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Trends in sub-daily precipitation in Tasmania using regional dynamically downscaled climate projections

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ABSTRACT

Study region: Island state of Tasmania, Australia.
Study focus: This study detected monotonic and step trends in maximum sub-daily precipitation for durations ranging from 3 to 24 h over the period 1961–2100. It also looked at whether or not there is agreement between six dynamically downscaled global circulation models (GCMs) in terms of the extent and magnitude of monotonic and step trends in the dataset. This was done using a split-apply-combine approach for data manipulation. The study included trend evaluation, application of a smoothing algorithm, and the application of non-parametric and parametric statistical tests on low pass filtered series.
New hydrological insights: Monotonic and step trends in maximum sub-daily precipitation occurring in each month were identified across the state. Decreasing trends were found to become more evident in the Central Plateau region. There was reasonable agreement between GCMs on the sign and the magnitude of the precipitation changes, with the exception of the Central Plateau region of Tasmania, where the GCMs disagreed as to the spatial extent of the decreasing in trends.

The duration and intensity (percentile) of maximum sub-daily precipitation were found to influence trends in sub-daily precipitation. Evidence of spatial patterns in monotonic and step trends for the data between the baseline period (1961–1990) and future climates (2010–2039, 2040–2069, and 2070–2099) have been evaluated.

1. Introduction

While many variables play a role in the hydrologic cycle, it is readily accepted that precipitation is key particularly for places such as Tasmania where snowmelt and other processes are often not significant (Yenigun et al., 2008). For this reason, identifying trends in precipitation plays a significant role in climate change adaptation and water resource management. The IPCC (2012) found robust evidence of changes in the intensity-duration-frequency (IDF) relationship for extreme precipitation. In particular, they reported that the frequency of heavy precipitation events, or the proportion of total precipitation from heavy falls, has increased over most areas during the late 20th century (Bonnin, 2010). This is further supported by several studies that have found that the frequency and intensity of heavy and extreme precipitation events are projected to increase across many parts of the world (e.g. Kamruzzaman et al., 2016; IPCC, 2012; Westra et al., 2012; Arnbjerg-Nielsen et al., 2013; Brown et al., 2011; Bennett et al., 2012; Burauskaite-Harju et al., 2011; White et al., 2010, 2013; Ntegeka and

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Willems, 2008). Furthermore, the IPCC (2012) stated that these trends are very likely to persist during the 21st century. These studies have largely focused on daily or longer duration events without considering changes in the intensity, frequency and duration of sub-daily precipitation events. Kamruzzaman et al. (2015) have demonstrated an increase in the variability of monthly extreme rainfall across South Australia and provides evidence of a reduction in total monthly rainfall.

Arnbjerg-Nielsen et al. (2013) suggested that climate change impacts can be mitigated to acceptable levels through implementation of reasonable measures once the risk is properly understood. Australia is identified as being particularly vulnerable to climate change, with "...substantial impacts on water resources, coastal ecosystems, infrastructure, health and agriculture" (White et al., 2013; IPCC, 2012). As a natural resource, precipitation is important to the planning and design of infrastructure to reduce the risk to the environment, the integrity of assets, and human health and safety. Predictions and observations of changes in the distribution of precipitation resulting from climate change are found to be significantly impacted by anthropogenic regulation and the influence of climatic drivers on precipitation (Kamruzzaman et al., 2013).

Tasmania continues to present a number of challenges to climate modelers, partly due to the heterogeneous distribution of precipitation across the state and partly due to the difficulty in determining the position of a boundary between the subtropics and higher latitudes that falls in the vicinity of Tasmania (Pook et al., 2010; White et al., 2010; Grose et al., 2010).

