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# MODELLING THE FIRE WEATHER OF THE COONABARABRAN FIRE OF 13 JANUARY 2013

**Proceedings of the Research Forum at the Bushfire and Natural Hazards CRC & AFAC conference**
**Wellington, 2 September 2014**

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**Publisher:**
Bushfire and Natural Hazards CRC

February 2015

# TABLE OF CONTENTS

# ABSTRACT

We will exhibit state-of-the-art high-resolution numerical weather prediction simulations and radar imagery for Sunday 13 January 2013, with a specific focus on the region of the Coonabarabran fire which started at around 1600 Eastern Daylight Time (EDT) on 12 January in the Warrumbungle National Park. The simulations show a complicated range of meteorology including weather features that would affect fire behaviour critical for fire-fighter safety.

Features such as convection outflow gust fronts are displayed in the simulations in the north-westerly wind ahead of the main wind change, together with boundary-layer rolls, and sea-breeze-like wind changes proceeding inland from the coast. In addition, small-scale vortices are modelled on the main change: these lead to hazardous local spikes in the modelled Forest Fire Danger Index. Exceptionally strong north/south temperature gradients were observed over inland New South Wales on the Sunday and these are also seen in the simulations.

Sunday 13 January brought difficult conditions for fire fighting. When the fire was declared “out” on 24 January, it had burnt an area of 55,210 ha west of Coonabarabran, 53 homes, 131 other buildings and 95% of the Warrumbungle National Park.

The simulation has been performed using the Australian Community Climate and Earth-System Simulator (ACCESS), and involves a sequence of nested limited area model runs embedded in the ACCESS global model run, with a finest grid spacing of 550 m. 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 of Meteorology for operational numerical weather prediction, but is used here in research mode at resolutions much finer than current operational ones.

# INTRODUCTION

A fire started around 1600 Eastern Daylight Time (EDT) on Saturday12 January 2013 in the Warrumbungle National Park (WNP) in north-east New South Wales. The weather on Sunday 13 January brought difficult conditions for fire fighting (NSW RFS 2013) and exceptionally strong north/south temperature gradients over inland NSW (M Logan pers. comm.). When the fire was declared out on 24 January, it had burnt an area of 55,210 ha west of Coonabarabran (NSW RFS 2013).

In this paper, we exhibit state-of-the-art high-resolution numerical weather prediction simulations and radar imagery for Sunday 13 January 2013, with a specific focus on the region of the Coonabarabran fire. The simulations show a complicated range of meteorology including weather features that would affect fire behaviour critical for fire-fighter safety.

Features such as convection outflow gust fronts are displayed in the simulations in the north-westerly wind ahead of the main wind change, together with boundary-layer rolls, and sea-breeze-like wind changes proceeding inland from the coast. In addition, small-scale vortices are modelled on the main change: these lead to hazardous local spikes in the modelled Forest Fire Danger Index. Exceptionally strong north/south temperature gradients were observed over inland New South Wales on the Sunday and these are also seen in the simulations.

# SYNOPTIC METEOROLOGY

Figure 1 shows the mean sea-level pressure (MSLP) analysis for 1700 EDT on 13 January 2013. The primary meteorological feature is the trough (the dashed line in Figure 1) which moves northeastward through the course of the afternoon on 13 January. This manifests at the surface as a significant wind and temperature change with strong frontal characteristics. At Coonamble for example (Figure 3), the wind direction changes from northerly/northwesterly around to a southerly. The synoptic situation resulted in one of the largest southwest-to-northeast gradients in daily maximum temperature across New South Wales in a hundred years. For example, the average maximum temperature on that day across Rainfall District 52 (containing Mungindi and Walgett) in the northeast was 20°C higher than that for Rainfall District 74 (containing Narrandera, Wagga Wagga and Deniliquin) in the southwest, according to the Bureau of Meteorology's operational daily temperature analyses (Jones et al. 2009).

