Modelling the fire weather of the Dunalley, Tasmania fire of January 2013: an ACCESS case study

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Introduction

On 4 January 2013, a day of significant fire activity in southeast Tasmania, a familiar set of Australian summer meteorological ingredients, (i) an approaching cold front west of Tasmania, and (ii) an anticyclone in the Tasman Sea between New South Wales and New Zealand (Figure 1), brought strong hot northerly to northwesterly winds over southeast Australia and Tasmania in particular. These conditions occurred during a significant national heatwave that contributed to January 2013 being the hottest month on record for Australia (BoM 2013a).

Two weather stations in southeast Tasmania (Hobart and Campania) measured “catastrophic” FFDRs at routine observation times on the hour. Over periods ranging from one minute to one hour, five weather stations registered “catastrophic” FFDRs, these being Hobart, Campania, Hobart Airport, Bushy Park and Dunalley (all near to, but not on, the TP). [In Tasmania, the FFDR is associated with a Forest Fire Danger Index (FFDI) being in a particular range of values (BoM 2013b), it being the FFDI which is actually forecast and observed.] At Dunalley, as fire swept through the township, radiant heat from the fire corrupted the air temperature readings at the Bureau of Meteorology’s (hereafter, the Bureau) automatic weather station. In fact, the fire came close enough to the Stevenson Screen housing the thermometer to blister the white paint on the Screen (BoM

Figure 1 Mean sea-level pressure analysis for 0000 UTC (1100 EDT) on 4 January. Pressures are in hPa. Image courtesy of the National Meteorological and Oceanographic Centre.

On the previous day (3 January), Forest Fire Danger Ratings (FFDRs) reached the “very high” range over much of the eastern half of Tasmania and the “severe” range in the southeast, as temperatures reached the mid 30s (°C) and gusty westerly to northwesterly winds developed. These weather conditions were coincident with the spreading of two fires, the Lake Repulse fire and the Forcett fire, both of which started that day (BoM 2013b). The 4th of January saw numerous high temperature records set in southern Tasmania (Figure 2), most notably its capital city Hobart, whose maximum of 41.8°C was the highest in 120 years of records there, the highest on record anywhere in southern Tasmania, and the second-highest for the State as a whole (BoM 2013a). On that day, thousands of people, including summer holiday makers, were stranded on the Tasman Peninsula (TP) as bushfires cut off road access, with many evacuated by water back to Hobart. The fires destroyed many properties in Tasmania, news media reporting at least one hundred, with Dunalley particularly badly hit.

Figure 2 Percentiles of daily maximum temperature for 4 January 2013. The figure is calculated using all the January daily maximum temperature analyses of Jones et al. (2009) between 1 January 1911 and 4 January 2013. Highest-on-record January daily maximum temperatures were seen in the analyses in southeast Tasmania and at the top of Spencer Gulf in South Australia.

2013b), We present the results of high-resolution (0.012°-grid-spacing) and very-high-resolution (0.004°-grid-spacing) simulations of the fire weather over southeast Tasmania around the time of the start of the Dunalley fire. The simulations were performed using the Australian Community Climate and Earth-System Simulator (ACCESS), and involve a cascade of nested model runs starting from a global model run initialised with an initial condition prepared by the Bureau's National Meteorological and Oceanographic Centre. Our analysis will focus on how well the simulations capture the meteorological factors that promote extreme fire behaviour. The ACCESS model is used at the Bureau for operational numerical weather prediction, but is used here in research mode at much finer resolutions than current operational ones.

The 0.004°-grid-spacing simulations show notional instantaneous FFDI (a Drought Factor of 10 is assumed) values peaking in the FFDR “catastrophic” range (> 100) across the TP, comparable to the observed “catastrophic” values at the non-TP sites mentioned above, but the 0.012°-grid-spacing simulations show less intense values, mostly peaking within the “severe” range (50-74) with a few grid cells peaking in the “extreme” (75-99) range. Operational FFDR forecasts for 4 January 2013 for the various Tasmanian forecast districts ranged from “very high” to “extreme”, without reaching the highest “catastrophic” category (BoM 2013b), although it should be noted that a particular district forecast FFDR does not preclude individual grid points within the district from having a higher forecast FFDR.] Afternoon maximum temperatures and wind directions are generally well modelled, although some of the fine-scale local wind changes were not captured in the simulations. The passage of the primary wind change (from northerly to southerly) in the simulations shows a complicated interaction with the topography and coastline of southeast Tasmania. Wind changes such as this one can have a significant (and dangerous) impact on the behaviour of bushfires in southeast Australia, and their prediction forms an important component of fire weather prediction.

