Australian Meteorological & Oceanographic Society

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18 January, 2013

Committee Secretary,
Senate Standing Committees on Environment and Communications,
PO Box 6100,
Parliament House,
Canberra ACT 2600

Dear Sir/Madam,

The Australian Meteorological and Oceanographic Society Inc. welcomes the opportunity to make a submission to the Senate Inquiry on "Recent trends in and preparedness for extreme weather events". As the responsible professional body for scientists and operational practitioners in the atmospheric and oceanographic science, we believe our membership has a wide range of expertise which will be of assistance to the Committee.

The Society's annual conference, which will be attended by many Australian climate researchers, will be taking place in Melbourne from 11-13 February. This may be of assistance to the Committee in determining the scheduling of hearings.

Our contact details are listed at the top of this letter.

Yours sincerely,

Blair Trewin
President
Australian Meteorological and Oceanographic Society Inc.

Senate inquiry on recent trends in, and preparedness for, extreme weather events

Submission by Australian Meteorological and Oceanographic Society Inc.

The Australian Meteorological and Oceanographic Society is the professional body representing those engaged in the atmospheric and oceanographic sciences, including those in scientific research, as well as those with operational roles in forecasting (both at day-to-day and seasonal timescales) or climate monitoring.

Our submission is mainly directed at the Inquiry's terms of reference (a) and (b)(i):

(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.

There are numerous institutions that are carrying out scientific activities within the fields covered by the inquiry's terms of reference. These include the Bureau of Meteorology (who, in addition to their forecasting role, are responsible for monitoring observed climate change in Australia), CSIRO (particularly in the areas of projections of future climate change, as well as observations and projections of sea level), and the ARC Centre of Excellence for Climate System Science, a consortium of five Australian universities with numerous partner organisations. Significant activities are also taking place in universities outside the Centre of Excellence framework and various other agencies at State and Commonwealth level, whilst considerable research relevant to the Australian region and the rest of the world also takes place internationally.

Research in this area falls under the National Research Priority "An environmentally sustainable Australia", and the most relevant Priority Goals are: 1. Water – A Critical Resource, and 7. Responding to Climate Change and Variability. With the exception of the Bureau of Meteorology, who conducts some of this research under core institution funding, the vast majority of this research is funded from external sources. The Bureau of Meteorology and CSIRO receive funding from the Australian Climate Change Science Program. The Australian Research Council supports most of the University activity. Other private organizations (e.g., members of the insurance industry) fund directed research in this area too.

As will be discussed later in this submission, there are some types of extremes for which the knowledge base is good (for observed changes, projections or both), some where it is weaker but is likely to improve with further research and analysis, and some where inherent issues with analysis make it unlikely that robust conclusions will be reached in the foreseeable future. As a result, it is inevitable that in some areas, policy-makers will need to make decisions about suitable responses to the risk of extreme events in the absence of robust knowledge about likely changes in that risk.

It is not the purpose of our submission to undertake a comprehensive review of scientific findings related to terms of reference (a) and (b)(i), as we understand that this will be covered in submissions by the Centre of Excellence and the Bureau of Meteorology (among others). Rather, our submission will focus on identifying knowledge gaps and whether these can realistically be addressed (and, if so, how), as well as providing the Inquiry with information which may assist in reconciling apparently conflicting findings in particular areas of the science.

Some definitions relevant to this submission

Some terms which are relevant to this report include:
Detection – this refers to the identification of a significant change in observed data, without any assessment of the cause of such a change.

Attribution – this refers to the assessment of the extent to which a particular forcing or forcings (e.g. changes in the concentration of greenhouse gases) contributes, or does not contribute, to a change which has been detected.

Projections – this refers to forecasts, based on a specific scenario of emissions into the future, of expected climate changes in the future, relative to a baseline (which is often quoted as a specific year but is in fact a multi-year average centred on that year, e.g. '1990' is often quoted as a baseline year but typically this refers to a 1980-1999 average).

Key reports relevant to climate extremes in Australia

The most comprehensive global assessment of climate extremes is the Intergovernmental Panel on Climate Change (IPCC) 2012 Special Report, 'Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation' (hereafter referred to as SREX). The current state of the science is largely discussed in Chapter 3, 'Changes in Climate Extremes and their Impacts on the Natural Physical Environment', but several other chapters of SREX are also relevant to the Inquiry's terms of reference, including Chapters 5, 6, 7, which deal with managing the risks from climate extremes at the local, national and international level respectively. SREX updates the 2007 IPCC Fourth Assessment Report (AR4), although its conclusions in some areas (notably with respect to drought and tropical cyclones, for reasons which are discussed later in this submission) differ somewhat from those of AR5. Preparation of the Fifth Assessment Report (AR5) is well under way, with release expected in three stages from late 2013 to early 2014.

