Australian Academy of Science

Submission to the Senate Standing Committee on Environment and Communications

Inquiry into recent trends in and preparedness for extreme weather events

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Summary

- This submission addresses Inquiry Terms of Reference (a) and (b)(i) (see Appendix).
- While extreme events are a natural feature of Australian climate, a shift in the climate baseline will change the frequency and intensity of extreme events. For example, an increase in mean temperature will increase the frequency and intensity of heat waves; higher mean sea level will increase the frequency and intensity of coastal flooding associated with storm surges.
- The number of record hot days in Australia has increased from decade to decade since 1960, particularly since 2000, and the number of record cold days has declined. These trends are consistent with global warming and are consistently observed across the globe.
- Further warming in future, associated with continuing emissions of greenhouse gases and their accumulation in the atmosphere, is nearly certain.
- There is very strong evidence that increases in high-temperature extremes, in both magnitudes and numbers of occurrences, are associated with warming. This implies near-certain future increases in direct heat-related impacts, including bushfires, heat stress and damage to agricultural systems and ecosystems.
- Observed Australian rainfall trends over the last 50 years show decreases in the southwest and east, especially in autumn and winter rainfall, and increases in the north and northwest. There is high rainfall variability in all Australian regions, linked with normal climate variability through influences of the Pacific and Indian Oceans.
- Continuance of these observed trends is projected by climate models and by observed correlations of temperature and rainfall trends with the changes in the intensity of the subtropical high-pressure ridge. For southern Australia, the combination of ongoing high natural variability with a reduced mean rainfall over decades suggests increased incidence and severity of droughts.
- There is strong evidence that changing occurrences of extreme events are related to climate change, and that such changes will continue with further climate change. This is almost certain for temperature-related extremes and likely for rainfall-related extremes.
- There will be many adverse impacts from extreme events related to climate change. These will include large increases in bushfire risk; likely reduced water availability in southern Australia; coastal impacts from increased frequency of coastal flooding and erosion related to storm surges; higher energy demands, especially for cooling on very hot days; increased heat stress and associated health problems; significant disruptive changes to ecosystems in vulnerable tourist areas; threats to agricultural productivity; and threats to vulnerable natural ecosystems.
- There is a need for policy responses that reflect a balance between the level of certainty about future changes in extreme events and the impacts of these changes.
- Policy responses require a portfolio of actions combining both adequate mitigation and adaptation. Neither alone will be sufficient to avoid major risks from the impacts of increased heatwaves, rainfall extremes (including drought) and coastal flooding.

- Policy responses should not depend on perfect knowledge, but rather on an assessment that sufficient knowledge exists to identify an unacceptable risk of outcomes that need to be avoided.

Introduction: links between extreme weather events and climate change

It is often asked whether a particular extreme weather event (such as the January 2013 heatwave) is caused by climate change. This is not a useful question, because any one weather event has multiple causes originating in both the recent past (weather over prior days to months) and also in the longer-term systemic behaviour of the climate system. Two more useful questions are "Are there changing patterns of occurrence in extreme events related to climate change?" and "Will these changes increase with further climate change?"

In this submission we will summarise evidence showing that for many extreme events such as heatwaves and associated impacts, the best answer to both questions from recent science is "yes". For other extreme events such as drought in southern Australia, best answers at present are "likely". These assessments are based on recent scientific advances, reviewed briefly here and much more comprehensively elsewhere (for instance [1]).

It is critical to note that scientific assessments of links between extreme events and climate change are not based on recent experience of any particular event, but rather on the observed evidence and climate model projections over many decades and across different regions. In contrast, public and media perceptions of the link between extreme events and climate change depend strongly on recent and current experience. The media report weather extremes, including droughts, fires, floods and storms, as stories with a turnover time of days to hours. It is natural for the public to interpret these events – experienced either personally or through a media lens – with emphasis on the present rather than the long term. Public perceptions of the reality of climate change are strongly correlated with current weather, especially with temperature; when current conditions are warmer or drier (in Australia) than normal there is an increase in the proportion of people agreeing with statements like "global warming is occurring " and "human activities are responsible", with a converse decrease in agreement when current weather is unusually cool [2]. Policy responses to the risks posed by increased weather extremes induced by climate change need to be immune to these short-term, weather-related fluctuations in public sentiment, which randomly sway support for action in both directions.

