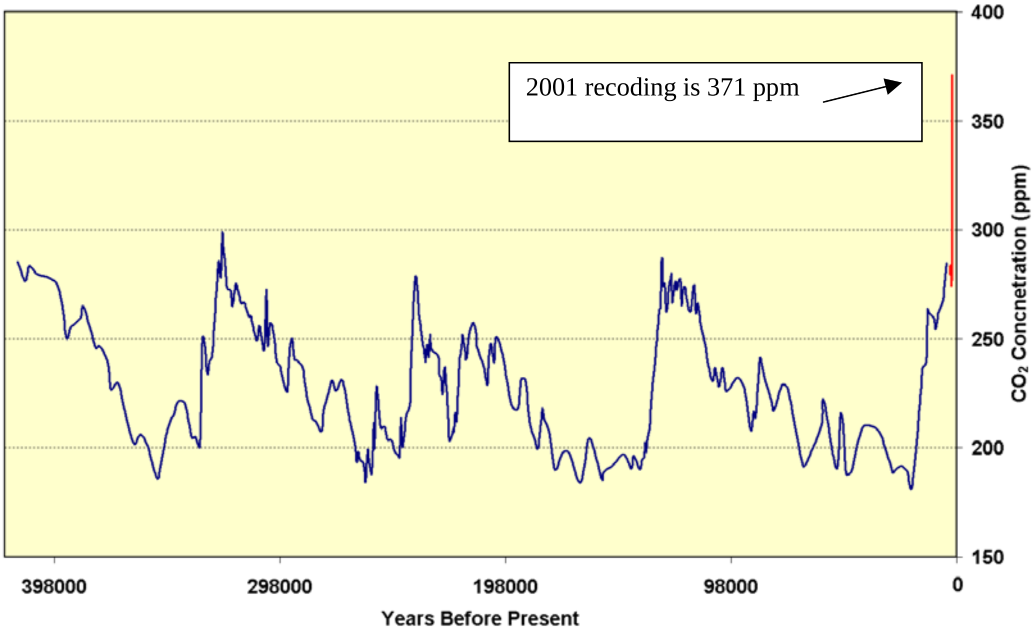


Figure 7 Carbon Dioxide levels CO_2 recorded in the past 400,000 years. Note the current level is 371ppm – significantly the highest ever recorded.

The CSIRO analysed the correlation between atmospheric CO_2 and temperature over the past 1000 years (CSIRO, 2003). The research found a very high correlated trend between increased CO_2 level and increased temperature in the past 100years (Figure 8).

A more detailed analysis of this data provides evidence of the link between anthropogenic activity and the changes in temperature that are being recorded (CSIRO 2003). The natural sources of variability such as solar and volcanic activity result in random variation along a continuing average. The trend is the same as what has been experienced for thousands of years. However, when the addition of greenhouse gas emissions and sulfates from industrial activity are added to the model the increases recorded in our current temperature is accounted for (Figure 9).

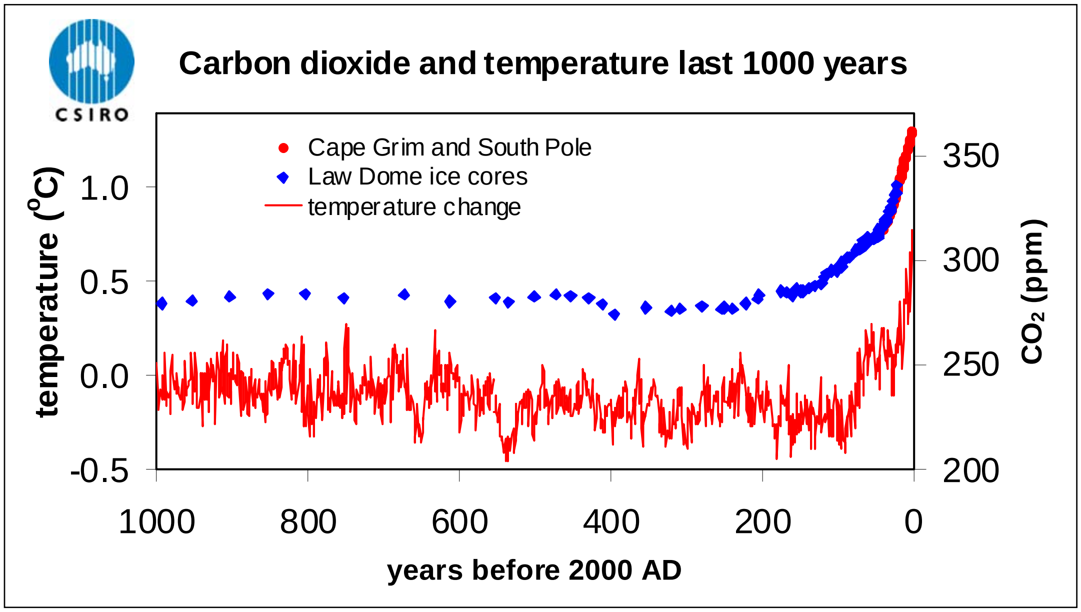


Figure 8. The correlation between temperatures change and CO_2 levels over the past 1000 years (Source CSIRO 2003)

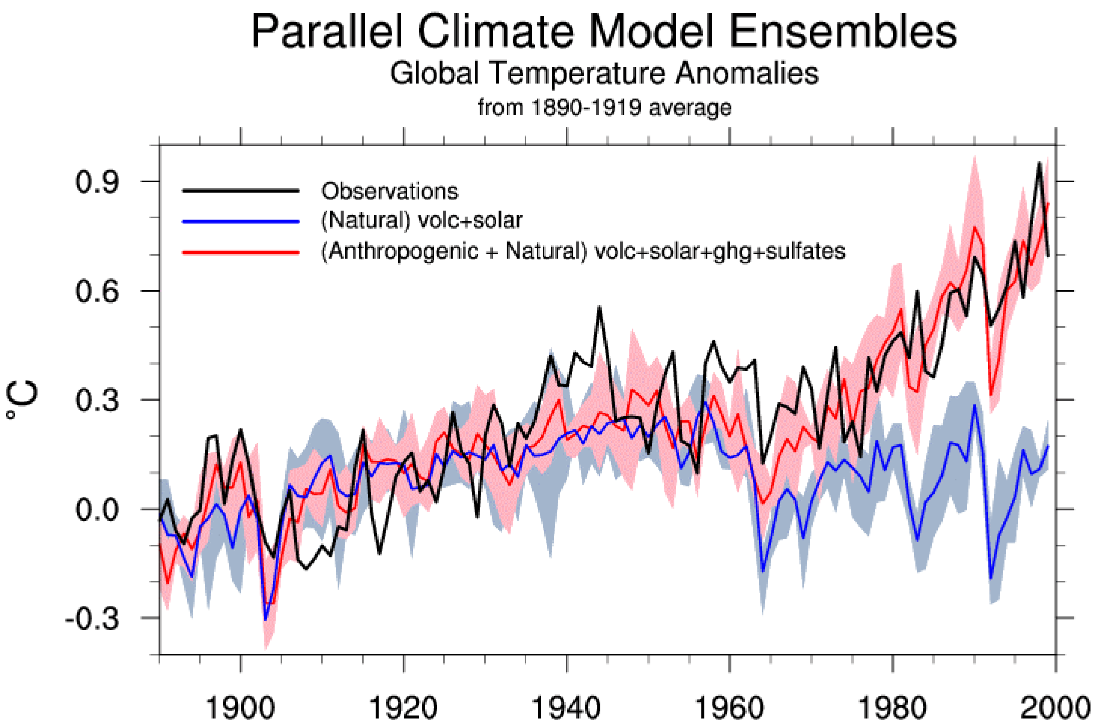


Figure 9. Parallel climate model ensembles of global temperature anomalies (Source CSIRO 2003)

Temperature changes for much of Australia are expected to increase by as much as six degrees by 2070 (IPCC 2001c) (figure 10). Such increases will have a significant impact on pests. For example, the extent and spread of the mosquito borne diseases such as Malaria and Ross River Fever (IPCC 2001c). In addition the temperature increases will have significant impact on our ageing population and their general well being (IPCC 2001c). This will be particularly evident as the number of days increase above the comfort thresholds of 27^0C. As indicated above, projection for the number of days where the temperature reaches above 35^0C in summer for Brisbane are expected to increase from the current three to over thirty in the next 70 years. Concurrent with an increase in temperature is an increase demand on energy to cool our buildings (IPCC 2001). This compounds a problem of how to source this energy without creating more greenhouse problems.

