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ARC CENTRE OF EXCELLENCE FOR CLIMATE SYSTEM SCIENCE

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Senate Inquiry into Recent Trends in and Preparedness for Extreme Weather Events
Senate Standing Committees on Environment and Communications

Please find attached a submission to the Senate Inquiry into recent trends in and preparedness for extreme weather events.

Our submission is focused on the first two Terms of Reference. It has been prepared through the Australian Research Council's Centre of Excellence for Climate System Science by Professor David Karoly and Andy Pitman and Dr Lisa Alexander, Markus Donat and Sarah Perkins. It is based on a suite of internationally peer-reviewed publications which are available on-line but should the Inquiry request copies of these papers we can provide them promptly.

We look forward to hearing more about this timely and important inquiry. We are happy to appear before the Committee to answer questions if you consider this appropriate.

Yours faithfully,

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Director of the ARC Centre of Excellence for Climate System Science

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Submission to:
Inquiry into Recent Trends in and Preparedness for Extreme Weather Events
Senate Standing Committees on Environment and Communications

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This submission addresses the first two Terms of Reference:
(a) recent trends in 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 IPCC and CSIRO 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.

Summary

Comprehensive assessments of recent observed trends and projected future changes in temperature and rainfall extremes are available globally (IPCC, 2012; Donat et al. 2012a; Orlowsky and Seneviratne, 2012) and for Australia (CSIRO and BoM, 2007; Alexander and Arblaster, 2009; CSIRO and BoM, 2012).

There is large year-to-year variability in the frequency of hot extremes and heavy rain events, heatwaves, droughts and floods across Australia. These are associated with the natural variability of Australia's climate, particularly influenced by large-scale phenomena like El Niño-Southern Oscillation. In eastern Australia El Niño is associated with increased frequency of droughts, while La Niña is associated with increased frequency of heavy rain events and flooding.

There have been recent significant observed increases in the frequency of hot days and hot nights and decreases in cold days and cold nights across Australia over the last 50 years, consistent with the increase in Australian average temperature. There is a small increasing trend in the frequency of heavy rain days across Australia, with large increases in the north-west and decreases in the south and east. The contribution of heavy rain events to the total annual rainfall shows an increasing trend, as expected in a warming climate. There have been recent observed increases in the frequency of days with severe fire danger in many parts of Australia, particularly the southeast.

Projections of future trends in extremes in Australia indicate with high confidence that there will be increased frequencies of hot days, hot nights and heat waves, reduced frequencies of cold days and frosts. There is lower confidence of future changes in precipitation but studies point to increased frequencies of droughts and consecutive dry days, as well as increased frequencies of heavy rain days. The increases in hot days and in droughts will lead to increased frequencies of days with extreme fire danger. There will still be large natural variations in these extremes from year-to-year and between different regions. The projected changes in these extreme events are related to the changes in global average and Australian average temperature. Thus, smaller increases in global average temperature are likely to lead to reduced changes in extreme events. However, it is a robust feature of changes in some extremes, including temperature-related extremes, that a small increase in average temperature will lead to larger changes in extremes.

Observed variations in weather and climate extremes

Australia has a highly variable climate, with large variations in seasonal mean temperature and rainfall from year to year. These are associated with large variations in the frequency and intensity of weather extremes, including heat waves, cold spells, droughts and floods. Small variations in mean climate lead to disproportionately larger changes in extremes, both for temperature and rainfall extremes. This applies to year-to-year variations, as well as longer-term trends. Extensive weather and climate data for Australia for the period since 1910 maintained by the Bureau of Meteorology, and substantial research over the last three decades, has improved understanding of the causes of these observed variations in Australian weather and climate extremes.

These variations in extremes are associated with the natural variability of Australia's climate, particularly influenced by large-scale phenomena like El Niño-Southern Oscillation (CSIRO and BoM, 2007). El Niño is associated with increased frequency of droughts in eastern Australia while La Niña is associated with increased frequency of heavy rain events and flooding in eastern Australia and increased frequency of tropical cyclones in northeastern Australia, such as in 2010-12 (CSIRO and BoM, 2012). The peak phase of La Niña is associated with reduced intensity of extreme maximum temperatures compared with El Niño events (Arblaster and Alexander, 2012), likely associated with the increased rainfall and cloud cover during La Niña.

