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Changes to the drivers of fire weather with a warming climate – a case study of southeast Tasmania

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Abstract Projected changes to the global climate system have great implications for the incidence of large infrequent fires in many regions. Here we examine the synoptic-scale and local-scale influences on the incidence of extreme fire weather days and consider projections of the large-scale mean climate to explore future fire weather projections. We focus on a case study region with periodic extreme fire dangers; southeast Tasmania, Australia. We compare the performance of a dynamically downscaled regional climate model with Global Climate Model outputs as a tool for examining the local-scale influences while accounting for high regional variability. Many of the worst fires in Tasmania and the southeast Australian region are associated with deep cold fronts and strong prefrontal winds. The downscaled simulations reproduce this synoptic type with greater fidelity than a typical global climate model. The incidence of systems in this category is projected to increase through the century under a high emission scenario, driven mainly by an increase in the temperature of air masses, with little change in the strength of the systems. The regional climate model projected increase in frequency is smaller than for the global climate models used as input, with a large model range and natural variability. We also demonstrate how a blocking Foehn effect and topographic channelling contributed to the extreme conditions during an extreme fire weather day in Tasmania in January 2013. Effects such as these are likely to contribute to high fire danger

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throughout the century. Regional climate models are useful tools that enable various meteorological drivers of fire danger to be considered in projections of future fire danger.

1 Introduction

Fire danger in Australia is typically described using the McArthur Forest Fire Danger Index (FFDI), which incorporates temperature, relative humidity, wind speed and a measure of the proportion of potential fuels available to burn obtained from recent rainfall (McArthur 1967). The prevailing meteorological conditions, known as fire weather, is a key driver of the frequency, intensity and duration of *"Severe", "Extreme"* and "*Catastrophic"* fire danger classifications, with the very worst fire weather days contributing to large, uncontrollable fires that have the greatest impact (Blanchi et al. 2010). An understanding of projected changes to the incidence of extreme fire weather is therefore essential to understand, and prepare for, the impact of climate change on fire danger.

The only quantitative approaches to examine fire weather in future scenarios use projections from global climate models (GCMs) or downscaling of those GCMs. There are three main scales at which model output can be used to examine fire danger; the site-scale fire danger indices, the synoptic-scale (or weather scale) drivers of bushfire weather and the mean climate and drivers at the large scale. GCMs are very useful in projecting changes to the mean conditions, such as rainfall and temperature, but may have limitations in simulating the site scale or weather scale processes.

The most direct approach is to calculate fire weather indices at the site scale, and many studies either calculate indices directly from model outputs (Williams et al. 2001; Clarke et al. 2011) or through decile scaling of observations using the projected change from models (Hennessy et al. 2005; Lucas et al. 2007). Results of this approach indicate a projected increase in the frequency of *very high* and *extreme* fire dangers in many southeast Australian sites, with the exception of Tasmania (Hennessy et al. 2005; Lucas et al. 2007). However, there are reasons to treat the representation of fire danger in GCMs with some caution. GCMs have biases in the contributing variables of FFDI and GCMs are generally better at representing the mean conditions rather than extremes, and often show a compressed range of variability compared to observations (Randall et al. 2007). Also, the coarse resolution of GCMs means that Tasmania is excluded from some studies altogether (Clarke et al. 2011), and regional scale phenomena such as Foehn winds and other topographic influences are poorly resolved. Dynamically downscaled model projections may be a useful complement to GCM outputs as they may have lower biases at the regional scale and may also resolve local-scale processes. Downscaling has shown some advantages over GCM outputs in examining fire indices (Clarke et al. 2013a; Fox-Hughes et al. 2014), and in modelling of fuel moisture (Matthews et al. 2011).

The next spatial scale is the intermediate scale of synoptic weather systems, where there is potential for generic synoptic types to be used to predict local conditions. The strong pre-frontal winds experienced in southeast Australia during Ash Wednesday 1983 were associated with a trough in the top 0.1 % of the strength range, as measured by the intensity of the 850 hPa temperature gradient over Victoria (Mills 2005). Furthermore, it was shown that many other extreme fire weather events including the 1967 Tasmanian fires were associated with this strong temperature gradient, and the metric was suggested as a way to identify severe fire weather events in climate models (Mills 2005). The method was adapted for use with 10 GCMs by Hasson et al. (2009). Under the A2 emissions scenario from the special report on emissions scenario (SRES) of Nakicenovic et al. (2000), the 10 GCMs showed a wide range of projected changes; some models showed very little change in the frequency of these events, while a few models showed a large increase. The multi-model mean showed an increase from approximately 0.5 events per year in the recent past, to 1 event per year by 2,055 and 1 to 2 events per year by the end of the century (Hasson et al. 2009). Consistent differences compared to reanalysis were overcome using a percentile approach rather than absolute thresholds, but there were also some non-trivial biases in the shape of the synoptic pattern in many models (Hasson et al. 2009). There may be advantages in dynamically downscaled simulations, both in terms of the suitability of the outputs and realism of the simulated synoptic types.

The third scale at which we can examine fire danger is from large-scale drivers and mean climate. For example, fire danger is greater in times of drought, where dry and hot conditions precondition bushfire fuels for fire and the incidence of fire weather can be more extreme. These can lead to relationships such as a correlation between the total area of burned forest in Tasmania with total rainfall in October-March (Nicholls and Lucas 2007). Projected changes to mean climate and drivers of variability may therefore inform future scenarios of fire danger.