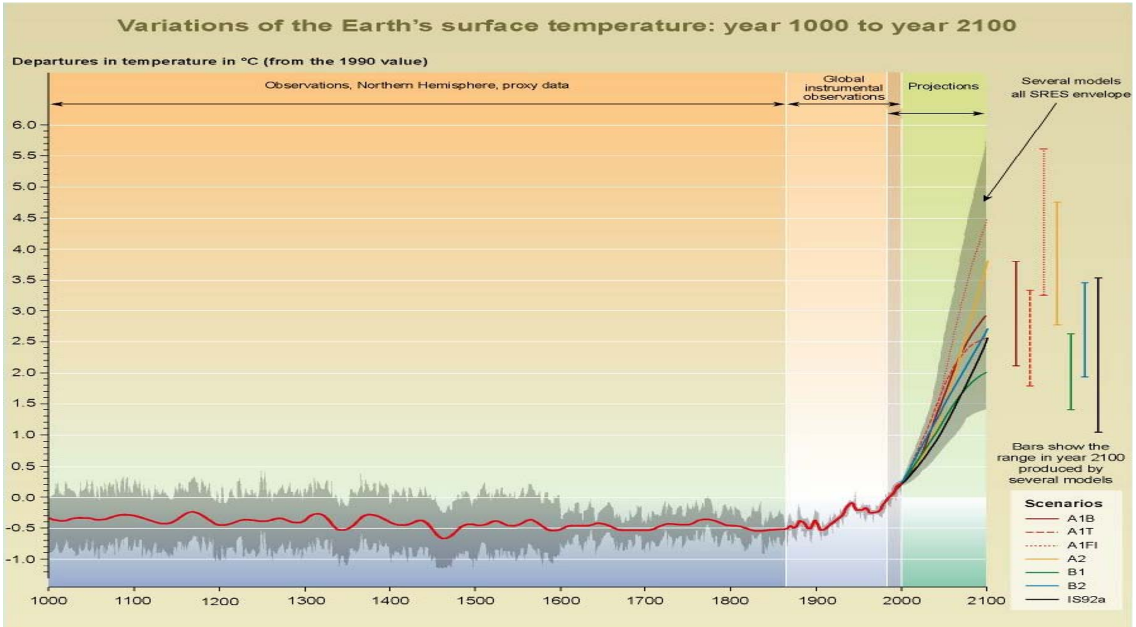
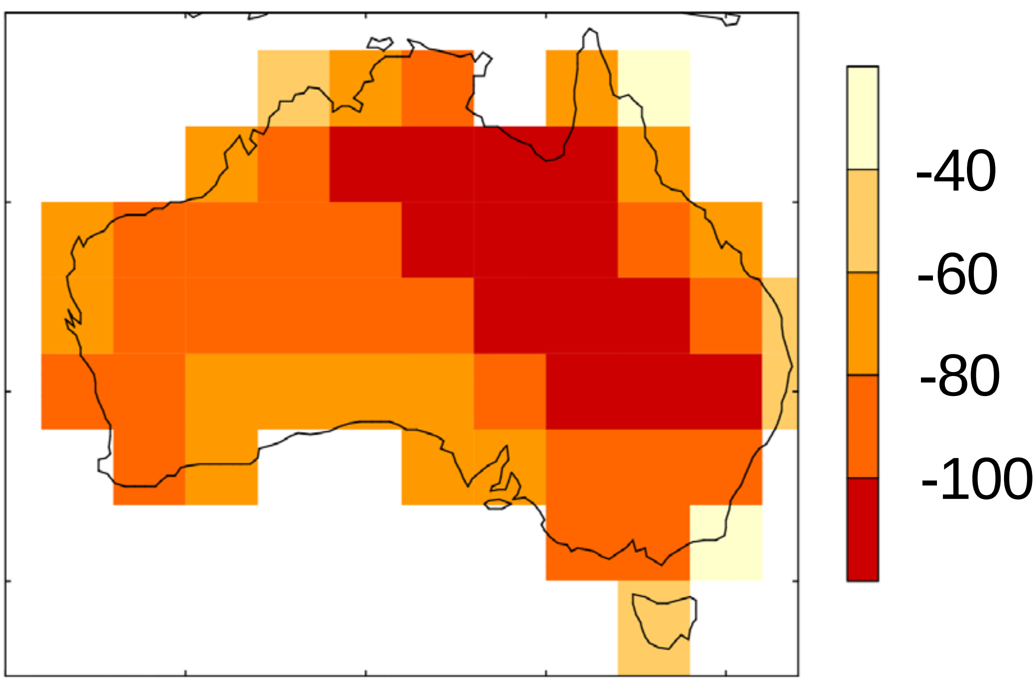


Figure 10 Variations and projected increases in global temperature

The other by-product of increasing temperatures is the effect the increasing temperatures will have on the water balance. Much of Queensland is expected to experience an increase deficit in the water balance of the order of 40 to 130 mm per annum caused by evaporation (CSIRO 2003) (figure 11). The impact here will be felt most strongly on plant and crop growth and loss of water from water storages (IPCC 2001c).



http://www.dar.csiro.au/publications/projections

Figure 11 Annual water balance change for Australia by 2030

mm/annum

Not only is the climate in Australia becoming hotter but there are significant regional changes in rainfall (BoM 2003). In analysing the regional variability in rainfall, Queensland has experienced a significant reduction in rainfall in the past 100 years. For example, the central Queensland coast has experienced a gradual and progressive decline in rainfall over the past 100 years (figure 12). In this example the rainfall recorded by the Australian Bureau of Meteorology for Rockhampton has been smoothed using a twenty year moving average to compress the short term variability and highlight the longer term trend. While inter decadal variability is evident there is a progressive and gradual decline in rainfall recorded.

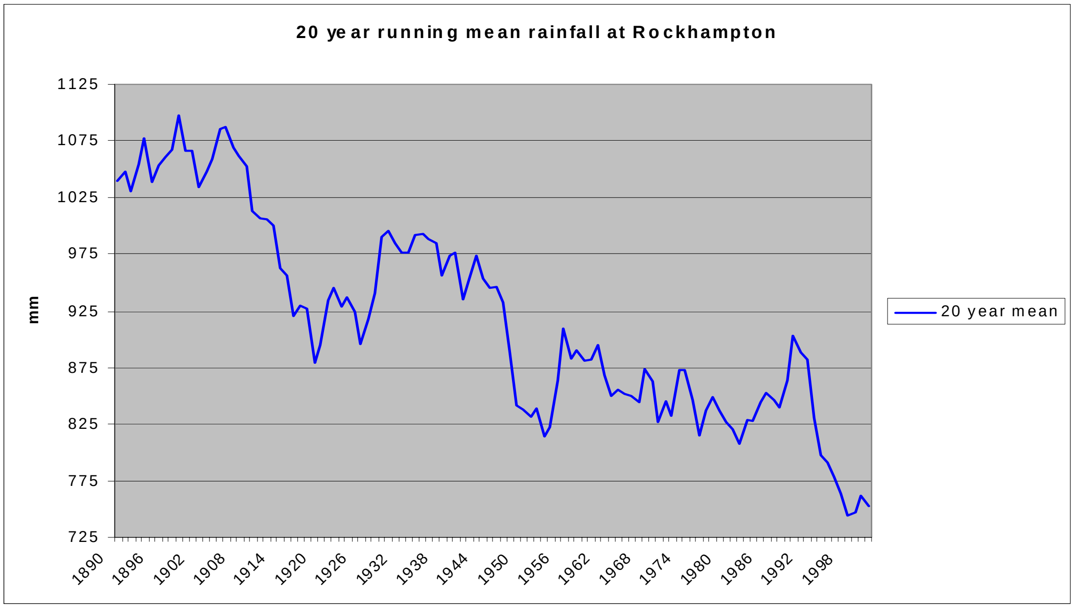


Figure 12. 20 year running mean rainfall 1890 - 2003 for Rockhampton Queensland. (BoM 2003)

This same trend is evident for many areas of regional Queensland (figure 13). The trend is even more pronounced in the past 50 years (figure 14). This trend extends down the entire eastern seaboard of Australia (figure 14 and 15).

The changes presented in figure 15 indicate an increase in average rainfall down the Western Australian interior. This is as a consequence of the changes to cyclonic activity in El Nino years. As discussed earlier, during El Nino years cyclones on the eastern sea board track south, then east and move away from the Queensland coast line. In Western Australia the cyclones form in the tropics and move south, then east and cross the Western Australian coast, weaken into rain depressions and track south through the interior.