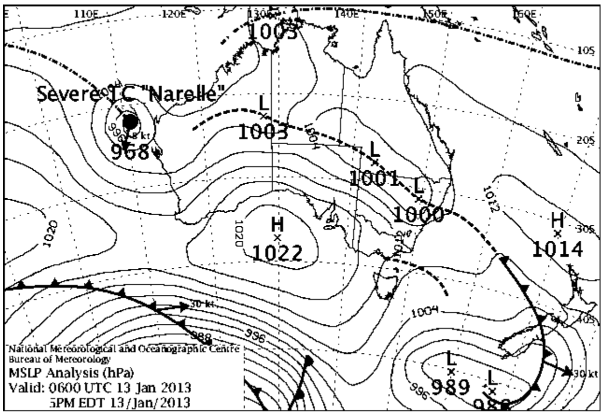


**Figure 1: Mean sea-level pressure analysis (in hPa) for 0600 UTC (1700 EDT) on 13 January 2013.**

# MODEL DETAILS

To reconstruct the weather conditions across New South Wales on 13 January 2013, a sequence of nested model runs was employed. There were five stages and the nesting was one-way, which means that meteorological information only passed from the coarser resolutions to the higher resolutions. The first stage was a global model run, with a longitude spacing of 0.5625° and a latitude spacing of 0.375°. The second stage had a latitude-longitude grid spacing of 0.11° for a wide region covering Australia and surrounding waters, while maintaining a 20° buffer to the south, 35° to the east and 35° to the north. The third stage (hereafter G36) had a grid spacing of 0.036° (approximately 4.0 km in the north-south direction and 3.4 km in the east-west direction at the latitude of Coonabarabran Airport, 31.333°S). The fourth stage (hereafter G12) had a grid spacing of 0.012° (approximately 1.33 × 1.14 km), with the last stage (hereafter G075) having a grid spacing of 0.0075° (approx. 0.83 × 0.71 km). A parallel version of the last stage was also attempted over the G075 domain, having a finer grid spacing of 0.005° (approximately 0.55 × 0.47 km, hereafter G05). The model boundaries are shown in Figure 2.

The atmospheric model within ACCESS is non-hydrostatic, with an Arakawa-C grid in the horizontal and a Charney-Phillips grid in the vertical (Puri et al. 2010). Consequently, regridding was required for the calculation of some fire-relevant meteorological quantities, such as wind speed and direction.

All five stages of the modelling used 50 vertical levels, with the lowest model level being approximately 10 metres above the surface for some variables (e.g., the u and v components of the horizontal wind) and approximately 20 metres above the surface for other variables (e.g., potential temperature θ). The top level was around 60 km above sea level. The vertical aspects of the gridding were the same across all five stages; a stretched grid with 10 levels in the lowest 2000 m.

For the coarser resolutions (0.036° and above), the model used a parameterised convection scheme. The lowest 13 model levels, approximately the lowest 3000 metres of the atmosphere, were treated as being potentially boundary-layer levels. Boundary-layer mixing was parameterised using the one-dimensional scheme of Lock et al. (2000). For the finer resolutions (G12, G075 and G05), the parameterised convection scheme was turned off. Also turned on at these finer resolutions was a sub-grid turbulence scheme applied in three dimensions for model levels 2 to 49. The whole vertical extent of the model domain was in effect treated as being potentially available for the boundary layer to grow into, and in fact boundary-layer depths of up to 5000 metres were seen in the simulations.

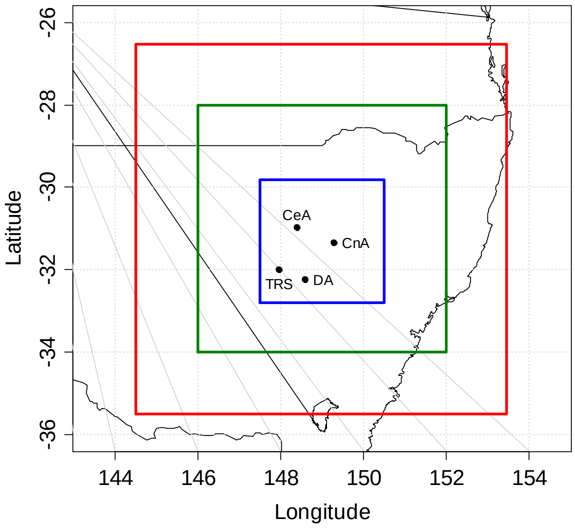


**Figure 2: Model domains and resolutions (G36 in red, G12 in green and G075/G05 in blue). The locations of Coonabarabran Airport (CnA), Coonamble Airport (CeA), Trangie Research Station (TRS) and Dubbo Airport (DA) are indicated. The fire was located in the Warrumbungle National Park, west of Coonabarabran and in the middle of the G05 domain.**

# MODEL VALIDATION

The meteorological quality of the simulations may be assessed in a qualitative sense by direct comparison of model grid-point data against independent observational data from automatic weather stations (AWSs). These observational data are independent in the sense that they have not been used to prepare the global initial state employed at the start of the model numerical integration. The observational data were obtained from the Bureau of Meteorology's Australia Data Archive for Meteorology (ADAM) database.

Figure 3 shows one such comparison for Coonamble Airport northwest of the fire. As with our previous studies (Fawcett et al. 2012, 2013), we find that air temperatures and wind directions are generally well-simulated. Dewpoint temperatures are less well-simulated, and peak wind speeds tend to be under-estimated.

