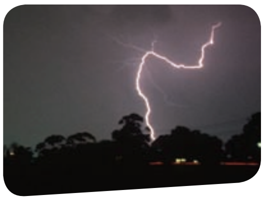
climatechange in Australia

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Contents

Executive summary

Climate Change in Australia is based on international climate change research including conclusions from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), and builds on a large body of climate research that has been undertaken for the Australian region in recent years. This includes research completed within the Australian Climate Change Science Program by CSIRO and the Australian Bureau of Meteorology in partnership with the Australian Greenhouse Office.

The purpose of this report is to provide an up-to-date assessment of observed climate change over Australia, the likely causes, and projections of future changes to Australia's climate. It also provides information on how to apply the projections in impact studies and in risk assessments. The two main strategies for managing climate risk are mitigation (net reductions in greenhouse gas emissions) to slow climate change and adaptation to climate impacts that are unavoidable.

A number of major advances have been made since the last report on climate change projections in Australia (CSIRO 2001) including:

- a much larger number of climate and ocean variables are projected (21 and 6 respectively)
- a much larger number (23) of climate models are used
- the provision of probabilistic information on some of the projections, including the probability of exceeding the 10th, 50th and 90th percentiles
- greater emphasis on projections from models that are better able to simulate observed Australian climate
- a detailed assessment of observed changes in Australian climate and likely causes; and
- information on risk assessment, to provide guidance for using climate projections in impact studies.

Past climate change

Temperature and rainfall

Australian average temperatures have increased by 0.9ºC since 1950, with significant regional variations. The frequency of hot nights has increased and the frequency of cold nights has declined.

Rainfall trends from 1900 to 1949 were generally rather weak and spatially incoherent. Rainfall trends since 1950 are both large and spatially coherent. The east coast, Victoria, and south-west Australia have all experienced substantial rainfall declines since 1950. Across New South Wales and Queensland these rainfall trends partly reflect a very wet period around the 1950s, and recent years that have been unusually dry. In stark contrast, north-west Australia has experienced an increase in rainfall over this period.

Trends in extreme daily rainfall vary across Australia. From 1950 to 2005, there have been increases in north-western and central Australia and over the western tablelands of New South Wales, but decreases in the south-east, south-west and central east coast. Trends in most extreme rainfall events are rising faster than trends in the mean.

Since the start of the 20th century, the period with the lowest rainfall was from the 1930s to the early 1940s. However recent droughts have been hotter, with both the maximum and minimum temperatures higher than in the earlier dry periods.

Maximum winter snow depth at Spencers Creek in the Snowy Mountains has decreased slightly since 1962, and the snow depth in spring has declined strongly (by about 40%).

Tropical cyclones and hail

Large changes have occurred in our ability to detect tropical cyclones since the advent of regular radar observations in the 1950s and with the development of meteorological satellite-based detection techniques in the 1970s and 1980s. Our ability to detect significant trends in the intensity of tropical cyclones in the Australian region is limited because of changes to techniques, and particularly the use of less accurate methods in the past.

There are no comprehensive studies of changes in hail occurrence in Australia, but one study for the Sydney region showed a 30% decline in the number of hailstorms affecting Sydney from 1989-2002 compared with 1953-1988. However, the most severe hail storm affecting Sydney occurred in April 1999, causing Australia's largest insurance loss ($1.7 billion) due to a natural disaster.

Oceans

Global sea levels rose by approximately 17 cm during the twentieth century. The average rate between 1950 and 2000 was 1.8 ± 0.3 mm per year, but for the period when satellite data are available (i.e. from 1993), the rate increased to 3 mm per year. Since 1990, the observed rate of global sea level rise corresponds to the upper limit of IPCC projections. For the period 1950 to 2000, sea level rose at all of the Australian coastal sites monitored, with substantial variability in trends from location to location. Over the period 1920 to 2000 the estimated average relative sea level rise around Australia was 1.2 mm per year.

Substantial warming has occurred in the three oceans surrounding Australia. Warming has been large off the south-east coast of Australia and in the Indian Ocean. The tropical Pacific Ocean has warmed over recent decades. Long term observations off Maria Island near Tasmania reveal a warming trend far greater than the global average, and this may be due to changes in the East Australian Current.