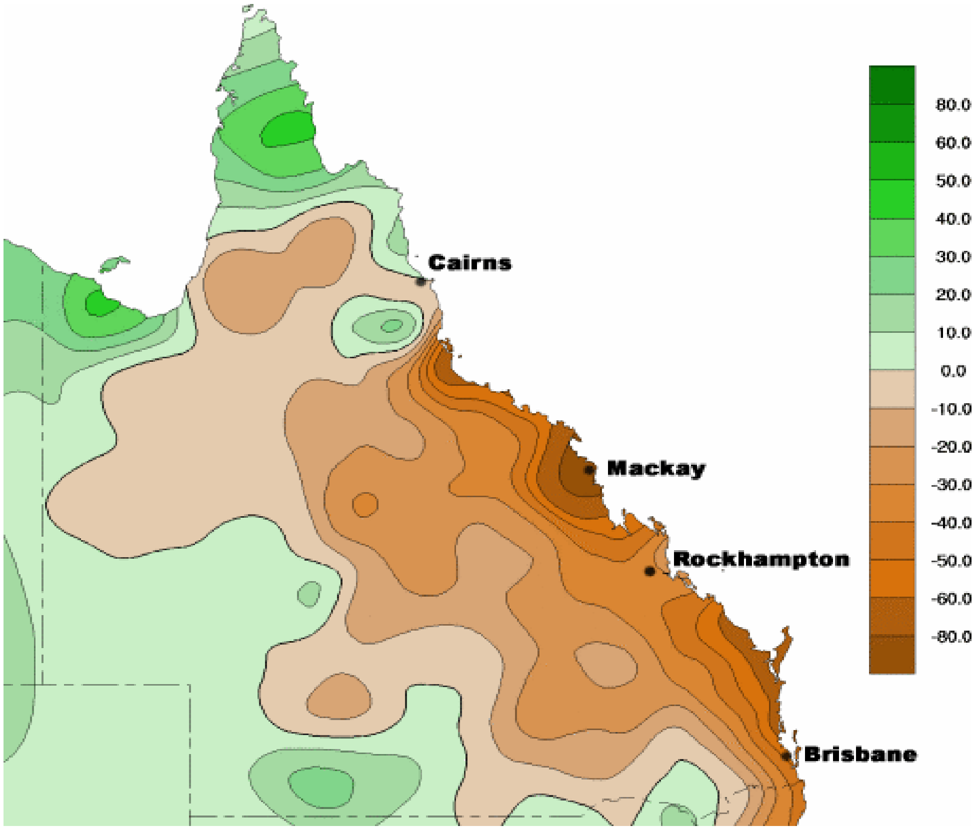


Figure 13 Changes in Rainfall trends for Queensland over the past 100years -– isohyets are in mm per decade (BoM 2003).

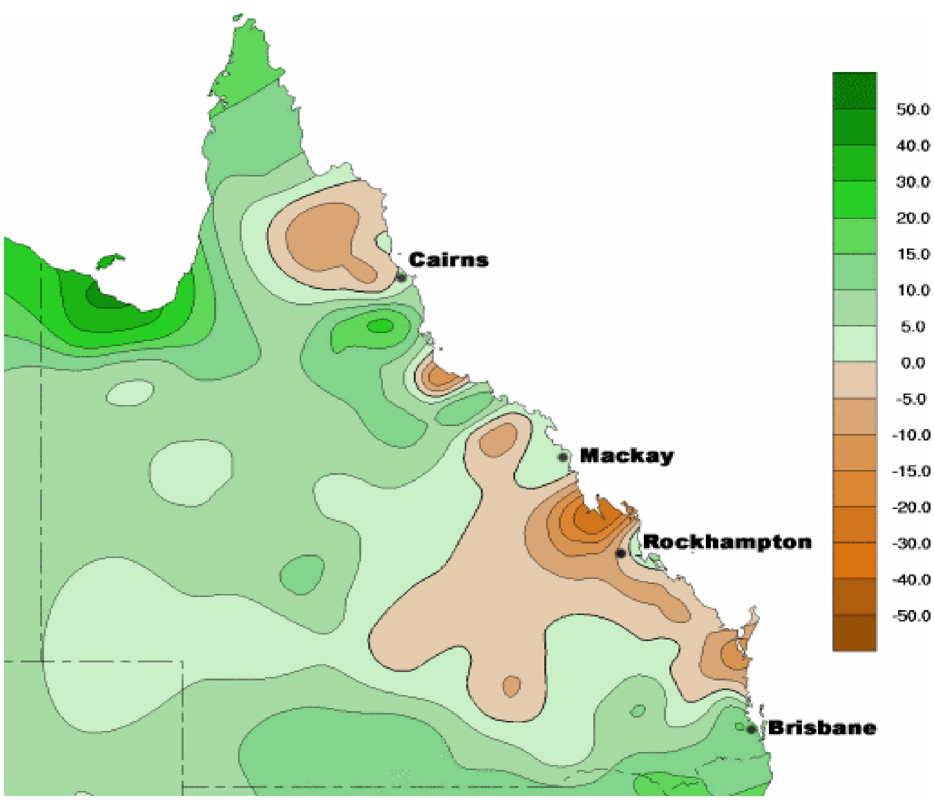
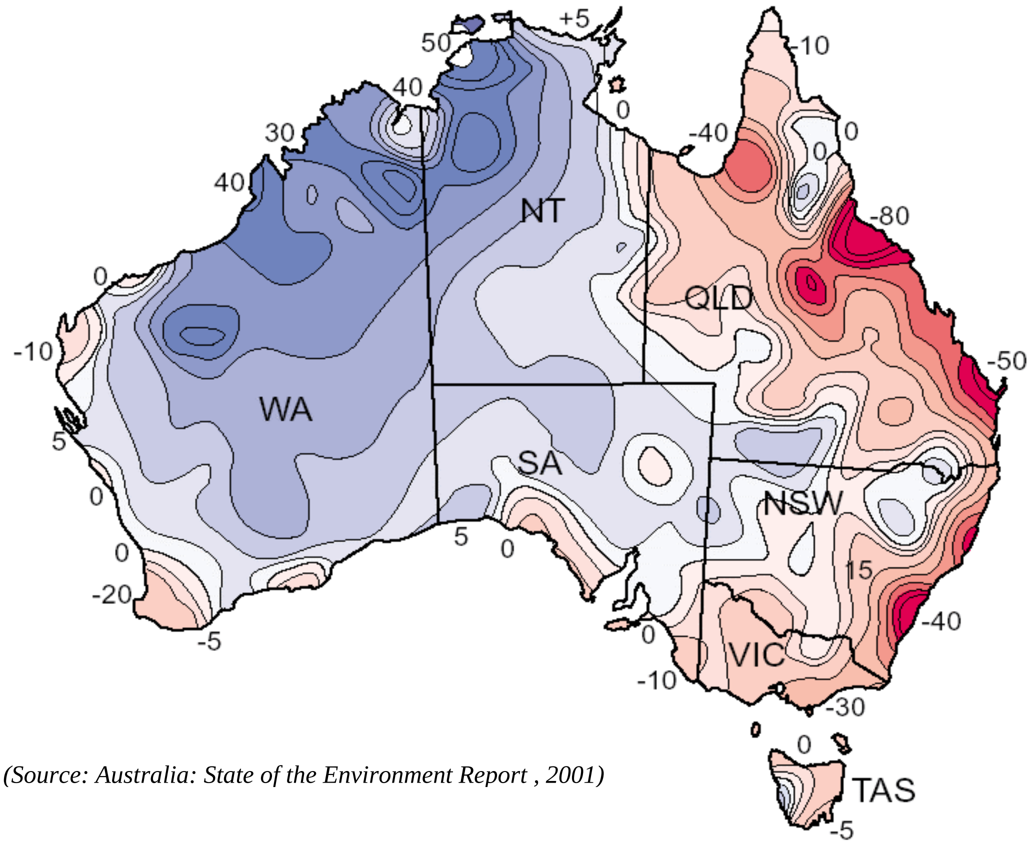


Figure 14 Changes in Rainfall trends for Queensland over the past 50 years – isohyets are in mm per decade (BoM 2003)



(Source: Australia: State of the Environment Report , 2001)

Figure 15 Rainfall trends for Australia 1950 – 1999. (Isohyets are in mm per decade)

As indicated in figure 15 the major recorded impacts of rainfall decline have been down the eastern sea board of Australia while increases in rainfall have tended to occur in the north western portion of Australia. This trend is correlated with the tendency of cyclones to track to the east in the predominately El Nino conditions (figure 6) The lower portion of Western Australia which has traditionally been described as a reliable Mediterranean style of rainfall has also shown considerable change. As this area had displayed high levels of reliability and predictability the change was quiet discernible and led to a major initiative called the Indian Ocean Climate Initiative. The Indian Ocean Climate Initiative (IOCI) is a climate research program established by the Western Australian Government in collaboration with the BMRC and CSIRO to identify the causes of the serious rainfall decreases and the consequential impact on water resources experienced in southwest Western Australia since the 1970s (figure 16). Figure 16 shows the average since 1911 to 2001 is 287GL while the average from 1975 to 2001 has declined to 167GL.

