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Variability and long-term change in Australian temperature and precipitation extremes

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A R T I C L E I N F O

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A B S T R A C T

Risks from weather and climate extremes to governments, industries and communities are increasing and, at present, are not well quantified. In the presence of climate variability and long-term change, it may not be appropriate to base an assessment of the likelihood of climate hazards on the long-term averages. Many weather and climate extremes have increased in frequency and/or intensity in recent decades with climate model projections showing that several trends are likely to continue. The analysis of historical records is complementary to the use of climate models in understanding the changing nature of extremes.

In this study, we apply a consistent methodology to examine the modulation in the probability of extremes in temperature and rainfall as they are influenced by climate change over the past century and natural climate variability and present summary tables and charts for a comprehensive comparison. The daily temperature data – maximum (Tmax) and minimum (Tmin) air temperature – are from a 'high-quality' dataset developed at the Australian Bureau of Meteorology – the Australian Climate Observations Reference Network (ACORN) Surface Air Temperature (SAT) dataset. In the absence of a comparable dataset for daily rainfall, we analysed rainfall data at ACORN-SAT locations. Our analyses of extremes are based on annual maxima (annual minima for Tmin) of daily time series from 58 Australian sites over the period 1910–2009.

We found statistically significant long-term increases in extreme maximum temperatures but with marked regional and seasonal variations. The increase in the lowest minimum temperature extremes typically exceeds the increase in the extremes of maximum temperature. Daily precipitation extremes rarely exhibit long-term change over the century but are strongly modulated by the El Niño Southern Oscillation (ENSO). The relative importance of long-term change and climate variability therefore depends on the variable or index.

We conclude that in assessing the likelihood of climate hazards, one needs to consider the modulation of climate extremes due to both long-term change and climate variability. Our findings imply that when planning for adaptation, different emphasis needs to be given to changing temperature and precipitation extremes.

1. Introduction

Globally many weather and climate extremes have increased in frequency and/or intensity in recent decades with climate model projections showing that several trends are likely to continue. It is very likely that the number of warm days and nights has increased and models project substantial warming in temperature extremes by the end of the 21st century (IPCC, 2012). There have been statistically significant trends in precipitation extremes for some regions of the globe but there are strong regional variations in these trends. However, there is less confidence in the projected changes in precipitation extremes. The analysis of historical records is complementary to the use of climate models (Stephens et al., 2010) in understanding the changing nature of extremes. Historical data are important to address known shortcomings in models; especially projections at regional and smaller scales, for precipitation and for extremes.

Risks from weather and climate extremes to governments, industries and communities are increasing and, at present, are not well quantified. The National Emergency Risk Assessment Guidelines (2010) for Australia sets out how to derive the risk rating for a particular hazard. This approach requires a consequence rating and a likelihood rating. In the presence of climate variability and long-term change, it may not be appropriate to base an assessment of the likelihood of climate hazards on the long-term averages. But for the design of infrastructure with long life spans it becomes important to assess the likelihood of failure of a structure throughout its lifetime.

In this study, we examine the probability of extremes in temperature and rainfall as they are influenced by (a) the climate change over

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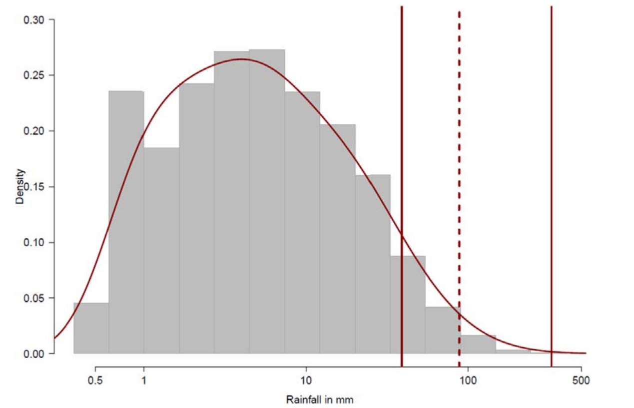

Fig. 1. Illustrating rainfall extremes for Sydney Observatory Hill (1910–2009). The grey bars in the background are the histogram for daily rainfall totals (above 0.5 mm). The curve indicates the associated (smoothed) density plot. The solid vertical lines indicate the range of the annual maxima and the dashed vertical line indicates the 99th percentile.

Table 1
Range of AEP values used and corresponding ARI values.