Southern Ocean temperatures have warmed since the 1950s to a depth of 1000 m in some locations. The warming is associated with a 50 km southward migration of the Antarctic Circumpolar Current. Seawater near the bottom of the ocean off Antarctica has rapidly become less salty and less dense. This freshening may be the signature of increased melt from Antarctic glaciers.

El Niño – Southern Oscillation and the Southern Annular Mode

Instrumental and palaeo-climate records show large variations in the frequency and intensity of the El Niño – Southern Oscillation (ENSO), and the impact of ENSO on Australia has varied from decade to decade. This variability has been accompanied by a downward trend in the Southern Oscillation Index (SOI, an index used to track ENSO) since 1876, consistent with a weakening of the Walker Circulation. While there has been an increase in the frequency of El Niño events in recent years, there is no consensus amongst current climate models that global warming should cause an increase. The increase might therefore reflect naturally occurring variability.

The relationship between the SOI and Australian temperature and rainfall has changed. For example, all-Australia rainfall and temperature since the mid 1970s have been higher for any given value of the SOI than they were previously.

Mid-latitude westerly winds appear to have decreased, with a corresponding increase in wind speed in the polar latitudes in most seasons from 1979 to the late 1990s. There has been a 20% reduction in the strength of the subtropical jet over Australia and an associated reduction in the likelihood of low pressure systems developing over south-west Western Australia since the early 1970s. This is linked to winter rainfall declines along the southern coastal regions of Australia and a poleward shift of storm tracks in winter.

Palaeo-records

Pollen records of past vegetation in eastern Australia indicate precipitation was generally higher than present between 9,000 and 3,500 years ago. This is consistent with a regional climatic shift, possibly related to the movement of the subtropical anti-cyclone belt, the westerlies and/or the monsoon. Evidence from lakes in Victoria suggests that conditions between about 1800 to 1840 were wetter than present, after which the dry conditions of the recent instrumental period became established. There is less information relating to past temperature variations.

The tropical cyclone palaeo-record from the past 5,000 years for Cairns and the Great Barrier Reef suggests that the historical record may greatly underestimate the frequency of the most severe tropical cyclones likely to strike the region.

Evidence from Tasmanian tree rings indicates significant shifts in the intensity of climate variability over the last 3,000 years, with a recent shift occurring around 1900.

Causes of past climate change

Climate can change as a result of both natural and anthropogenic factors. Detection and attribution studies attempt to tease out the anthropogenic component of this variability.

Temperature

Australian surface temperatures have risen significantly over the past century. Warming since the middle of the 20th century is likely to be mostly due to anthropogenic increases in greenhouse gases.

Rainfall

The rainfall decrease in south-western Australia since the mid-1970s is likely to be at least partly due to anthropogenic increases in greenhouse gases. It is not yet possible to attribute the post-1950 rainfall decreases in eastern Australia and rainfall increases in north-western Australia to human activities.

Drought

Recent Australian droughts have been accompanied by higher surface temperatures due to anthropogenic warming. This may have exacerbated the impact of drought in regions where warming increases water demand and surface water loss.

Snow

The decline in snow cover observed in recent decades is probably due to anthropogenic warming.

Extremes

There has been an increase in the frequency of warm days and warm nights and a decrease in the frequency of cool days and cool nights. It is likely that these changes are mostly due to anthropogenic warming.

Oceans

Rapid warming in the Tasman Sea is likely to have been partly driven by Antarctic ozone depletion.

Global climate change projections

Scenarios of greenhouse gas emissions, concentrations and radiative forcing

The greenhouse gas and aerosol emissions described here are those due to human activities, such as energy generation, transport, agriculture, land clearing, industrial processes and waste. The IPCC (SRES) emission scenarios used in this report combine a variety of assumptions about demographic, economic and technological factors likely to influence future emissions. They allow projected carbon dioxide, methane, nitrous oxide and sulfate aerosol emissions to be determined. Carbon cycle models are used to convert emissions into atmospheric concentrations, allowing for uptake of emissions by the land and ocean, climate feedbacks, and transport and chemical reactions in the atmosphere. The projected greenhouse gas concentrations are converted to a radiative forcing of the climate system, where positive forcing warms the Earth, and negative forcing cools the Earth. Changes in radiative forcing are used as input to climate models.