The most recent climate change model projections for Australia were released in 2007, and were published in the CSIRO/Bureau of Meteorology report 'Climate Change in Australia' (www.climatechangeinaustralia.gov.au). The next release of climate change projections for Australia, based on the latest generation of climate models and emission scenarios, is scheduled for 2014. As these models generally operate at higher spatial resolution than their predecessors, it is expected that they will be able to support greatly improved projections of climate extremes, as well as more locally specific information, than is currently available. Updated assessments of observed climate change in Australia have been released in 2010 and 2012 in the CSIRO/Bureau of Meteorology 'State of the Climate' reports.

A number of regional assessments have also been produced. These include assessments for Western Australia (Indian Ocean Climate Initiative (IOCI), www.ioci.org.au), Tasmania

(Climate Futures for Tasmania, http://www.dpac.tas.gov.au/divisions/climatechange/ adapting/climate_futures) and south-eastern Australia (South-Eastern Australian Climate Initiative (SEACI), www.seaci.org). Neither IOCI nor SEACI, which were both joint projects involving various Commonwealth and State agencies, have received ongoing funding and both have been, or are in the process of being, wound up, which is a concern for the future availability of regionally-specific assessments.

Key outcomes of the IPCC SREX report

There were a number of relevant statements in the IPCC SREX report which are included here as a background to further discussion (as noted earlier, more detailed discussion of the science is expected to be contained in institutional submissions). It should be noted that the IPCC does no research of its own – the IPCC reports are an assessment of material already published (almost entirely in the peer-reviewed scientific literature). In the IPCC context, terms such as 'virtually certain', 'very likely' and 'likely' also have specific definitions which are described in the report.

Comments in square brackets are our commentary on the IPCC statements and are not part of their report.

- *Many weather and climate extremes are the result of natural climate variability (including phenomena such as El Niño), and natural or multi-decadal variations in the climate provide the backdrop for anthropogenic climate changes. Even if there were no anthropogenic changes in climate, a wide variety of natural weather and climate extremes would still occur.*
- *A changing climate leads to changes in the frequency, intensity, spatial extent, duration, and timing of weather and climate extremes, and can result in unprecedented extremes. Changes in extremes can also be directly related to changes in mean climate, because mean future conditions in some variables are projected to lie within the tails of present-day conditions. Nevertheless, changes in extremes of a climate or weather variable are not always related in a simple way to changes in the mean of the same variable, and in some cases can be of opposite sign to a change in the mean of the variable.*
- *It is very likely that there has been an overall decrease since 1950 in the number of cold days and nights, and an overall increase in the number of warm days and nights, at the global scale. It is likely that these changes have also occurred at the continental scale in North America, Europe and Australia.*
- *It is likely that there have been statistically significant increases in the number of heavy precipitation events in more regions than there have been statistically significant decreases, but there are strong regional and subregional variations in the trends.* [As discussed later, over most of Australia signals in extreme precipitation are weak relative to those which exist at many higher-latitude locations, especially in the Northern Hemisphere].
- *There is low confidence that any observed long-term increases in tropical cyclone activity are robust, after accounting for past changes in observing capabilities.*
- *It is likely that there has been a poleward shift in the main Northern and Southern Hemisphere extratropical storm tracks.* [This is relevant to observed decreases in rainfall in southern Australia, especially south-west Western Australia].