Here, we use a dynamically downscaled climate model to examine the drivers of extreme fire danger and explore projected change to future fire danger. We focus on one case study location (southeast Tasmania, Australia) to highlight the importance of local scale meteorology and synoptic scale investigations of fire danger. We focus on Tasmania for several reasons. Firstly, it is a region with a high degree of variation in fire danger across a small area. For a given fire event, fire weather danger can be different from neighbouring Victoria and between different districts of Tasmania, with the southeast regions experiencing the highest fire dangers of any region in Tasmania (Fox-Hughes 2008). This regional detail is not well resolved in GCMs. Secondly, there is a high inter-annual variability in the peak fire danger (Luke and McArthur 1978) with the extreme fire dangers of the most interest occurring only rarely. These most severe events include those on 'Black Tuesday' on 7th February 1967 in southeast Tasmania, 12th February 1982 and the fires of 4th January 2013. As noted above, GCMs may not represent the changes to extremes as well as changes to mean conditions, so there may be advantages in using dynamically downscaling. We also propose that for events of this rarity it is more useful to understand and make projections of the drivers and processes involved rather than deriving fire indices from GCM outputs.

2 Methods and data

We examine typical high fire danger days with strong prefrontal winds identified by Mills (2005). These days are detected using the maximum gradient (TGRAD) across a box over Victoria and Bass Strait (135–150 °E, 35–40 °S), and maximum temperature along the centre line of this box at 37.5 °S (Tmax), shown in Fig. 1. To assess the impact of topography and local effects on fire danger in southeast Tasmania we examine a case study of the fire weather event of 4th January 2013. First we establish whether the signature synoptic pattern is present in NCEP/NCAR Reanalysis 1 (Kalnay et al. 1996). This reanalysis was used for consistency with Mills (2005) and Hasson et al. (2009). We then examine local scale processes over Tasmania on that day using the spatial pattern of daily maximum temperature from the Australian Water Availability Project (AWAP) dataset (Jones et al. 2009), and by assessing temperature, relative humidity and wind speed measurements from individual weather stations along a northwest-southeast transect across Tasmania at 1,500 DST (Daylight Savings Time, 11 h ahead of Coordinated Universal Time, UTC). Weather station data was obtained from the Bureau of Meteorology website (www.bom.gov.au).

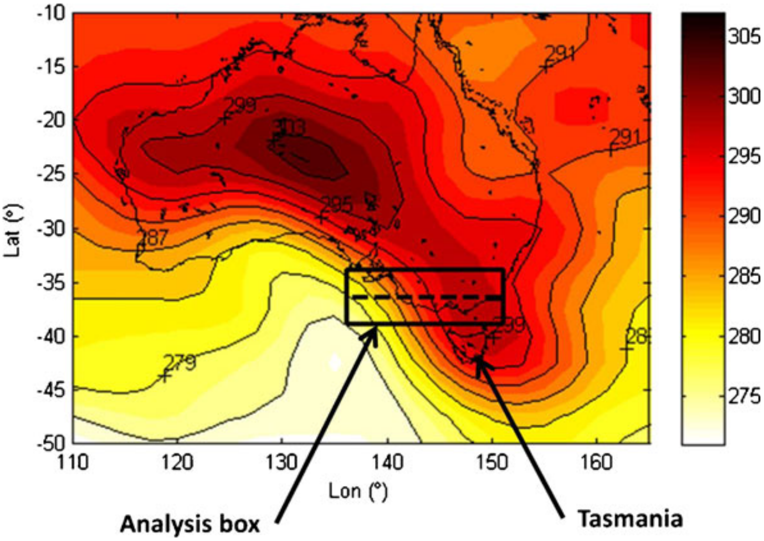

Fig. 1 850 hPa temperature (K) on 12:00 UTC, Ash Wednesday 16 February 1983 in NCEP/NCAR Reanalysis 1, showing location of the analysis box for TGRAD and line for Tmax

To examine the projected change to the typical synoptic pattern we calculate the frequency of events present in climate models in the current climate and in future periods, using methods similar to Hasson et al. (2009). We use outputs from six GCMs from the Coupled Model Intercomparison Project phase 3 (CMIP3) archive (Meehl et al. 2007), dynamically downscaled using the Conformal Cubic Atmospheric Model (CCAM). The six models were chosen for their performance over southeast Australia and the simulations have 0.5° lat/lon resolution. A full description of the methods are outlined in Corney et al. (2013). Outputs from the historical and the SRES A2 emissions scenario simulations were examined in summer (December January February) in three 39-year periods (1964–2002, 2022–2060 and 2062–2100). Simulations of the baseline period (1964–2002) were compared to the equivalent period in reanalysis. Direct output from an example GCM (GFDL-CM2.0) from the 20th Century simulation was examined in a similar baseline period of 1961–2000 for comparison.

The method was more directly applicable to the finer spatial and temporal resolution model output of CCAM than most GCMs. CCAM output was interpolated using cubic splines to 2.5° lat/lon spatial resolution, then the same TGRAD box and Tmax line were used as for the reanalysis. CCAM TGRAD and Tmax were both consistently higher than reanalysis values, so the percentile-based thresholds of Hasson et al. (2009) were used (TGRAD within the top 1.13 % of its distribution and Tmax within the top 28.39 % of its distribution), rather than the absolute thresholds of Mills (2005). We analysed high risk days for the two future periods in the CCAM simulations, finding the change in the percentile value of both TGRAD and Tmax, and the change in frequency of events exceeding the baseline thresholds.