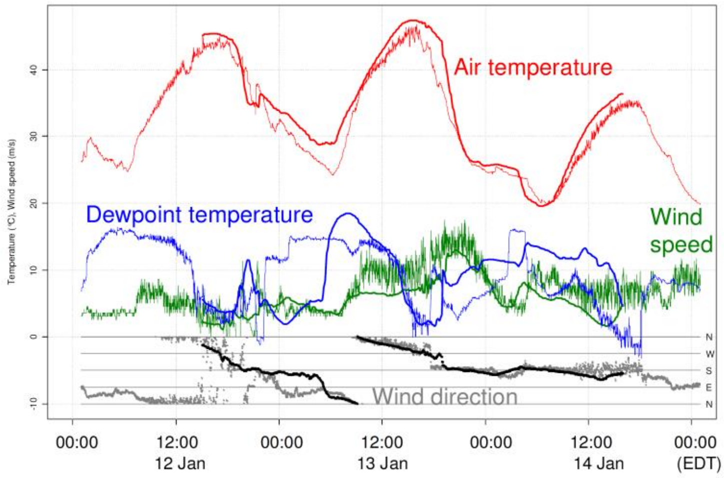


**Figure 3: Near-surface (10-metre) wind and screen air/dewpoint temperature data for Coonamble Airport, northwest of the fire on 12 to 14 January 2013. Thick lines / black dots are five-minute model data from the G12 model run, thin lines / grey dots are one-minute-interval Automatic Weather Station (AWS) data. Model data are from the grid point nearest the AWS location.**

An additional route to model verification is through the use of radar data. Figure 4 shows a comparison between the modelled screen-level dewpoint temperature and 10-metre wind field at one point in time (0715 UTC on 13 January) and radar reflectivity observations one minute earlier. Two lines of convection are visible in Figure 4 and Figure 5. The more southerly one travels in a northeasterly direction across the southwest quadrant of the radar's field of view, from around 0530 UTC until 0830 UTC. This feature is well captured by the modelling: in Figure 4a it takes the form of elevated surface dewpoint temperatures (i.e., locally moister air) and divergent surface winds (indicative of downdrafts). Several air-mass boundaries are evident in the modelling: these take the form of dewpoint temperature discontinuities in Figure 4a.