- *There is low confidence in observed trends in small-scale phenomena such as tornadoes and hail because of data inhomogeneities and inadequacies in monitoring systems.*
- *There is medium confidence that since the 1950s some regions of the world have experienced a trend to more intense and longer droughts, in particular in southern Europe and West Africa.* [The only Australian reference here is a reference to reduced drought in northwestern Australia].
- *There is low confidence at the global scale regarding observed changes in floods.*
- *It is likely that there has been an increase in extreme coastal high water related to increases in mean sea level.*
- *It is likely that anthropogenic influences have contributed to warming of extreme daily temperatures at the global scale, and to increasing extreme global high water. There is medium confidence that anthropogenic influences have led to intensification of extreme precipitation at the global scale.*
- *It is virtually certain that increases in the frequency and magnitude of warm daily temperature extremes and decreases in cold extremes will occur through the 21st century at the global scale. A 1-in-20 year annual hottest day is likely to become a 1-in-2 year annual extreme by the end of the 21st century in most regions.*
- *It is likely that the frequency of heavy precipitation or the proportion of total rainfall from heavy rainfalls will increase in the 21st century over many areas of the globe. There is medium confidence that, in some regions* [including parts of Australia], *increases in heavy precipitation will occur despite projected decreases in total precipitation.*
- *There is generally low confidence in projections of changes in extreme winds because of the relatively few studies of projected extreme winds, and shortcomings in the simulation of these events. An exception is mean tropical cyclone maximum wind speed, which is likely to increase, although increases may not occur in all ocean basins. It is likely that the global frequency of tropical cyclones will either decrease or remain essentially unchanged.*
- *There is low confidence in projections of small-scale phenomena such as tornadoes.*
- *There is medium confidence in a projected poleward shift of mid-latitude storm tracks due to future anthropogenic forcings, and low confidence in the detailed geographical projections of mid-latitude cyclone activity.*
- *There is low confidence in projections of changes of large-scale patterns of natural climate variability, such as the El Niño-Southern Oscillation, the north Australian monsoon, the Indian Ocean Dipole and the Southern Annular Mode.*
- *It is very likely that mean sea level rise will contribute to upward trends in extreme coastal high water levels in the future.*
- *There is low confidence in projected changes in drought in Australia.*

The IPCC report states specifically that it does not provide assessments of projected changes in extremes at spatial scales smaller than for large regions (meaning, in the Australian context, regions smaller than the northern, or southern, halves of Australia). This means its findings do not resolve relatively small but significant regions such as the south-west of Western Australia or the major capital cities. The upcoming 2014 CSIRO projections will be very important in this respect. The IPCC also only gives limited coverage to elements which are relevant to Australia but less relevant (at least in the same form) to other parts of the world, such as fire danger indices; however, this is an area where the domestic knowledge base is strong.

It is also worth noting that, the larger the area that is being assessed, the more likely it is that a long-term climate change signal can be detected against the background of natural climate variability (as the process of averaging over a wide area smooths out some of that natural variability) or, for projections, model uncertainty. This explains why confidence in changes at the global scale is often stronger than confidence in changes at the national or regional scale.

Some specific knowledge gaps and prospects for addressing them

The assessment of changes in extremes is inherently more challenging than the assessment of changes in the average. By definition, extremes are rare events, and as a result, changes in some extremes have to be quite large before they can be distinguished, with some level of confidence, from the level of variability that could be expected with natural climate variability. This issue is most acute for the most extreme extremes, which are also, in general, the events of greatest interest because they have the largest impacts.

There are a number of possible approaches to addressing this problem, including aggregating results over a large area (for example, counts of the total number of record high and low temperatures over Australia, as opposed to the number of records at a specific location), or assessing changes in properties of the frequency distribution (e.g. standard deviation) which may be more robust than changes in the extremes themselves. Different sources of information are also used, ranging from observational data from the instrumental record to projections of the changes in extremes from climate models.

Tropical cyclones

As noted by IPCC, the evidence for observed changes in tropical cyclone activity (both number and intensity) is weak.

This is principally a consequence of the methods used for observing tropical cyclones. Most tropical cyclone observations in the Australian region are made by satellite (with cyclone intensity being inferred from satellite cloud properties), supplemented by radar if the cyclone is within radar range, and observations from nearby land-based observations and ocean buoys, if there are any. This is true of most parts of the world, except the North Atlantic where aircraft are flown into some tropical cyclones to make measurements.

As a result, records of tropical cyclone intensity in the Australian region can only be considered reasonably consistent since the early 1980s, when observation methods reasonably close to those currently in use came into use. Prior to the 1980s cyclone intensity was routinely underestimated except for those (few) systems which made landfall near an observation site. Tropical cyclone counts are probably reasonably reliable in the Australian region since about 1960, with records extending back to the 19th century for coastal crossings in Queensland from Cooktown southwards. Prior to 1960, many cyclones which never made landfall, or which did so in remote areas, are likely to have gone unreported. The issue of long-term consistency of tropical cyclone observations has become increasingly apparent since the publication of AR4 and the confidence level of conclusions regarding tropical cyclones was consequently weakened in SREX.

Whilst nothing can be done to recreate observations which were never made, there are some prospects for being able to extend consistent records of tropical cyclone intensity back to about 1970 by re-analysing the satellite imagery available from that era using more modern methods. Some progress is being made towards this in the Bureau of Meteorology but further work is needed.