Key findings from the IOCI study are that:

- Winter rainfall has decreased sharply and suddenly in the region since the mid 1970s;
- The decline was not gradual but more of a switching to an alternative rainfall regime;
- The rainfall decrease accompanied and was apparently associated with documented change in large scale atmospheric circulation at the time. See also the trip in the 70's in the SOI (Figure 5) (IOCI 2002)

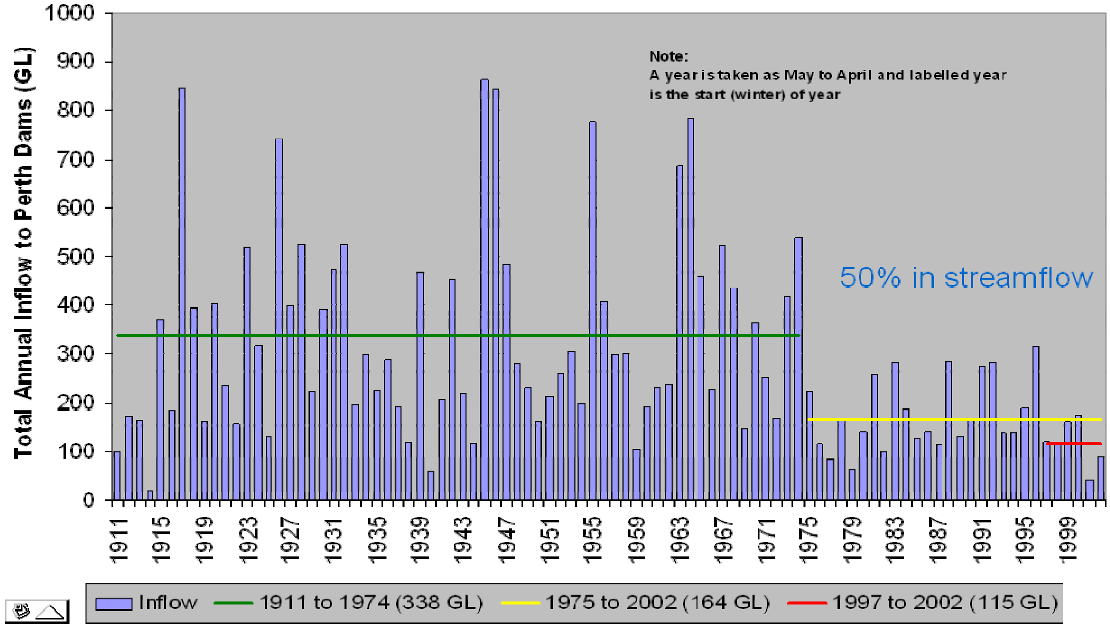


Figure 16 Yearly inflow into Perth's water supply (columns) also showing the ten year moving average (solid line) (Source AGBM 2003)

Implications for policy makers and planners

The current shifts in climate and the projected changes are of significant interest to policy makers, community, business and industry sectors. The data collected on climate change and measures of the impact are increasingly being applied to and tested against a diverse range of industry sectors by scientists, the government and by members of the general public concerned over future impacts. Implications of climate change include impacts and implications for the planning of infrastructure, structural design, risk management, business investment and directly on the formulation of government policy. The next section deals with a range of industry sectors and areas that climate will impact on and provides at a general level an insight as to what the potential implications are likely to be.

Agriculture and Natural Resource Management

There are numerous studies on the problems faced by our natural resources under current land use practices. Climate change will significantly add to this pressure as there is a complex inter-relationship between climate and environment - with changes in each impacting on the other, often interactively.

A significant amount of research is currently underway to better understand these relationships and the risks climate change poses (See BoM 2003 for a review of this work). Many agencies (eg Commonwealth and State Government Departments, Universities, CSIRO and private sector organisations) are engaged in assessing the risk and management associated with climate variability and climate change implications in Agriculture and natural resource management. This research has identified a number of serious points of concern and questions are now being raised (BoM 2003).

For example, pasture growth rates (kg dry matter/ha/yr) and the subsequent growth rates of animals (live-weight gain) and wool production are totally dependent on rainfall. Minor changes in rainfall in terms of seasonality, intensity and duration all have a major impact on the species mix within the pastures the resilience and stability and productivity of the grazing landscape. In sheep production systems the tensile strength and fineness of the fibre can be adversely affected by changes in pasture quality and quantity.

Researchers at Queensland Department of Natural Resources and Mines (Crimp et al 2002,) used a pasture production model (GRASP) to explore the impact of climate change on native grasses. Their modeling showed that with even a small increase in temperature and a decrease in rainfall such as those projected for 2030 by CSIRO, pasture growth would decline by 10-50%.

Water use by plants is affected by increases in temperature, and grain yield and quality are affected by both the quality and timeliness of the rainfall (Howden et al 2001. Changes in frost incidence and number of frosts also have implications for fruiting of horticultural and grain crops (Basher et al 1998; Spellman 1999). Examples of this include olives in Victoria, grapes in South Australia and citrus in Queensland. Climate change modeling is needed to determine the future suitability of areas for various land use practices in terms of sustainability, as changes in rainfall and temperature will affect economic viability and production risk (Howden et al, 2003). Implications of climate change will be likely to be seen in producer viability, the cost of some commodities, national disaster relief and assistance and restructuring programs.

Climate change is already affecting Australian cropping systems and the way they are managed, according to scientists from the Queensland Department of Primary Industries and Fisheries (Menke 2005 pers com see also Howden et al, 2003). Continuing increases in the concentration of atmospheric carbon dioxide will affect growth patterns of crops, trees and pastures, while changes in rainfall patterns will influence production (Howden et al 2001). Temperature increases are already leading to changes such as the planting dates for wheat. For example, in Emerald, in Central Queensland, there are around three weeks each year of frost, compared with the 10 weeks experienced each year in the 1900's (Stone et al 1996). Further temperature increases will also affect crop rotations and limit the expansion of crops such as canola in Queensland, or supporting the expansion of cotton production further south than it is grown today. Farmers in marginal regions might need to switch from their current grain/grazing mixed operations to grazing or even plantation forestry – evidence of this is already seen in the marginal areas of the Western Downs in Queensland around Miles and Roma. Management changes recommended to farmers may now need to include changes in varieties and planting dates, changes in crop species, erosion and salinity management, pest and disease management, and greater use of seasonal forecast information (Crimp 2005 pers com).

CSIRO researchers have shown that under climate change many of Australian viticultural regions (particularly in the north) are projected to experience warmer and drier conditions particularly in winter and spring. It is expected that this will result in earlier ripening and a possible reduction in grape quality. However in the cooler, south-ern regions higher temperatures may allow for new varieties. Higher carbon dioxide concentrations may lead to more canopy growth and shading, leading to decreased fruitfulness. Water supplies available and the reliability of supply for irrigation may decrease (IPCC 2001a).

The sugar cane industry is another example of an industry susceptible to climate change (BoM 2003). Already under financial stress through global competition the industry involves an integrated value chain in which climate influences many factors, including: determining the amount of sugar produced by sugar cane; controlling the development and spread of fungal diseases, insects, pests and weeds; influencing runoff and deep drainage, with possible environmental impact associated with nutrients and pesticides; and also affecting the harvesting, transport, milling, marketing and shipping of the product.

Long term crops such as forestry are also likely to be affected and susceptible to changes in climate (Hughes et al 1996). For example, Pine species planted along the coast on the expectation of rainfall above 1000mm may not grow or mature in a climate that yields less than 800mm as is the case in some coastal Queensland areas traditionally considered suitable for forestry.

Many wetlands in Australia are under threat from agriculture, dams, irrigation, coastal urban development, and the pollution of the waterways. As an example the Murray-Darling Basin Commission reported that the quality of wetlands has significantly reduced in the Murray-Darling Basin, particularly between the Hume Dam and Mildura (MDBC 2001). Climate change will add to the vulnerability of these sensitive wetlands. Furthermore in the gulf country of northern Australia if the projected sea levels rise occur, the vast freshwater floodplains of the north will be subject to significant saltwater inundation (CSIRO, 2002).