3 Local scale effects

The importance of regional local influences on fire danger can be illustrated by examining particular fire weather events. The recent Tasmanian fire of 4th January 2013 was associated with a signature pattern of 850 hPa temperature identified by Mills (2005), with a strong gradient and high maximum across Victoria and Bass strait indicating a strong front (Fig. 2). The maximum 850 hPa temperature across Bass Strait of 300.8 K was well above the threshold of 290 K set by Mills (2005), and the maximum gradient of 3.4 K 100 km^{-1} across this box was just above the minimum gradient (3.2 K 100 km^{-1}). This indicates that the event was associated with a very hot air mass advected over southeast Australia but a cold front that was not extraordinary in comparison to other large fire events. This pattern is reflected in the strength of wind strength observed during the day, which were strong but not extreme (13.9 ms^{-1} in Hobart at 1,500 DST). There were, however, extreme winds in the vicinity of the large fires on the day associated with the bushfire convective cell. The hot air mass was also unusually large, indicated by the size of the region above 290 K in southeast Australia and over the Tasman Sea (Fig. 2), which is larger than that identified for Ash Wednesday (Fig. 1).

The daily maximum screen temperature shows a strong gradient from ~25 °C in the northwest to ~40 °C in southeast Tasmania (Fig. 3a), with the steepest gradient on the lee slope of the Central Plateau region. Along the line of stations at 1,500 DST (Fig. 3b), wind speed was ~3.6 ms^{-1} in an east-northeast direction at Wynyard in the northwest, in contrast to the general north-westerly flow. On the Plateau and down into the Derwent Valley leading to Hobart winds were north-westerly, increasing in strength down slope (Fig. 3c). Similarly, relative humidity was 59 % at Wynyard, decreased from Liawenee through the Derwent Valley, reaching a minimum of 10 % in Hobart. There was also a difference in mean sea level pressure (MSLP) on either side of the Plateau, with >1,005 hPa to the northwest and 999 hPa in Hobart.

A commonly held view of a thermodynamic Foehn wind effect is of an upslope wind leading to condensation or precipitation, then heating and drying on the subsequent downslope (Whiteman 2000). On the 4th of January there were low temperatures, high relative humidity and light east-northeast winds to the windward side of the Central Plateau. This does not indicate this thermodynamic Foehn wind was present, but suggests that air pooled near the surface in a maritime boundary layer (Fig. 3). However, it appears that the hotter drier wind above this maritime boundary layer then made contact with the surface on the Central Plateau

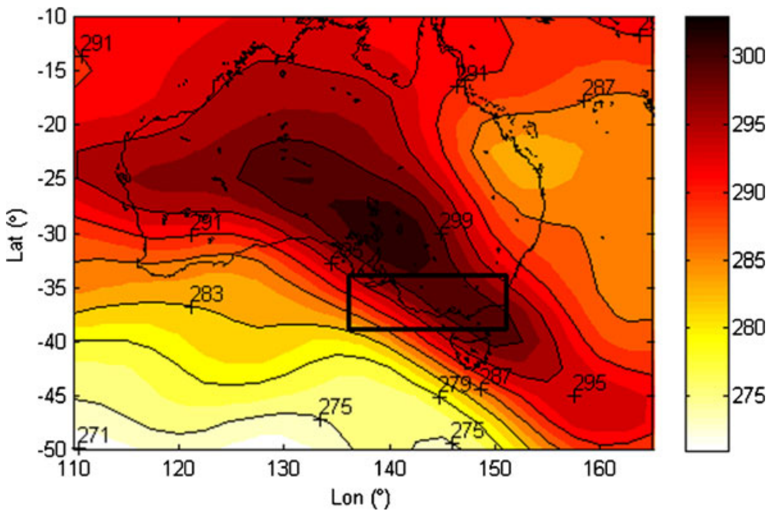

Fig. 2 Temperature field (K) 850 hPa over Australia on 4th January 2013 1,800 UTC from NCEP/NCAR Reanalysis 1. The rectangle indicates the box used in calculations of maximum gradient