In addition to the large natural variability of extreme temperature and rainfall, there have been marked trends in some observed Australian extremes, particularly temperature-related extremes. A number of indices of observed extreme daily maximum and minimum temperatures and daily rainfall globally and for Australia (Donat et al., 2012a, b) can be used to describe these longer-term trends. Figure 1 shows time series of indices of the number of warm/cool days (daily maximum temperatures outside the 90th /10th percentile) and warm/cool nights (daily minimum temperatures outside the 90th /10th percentile) averaged over Australia for the period 1951-2010, together with maps of the linear trends over this period. There have been significant increasing trends in the number of warm days and nights across Australia and decreasing trends in the number of cool days and nights (Gallant and Karoly, 2010; CSIRO and BoM, 2012; Donat and Alexander, 2012; Donat et al., 2012a,b). These have been associated with increasing frequency and intensity of some measures of heat waves in Australia (Perkins and Alexander, 2012), as well as decreasing numbers of frosts in most parts of southern Australia. These observed trends are consistent with climate model responses to increasing greenhouse gases (Alexander and Arblaster, 2009; CSIRO and BoM, 2007).

Variations in rainfall extremes in Australia show greater variability and less clear long-term trends, compared with temperature extremes. Figure 2 shows a time series of the area-average number of heavy rain days (daily rainfall greater than 20mm) across Australia over 1951-2010, as well as a map of the linear trends in the number of heavy rain days in different regions Donat et al., 2012b). The small increasing trend in heavy rain days averaged across Australia is not significant, with significant increasing trends in northwestern Australia and decreasing trends in southeast Australia, consistent with the pattern of trends in mean rainfall. In a warmer climate, the moisture content of the atmosphere is expected to increase, as has been observed over the last 30 years. Increased moisture content is expected to lead to an increasing contribution to the annual rainfall from heavy rain days. A significant increasing trend has been found across Australia in the proportion of the annual rainfall associated with heavy raindays, even including regions where the annual rainfall has been decreasing (Gallant and Karoly, 2010).

Very high fire danger conditions in Australia are associated with high maximum temperatures, extended periods of low rainfall, low humidity, and strong winds. In an analysis by Clarke et al. (2012), a data set of observed fire weather in Australia from 1973–2010 was examined. In common with many studies they searched for trends using the McArthur Forest Fire Danger Index (FFDI). Annual cumulative FFDI, which combines daily fire weather across the year, increased significantly at 16 of 38 stations. Annual 90th percentile FFDI increased significantly at 24 stations over the same period. None of the stations examined recorded a significant decrease in FFDI. There is an overall bias in the number of significant increases towards the southeast of the continent. The largest increases in seasonal FFDI occurred during spring and autumn, although with different spatial patterns, while summer recorded the fewest significant trends. These trends suggest increased fire weather conditions at many locations across Australia, due to both increased magnitude of FFDI and a lengthened fire season. These trends are consistent with projected impacts of climate change on FFDI but since this study was purely based on observational data it could not separate the influence of climate change with that of natural variability.