Fisheries (commercial and recreational) are another industry likely to be affected by climate change. Recruitment and survival of coastal and riverine breeding species are likely to be affected by changes in rainfall and temperatures. Sediment transport and deposition following heavy rainfall can smother extensive areas of estuarine habitat, killing trees and resulting in loss of breeding habitat essential to many coastal fish species, dugong and turtles (Semeniuk 1994; CSIRO 2002). Any increase in extreme rainfall events and sedimentation would be likely to have major impacts on river, lake, estuarine and coastal waters and lead to reduced ecosystem health and reduced recreational and tourist use. There may be impacts on commercially important fisheries such as lobster (Pearce and Phillips 1994), prawns and barramundi but the economic impacts are unclear (CSIRO 2002; Pittock 2003).

Mangroves occur on low-energy, sedimentary shorelines and are the nursery areas for many commercially important fish, prawns and mudcrabs. They are highly vulnerable but could be adaptable to climate change, migrating shorewards in response to gradual sea level rise (Semeniuk 1994). However, in many locations this adaptation will now be inhibited by human infrastructure such as causeways, flood protection levees and urban and tourist developments, leading to a reduction in the area of wetland or mangrove (CSIRO, 2002).

While it is easy to focus on the negative it should also be remembered that opportunities emerge out of change. For example, a collaborative project between CSIRO Marine Research and CSIRO Sustainable Ecosystems investigated connections between ocean temperatures and farm management. Using sea surface temperature measurements to estimate atmospheric changes up to six months ahead, researchers have revealed that production increases in Northern Australia of 16 per cent are possible, as well as a 12 per cent reduction in soil loss (CSIRO 2002).

Insects, pests and weeds

Australia's crops, horticulture and forestry are vulnerable to introduced pests that have no local biological controls (White et al 2003). Climate change may increase the chance that such pests will become established (Dukes and Mooney 1999). Researchers at the CRC for Australian Weed Management Systems have found that the moths, weevils and beetles that play a vital role in bio-control of weeds are suffering severely in the current drought.

Researchers at the University of Queensland and CSIRO (White et al 2003) investigated the vulnerability of the Australian beef industry to the cattle tick *Boophilus microplus* under climate change. Compared to current estimated losses of 6000 tonnes per year, they found potential losses in live weight gain from 7800 tonnes per year by 2030 to 21,600 tonnes per year by 2100. These figures are in the absence of adaptation measures such as changing to tick-resistant breeds or increasing tick control treatment.

Many insect populations will be affected by climate change. As an example Macquarie University researchers reported on the current distribution of 77 species of Australian native butterflies, and the potential changes in distribution of 24 species in response to climate change (Beaumont and Hughes 2002). They found that even species with currently wide climatic ranges are vulnerable to climate change. Under a very conservative climate change scenario of a temperature increase of 0.8-1.4°C by 2050, the distribution of 88% of species of Australian native butterflies would decrease and 54% of species distributions would decrease by at least 20%. Under an extreme scenario (temperature increase of 2.1-3.9°C by 2050) 92% of species distributions decreased, and 83% of species distributions decreased by at least 50%. Other research at Macquarie (Beaumont and Hughes 2002) University found that a moth introduced to Australia to control the Paterson's curse weed, *Dialectica scalariella*, showed longer development times, higher mortality and reduced adult weight when fed foliage grown under elevated carbon dioxide conditions**.** Hence the potential changes for insects may be hidden or well removed from the temperature and rainfall distribution impacts.

Water Management and Use

Efficient management of water will become increasingly important as we enter times of increasing water use and shrinking sources of supply (IPCC 2001a). Climate variability is the main factor impacting on the availability and reliability of water resources. Improved understanding of the processes linking rainfall, evaporation, soil moisture, groundwater and surface water rely heavily on long time series of hydrological or climate-related data. Long time series also underpin the risk-based management of water resources.

Management of Australia's water resources is the responsibility of the State and Territory Governments. National coordination of resource management policy is through the Natural Resource Management Ministerial Council (NRMMC) and its underpinning structure of committees. It of interest to note that the bulk of Australia's surface water resources occur in the eastern potion of Australia which is also the area currently recording the highest rate of reduction in rainfall (Figure 17). It is also the area of highest population density.

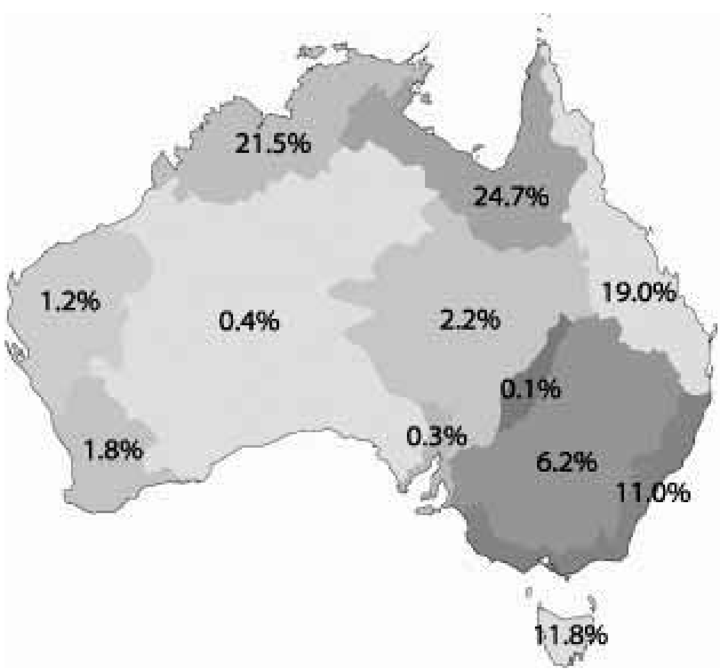


Figure 17 Percentage of Australia's surface water resources by major drainage system (AGO 2003).

Low rainfall conditions during the year 2002 resulted in this being one of the driest years on record for Australia. Much of eastern Australia and south-western Australia also experienced a dry year in 2001. In parts of southeastern Australia these two dry years came on top of below average rainfalls over a prolonged period of about 6 years. The successive dry years have had a serious impact on water resources in eastern Australia with increasingly severe water restrictions being placed on the availability of irrigation supplies and urban water use. In Victoria during February 2003, many streams had dried up and irrigation and/or water diversion bans were in place in 23 of the 28 river basins. Restrictions were in force in 268 towns, of which 20 were on severe levels of restriction, 90 on moderate levels and 158 on low levels. By November 2002, almost 62% of Australia had serious or severe nine-month rainfall deficiencies, making it the most widespread nine-month drought on record (BoM 2003).

High temperatures were also a feature of this drought, with Australian-average maximum temperature the highest on record. On an annual basis, maximum temperature and rainfall are negatively correlated, i.e. droughts tend to have anomalously high temperatures. However, since about 1973, temperatures have tended to be higher for a given rainfall amount, i.e. droughts have become hotter. Australian researchers concluded that the drought of 2002 and the associated impacts on agriculture, water resources and fire were made more severe than past droughts due to the high temperatures and evaporation which may be partly due to human-induced global warming (Karoly et al 2003, Nicholls 2003).

One of the greatest challenges facing Australia is how to stop using more water, and to use what we have more efficiently. Water supplies per capita have fallen dramatically since 1970 and are set to continue declining, according to a United Nations report (UN 2003). In Australia, consumption of freshwater resources rose from 14 600 GL in 1983-4 to 23 300 GL in 1996-7. Irrigation increased by 30% between 1990 and 2000. Many solutions have been canvassed, including water trading and more efficient irrigation methods.

In many Australian communities, much of their limited water supply is used to provide evaporative air-conditioning during hot weather. For example, during a three week period during early 2003 in Cobar, the maximum temperature did not drop below 40 degrees Celsius. Even with water restrictions, the town used a million litres of water a day on air-conditioning (BoM 2003). At this rate of usage, the town's water supply was predicted to run out by June 2003. In 2002 the Queensland Government formed a special cabinet committee to address the emerging water crisis with over 80% of towns in Queensland facing severe water shortages. In February 2002, most of these communities had less than 6 months water supply left.

Australia’s highly variable climate creates uncertainty in hydrologic systems that must be taken into account in the design and operation of water resource projects. As reported earlier (figure 16) Perth’s water supply reduced by 50% following a 25% reduction in rainfall (IOCI 2002). In June 2005 many of the water storages in eastern Australia contained less than 30% capacity and water restrictions were in place in the major capital cities.

Community Health and Wellbeing

Environmental health is the interaction between the environment and the health of populations of people and has been defined as "those aspects of human health determined by physical, biological, and social factors in the environment". Climate is one of those factors and the number of studies examining the influence of climate is growing. A recent investigation by the Bureau of Meteorology’s Northern Territory

Regional Office and the Australian National University on the influence of climate on outbreaks of meningitis among indigenous people of central Australia provides an example (BoM 2003).