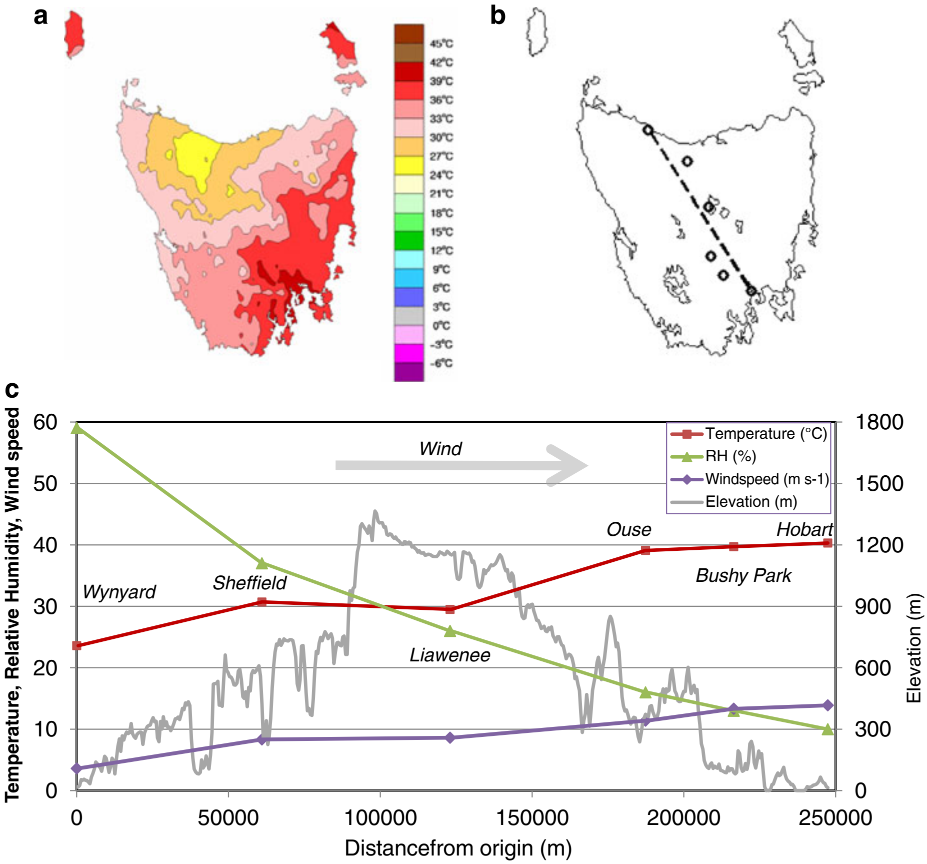

Fig. 3 Meteorological conditions and surface elevation across Tasmania on 4th January 2013, (**a**) daily maximum temperature (AWAP gridded dataset, obtained from www.bom.gov.au), (**b**) map showing location of stations and transect used, (**c**) surface elevation along the transect along with 1,500 DST observations of surface temperature, relative humidity and wind speed at stations (as marked)

and descended through the Derwent Valley, resulting in hot dry winds in the far southeast. This indicates the presence of a "blocking Foehn" wind, as documented in other regions of southeast Australia (Sharples et al. 2010a). The temperature change of ~10.8 °C over the 1,100 m drop in elevation between Liawenee and Hobart fits closely with the ~9.8 °C per 1,000 m dry adiabatic lapse rate (Whiteman 2000). The increasing wind speeds and ~17 % drop in relative humidity are also consistent with descending air.

In addition to adiabatic warming, as air descends through the Derwent Valley the surface topography and fall lines indicate that air will tend to converge (Fig. 4), implying some degree of forced channelling of the descending north-north-westerly air flow. Channelling and localised wind effects have been documented over complex terrain in southeast Australia, including dangerous effects on lee slopes when wind speeds exceed 30 km h^{-1} (Sharples et al. 2010b). The westerly edge of the valley also marks a sharp rainfall gradient from a high rainfall area to the west and the rain shadow region of the midlands, and also a sharp vegetation boundary between forest and grassland that was present prior to land clearing. The environmental gradient suggests a bioclimatic boundary that is also reinforced by the

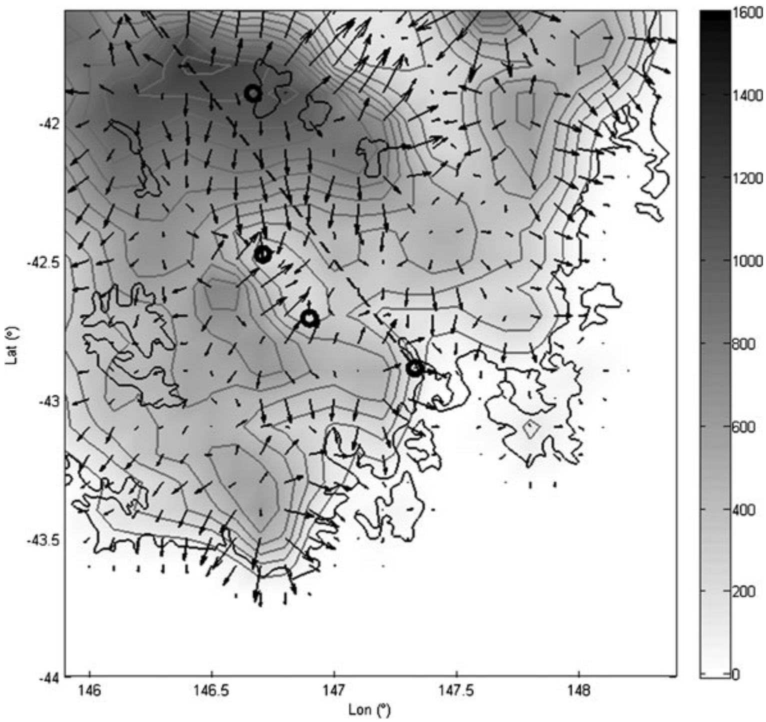

Fig. 4 Smoothed topography of southeast Tasmania (*grayscale*), showing contour lines at 100 m intervals (*dark gray lines*), fall lines (*arrows*), the stations used in Fig 6 (*circles*) and the transect (*dashed line*)

dominant fire regime, including a strong influence from fire weather. However, the low density of station measurements in the valley makes this hypothesis hard to confirm.