This work arose through a project funded by the Bushfire Cooperative Research Centre, to produce very-high-resolution meteorological simulations for significant recent fire events. The intent is for a better understanding of the meteorology of those events and the use of the simulation results in fire spread and fire impact modelling.

**Modelling**

The high-resolution and very-high-resolution numerical weather prediction (NWP) modelling described in this paper was performed using ACCESS, and in particular the United Kingdom Meteorological Office’s (UK Met Office) atmospheric model which comprises the atmospheric component of ACCESS. In order to simulate the weather conditions on the 4th of January, a sequenced of nested model runs was employed, starting with a global model run and progressively nesting down to a region of approximately 3°x3° (330 km × 240 km) for the finest-resolution simulation. In these simulations, meteorological information flows from the coarser-resolution simulation to the finer-resolution simulation, but not in the other direction. Further, the fires are not represented in the simulations.

In total, there were five levels to the nesting process. The second-level domain (0.11° grid spacing, i.e., ≈ 12 km) extends well to the west of Australia, while maintaining a 20° buffer to the south, 35° to the east and 35° to the north. The third level (0.036° grid spacing, i.e., ≈ 4 km) covers all of Tasmania and surrounding waters, while the fourth level (0.012° grid spacing, i.e., ≈ 1.3 km) covers the main island of Tasmania and the fifth level (0.004° grid spacing, i.e., ≈ 440 m) southeast Tasmania. Domain boundaries have been placed, where possible, to avoid regions of significant topography (Figure 3).

![Figure 3 Model domains for the 0.036°-grid-spacing (blue box), 0.012° grid spacing (green box) and 0.004° grid-spacing (red box) simulations of the meteorology on 4 January 2013.](http://www.cawcr.gov.au/publications/researchletters.png)

All five levels of nesting use 50 vertical levels in the atmospheric model, with the lowest model level being approximately 10 m above the surface for some meteorological variables (e.g., the u and v components of the horizontal wind) and approximately 20 m above the surface for other variables (e.g., potential temperature and the vertical component of the velocity). The highest
model level is around 60 km above mean sea level.

The simulations use global initial conditions obtained from the Bureau of Meteorology. Three initialisation times were explored; 0300 UTC, 0900 UTC and 1500 UTC on 3 January 2013. All simulations ran for 50 hours of model time, so (for example) those initialised at 0300 UTC cover the period from 0300 UTC on 3 January to 0500 UTC on 5 January. Results presented in this paper pertain to the 0300 UTC initialisation simulations, unless otherwise stated. All five levels of nesting were initialised from the same base time: accordingly little attention was paid in the finer-resolution simulations to the first 12 hours of the model integration. This is because at the start of the integration, each nesting level is essentially presenting just the detail which is present in the global analysis: it takes some time for the model atmosphere to interact with the high-resolution model topography to develop the fine-scale local details. Instantaneous outputs for the model surface fields (e.g., those used in Figures 4, 5 and 6) were archived at five-minute intervals, while those for the model levels describing the atmosphere above the surface were archived at 15-minute intervals.

**Model validation**

For simulations of recent events such as this one, the model results can be validated against a range of meteorological data obtained from sources such as automatic weather stations (AWSs), radiosondes (balloon flights), weather watch radars and meteorological satellites. In validating the simulations against AWS data, the nearest model grid point to the AWS location was generally chosen. The exceptions to this rule were in the southeast of Tasmania, particularly around the TP where the coastline is quite complicated and consequently the nearest model grid point is often a *marine* grid point. For these sites, a representative *land* grid point in the model near to the AWS was chosen. The chosen point usually depends on the grid spacing.

Figure 4 shows a comparison between observational data from Hobart Airport AWS and a nearby model land point in the 0.004°-grid-spacing simulation initialised at 0300 UTC on 3 January 2013. The afternoon maximum temperature on 4 January 2013 is well simulated, although the overnight cooling is underestimated with the morning minimum temperature on the 4th being somewhat in error. The minimum temperature on the 5th is rather better hindcast. The change in the wind direction from northerly to southerly just after midnight EDT (Eastern Daylight Time = UTC + 11 hours) on the 5th is around 75 minutes early in this simulation (although around 30 minutes early

in the parallel simulation initialised at 0900 UTC on 3 January 2013).