Extreme rainfall

The assessment of extreme rainfall events (which in this context, refers to events covering periods of a few days or shorter) is more challenging than the assessment of extreme temperature events. In part, this is because some extreme rainfall events (particularly those related to severe thunderstorms) are quite localised and may not necessarily be captured by the rain gauge network (even though the number of rainfall observing stations in Australia is about ten times the number of temperature stations). A number of definitions also exist which can be used to define an extreme rainfall event – for example, one might consider number of days above 20 millimetres, or the wettest 5% of days – but none are ideal at consistently defining extremes (e.g. a 20-millimetre day is not particularly extreme in the tropics, whilst in the driest parts of central Australia where rain only falls on about 5% of days, any rain day will be above the 95th percentile).

The last comprehensive national assessment of extreme rainfall based on station data in the peer-reviewed literature was published in 1999[1], although more recent results have been published in various reports (e.g. the 2007 'Climate Change in Australia' report), and regional assessments have also been published (e.g. Gallant et al, 2007[2]). The Bureau of Meteorology also reports on some aspects of extreme rainfalls as part of its routine climate monitoring. Australian results have also been reported as part of global analyses[3]. Many more recent analyses have been based on gridded data rather than station time series, but it has been found[4] that gridded data sets may not adequately represent rainfall extremes, especially in remote data-sparse areas.

As a generalisation, most studies of rainfall extremes in Australia have found increases in those areas where mean rainfall is increasing (e.g. north-western Australia) and decreases in those areas where mean rainfall is decreasing (e.g. the south-west of Western Australia), but specific results tend to vary depending on the method and index used.

There is very limited information available on observed changes in extreme rainfall over periods shorter than one day, due to a lack of reliable long-term observations of sub-daily rainfalls.

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[1] Hennessy, K. et al. 1999. Australian rainfall changes, 1910-1995. Australian Meteorological Magazine, 48, 1-13.

[2] Gallant, A. et al. 2007. Trends in rainfall indices for six Australian regions: 1910-2005. Australian Meteorological Magazine, 56, 223-239.

[3] Donat, M. et al. 2012. Update analyses of temperature and precipitation extreme indices since the beginning of the twentieth century: the HadEX2 dataset. Journal of Geophysical Research – Atmospheres, in press.

[4] King, A. et al. 2012. The efficacy of using gridded data to examine extreme rainfall characteristics: a case study for Australia. International Journal of Climatology, published online 11 September 2012.

A priority is to extend a national assessment of rainfall extremes at individual long-term stations, along the lines of an extended version of the 1999 Hennessy et al. analysis. Work is currently in progress in the Bureau of Meteorology on developing an updated long-term, station-based rainfall data set which should facilitate this work. A potential barrier to a full assessment is that the existence of good-quality long-term daily rainfall records is highly variable over Australia; there is excellent coverage of many areas, especially the agricultural regions, but poorer coverage of other areas – as might be expected, there are few good long-term records in remote areas, but perhaps more surprisingly, there are also few on or near the coastal escarpment along most of the New South Wales coast, an important region as it forms the upper catchment of many flood-prone NSW rivers.

Drought

Drought exists on a wide range of timescales and a wide range of indices exist for assessing it. In Australia, the focus has traditionally been on drought on a timescale centred on individual cropping seasons, i.e. from periods of a few months to 1-2 years (referred to here as 'short-term drought'). More recently, the dry periods in eastern and south-western Western Australia increased focus on longer-term drought on timescales of several years (there is also the question, which is as much philosophical as scientific, of the point at which a robust rainfall decline, as exists in the south-west of Western Australia, stops being long-term drought and starts being the 'new normal').

Numerous indices have been developed to assess drought on a seasonal timescale. Some are purely based on rainfall, others include factors such as temperature or evaporation (measured or estimated) in an attempt to more comprehensively gauge moisture stress.

A number of global studies have reported on drought in Australia, with generally inconclusive results. Results have also varied depending on the index used (e.g. indices which include temperature suggesting an increase in drought which is not matched in indices based purely on rainfall), with some initial conclusions being reassessed as studies using different indices found different results (this accounts for the fact that the conclusions of SREX with respect to drought were weaker than those for AR4). Findings (which in some cases have been widely reported in the media) suggesting no significant changes in drought in Australia should be considered with some caution; in some cases they aggregate data at the national scale, therefore combining wetter areas in northern Australia with drier regions in the south, while other studies have used indicators such as the maximum number of consecutive dry days in each year, which have weaknesses in climates which have significant seasonal variations in rainfall (to give an example, in the wheat belt of Western Australia, where most rain falls in the winter half of the year, the year's longest run of consecutive dry days will almost always occur in summer or early autumn, but this is largely irrelevant to the cropping season).