The extent to which the regional effects occurring in this example event are typical is unknown. However, it is plausible that the 'blocking' Foehn described by Sharples et al. (2010a) is commonly associated with north-westerly flow from the synoptic type described above, and affects fire danger in southeast Tasmania in these cases on many typical fire danger days. It is also possible that a blocking Foehn effect during north-easterly flow contributes to the high fire dangers in southwest Tasmania documented by Fox-Hughes (2008). Since the topography remains constant, this regional effect during these typical events is expected to be present in future conditions throughout the century under any scenario.

4 Synoptic scale effects

4.1 Evaluation of synoptic pattern in CCAM vs. GCM

Composites of all events in the baseline period in CCAM using GFDL-CM2.0 as its host (Fig. 5e) more closely match that of NCEP/NCAR Reanalysis 1 (Fig. 5a) than the raw output of the GCM (Fig. 5c). The temperature isobars over the Australian Bight region are more cyclonically curved than for the GCM, indicating a more consistent simulation of a strong cold front and deep trough. Similarly, the 290 K contour of each detected event in CCAM (Fig. 5f) shows more consistent similarity to the reanalysis (Fig. 5b) than the host model (Fig. 5d),

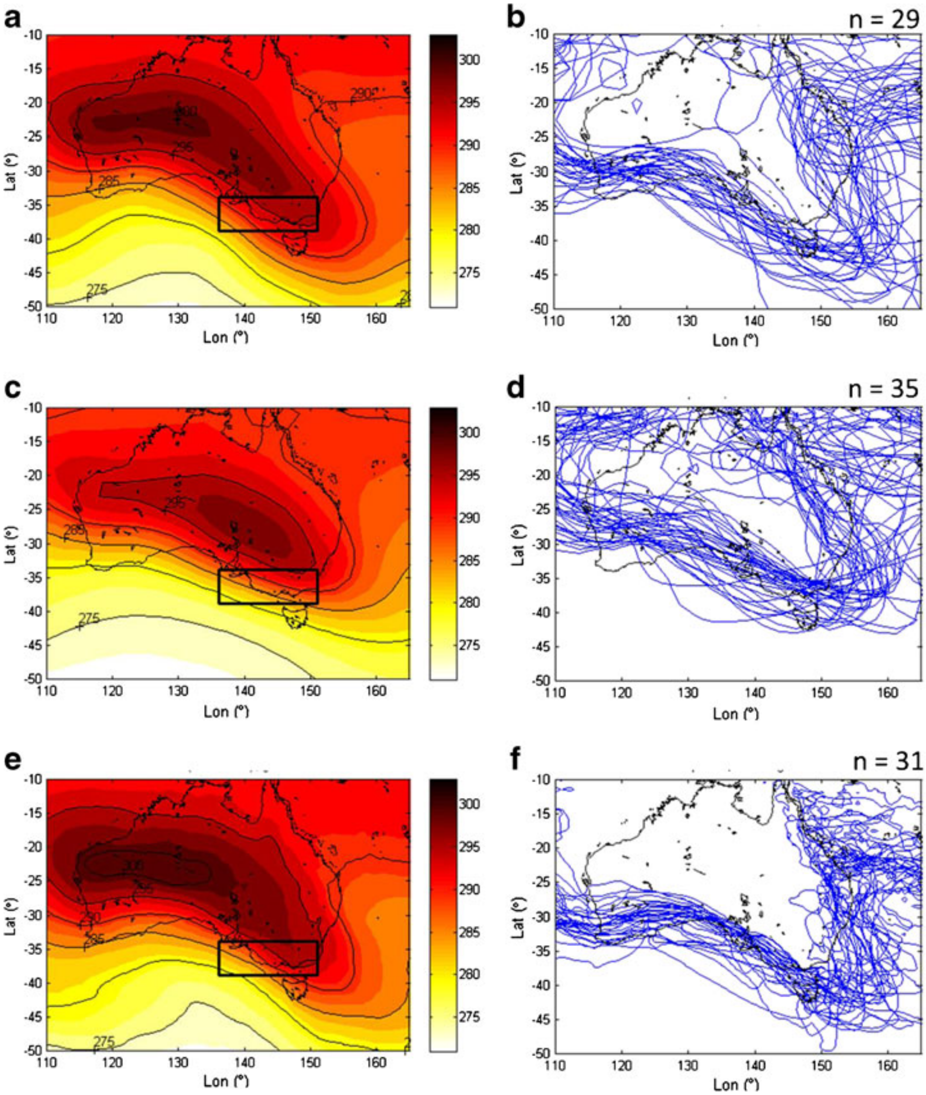

Fig. 5 850 hPa temperature (K) during fire weather events in southeast Australia identified in various model outputs, left column shows a composite of events in DJF and right column shows the 290 K contour of each of those events, (**a**-**b**) NCEP1 in DJF in 1964–2002, (**c**-**d**) GFDL-CM2.0 GCM in 1961–2000, (**e**-**f**) CCAM using GFDL-CM2.0 as the host model 1964–2002, the number of events is indicated above each plot on the right

including a more consistent latitudinal extent than the example GCM. The CCAM temperature composite has a higher spatial correlation and a lower root mean square error compared to the NCEP composite over this domain (0.99 and 1.3 K respectively) than the GCM composite (0.97 and 2.8 K).