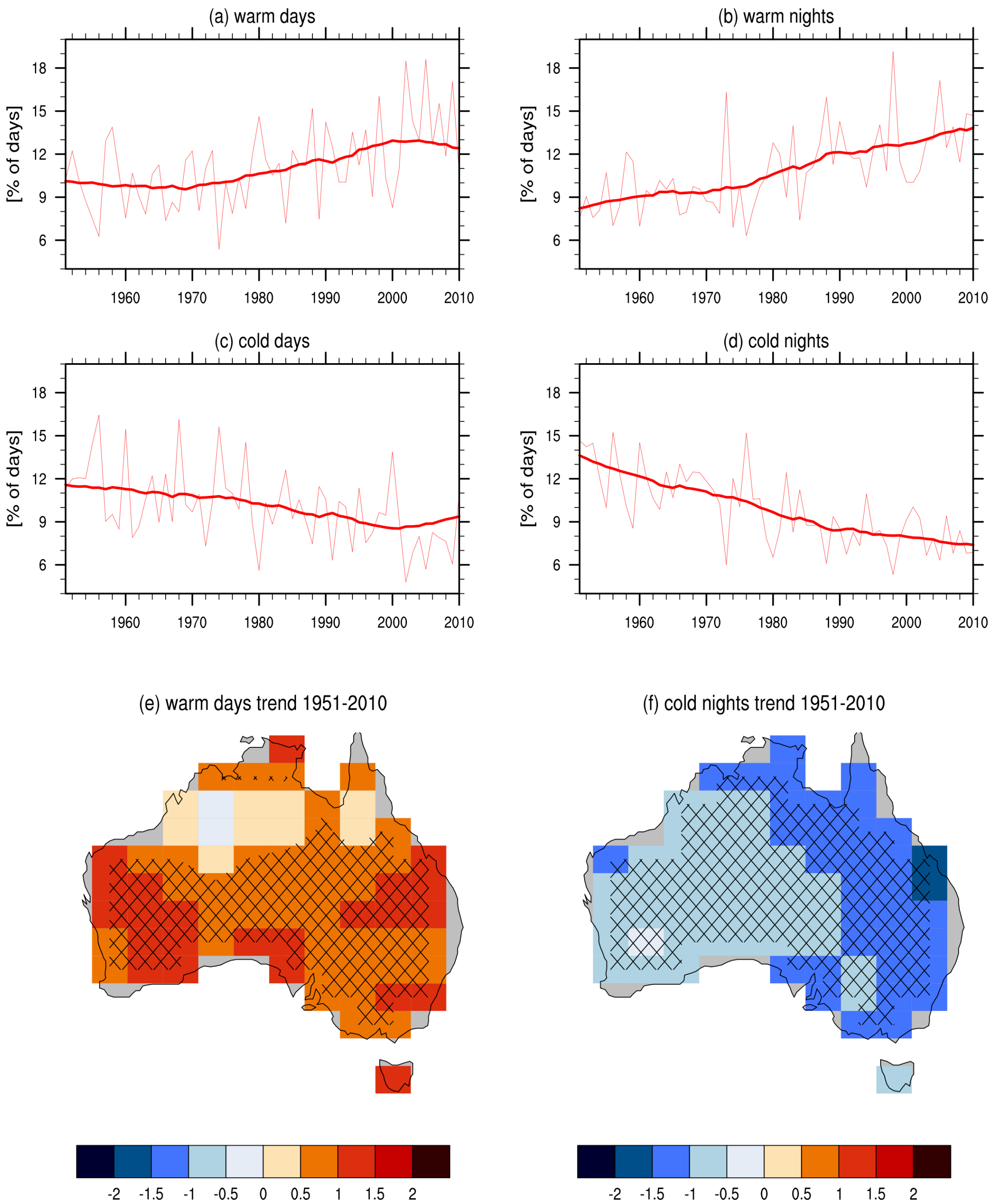

Figure 1: Trends in indices for temperature extremes in Australia over 1951-2010 from the HadEX2 dataset (Donat et al., 2012a). Time series of the area-average across Australia of the frequency of (a) warm days, (b) warm nights, (c) cool days and (d) cool nights, which each have a long-term expected value of 10%. Spatial distribution of the linear trends over 1951-2010 in (e) warm days and (f) cool nights in percent per 20 years. Hatching indicates trends significant at the 5% level.

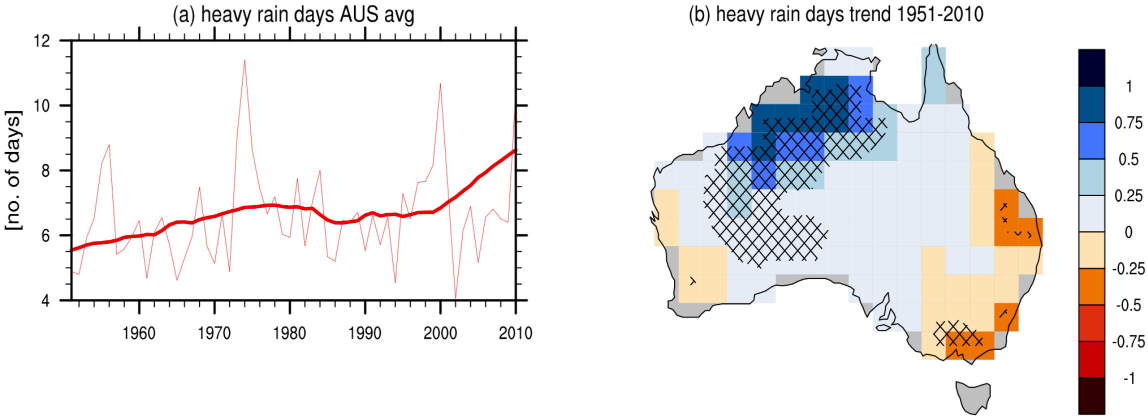

Figure 2: Trends in an index for heavy rain days (daily rainfall > 20mm) in Australia over 1951-2010 from the GHCNDEX dataset (Donat et al., 2012b).
(a) Time series of area-average number of heavy rain days per year across Australia.
(b) Spatial distribution of the linear trend over 1951-2010 in the number of heavy rain days. Hatching indicates trends significant at the 5% level.