AEP (%)	ARI (years)
50	1.44
10	9.49
5	19.5
1	100

the past century and (b) natural climate variability. Major drivers for the Australian climate (Risbey et al., 2009) are the El Niño Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD), the Southern Annular Mode (SAM) and – on longer time scales – the Interdecadal Oscillation (IPO). ENSO is the dominant driver. However, the impact of ENSO can be strongly modulated by the IOD (Meyers et al., 2007). Our analyses will therefore focus on the effects of ENSO but for completeness we will also briefly present results from our analysis of the effects of the IOD, highlighting similarities and differences between the effects of both climate drivers.

There is much literature that examines the relationships between mean state climate variability and phenomena. However, less is known about the influence of major climate drivers on extremes. Our analyses of extremes are based on annual maxima of daily time series, corresponding to about the 99.7th percentile, as shown in Fig. 1. In this study the focus was on highlighting contrasts in observed variability and long-term change for Australian temperature and precipitation extremes respectively. Our findings imply that different emphasis needs to be given when planning for adaptation to temperature and precipitation extremes.

The motivation behind this paper is to communicate our results to decision-makers. We have therefore developed figures to synthesise and visualise our results, and to contrast the changes related to variability and long-term change on the one hand and temperature and precipitation on the other.

2. Data

2.1. Temperature data

The daily temperature data – maximum (Tmax) and minimum (Tmin) air temperature – used here are from a 'high-quality' dataset developed at the Australian Bureau of Meteorology – the Australian Climate Observations Reference Network (ACORN) Surface Air

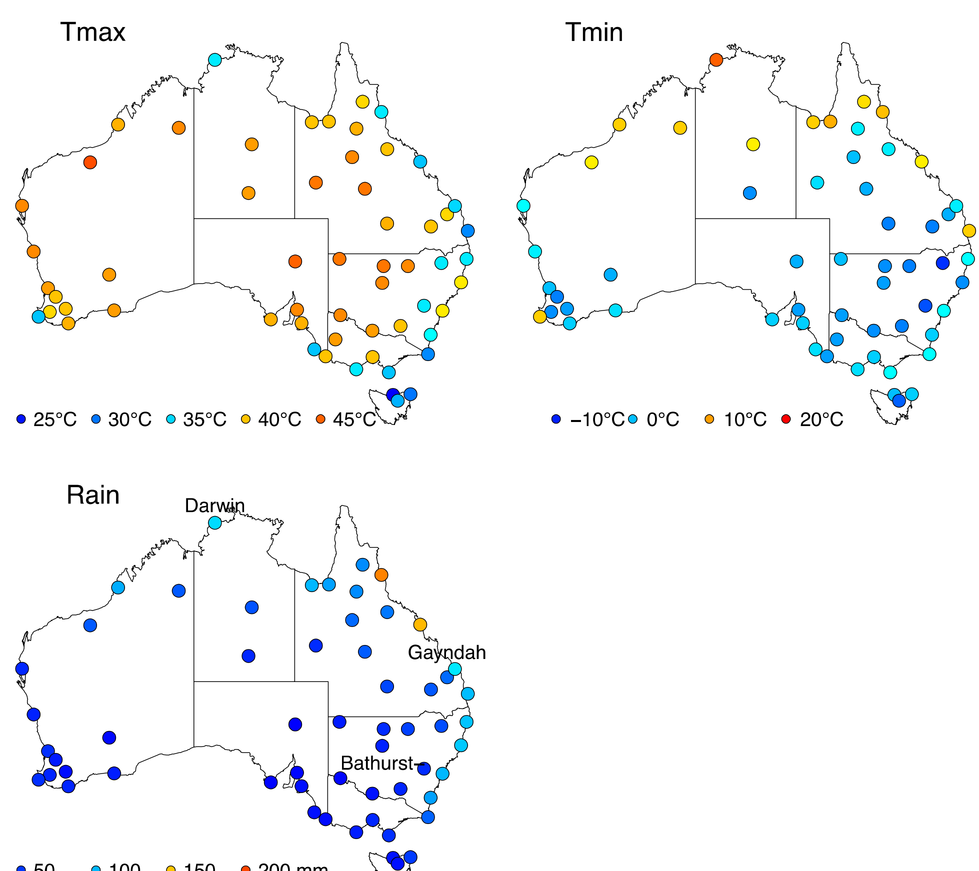

Fig. 2. The spatial distribution of extreme high maximum temperature (top left), extreme low temperature (top right) and extreme daily precipitation (bottom) for Annual Exceedance Probability (AEP) 50%. The location of three sites used to illustrate typical changes in extremes (Darwin, Gayndah and Bathurst) is shown in the bottom left panel.