![Figure 4 Comparison between the 0.004°-grid-spacing simulation initialised at 0300 UTC on 3 January 2013 (thick lines, black dots, five-minute-interval data) and AWS observations (thin lines, grey dots, one-minute-interval data) for Hobart Airport (094008). Air temperature (in °C, red lines), dewpoint temperature (in °C, blue lines), 10 metre wind speed (in m s⁻¹, green lines) and direction (dots). The horizontal axis shows time in days from midnight EDT on 3 January 2013.](http://www.cawcr.gov.au/publications/researchletters.php)
Figure 5 As for Figure 4, but for Maria Island (092124).

Figure 6 Direction of the 10-metre wind at 1530 UTC on 4 January (0230 EDT on 5 January) in the 0.004°-grid-spacing simulation, around the time the wind change is passing over the northern end of Maria Island. The wind has swung easterly (blue shades) over a small patch in the vicinity of the AWS at Point Lesueur on Maria Island (see also the inset which expands the region surrounding Maria Island), which sits within a larger region of more southerly flow (green shades).

Figure 7 Comparison between the 0.036°-grid-spacing simulation initialised at 0300 UTC on 3 January 2012 (thick lines) and radiosonde observational data (thin lines) for Hobart Airport at 2300 UTC on 3 January 2013 (1000 EDT on 4 January). Air temperature (in °C, red lines), dewpoint temperature (in °C, blue lines), both skewed, and horizontal wind speed (in m s⁻¹, green lines) are shown. The model grid point nearest to the nominal release point of the balloon has been chosen for comparison.

**Modelled FFDI**

Figure 8 shows the modelled notional instantaneous FFDI Mark 5 (Noble et al. 1980), calculated assuming a maximal drought factor of 10, for two time steps in the 0.004°-grid-spacing simulation initialised at 0300 UTC on 3 January 2013. The modelled FFDI exceeds 150 on some of the more elevated parts of the plotted region and is widely in the "extreme" (FFDI: 75 to 100) to "catastrophic" (FFDI: > 100) ranges. Peak values near Dunally exceed 100. Peak values on the TP likewise exceed 100 in small areas in this very-high-resolution simulation. It is noted that values over the TP in the 0.012°-grid-spacing simulation are not as high, as reported in the Introduction.

The FFDI shows a strongly banded pattern, with wider regions of elevated FFDI interspersed with narrower regions of lower FFDI. Analogous bands are present in the 10-metre wind field, a component in the FFDI calculation, and appear to be tied to the orography rather than being free atmospheric oscillations (such as boundary-layer rolls). The orientation of these bands changes with the orientation of the broader-scale flow, resulting in local fluctuations in FFDI value as the bands pass across particular locations. These bands appear to be similar to the orographic wakes reviewed by Belcher and Hunt (1998, section 6).
coast of the State. This is illustrated in Figure 9, which shows isochrones of the 240° (approximately southwesterly) wind direction at four times in the evening on 4 January 2013. Out over the ocean, the isochrones can be traced with some degree of clarity, although there is much in the way of interesting fine-scale structure to the wind change, but around the coastline, there is considerable complexity. Such complexity represents a significant forecasting challenge, both in the assimilation of the meteorological detail (and its implications for any active fires) by the professional weather forecaster in a Regional Forecasting Centre, and the communication of the salient features of the meteorology to firefighters trying to fight such fires.

![Figure 9](image)

**Figure 9** Isochrones of the 240° wind direction isogon at four times (0900 UTC, red lines; 1000 UTC, orange lines; 1100 UTC, light green lines; and 1200 UTC, dark green lines) on 4 January 2013, from the 0.004°-grid-spacing simulation initialised 0300 UTC on 3 January 2013.

### Discussion and Conclusions

The atmospheric flow modelled in the higher-resolution simulations around the southeast of Tasmania is quite complicated. This appears to be due to both the orography (e.g., the inland mountains) and the complicated nature of the coastline, which itself complicates the modelling process because a certain amount of “simplification” of the orography and coastline is required to enable the NWP to function. Figure 8 (both panels) for example shows converging bands of low FFDI where the downstream flow from two different parts of the orography merge (indicated by asterisks in the Figure). Arguably of more importance is the very detailed way in which the synoptic wind change wraps around the southeast

### References