Projected future changes in weather and climate extremes
Projections of future changes in temperature and rainfall extremes for Australia have been assessed by CSIRO and BoM (2007), Alexander and Arblaster (2009) and IPCC (2012).

A summary of the projected changes in extremes, using time series of extreme temperature and rainfall indices averaged across Australia, is shown in Figure 3 from Alexander and Arblaster (2009). This shows increased frequencies of hot days, hot nights and heat waves, reduced frequencies of cold days and frosts, increased frequencies of consecutive dry days, as well as increased frequencies of heavy rain days. There will still be large natural variations in these extremes from year-to-year and between different regions. Note that the uncertainties in some of the projected temperature extremes, such as warm nights and warm days, are much smaller than for the rainfall extremes, due to greater agreement in projected changes between the different models and relatively smaller natural variability.

The projected changes in these extreme events are related to the changes in global average and Australian average temperature due to increasing greenhouse gases. Thus, smaller increases in global average temperature are likely to lead to reduced changes in extreme events. However, it is a robust feature of changes in some extremes, including temperature-related extremes, that a small increase in average temperature will lead to larger increases in extremes.

Projected changes in temperature extremes over Australia based on the skill of individual climate models was analysed by Perkins et al. (2009, 2012) using the same data as used by the 4th Assessment Report of the Intergovernmental Panel on Climate Change. They showed that some climate models, that could be shown to simulate the current climate relatively poorly over Australia, tended to simulate larger increases in extremes than the better models. Excluding weaker models tended to reduce the magnitude of increases in temperature extremes projected by the remaining models. However, the magnitude of the increase in extreme temperatures simulated for 2050 and 2100 in those models with skill in simulating current extreme temperatures remained very high (4-6^{o}C under a high emissions future by 2050).

Other causes of changes in extremes have been examined; including the impact of land use and land cover change on extremes. The first multi-model examination of how land use and land cover change affects extremes (Pitman et al., 2012) suggests that locally significant changes in extremes can occur, particularly on temperature-related extremes. However, these tend to offset global warming-related increases in extremes. Thus, changes in land cover do not explain the widespread and on-going contribution to the increases in extremes observed over Australia and globally.

The projected increases in hot days and in consecutive dry days and droughts will lead to increased frequencies of days with extreme fire danger. An analysis of the impact of climate change on bush fire risk was undertaken by Clarke et al. (2011). A set of skill-selected global climate models were used to explore the effect of future climate change on regional bushfire weather in eastern Australia. Daily Forest Fire Danger Index (FFDI) was calculated in four regions of differing rainfall seasonality for the 20th century, 2050 and 2100 using the A2 scenario from the Special Report on Emissions Scenarios. Projected changes in FFDI vary along a latitudinal gradient. In summer rainfall-dominated tropical north-east Australia, mean and extreme FFDI are projected to decrease or remain close to 20th century levels. In the uniform and winter rainfall regions, which occupy south-east continental Australia, FFDI is projected to increase strongly by 2100. Projections fall between these two extremes for the summer rainfall region in the rest of Australia, which lies between the uniform and summer tropical rainfall zones. Based on these changes in fire weather, the fire season is projected to start earlier in the uniform and winter rainfall regions, potentially leading to a longer overall fire season.