Heat and its impacts

Past trends

Average Australian temperatures increased by about 0.9°C from 1900 to 2012 [3, 4], slightly more than the global increase of about 0.8°C over the same period [5, 6, 7]. Along with the increase in average temperatures there has been a significant shift in observed extremes: the number of record hot days in Australia has increased from decade to decade since 1960, particularly since 2000, and the number of record cold days has declined [3]. This shift in the probabilities of extreme temperature events echoes global trends [8, 9]. The global probability of maximum temperatures has shifted over successive decades since 1950. In the latest decade (2001-2011), a new class of extreme warm temperatures, outside the former range, is now being observed [8]. The probability of this class of events is increasing not only because temperature distributions are becoming warmer, but also because the distributions are becoming broader.

There is a clear observed association between extreme heat and catastrophic bushfires [10]. In the first two weeks of January 2013, Australia experienced a heatwave of record-breaking extent and severity [11], extending an abnormally hot last four months of 2012. Many temperature records were broken, and major bushfires occurred in Tasmania, Victoria, NSW and central Australia with extensive property loss. These follow the horrific Black Saturday fires in Victoria on 9 February 2009, in which 173 people died, and earlier southern Australian firestorms (January 2003, February 1983 and others).

Heatwaves have significant health impacts, resulting in increased hospital admissions and deaths from conditions associated with heat stress [12]. In the heatwave associated with the Victorian Black Saturday (2009) bushfires, heat stress caused an estimated 374 excess deaths [13], more than twice the number of deaths from the fire itself.

Future trends

Further warming in future is nearly certain, associated with continuing increases in the levels of carbon dioxide (CO_2) and other greenhouse gases in the atmosphere [14, 15]. Future global warming by 2100 will be around 3°C (relative to a preindustrial baseline, and with an uncertainty range[1] from 2 to 4.5 °C) under circumstances where significant efforts are made to reduce greenhouse-gas emissions, and 4 to 5 or more degrees (with a larger uncertainty range) assuming "business as usual", that is, no attempt to curtail emissions as demands for energy continue to rise. These estimates are consistently obtained both from independent studies with climate models, and also from the close relationship between cumulative CO_2 emissions and warming [16, 17, 18, 19, 20].

There is very strong evidence that increases in high-temperature extremes are associated with warming [8, 9].

Rainfall and drought

Past trends

Rainfall trends are difficult to determine from data because of very high year-to-year and place-to-place variability. In Australia over the period 1960-2012, there have been pronounced drying trends in southwest Western Australia (where mean annual rainfall has decreased by about 20%), and in the east and southeast (including Victoria, South Australia, eastern New South Wales and southeast Queensland). These trends have been most apparent for winter and spring rainfall [3, 4]. In the northwest, there has been a trend towards increasing rainfall.

There is high rainfall variability in all Australian regions, linked with natural year-to-year climate variability related to climate phenomena such as El Niño-Southern Oscillation in the equatorial Pacific Ocean and the Indian Ocean Dipole Mode in the equatorial Indian Ocean [21, 22].

Observed rainfall trends in both southern and northern Australia have been associated with changes in the large-scale behaviour of the climate system, particularly the intensity of the subtropical high-pressure ridge over southern Australia, and in turn, the subtropical ridge intensity is well correlated

[1] The temperature range of 2 to 4.5°C encompasses 2/3 of the assessed probability range of outcomes. There is a 1/6 probability warming will exceed 4.5°C, and a 1/6 chance that it will be less than 2°C.

with global warming over the last century [23, 24, 21, 25]. This is an important finding that establishes a relationship between global warming and observed southern Australian rainfall.

Southeast and eastern Australia experienced the longest and most widespread drought on record from 2000 to 2009. The drought was broken by intense summer rains in 2010-2011 associated with a major La Niña event in the Pacific Ocean (La Niña brings higher-than-average rainfall to eastern Australia, especially in the northeast). The drought-breaking rains fell mainly in summer, leaving autumn and winter rains at average or lower levels throughout Australia except in the north and centre [4].