Arboviruses

In Australia, there are more than 70 viruses that are spread by insects, which can breed rapidly during unusually rainy periods. Murray Valley Encephalitis (MVE), Kunjin (KUN) Disease, Barmah Forest Disease, Dengue Fever and Ross River Fever are examples of diseases observed in Australia, which are carried by mosquitoes (Lindsay et al 1989). An outbreak of Barmah Forest virus disease in Victoria in early 2002 (and many cases of dengue fever in Cairns in early 2003) have highlighted the public health threat from arboviruses (diseases carried by arthropods).

MVE is carried from northern Australia by migratory water birds (hosts), which move far into the southern parts of Australia during very wet years. Mosquitoes (vectors) can carry the virus from infected water birds to humans. Monitoring of weather conditions and vector surveillance determines whether there is a potential for MVE activity to occur (BoM 2003).

Government (Federal, State and Local) based programs in most Australian states undertake mosquito monitoring and virus surveillance from mosquitoes. They also aim to provide increasing understanding of interrelationships between arboviruses, vectors and climatic conditions. Organisations involved include State Health departments, the Department of Medical Entomology at Westmead Hospital and the Queensland Institute for Medical Research's Mosquito Control Laboratory. The Bureau of Meteorology's Seasonal Climate Outlook is used to predict likely arbovirus risk in the coming summer.

The National Centre for Environmental Public Health (NCEPH) have carried out studies of how climatic variations influence the occurrence of several infectious diseases, especially Ross River virus disease and bacterial food poisoning (cited in BoM 2003). For example, Ross River Virus in the north of Australia has been shown to be directly linked to the El Nino-Southern Oscillation phenomenon, as La Niña (rainy) years provide ideal conditions for the breeding of the virus' hosts and vectors. Health authorities are concerned that climate change could be bringing Ross River virus further south, threatening Australia's southern cities.

Between 1991 and 2002 in Australia there were 51,761 notifications of the disease of Ross River virus and it is well recognised that weather directly affects the breeding, abundance, and survival of mosquitoes, the principal vector of many arboviruses such as Ross River Fever. Hence, researchers from the Australian National University believe that an increase in incidence of these diseases is highly likely under the projected climate changes.

Malaria is not endemic in Australia, however modelled results in a health risk assessment report of McMichael et al (2002) indicate that under climate change there is a hypothetical risk of the zone where Australia's only malaria vector could exist expanding as far south as Rockhampton, Gladstone and Bundaberg.

From 1991, when national reporting began, to 2002, 2,595 cases of dengue had been recorded. The health risk assessment under climate change by McMichael et al, (2003) estimated the region climatically suitable for dengue transmission include Broome, Darwin and Katherine in northern Australia and some coastline areas between Townsville and Mackay.

Higher global temperatures could increase cyanobacteria (blue-green algae) in water supplies and recreational water bodies, which can cause gastrointestinal and dermatological symptoms (BoM 2003).

Natural Hazards

The increased incidence of extreme weather events as predicted by the IPCC (2001a) is significant in terms of the social economic and environmental impacts (figure 18. The degree of concern over this is reflected in the investment in research into such impacts. For example, the Natural Hazards Research Centre (NHRC) at Macquarie University now record and model the impacts and fatalities caused by tropical cyclones. Data recorded include the effect on areas such as health, the built environment, agriculture, the physical environment, economics and the bio-system as well as the characteristics of the tropical cyclones. Such data bases will prove invaluable in determining risk and exposure into the future.

Mood and Violence

The Australian Institute of Suicide Research and Prevention has found suicide rates are higher during the hottest times of the year; changes in temperature appear to be a major contributing factor for people who are vulnerable to suicide. It is reasonably well established that violent crime also increases with increasing temperature. Researchers at James Cook University's psychology department have linked the unusually hot 2002-03 summer in North Queensland with mood problems among people in the region.

Heat Stress

Evaluation of the impact of high temperatures and heat stress is important in areas such as air-conditioning design, industrial relations and sports medicine. Heat is an issue of fundamental concern to those who play sport because it is potentially fatal. Sporting organizations such as Soccer Australia have guidelines for event planning and cancellation, based on thermal conditions (temperature and humidity) (McCarthy et al 2001; Martens and McMichael et al 2002).

Skin Cancer

Skin cancer in humans is linked with sunlight exposure. It is the most common and the most costly cancer in Australia, where light coloured skin and high levels of solar radiation predominate. Australia is recognised as a leader in the field of skin cancer research with one in four adults likely to contract some form of skin cancer during their life (Martins and McMichael 2002). Skin cancer is directly linked to exposure to the sun and climate change will have a significant negative impact. The World Health Organization has begun work in estimating the global burden of disease attributable to UV exposure - with particular attention to skin cancers, impacts on the eye, and effects due to alterations of immune activity and vitamin D synthesis (Martins and McMichael 2002).

Human health

Climate change can affect human health directly through, for example, heat stress or the consequence of natural disasters, and indirectly through, for example, disrupted agriculture. Several of the health impacts of climate change identified by the IPCC (McCarthy et al 2001, Martins and Mc Michael 2002) are relevant to Australia, including an increase in vector, food and water-borne infectious diseases; a decrease in winter deaths but an increase in heat-related deaths and illness.

In Australia over 1100 people aged over 65 die from temperature-related causes each year. The projected rise in temperature for the next 50 years is predicted to result in a total of three to five thousand additional heat-related deaths a year (McMichael et al., 2002). Under climate change modelling, temperate cities show higher rates of deaths due to greater temperature extremes than tropical cities. The estimated increases in heat-related deaths were predicted to be far greater than the decreases in cold-related deaths.

The built environment

Climate information is essential in most aspects of building siting and design. Energy efficiency, structural integrity, even protection of verandahs and loading zones from wind-driven rain are among the climate sensitive aspects of building design.

Low-energy building design

Many architecture schools now place considerable emphasis on the use of climate data for design of climate-responsive buildings. Consulting practices such as the University of New South Wales’ and Queensland’s’ University of Technology Centre of Sustainable Built Environments, Energy Partners and Solar Logic have expertise in design of low-energy (hence climate sensitive) buildings. Taylor Oppenheim Architects undertake projects such as research into energy use in buildings, post occupancy evaluations of a building's thermal performance and the development of guidelines and performance indicators for energy and environmental use in buildings (BoM 2003).

It is of note that the construction and operation of homes, industry and urban infrastructure and use is one of the most significant human activities contributing to global warming (BoM 2003).

Solar Energy

The continued use of fossil fuel energy is likely to affect the global climate. Australian organisations are among world leaders in research and development of renewable energy technology. Renewable energy, mainly hydro, now accounts for about 10.5% of all power generated in Australia. The Federal Government’s Mandatory Renewable Energy Target requires that two percent of the forecast market in 1997 must come from renewable energy by 2010. The photovoltaic industry (solar electricity) is currently growing at around 30% a year worldwide. Australia is already a key player in photovoltaics as the largest manufacturer per capita and a research leader (Wolfs per com 2005).

Wind energy

Australia has one of the world's best wind resources, particularly along the southeastern coast. Approximately 40 proposals for installation of wind power systems await evaluation in South Australia, including one of the nation's largest wind farm projects at Lake Bonney, in the southeast. South Australia is expected to be the largest producer of wind power in the south-east Pacific area within 10 years. Analyses from the Bureau of Meteorology's regional prediction model and CSIRO's Air Pollution Model are being used to model the potential for wind power generation throughout eastern Australia's mountainous regions.

Industry viability

Climate variability has huge economic impacts, most clearly shown by the financial impact of drought on the Australian economy, but also evident in many industry sectors, such as retailing and tourism. Professional agricultural associations monitor the effect of climate variability on the incomes of those on the land.

Dealing with drought is a difficult but essential part of farming in Australia. Climate statistics confirm the 2002 drought ranks as one of the worst. The drought has had a significant impact on economic growth in Australia through the direct and indirect linkages between agriculture and other industries. In March 2003, the drought was estimated to reduce the rate of economic growth in Australia in 2002–03 by around 0.7 percentage points, or around $5.4 billion, from what would otherwise have been achieved.

The insurance sector is particularly vulnerable to natural hazards such as droughts storms and floods (Figure 18). The trend toward higher insured losses continues in view of the risk factors; higher population densities and higher concentrations of insured values, especially in endangered areas such as coastal zones. The effects of this trend are illustrated by the experience of Christmas Island and Cocos Island, where the sole insurer withdrew all forms of insurance from the islands due to climatic risk.