Mean values of TGRAD and Tmax in CCAM were consistently higher than in NCEP/NCAR Reanalysis 1 in the baseline period, as were the values at the threshold for identifying the synoptic type (Fig. 6). This indicates some systematic biases in CCAM compared to this reanalysis. However, this difference may not indicate a problem only with

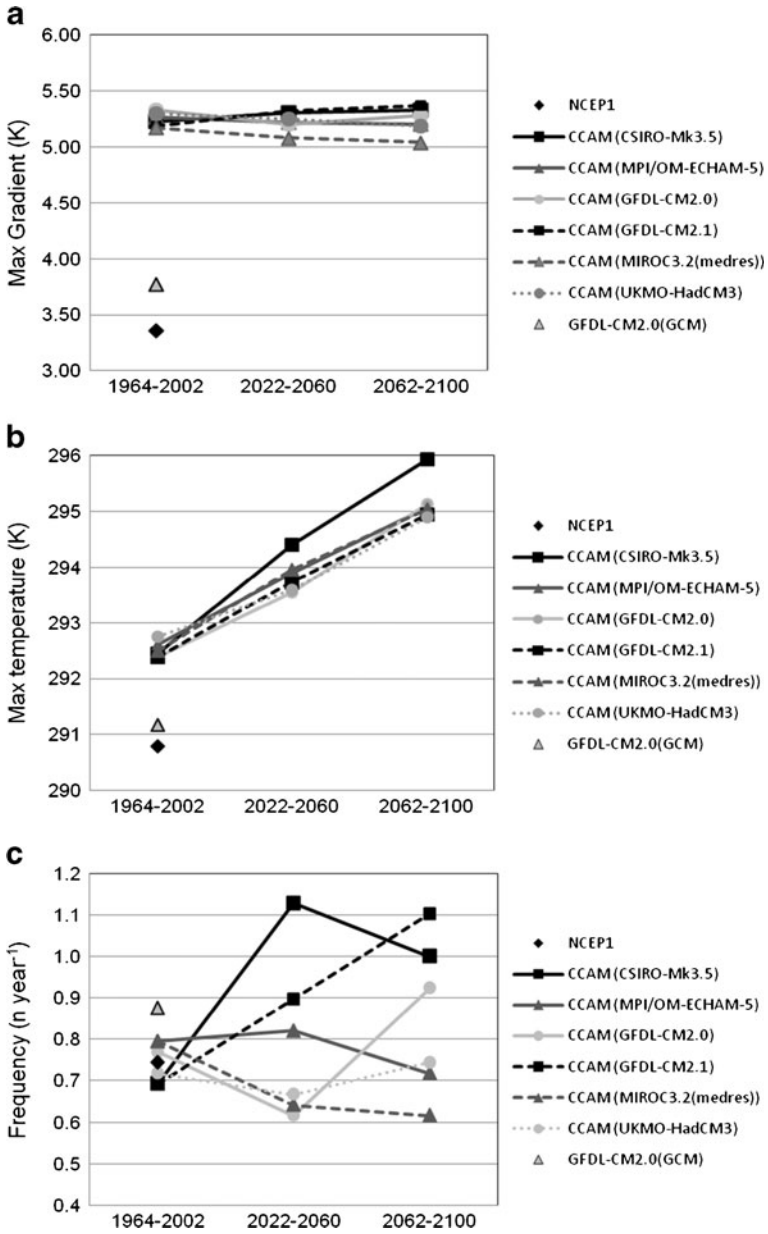

Fig. 6 Time series of the components of the fire weather driver analysis and the frequency of events in NCEP/NCAR Reanalysis 1, CCAM and in the GFDL-CM2.0 GCM: (**a**) the threshold value of the maximum temperature gradient in the 850 hPa temperature field across the Victoria box (98.87 percentile), (**b**) the threshold value of maximum 850 hPa temperature across the Victoria box (71.61 percentile) and (**c**) the frequency of events per year, baseline period for the GCM is slightly different than for reanalysis and CCAM (1961–2000)

CCAM, as there are also some systematic differences between NCEP/NCAR and ERA40 reanalyses (Hasson et al. 2008). The CCAM simulations were all very similar in the current climate, with the baseline thresholds of both Tmax and TGRAD being highly consistent

(<0.3 K range for both). Once the percentiles approach was used, the frequency of events in CCAM was also very uniform in the baseline period (0.69–0.79 events per year), and similar to reanalysis (0.74 per year). Importantly, the pattern was more consistently simulated and detected in CCAM than in the corresponding example GCM.

4.2 Projection in CCAM

TGRAD at the percentile threshold showed little change in any simulation in the future periods compared to the baseline (Fig. 6a). This indicates that there is no marked increase in the strength of the fronts and troughs associated with these events with the warmer climate under the A2 scenario. In contrast, the Tmax at the percentile threshold shows a strong increase in the future periods compared to the baseline, increasing by an average of 1.3 °C by 2022–2060 and 2.7 °C by 2062–2100 (Fig. 6b). The magnitude of this change is the same as the change in the mean of Tmax for this box (1.3 °C and 2.7 °C respectively), and similar to the change in mean surface air temperature in Tasmania and southeast Australia in these simulations (Grose et al. 2010). The greater change in Tmax compared to TGRAD can also be seen in the composites of events in the baseline and two future periods shown for the example of CCAM using GFDL-CM2.0 as its host (Fig. 7). There is no discernible difference in the sharpness of the front and trough indicated by curvature of the isotherms in each period, but there is an obvious increase in air temperature through the century.