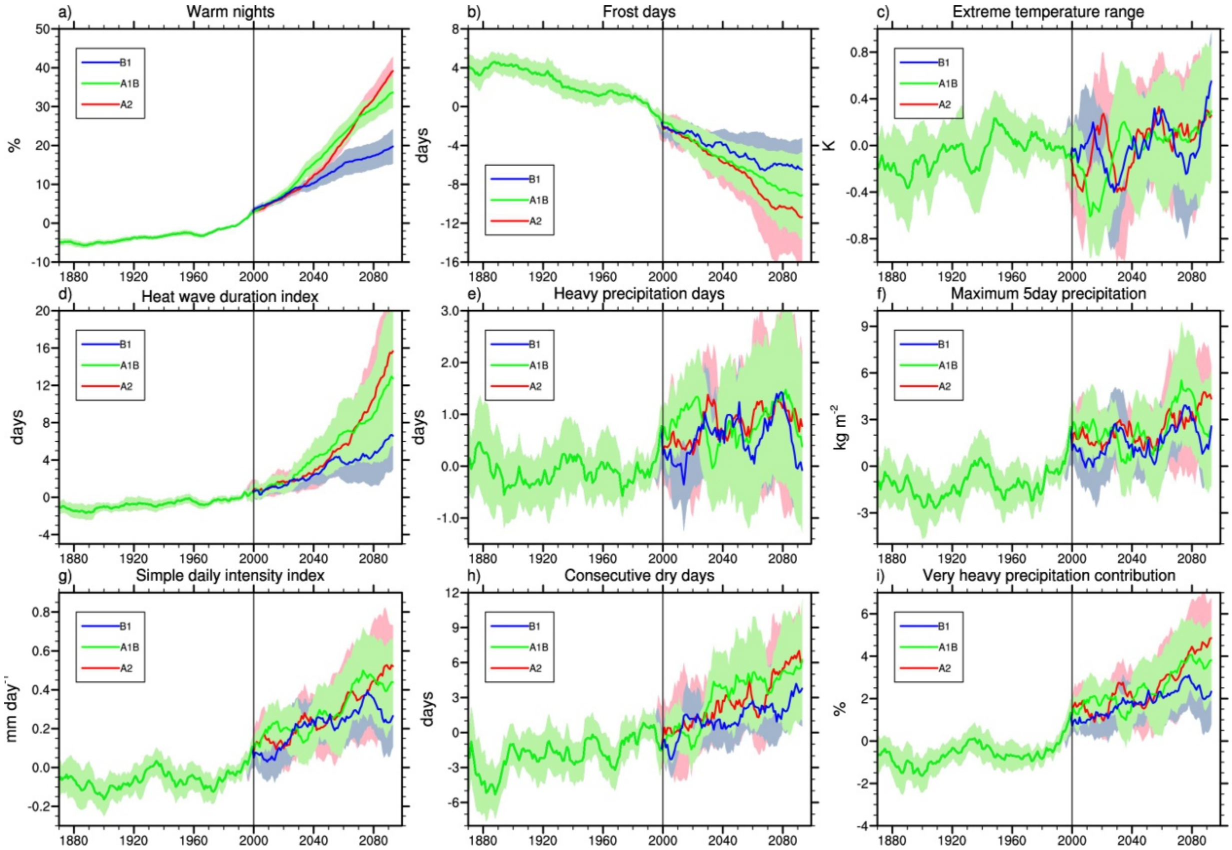

Figure 3: Time series of Australian area-average extremes indices between 1870 and 2100 using regions in Australia with observed data. The multi-model ensemble mean (solid lines) of nine different climate models from the CMIP3 dataset is shown for the SRES B1 (low), A1B (medium) and A2 (high) greenhouse gas emission scenarios, with shading representing the inter-model uncertainty. All model time series are smoothed with a ten-year running mean. From Alexander and Arblaster (2009).

Background

The Australian Research Council's Centre of Excellence for Climate System Science (http://climatescience.org.au/) is an international research consortium of five Australian universities and a suite of outstanding national and international Partner Organizations. It is building on and improving understanding of the modeling of regional climates to enable enhanced adaptation to and management of climate change, particularly in the Australian region.

The Centre was established in 2011 with extensive investment from the Australian Research Council, the University of New South Wales, the Department of Climate Change and Energy Efficiency, New South Wales Government, Monash University, the Australian National University, the University of Melbourne, and the University of Tasmania. It has strong links with the Australian Community Climate and Earth System Simulator (ACCESS) initiative and works in partnership with the National Computational Infrastructure (NCI) Facility.

The Centre's Research program on "Mechanisms explaining changes in Australian climate extremes" is examining the key processes that effect long- and short-term weather and climate events, including determining the likely role that climate change plays as well as exploring how extremes may change in the future. As part of this research, the Centre is exploring whether individual extreme weather events can be directly attributed to climate change. It is also exploring the ways that year-to-year climate variations, such as El Niño, affect Australian weather extremes.

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Dr Markus Donat and Dr Sarah Perkins are research fellows in the Centre and in the Climate Change Research Centre at the University of New South Wales.

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