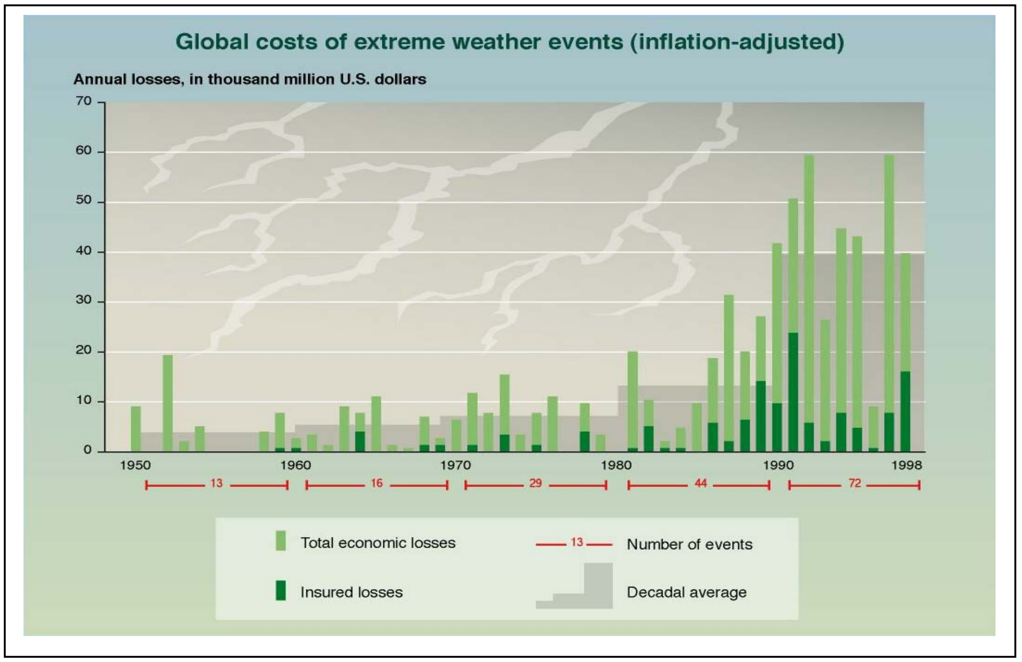


Figure 18. Global costs of extreme events and percentage covered by insurance (BoM 2003)

Marine ecosystems

Evidence of a global rise in sea level over the past 100 years of between 10 and 20 cm comes from measurements around the world, corrected for land movements (Hennecke et al 2000). The rise is primarily a result of increasing water temperatures and consequential? expansion, with some contribution from melting land ice. Additional evidence of sea level rise in Australia has come to light following the discovery of 160 year old records of observations taken at Port Arthur, Tasmania. The observations, compared with data from a modern tide gauge, indicate an average sea level rise of about 1mm a year, consistent with other Australian observations and the lower end of estimates from the IPCC (BoM 2003).

Another consequence of rising water temperatures is coral bleaching (figure 19). Coral reefs around the world are becoming stressed by a number of factors; bleaching due to warmer oceans, occasional reductions in salinity due to extreme river outflows, increased cloudiness of water, chemical pollutants, local fishing practices and damage from tropical cyclones (Lough 2000). The frequency of occurrence of mass coral bleaching (when reef-building corals lose their symbiotic algae and associated pigments) have increased globally since the late 1970s. During 1997-98 coral bleaching was reported on many of the world's coral reefs and also affected coral reefs in parts of Australia's Great Barrier Reef (GBR) and northwest shelf. Mass coral bleaching was again observed on the GBR in early 2002.

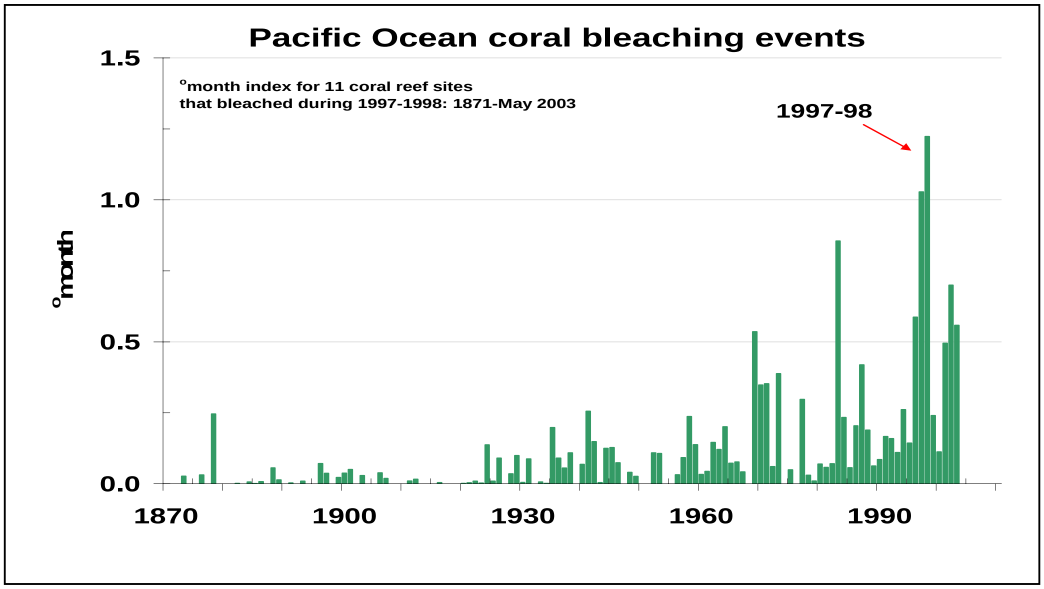


Figure 19. Incidence of coral bleaching events in the Pacific Ocean (Lough 2000)

Australian Institute of Marine Science (AIMS) researchers are investigating whether the Great Barrier Reef will survive global warming. A rise of 1°C, predicted to occur within 50 years, could cause mass bleaching of coral reefs when combined with seasonal fluctuations. AIMS researchers heated to various temperatures tanks containing different corals. They found some corals bleached or even died, while others coped under the same conditions. They conclude global warming will not destroy the Great Barrier Reef, but there may be a reduction in species of coral, leaving only those species with a special protein that protects them from prolonged temperature rises. However, CSIRO research has shown an increase of 2°C is likely to change the tropical near-shore marine life from coral to algal dominated communities (CSIRO 2002).

Coastal communities and infrastructure

A decrease in tropical cyclone numbers affecting the Eastern Australian region has occurred between 1969 and 2004, but there has been an increase in the number of intense tropical cyclones with pressures of less than 970hPa (CSIRO 2002).. Recent decades have also seen a reduction in the number of mid-latitude storms to the south of Australia, but the intensity of these storms has on average increased. Climate models suggest a future decrease in the number of storm centres over southern Australia but an increase in their intensity (CSIRO 2002).

By 2050, the sea level may rise 0.1 to 0.4 metres and tropical cyclone intensity (not frequency) around Cairns in northern Queensland could increase by up to 20%. This would increase the flood level associated with a 1-in-100 year flood in Cairns from the present height of 2.3 to 2.6 metres to 2.7 to 3.0 metres (BoM 2003). This equates to floods occurring over an area about twice that historically affected. It is also of note that the incidence of tropical cyclones influencing and crossing the north-western portion of Australia have increased in the past 30 years resulting in an increase in rainfall in that region (Figure 14).

More than 80% of Australia's population lives within 50km of the coast (ABS 2001). This population is growing rapidly and this growth adds to the exposure of the community to extreme events such as tropical cyclones, storm surges and river flooding. CSIRO (2002) reports that coastal communities and urban infrastructure will be affected by changes in sea level and extreme weather. Torrential rainfall over cities and surrounding catchments can produce severe runoff and flooding and more frequent high-intensity rain in some areas could also be expected to increase the risks of landslides and erosion, particularly in the urbanised catchments on Australia's east coast as evidenced in the June 2005 storm activity on Queensland Gold Coast and Northern NSW.

As sea level rises, sediment from sandy shorelines is eroded from the beach and the shoreline recedes. It is generally accepted that the coastline will retreat horizontally 50 to 100 times the vertical sea level rise (Greve et al 2000). Hence, global sea level rise of between 9 and 88 cm as projected to occur by 2100 under the IPCC range of emission scenarios would cause a coastal recession of sandy beaches by 5.5 to 88 metres. The Bureau of Meteorology now recommend allowance should be made for the estimated rise in sea level due to the enhanced greenhouse effect and a 120% increase in the maximum intensity of tropical cyclones.