Future trends

The observed trends toward lower autumn and winter rainfall in southern Australia are occurring more quickly than implied by (very scattered) model predictions [Timbal and Lucas, *pers. comm.*]. Further rainfall reductions in southern Australia, typically around 5% by 2050, is projected by climate models [14, 26]. The drying will be more severe if there is continuance of the trend that rainfall declines are greater than those projected by the models. Such a drying trend would lead not only to lower mean rainfall and runoff but also to increased incidence and severity of droughts, because of the combination of ongoing high natural variability with a reduced mean rainfall.

Sea level rise

Past trends

Sea level rise is an inevitable consequence of global warming because ocean water expands as it warms, and because an increase in melted ice from the land adds more water to the oceans. The rate of rise increased from the 19th to the 20th centuries, with the result that ocean levels are now more than 0.2 m higher than in 1870. Satellite and coastal measurements show that the rate of sea level rise since the early 1990s has been about 3 mm per year. This is substantially larger than the average rate for the 20th century, although only slightly larger than the rates in the 1940s. The observed rise is consistent with observed rates of ocean warming, ice melt (including contributions from Arctic and Antarctic land ice and non-Arctic glaciers) and changes in water stored in terrestrial aquifers and reservoirs [27].

Future trends

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment in 2007 projected an ongoing sea level rise of up to 0.6 m from 1990 to 2100, if emissions of greenhouse gases follow a high pathway [14]. This estimate did not include an allowance for rapid ice sheet dynamic response, but a simple scaling argument suggested an additional 0 to 0.2 m from this mechanism. Several subsequent assessments have produced higher estimates of sea level rise by 2100, for example ranging from 0.75 to 1.9m [28], but there is little consensus on these higher projections and it has not yet been possible to assign a confidence level to them.

Although the magnitude of future sea level rise by 2100 is uncertain, there is high confidence that sea levels will continue to rise over the 21st century and beyond, and that the rate of rise will be faster than the average rate over the past half century.

The frequency and impacts of coastal flooding from extreme events such as storm surges will be significantly amplified by sea level rise, because the surges take place on a higher background sea level.

Impacts of extreme events

Extreme events associated with climate change will produce many significant impacts following inevitably from physical climate changes, including temperature increases, changes in rainfall patterns and sea level rise. Examples of important impacts include the following [partly adapted from ref. 29], most of which are associated with extreme events:

- *Bushfires:* A rise of a few degrees in mean temperature would greatly increase the number of days of extreme heat and extreme or catastrophic bushfire risk, for example from a few days to tens of days per year in southern and eastern Australia [10].

- *Water availability:* There will likely be reduced water availability in southern Australia for agriculture, urban consumption and ecosystem maintenance. Causes include the combined effects of rainfall losses across much of the continent [14, 26], increased evaporation associated purely with warming [30], and changed seasonality and rainfall intensity. Percentage reductions in water availability (for example, measured as streamflow) will be 2-3 times larger than reductions in precipitation [30].

- *Coastal impacts:* Coastal communities will face generally higher sea levels (regionally modulated by temperature, ocean and atmosphere circulation patterns) and will be exposed to more frequent extreme coastal flooding events associated with storm surges. It has been estimated that for low-lying coastal regions, shoreline retreat by coastal erosion (a phenomenon associated mainly with storm surges) averages of order 100 times the mean sea level rise (depending greatly on location) [31].

- *Energy security:* There will be impacts from higher thermal loads and changed seasonal and diurnal demands, particularly for cooling on very hot days.

- *Major infrastructure:* There will be changed demands for drainage infrastructure due to higher intensity precipitation and changed rainfall patterns, together with increased energy use due to increased thermal stress.

- *Health:* There will be increased heat stress and associated health problems, from a higher frequency of extreme temperatures, but some reduction in low-temperature stress. Increased exposure to disease-bearing vectors such as mosquitoes is likely.

- *Tourism:* There will be significant disruptive changes to ecosystems in vulnerable tourist areas, in particular the Great Barrier Reef [32], Kakadu and alpine regions; many of these impacts will be related to extreme events.