It is likely that extrapolating climate change impacts from trends observed in daily to sub-daily precipitation data will result in significant errors. Errors are likely to arise based on several factors, one of which being that climate drivers that result in daily or multi-day precipitation events are driven by different climate drivers than those resulting in sub-daily precipitation events (Pook et al., 2010; White et al., 2010, 2013; Beck et al., 2015). This study has not assumed that relationships exist between trends in daily and sub-daily precipitation over Tasmania. Westra (2011) identified evidence that sub-daily precipitation will change more rapidly than daily precipitation. Further to this, Westra (2011) reported that statistically significant trends are observed for sub-hourly precipitation. It was suggested that the impact of changes to gauging technologies on measurements of sub-hourly precipitation should be assessed prior to this data being used to evaluate future climate scenarios (Westra, 2011). Burauskaite-Harju et al. (2011) found that trends in precipitation data derived from evaluating trends in annual percentiles based on sub-daily precipitation data could vary strongly with duration. Variation in sub-daily precipitation trends identified during this study saw changes in both the magnitude and direction of trends.

White et al. (2010) reported that several studies have demonstrated an intensification and southward shift in the subtropical ridge of high-pressure north of Tasmania and that change in Tasmania's precipitation are linked to this shift. They also identified an increase in the frequency of El Niño events and a strengthening of the Southern Annular Mode. To date, it is unknown to the degree to which these climate indices are impacting on precipitation (Sachindra et al., 2014).

This study detects monotonic and step trends in maximum sub-daily precipitation occurring in each month for durations ranging from 3 to 24 h (max3hr, max6hr, 9maxhr, 12maxhr, 18maxhr, and 24maxhr) over the period 1961–2100. We considered whether or not there is agreement between the six dynamically downscaled global circulation models (GCMs) assessed during this study in terms of the extent and magnitude of monotonic and step trends in the dataset.

2. Data sources and method

2.1. Study area and data sources

Fig. 1 shows the island state of Tasmania, which is located 240 km south of the southeastern Australian mainland. Tasmania contains mountainous areas in the south and west, a centrally located plateau and lowlands in the north and east. Due to the topography of Tasmania, precipitation varies significantly between the west and east of the state, with much of Western Tasmania receiving in excess of 2000 mm of precipitation each year, rising to greater than 4000 mm on some mountain peaks, and eastern Tasmania receiving less than 600 mm on average over the same period (Jones et al., 2009). Pook et al. (2010) have found that the dominant cause of precipitation differs between western and eastern Tasmania, with the precipitation in eastern Tasmania dominated by east coast low systems and precipitation in western Tasmania dominated by frontal systems (Pook et al., 2010).

Gridded 3-h precipitation data generated as part of the Climate Futures for Tasmania (CFT) project using six GCMs and the A2 emissions scenario from the Special Report on Emissions Scenarios (SRES) has been used in this study (Corney et al., 2013). The gridded dataset has been manipulated to create a collection of monthly maximum precipitation data for 3-h, 6-h, 9-h, 12-h, 18-h and 24-h duration events with a spatial resolution of 0.1° for the period 1961–2100 (Corney et al., 2013).

Outputs from 23 GCMs were considered by the IPCC prior to the release of the fourth assessment reports (AR4), CFT limited itself to six GCMs. The six GCMs used in this study are briefly described in Table 1 below. The only outputs from GCMs that were used were sea surface temperature (SST) and sea-ice. GCMs were selected based on their ability to simulate the present-day climate across Australia for a range of climate indicators including present-day precipitation means and variability across Australia (Bennett et al., 2012; Corney et al., 2013; White et al., 2010, 2013). Criteria for GCM selection included their performance in simulating SST variability and modes such as ENSO (Corney et al., 2013).

GCMs typically output climate information with a spatial resolution of between 200 and 300 km along their horizontal and vertical axes. There is a clear need to downscale outputs from GCMs for the purpose of understanding that regional and local impacts. At the spatial scale of GCMs, the heterogeneous climate of Tasmania is represented by just a few grid cells (Corney et al., 2013). CFT dynamically downscaled the outputs from the six above-described GCMs to improve the spatial resolution