Using global climate models to estimate future climate change

Climate models are the best available tools we have for projecting climate. A climate model is a mathematical representation of the Earth's climate system based on well-established laws of physics, such as conservation of mass, energy and momentum. As our understanding of the underlying processes that govern the climate system improves, so too does our ability to represent the processes in climate models.

While projections of global and regional climate change contain uncertainties, global climate models continue to improve in their ability to represent current global and regional patterns of temperature, precipitation and other variables. Simulation of major patterns of climatic variability particularly relevant to Australia (e.g. ENSO, the Southern Annular Mode and the Madden-Julian Oscillation) has improved as well, increasing our confidence in the models.

A new set of experiments from 23 models from research groups around the world is now available and has been used in the generation of the climate projections for Australia. The models in this database represent the current state-of-the-art in climate modelling, with more sophisticated representations of physical and dynamical processes, and finer spatial resolution than in the past.

Each of the 23 models was given a skill score based on its ability to simulate the average (1961-1990) patterns of Australian temperature, rainfall and mean sea level pressure. These skill scores were used to weight regional climate projections based on the assumption that models with higher skill scores are likely to give more reliable projections of future climate.

Probability distributions were developed to represent the models' varying global warming projections for each year and emission scenario. These global warming probability distributions were essential for the creation probabilistic regional climate change projections.

Regional climate change projections

For annual and seasonal mean changes to temperature, precipitation, humidity, solar radiation, wind speed, potential evaporation and sea surface temperature, projections are provided in a probabilistic form. The other climate variables could not be treated similarly due either to the necessary data being unavailable, our assessment that the assumptions underlying the probabilistic approach may not be applicable (particularly relevant for some aspects of extremes), or that understanding of the topic was such that a qualitative assessment was all that was warranted.

Projections for 2030 demonstrate different patterns of regional change between climate models but little variation due to the different emission scenarios. This is because near-term changes in climate are strongly affected by greenhouse gases that have already been emitted. Climate changes centred on 2050 and 2070 are more dependent on the greenhouse gas emissions scenario, so variations due to emission scenarios are more significant. In each case, the best estimate is the median or 50th percentile, while the range of uncertainty is the difference between the 10th and 90th percentile.

Temperature

Projected warming by 2030

The best estimate of annual warming over Australia by 2030 relative to the climate of 1990 is approximately 1.0ºC, with warmings of around 0.7-0.9ºC in coastal areas and 1-1.2ºC inland. Mean warming in winter is a little less than in the other seasons, as low as 0.5ºC in the far south. The range of uncertainty is about 0.6ºC to 1.5ºC in each season for most of Australia. These warmings are based on the A1B emission scenario, but allowing for emission scenario uncertainty expands the range only slightly - warming is still at least 0.4ºC in all regions and can be as large as 1.8ºC in some inland regions. Natural variability in decadal temperatures is small relative to these projected warmings.

Projected warming for 2050 and 2070

Later in the century the warming is more dependent upon the assumed emission scenario. By 2050, annual warming over Australia ranges from around 0.8 to 1.8ºC (best estimate 1.2ºC) for the B1 (low emissions) scenario and 1.5 to 2.8ºC (best estimate 2.2ºC) for the A1FI (high emissions) scenario. By 2070, the annual warming ranges from around 1.0 to 2.5ºC (best estimate 1.8ºC) for the B1 scenario to 2.2 to 5.0ºC (best estimate 3.4ºC) for the A1FI scenario. Regional variation follows the pattern seen for 2030, with less warming in the south and north-east and more inland. In 2070, the risk of a warming above 4ºC in 2070 exceeds 30% over inland Australia under the A1FI scenario, whereas under the B1 scenario the warming is likely to be less than 2.0ºC except in the north-west.

Local variations to projected warming

Projected warming may vary significantly from that given by the global climate models in mountainous areas and near the coast. This has been demonstrated through the application of fine-resolution spatial downscaling techniques.

Extreme temperatures

Projected changes in maximum and minimum temperature indicate an increase in the diurnal temperature range in the south and a decrease in the north. This is associated with a projected strong increase in frequency of hot days and warm nights and a moderate decrease in frost. For the Murray-Darling Basin, a simulated increase in the day-to-day variability of minimum temperature reduced the impact of the mean warming on simulated frost frequency.