Some drought indices (e.g. the percentage of Australia's area with rainfall below the 10th percentile) are reported on as part of the Bureau of Meteorology's regular climate monitoring.

A study which would add to knowledge of drought in Australia would be a comprehensive assessment, using a wide range of indices and time periods to determine which results were robust to the method of assessment, and which were subject to more uncertainty.

Severe storms and small-scale phenomena

Small-scale phenomena such as tornadoes and hail are inherently very difficult to observe comprehensively as they tend to be very localised (at least in their most severe aspects) and may not be reported unless they affect a populated area. Whilst reporting of these events has improved, partly through improved observations technology, partly through better follow-up reporting of severe weather events, and in some cases because of increased population densities (as well as the presence of people actively chasing severe storms), it is extremely unlikely that reporting of such small-scale events will ever give 100% coverage, even in the more populated states. In turn, this will make it very difficult to draw conclusions on these events from observed data.

There has been some experimentation, particularly in North America, of studying trends in atmospheric indices favourable to the development of severe storms, rather than the severe storms themselves, although with inconclusive results so far. This approach has also been applied in Australia, and ongoing research using data and climate projections should provide improved insight into changes in severe storms in Australia.

There has also been low confidence in assessments of winds. Wind speed observations are particularly challenging to assess because they are highly vulnerable to changes in site exposure (e.g. buildings or vegetation growth), as well as instrument changes. Studies have been carried out[5] using pressure gradients as a proxy for extreme winds, finding a general decrease over south-eastern Australia, but this approach is only suitable for large-scale systems and will not detect extreme winds associated with, for example, severe thunderstorms.

Attribution of individual extreme events

Whilst there have been numerous studies which have assessed changes in the overall probability of certain extreme events over time, attempts to attribute individual extreme events (that is, to determine formally the extent to which anthropogenic climate change contributed, or did not contribute, to a specific extreme event) are in their infancy. An early attempt to carry this out for six significant global events in 2011, which also discusses the issues involved in more depth, is described in an article[6] in the July 2012 Bulletin of the American Meteorological Society. The approaches used, so far, are most promising when used with respect to events on the national or continental scale.

To our knowledge, no such detailed assessment has yet taken place of any Australian event. Record breaking events like the heatwaves of January/February 2009 and the heatwave of January 2013 would, however, appear to be amenable to this type of analysis. This is an active area of research internationally and Australian involvement in it (whether through the Bureau of Meteorology, CSIRO, the universities or a combination) is a high priority. The capacity to assess the contribution of anthropogenic climate change to an extreme event

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[5] Alexander, L. et al. 2011. Significant decline in storminess over southeast Australia since the late 19th century. Australian Meteorological and Oceanographic Journal, 61, 23-30.

[6] Peterson, T. et al. 2012. Explaining extreme events of 2011 from a climate perspective. Bulletin of the American Meteorological Society, 93, 1041-1067.

within a short time after the event would be a valuable addition to climate monitoring services in Australia.

The importance of observations in the monitoring of climate change

Long-term, consistent, high-quality sets of observed climate are critical to the detection of climate change. Many of these observations are derived from the Bureau of Meteorology's routine observing network. Australia is a world leader in the development of such data sets but their continuation is dependent on the existence of a high-standard observations network, and the availability of adequate resources to maintain that network at a high standard.

Observations are sparse in many remote areas of Australia. Whilst maintaining observations in a remote area is always challenging, the potential exists to reduce such data voids through the strategic opening of new stations; as these would be a long distance from any urban development or other land use changes they would also have the potential for providing baseline data sets into the future.

The need for ongoing funding

The study of extremes and climate change is a long-term problem that requires long-term research solutions. The Australian Government is investing significant funding towards this area through a number of channels. The resultant research has been shown by numerous reviews to be internationally competitive. However, inadequate funding, funding interruptions, or short-term funding cycles affect the world-class researchers at many Australian organizations, which ultimately limits progress. Ongoing and long-term funding is required; increases in funding will accelerate advances in the understanding of extreme weather and climate change. Large programs funded by the Department of Climate Change and Energy Efficiency, e.g. SEACI, have been essential for progress in the Government research sector. The Universities rely heavily on continued funding from the Australian Research Council through the Discovery, Linkage, and Centre of Excellence Programs. Moreover, since many Australian university researchers are externally funded, continued investment in the fellowship schemes (viz., DECRA, DORA, Laureate, and the soon-to-expire Future Fellowships) is essential.