There is a range of projected changes in frequency of events in the six CCAM simulations between the baseline period and the two future periods (Fig. 6c). The current mean in all CCAM simulations is 0.7 to 0.8 events per year, and by the late 21st Century period the range is between 0.6 and 1.1 events per year. The model mean change in frequency by mid-century is 8 % (−20 to 63 % model range) and by the end of the century is 11 % (−28 to 46 % model range). By 2062–2100, half the simulations show an increase in frequency and the other half show a decrease, however the frequency in the six simulations for the period 2062–2100 are statistically higher than that of the 1964–2002 period to the 90 % level (paired Students *t*-test, $p=0.10$). A range between models is expected, since the noise is higher when examining very rare events within the top percentile of the range. Also, there is large climate variability in extreme fire weather events in Tasmania at decadal scales and longer (Fox-Hughes 2008), which may affect results even in 39-year averages. The results indicate that an increase in frequency is likely, but there is large inter-model range and also large natural variability on top of this projection. Of the two input variables, the increase in frequency is driven more by an increase in temperature than in the strength of systems.

Extreme fire weather events that have had a particularly high Tmax but a TGRAD that did not meet the threshold of 3.2 K are present in several fire events, including the Tasmanian fires in December 1996 and the Tasmanian and NSW fires in December 1997 (Hasson et al. 2009). This supports the notion that the temperature of the air mass is an important driver of fire danger, given a sufficient strength of system. Also, on 4th January 2013 documented here, the Tmax was >10 K over the threshold but TGrad was only 0.2 K over the threshold (Fig. 2). There are comparable individual events >10 K over the percentile threshold of Tmax in the baseline period in the CCAM simulations, and there is a marked increase in the number of such days through the century (not shown).

The change in frequency in these CCAM simulations is at the lower end of the large range found in GCMs for this emissions scenario (Hasson et al. 2009). This is partly because the GCMs with the strongest change were not downscaled for this study, and possibly because only one downscaling model is considered. CCAM uses only sea surface temperature from the

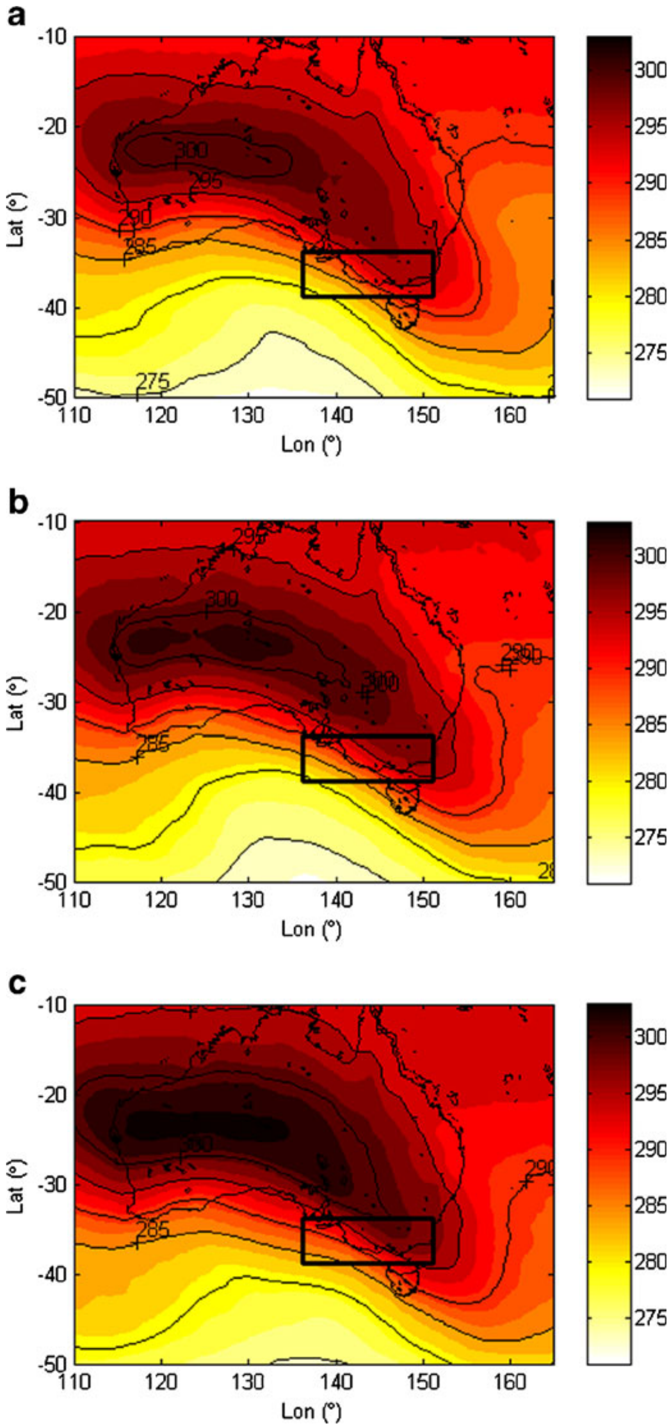

Fig. 7 Composite 850 hPa temperature (K) in CCAM climate simulation with GFDL-CM2.0 as the host model under the A2 scenario during events detected in (**a**) 1964–2002, (**b**) 2022–2060 and (**c**) 2062–2100

GCM and generates its own global atmosphere, so the configuration of CCAM used may have a strong influence on the results. Confidence in the projection is raised due to the closer match between the simulated synoptic type in CCAM and reanalysis compared to an example GCM (Fig. 5), and the finer resolution of processes at regional scales. However, the use of a single downscaling model with a limited number of GCMs as input means that the full range of plausible future conditions may not be accounted for.