Precipitation

Projected precipitation change for 2030

Best estimates of annual precipitation indicate little change in the far north and decreases of 2% to 5% elsewhere. Decreases of around 5% prevail in winter and spring, particularly in the south-west where they reach 10%. In summer and autumn decreases are smaller and there are slight increases in the east.

The range of precipitation change in 2030 allowing for model-to-model differences is large. Annually averaged, the range is around -10% to +5% in northern areas and -10% to little change in southern areas. Decreases in rainfall are thus more consistently indicated for southern areas compared to northern areas. Winter and spring changes range from decreases of around 10% to little change in southern areas of the south-east of the continent, decreases of 15% to little change in the south-west, and decreases of around 15% to possible increases of 5% in eastern areas. In summer and autumn, the range is typically -15% to +10%. Decadal-scale natural variability in precipitation is comparable in magnitude to these projected changes and may therefore mask, or significantly enhance, the greenhouse-forced changes.

Projected change for 2050 and 2070

Later in the century, the projected precipitation changes are larger and vary more according to emission scenario.

By 2050 under the B1 (low emissions) scenario, the range of annual precipitation change is -15% to +7.5% in central, eastern and northern areas, with a best estimate of little change in the far north grading southwards to a decrease of 5%. The range of change in southern areas is from -15% to little change, with a best estimate of approximately -5%. Under the A1FI (high emissions) scenario, changes in precipitation are larger. The range of annual precipitation change is -20% to +10% in central, eastern and northern areas, with a best estimate of little change in the far north grading to around -7.5% decrease elsewhere. The range of change in southern areas is from a 20% decrease to little change, with a best estimate of around -7.5%. Seasonal changes follow the pattern seen for 2030, but are larger under A1FI in 2050. The projected decreases in the south-west in winter and spring are up to 30%.

In 2070, precipitation changes under the B1 scenario are comparable to those for 2050 under the A1FI scenario. Those under the A1FI scenario in 2070 are substantially larger. The range of annual precipitation change is -30% to +20% in central, eastern and northern areas, with a best estimate of little change in the far north grading to around -10% in the south. The range of change in southern areas is from -30% to +5%, with a best estimate of around -10%. Seasonal changes may be larger, with the projected decreases in the south-west of up to 40%.

Local variations to projected change

As for temperature, statistical downscaling studies have shown that projected precipitation change can vary significantly at fine spatial scales, particularly in coastal and mountainous areas.

Daily precipitation intensity, frequency of dry days and extreme precipitation

Models show an increase in daily precipitation intensity but also in the number of dry days. Extreme daily precipitation tends to increase in many areas but not in the south in winter and spring when there is a strong decrease in mean precipitation.

Snow

Snow cover, average season lengths and peak snow depths are projected to decrease in Australian alpine regions, and there is a tendency for the time of maximum snow depth to occur earlier in the season.

Solar radiation, relative humidity and potential evaporation

Solar radiation

Projections of solar radiation generally show little change although a tendency for increases in southern areas of Australia is evident, particularly in winter and spring. The projected range of change is typically -1% to +2% in 2030. The magnitude of changes is larger in 2050 and 2070, particularly under higher emission scenarios.

Relative humidity

Small decreases in relative humidity are projected over most of Australia. The range of change in annual humidity by 2030 is around -2% to +0.5% with a best estimate of around a 1% decline. The projected changes are larger for 2050 and 2070, particularly under the higher emission scenarios.

Potential evapotranspiration

Annual potential evapotranspiration is projected to increase over Australia. Largest increases are in the north and east, where the change by 2030 ranges from little change to a 6% increase, with best estimate of around a 2% increase. By 2070, the B1 scenario gives increases of 0% to 6% (best estimate around 3%) in the south and west and 2% to 8% (best estimate around 6%) in the north and east, while the A1FI emissions scenario gives increases of 2% to 10% (best estimate of around 6%) in the south and west and 6% to 16% (best estimate around 10%) in the north and east.

Drought

Drought occurrence is projected to increase over most of Australia, but particularly in south-western Australia.

Wind

Average wind speed projections

There is a tendency for increased wind speed in most coastal areas in 2030 (range of -2.5% to +7.5% with best estimates of +2% to +5%) except for the band around latitude 30°S in winter and 40°S in summer where there are decreases (-7.5% to +2.0%, with best estimates of -2% to -5%).