- *Agriculture and forestry:* threats to productivity will arise from heat extremes, likely increased drought risk in southern Australia, and increased fire risk. Agriculture and forestry operations will be affected by infrastructure stress. Changes to oceanic productivity and distribution of marine organisms will affect fisheries.

- *Natural ecosystems:* There will be adverse impacts through changes in temperatures and water availability, as well as by storminess, extreme events and the acidification of oceans [33]. Along with other stresses, these will result in the loss of species (biodiversity) and the resilience of ecosystems. Conservation and ecosystem services will be affected.

Responses: mitigation and adaptation

Much of the future impact of long-term climate change will be experienced through extreme events, rather than merely through shifts in climatic average conditions. For Australia this is particularly true of the impacts of extreme heat and rainfall variability, including droughts and floods, and coastal flooding associated with the combination of sea level rise and storm surges..

There is a need for policy responses that combine two strategies: reduction of greenhouse-gas emissions to lessen ultimate levels of global warming and regional impacts (mitigation), and adaptive responses to lessen the impact of those changes that will be unavoidable (adaptation). Mitigation is essential to avoid the dangerous futures associated with "business as usual" scenarios for emissions, especially of CO_2, in which mean global temperatures warm by 2100 to 4 or more degrees centigrade above preindustrial temperatures with accompanying strong increases in extreme weather. To keep global warming below 2 ^{o}C with a 50% chance of success, global emissions in 2050 need to be reduced to less than 50% of emissions in 2000 [14, 16, 17, 19]. How this global reduction of emissions will be achieved is a complex international problem, demanding considerations of the relative energy resource distributions between nations, their respective economic well being, differential human and natural ecosystem exposures, accumulated relative responsibilities of developed nations for change that has already occurred or set in train, and humanitarian considerations of how poorer peoples may need assistance. On balance, there is a strongly held view within the climate science community that this demands a stronger response from developed nations such as Australia, and for such nations to set emissions-reduction targets at 80% below current levels by 2050.

These are very challenging targets. Contrary to the requirement for strong and sustained emissions reductions, global emissions since 2000 have increased at around 3% per year [34]. This makes it increasingly unlikely that global warming can be kept below 2 ^{o}C. Based on current emissions trends, together with climate, technical and political inertias, warming of at least 2.5 ^{o}C is now likely even with a strong global mitigation effort [35]. Therefore, a range of adaptation strategies is also essential, including increased preparedness, better early warning systems, more resilience in urban, agricultural and industrial systems and infrastructure, and improved disaster recovery mechanisms.

Adaptation alone will not be sufficient, because there comes a point beyond which systems cannot adapt to increasing stress. A combination of both mitigation and adaptation is essential.

Further information

The Australian Academy of Science would welcome the opportunity to give verbal evidence before the Committee.

Appendix: Terms of Reference

Terms of Reference for the Inquiry of the Senate Standing Committee on Environment and Communications into "Recent Trends in and Preparedness for Extreme Weather Events" are:

(a) recent trends on the frequency of extreme weather events, including but not limited to drought, bushfires, heatwaves, floods and storm surges;

(b) based on global warming scenarios outlined by the Intergovernmental Panel on Climate Change and the Commonwealth Scientific and Industrial Research Organisation of 1 to 5 degrees by 2070:

(i) projections on the frequency of extreme weather events, including but not limited to drought, bushfires, heatwaves, floods and storm surges,

(ii) the costs of extreme weather events and impacts on natural ecosystems, social and economic infrastructure and human health, and

(iii) the availability and affordability of private insurance, impacts on availability and affordability under different global warming scenarios, and regional social and economic impacts;

(c) an assessment of the preparedness of key sectors for extreme weather events, including major infrastructure (electricity, water, transport, telecommunications), health, construction and property, and agriculture and forestry;

(d) an assessment of the preparedness and the adequacy of resources in the emergency services sector to prevent and respond to extreme weather events;

(e) the current roles and effectiveness of the division of responsibilities between different levels of government (federal, state and local) to manage extreme weather events;

(f) progress in developing effective national coordination of climate change response and risk management, including legislative and regulatory reform, standards and codes, taxation arrangements and economic instruments;

(g) any gaps in Australia's Climate Change Adaptation Framework and the steps required for effective national coordination of climate change response and risk management; and

(h) any related matter.

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