5 Discussion and conclusions

There have been positive trends in various FFDI measures in recent decades in Tasmania, including an increase in the annual 90th percentile FFDI at both Hobart and Launceston, however many increases are less marked than for other states (Lucas et al. 2007; Clarke et al. 2013b). Projections of FFDI using GCMs as input indicate little change for Tasmanian fire danger (Hennessy et al. 2005; Lucas et al. 2007). However, there are several problems with examining fire danger indices in Tasmania calculated from the output of GCMs, including their coarse spatial resolution and biases in their output. There are therefore advantages in examining higher resolution downscaled model output. In a related paper (Fox-Hughes et al. 2014) we report that these CCAM simulations reproduce FFDI close to observed in the current climate, including reproducing the peak fire danger in the southeast. The models project increases in FFDI at all sites across Tasmania, with larger increases in the east coast and central region than on the west coast.

Along with examining downscaled model simulations, we propose there are advantages in understanding and projecting changes to the drivers of high fire danger rather than only examining fire indices. Fox-Hughes et al. (2014) reported a typical pattern of mean sea level pressure (MSLP) for events in the southeast in the current climate that is distinct from events in northern Tasmania. These MSLP patterns are similar in the projected future climate, but with higher values of MSLP. Here we examine the synoptic and local scale drivers associated with the many of the highest fire dangers, including those in the *"Catastrophic"* category. This initial case study demonstrates there is potential merit to both downscaling and examining drivers of change.

High fire danger in southeast Tasmania is associated with a typical synoptic type (Mills 2005) and a typical MSLP gradient (Fox-Hughes et al. 2014). The model mean projection from dynamical downscaled simulations is for an increase in the incidence of this synoptic type but with a large range between models and considerable natural variability. The main driver of the projected increase in the frequency of this synoptic type is an increase in the temperature, with little change to the strength of the cold front or pre-frontal winds. A blocking Foehn effect and topographic channelling that intensifies the fire danger in the southeast was present during the fires in January 2013, and is likely to be present in many bad fire days in the future. Decreased mean summer rainfall in western Tasmania and an increase in the incidence of drought also suggest an increase in the risk of fire through the pre-conditioning of fuels. These insights from the drivers of fire danger do not rely on the calculation of FFDI or other indices from model outputs.

Insights into fire danger at the local scale and synoptic scale can be combined with knowledge about projected change to the mean climate and large-scale climate drivers to provide a more complete picture of projected changes to fire weather. Total area burned in Tasmania has shown a weak but statistically significant correlation to total rainfall in October-March (Nicholls and Lucas 2007). The CCAM simulation used here project a rainfall decrease across the western and central districts in summer (~20 % by 2090 under A2), but no marked decline in the east and north-east (Grose et al. 2010, 2013). This rainfall trend implies a greater area burned in the western and central districts of Tasmania around the higher end of the present range (40,000 ha burnt) on average, assuming the link does not break down in future due to unprecedented climate conditions or the crossing of an important bioclimatic threshold where the relationship no longer holds. There is likely to be some interplay between fuel moisture and amount with fire weather in relation to large infrequent fires in a changing climate (Meyn et al. 2007).

The El Niño Southern Oscillation (ENSO) is a key mode of variability that affects parts of Tasmania. Drier conditions and more bushfire events occur on average in El Niño years (Williams and Karoly 1999) leading to a correlation between total area burned in Tasmania and the Southern Oscillation Index of the El Nino Southern Oscillation (Nicholls and Lucas 2007). Rainfall deficits during El Niño events may become stronger (Power et al. 2013), and this may lead to greater fire risks. Similarly, many large fires are preconditioned by positive Indian Ocean Dipole (IOD) events (Cai et al. 2009a). A warmer climate is expected to lead to more positive IOD events and this may result in an increase in the conditions suitable for fires in many regions of Tasmania (Cai et al. 2009a, b).

This paper has focussed on fire weather in summer, which is one important aspect of overall fire danger. Projected changes in other seasons are also relevant, including a widening of the peak fire danger season earlier into spring (Fox-Hughes et al. 2014). Also, changes to bushfire danger are influenced by changes to bushfire fuel amount, fuel moisture, fire management and other complex and interacting factors. Nevertheless, changes to fire weather in summer are an integral part of future fire danger, and the projected changes presented here should be valuable input into risk assessment and climate change adaptation for bushfire management.

These results suggest that a warmer climate is likely to increase the frequency and impact of the very worst fire-weather days, with important implications for fire management practice in the region. An understanding of the drivers of fire weather at both the synoptic and local scales along with the large scale is essential in projecting changes to future fire danger.

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