Later in the century, changes of wind strength can be larger, depending on the emission scenario. Under the A1FI scenario in 2070, best estimate increases of more than 15% apply in some regions, whereas under the B1 scenario increases are less than 10% everywhere.

Extreme wind speed projections

In winter, changes to extreme wind speed are likely to be similar to the changes to seasonal mean wind speed. However, there is little relationship between summer mean and extreme wind speed changes. Extreme winds in summer are likely to be governed more by small scale systems (including tropical cyclones). On the other hand, winter extreme wind events are more likely to be governed by larger scale systems (e.g. trade winds, mid-latitude cyclones).

Fire weather

A substantial increase in fire weather risk is likely at most sites in south-eastern Australia. Such a risk may exist elsewhere in Australia, but this has yet to be examined.

Sea level rise

Mean sea level rise

Global sea level rise is projected by the IPCC to be 18-59 cm by 2100, with a possible additional contribution from ice sheets of 10 to 20 cm. However, further ice sheet contributions, that cannot be quantified at this time, may substantially increase the upper limit of sea level rise.

Sea level extremes

Storm surges occurring in conditions of higher mean sea levels will enable inundation and damaging waves to penetrate further inland, increasing flooding, erosion and the subsequent impacts on built infrastructure and natural ecosystems. Changes to wind speed will also affect storm surge height.

Storm surge studies for portions of the Victorian and Queensland coasts demonstrate the potential for significant increases in inundation due to higher mean sea level and more intense weather systems.

Marine projections

Sea surface temperature

By 2030 the best estimate of sea surface temperature rise is 0.6-0.9ºC in the southern Tasman Sea and off the north-west shelf of Western Australia and 0.3-0.6ºC elsewhere. Allowing for model-to-model variations, the ranges are 0.4-1.4ºC in the southern Tasman Sea and 0.4-1.0ºC off the north-west coast.

Beyond the first few decades of the 21st century, the magnitude of the sea surface temperature change will become increasingly dependent on the emission scenario. Under the B1 scenario in 2070, the sea surface temperature best estimate increase is 0.6 to 1.0ºC along the south coast of Australia while elsewhere it is 1.2 to 1.5ºC. Under the A1FI emission scenario, the regions of highest warming are about 1.0ºC higher than those for the B1 scenario.

Ocean acidification

Increases in ocean acidity are expected in the Australian region with the largest increases in the high- to mid-latitudes. Under-saturation of aragonite could occur by the middle of the century in the higher latitudes, affecting the capacity for shell and endoskeleton creation by marine organisms.

East Australian Current

The East Australian Current is likely to strengthen throughout the 21st century, which will result in warmer waters extending further southward.

Severe weather

Tropical cyclones

Similar to studies for other basins, Australian region studies indicate a likely increase in the proportion of the tropical cyclones in the more intense categories, but a possible decrease in the total number of cyclones.

Severe thunderstorms

Conditions will become less suitable for the occurrence of tornadoes in southern Australia in the cool season (May to October). There is an indication that hail risk may increase over the south-east coast of Australia.

ENSO, the Southern Annular Mode and storm tracks

ENSO's impact on Australia under global warming

In south-eastern Australia, models analysed indicate that El Niño events will tend to become drier and La Niña events will tend to become wetter, even if Pacific Ocean variability linked to ENSO does not increase.

The Southern Annular Mode

All climate models exhibit a trend in the Southern Annular Mode towards its positive phase (weaker westerly winds over southern Australia, stronger westerly winds at higher latitudes) when driven with increasing greenhouse gas concentrations.

Storm tracks

A decrease in the occurrence of winter low pressure systems over south-west Western Australia is likely during the 21st century.

Application of climate projections in impact and risk assessments

Risk management is an iterative process, where scoping and risk identification usually takes place before more detailed assessments are carried out. Care must be exercised when using the projections in any risk assessment, particularly when selecting climate variables, determining temporal and/or spatial resolution, and dealing with uncertainty.

Detailed risk assessments generally require purpose-built climate projections, including time series, or probabilistic representations of future climate. Various tools have been developed which represent different methods for enhancing the delivery of climate information to stakeholders both for education and for risk assessment and management. Nevertheless, significant challenges remain for communicating climate risk in ways that can be effectively used in risk management.