Warmer temperatures favour pathogen survival and extreme rainfall events may increase nutrient levels. As Australian coastal waters are sometimes contaminated with untreated sewage, it is possible these combined effects may favour the production of harmful algal toxins, resulting in fish and shellfish food poisoning (McCarthy et al 2001).

The Bureau of Transport and Regional Economics (formerly the Bureau of Transport Economics) estimates that between 1967 and 1999, 112 storms occurred in Australia, each causing damage of more than $10 million. The total cost of damage from severe local storms over this period was A$9.4 billion. The data show a statistically significant increase in the damage due to severe storms over time, but this is due largely to increased population in the storm-prone coastal regions of Queensland and New South Wales (see also figure 18).

Estimates of the economic costs of natural disasters can be uncertain due to the difficulty of quantifying indirect costs. However, the Bureau of Transport and Regional Economics reports that the total estimated costs of all natural disasters exceeding $10 million each for the period 1967-99 was $37.8 billion. Of this, only $5 billion was not due to climate-related events. Floods were the most costly: for the past three decades, the total cost of floods has been about $10 billion. It has been estimated that more than 80% of the buildings at risk from flooding are located within Queensland and New South Wales. In Queensland, the Gold Coast City Council area has the greatest number of buildings at risk from a 100-year return period flood. Increases in population in risk-prone areas, combined with increases in storm intensities and rising sea levels, mean that the cost of flood damage to the built environment will increase. Severe storms and tropical cyclones have cost about $9 billion each over the past 30 years, while the cost of bushfires has been about $2 billion over the same period. The annual number of events shows an increasing trend in Australia as it has globally, but this is partly due to better reporting, increasing population and investment in vulnerable areas.

A study of flood damage along the Hawkesbury-Nepean corridor of New South Wales has shown that, by about 2070, average annual direct damage could increase significantly. At present, the 1-in-100 year flood would cause failure of about 70 dwellings and for the 2070 this rises to 1200 dwellings. Other intangible losses would include illness and death, and indirect losses such as alternative accommodation in the residential sector or loss of trading profit in the commercial sector (CSIRO 2002).

Conclusions

The evidence of climate change or at least a downward trend in long term rainfall patterns and enhanced variability is considerable and there is little doubt that the climate of the eastern Australian sea board is at present becoming dryer and hotter. Given this evidence it is appropriate to consider how the hotter and drier conditions can be factored into the decision making framework of the local, state and federal Government.

Concern over the risk of reliability in water supply and availability.
The research and data presented to date highlight the vulnerability of Australia's economy and community wellbeing to water shortages. Extending this to include potential changes to future international investment in Australia is demonstrated in the recent water shortage in the Awonga Dam in Central Queensland. This dam supplies the large industrial hub of Gladstone (also the fastest growing industrial sites in Australia). At this site the Queensland and Federal Government have invested considerable resources in attracting offshore investors in the heavy industrial estate. The significant water shortages experienced in the Awonga Dam in 2002 placed at risk the future investment in Australia by large scales multinationals.

In addition, in 2002/3 the plight of a large number of rural urban communities faced by extreme water shortages as the drought gripped the entire eastern sea board of Australia highlights the need for sound water risk management to include supply and distribution needs to be considered along with water use efficiency, reuse and alternatives such as desalinization.

Using other examples to demonstrate the potential risks and impacts can be seen in the current water shortages in the Fairburn Dam at Emerald. These shortages pose a considerable risk to the financial viability of the entire Emerald irrigation area should the supply fail. If the supply failed then the long terms crops such as the citrus and grape industries would take years to recover. The downstream employment effects on the industries that rely on the irrigation area are also at risk.

The pressure for downstream use of water and the need for environmental flows as well as equity of access is leading to considerable concern by some sectors of the Agricultural industry. Supply risk management and the development of water use efficiency strategies are seen as key imperatives for policy makers and industry groups.

Community health and wellbeing
There is now a near constant flow of reports and media articles throughout the world on the effects of higher temperatures, floods and droughts. Britain recently recording the highest temperatures on record (37^0C) on the same day in mid winter in Australia, Urandangie recorded 35^0C. The effect of high temperatures is known to impact on the personal comfort of all people and has considerable impact on the mortality rate of the aged. As reported earlier, in August 2003 France recorded over 15,000 deaths related to the recent European heat wave conditions. Huge rainfall events in California were reported in February 2005 and on the same day history was created with snow falling in Paris. Clear policies are needed on how community health and wellbeing are to be managed into the future under a scenario of climate change.

Shifts in Tourism
Many of the people who live on the coastline of Queensland have some reliance or connection with the Tourist industry. With current coral bleaching recorded by the Great Barrier Reef Marine Park Authority and a drier and hotter environment with the subsequent impact on the vegetation and aesthetics of the area, many tourists may not see the Queensland coast as a desirable tourist destination in the decades to come. The impact of this potential change in tourism on the economy and land values is significant concern for policy makers involved in the Queensland's development and growth.

Industry rationalization and investment changes
The financial viability of Australia's cropping and grazing industries are declining due to lower commodity prices and the extended droughts. Grazing representatives feel that

the Government needs to enhance drought assistance measures; others feel that the Government's policy should move toward self reliance in a deregulated environment. If the productivity of the landscape is reduced due to reduced rainfall and higher temperatures then the industry will need to consider what areas are suitable for continued cropping and what ones are not. If the productivity of the grazing lands declines then there is a need to reduce stocking rates to avoid land degradation. This has significant industry restructuring and industry viability considerations.

Producers from the cropping industry realize that after ten years of failed crops there is a need to look for alternatives. Examples of the need for industry restructuring included the eight years in ten that the grazing sector in Paroo River is drought declared. A further example of industry directed change is provided in the cropping industry in the Central Highlands of Queensland. This industry has shifted to pulse crops such as mung beans and chick peas after years of failed summer and winter crops. The impact of the changes on land values as other areas in Australia receive increased rainfall needs consideration.

Use and management of groundwater

Many rural communities and industries are dependent on ground water reserves from local aquifers. Examples in Queensland where concern is evident include the Yarwun-Targinni fruit growers around Gladstone, the Lucerne growers in the Callide Valley and the dairy farmers in the lower Fitzroy region of Central Queensland. All these industry groups/communities have experienced a significant and progressive decline in their under ground water reserves over the past 10 to 20 years. In the Callide valley irrigators have been working with the Department of Natural Resources to reassess water usage and reallocation. However, locally the problem is seen as over allocation as opposed to over use of a diminishing reserve.

Throughout much of Australia there is a high dependence on ground water reserves. As rainfall patterns change the recharge of these areas will be dependent of the intensity, frequency and duration of rainfall in the intake areas. Aquifiers in the Wet Tropics in the Cairns area have failed completely (Queensland Chamber of Commerce, February 2005). This was an important area requiring more detailed research, risk management and contingency planning by Government at all levels.

Water quality and health

Over the past two decades there has been considerable interest in blooms of blue green algae in many of our major water ways. The cause identified is a combination of increased inflow of nutrients, higher temperatures and fewer flows flushing the river systems. Direct costs included stock losses and water treatment for human consumption. Loss of the recreational resource was also regarded as a significant issue. People from the local Government reported that many local Government water supplies had to be treated extensively due to algal blooms. The Rockhampton City Council is given as an example.

Planning for infrastructure

There is considerable need to consider the adequacy of existing infrastructure to meet the future needs of communities. Particular emphasis needs to be placed on the adequacy of infrastructure such as water storages. Examples of this are seen in the discussion on the limits of the existing Sydney water supply to meet the future demand in 2004. Much of our existing infrastructure was built around a data set that was based on a higher rainfall period and may not adequately reflect the current and emerging risks margins.

It is clearly evident that the climate in Australia is changing. The climate on the eastern seaboard of Australia has become drier and hotter over the past 100 years, while the north western Australian coast and hinterland is becoming wetter. It is also clear that there is considerable regional variation and that the trend is accelerating and most evident in the past 50 years. While this report draws no conclusion as to the permanency of these changes, from the data available there is no evidence that the trend is likely to change in the immediate future.

The research undertaken by the IPCC (2001a) and others suggest that the trend is likely to increase. The implications for risk management in water supply, changes in land use, health, energy and infrastructure are significant. Water affects every part of our life and our lifestyles. Policy makers and planners should now factor the data and trends presented here into their planning horizons. The planning needs to consider how to accommodate or ameliorate these changes and avoid the crisis management that invariably follows major climatic events. There is more than enough evidence to suggest that the time for action is now.

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Wolfs P. Associate Dean (Research), James Goldston Faculty of Engineering and Physical Systems, Central Queensland University, Rockhampton, Queensland