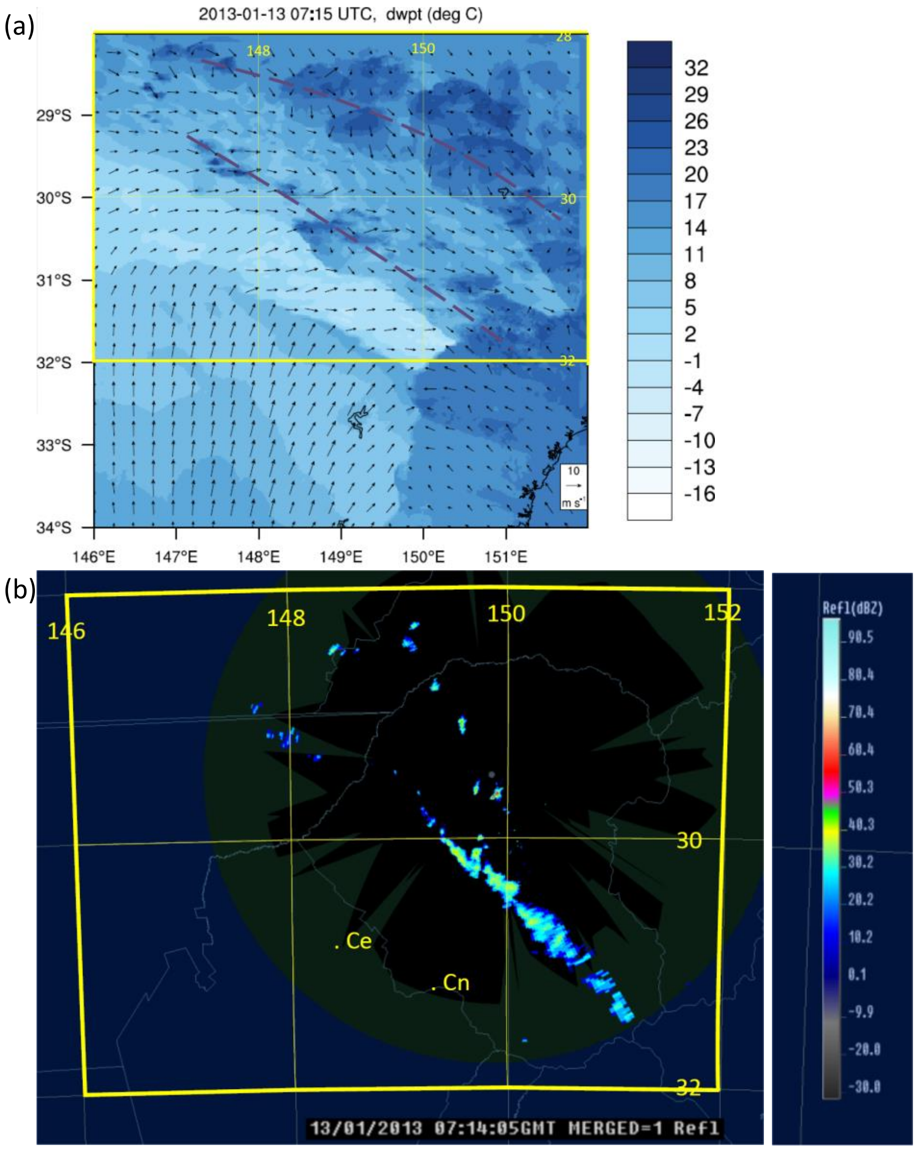
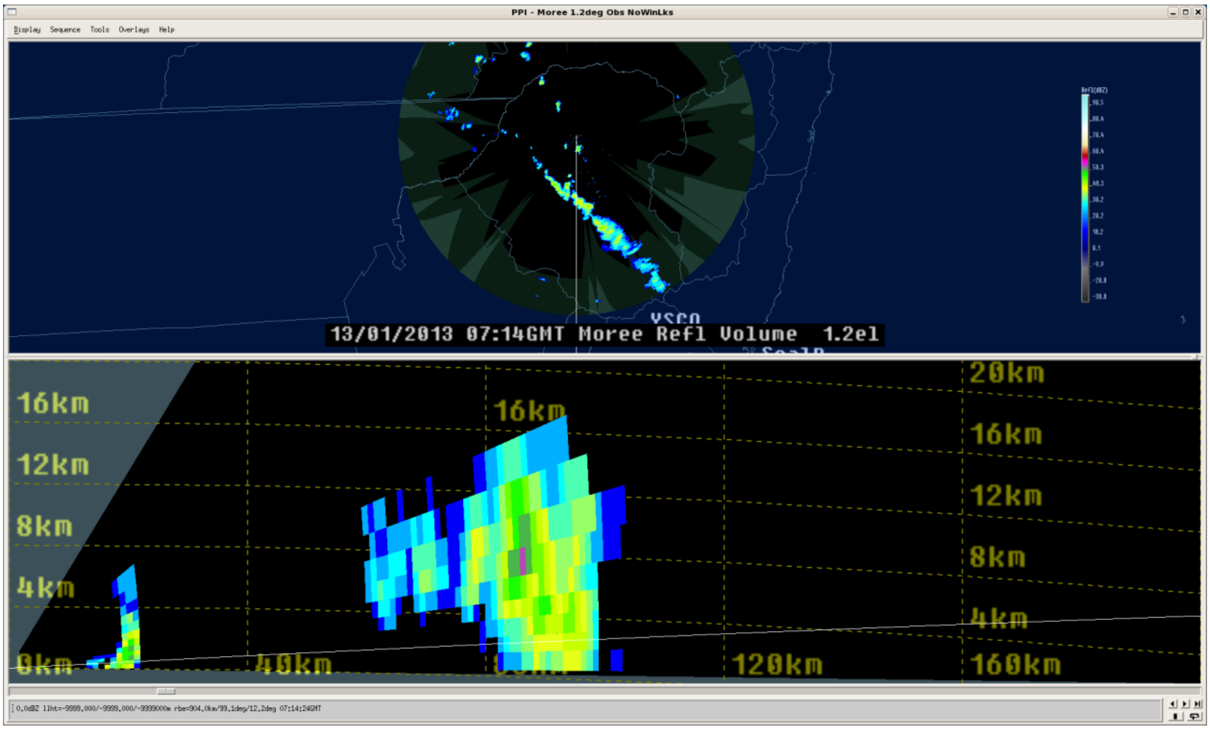


**Figure 4: (a) Modelled screen-level dewpoint temperature (in °C) and 10-metre wind vectors for 0715 UTC on 13 January 2013, from the G12 simulation, and (b) merged radar reflectivity (in dBZ) from the Moree radar for 0714 UTC. The location of the Moree radar is indicated by a grey dot in (b). Areas shaded dark blue in (b) are outside the radar's range. The yellow lines denote latitude/longitude lines at 2° intervals for purposes of comparison, as the map projections of the two panels are different. In (b), the locations of Coonabarabran (Cn) and Coonamble (Ce) are indicated. The entire G12 model domain is shown in (a). The dashed lines in (a) denote the approximate positions of the lines of modelled convection.**



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0.0dBZ llht=-9999.000/-9999.000/-9999000m rbe=904.0km/99.1deg/12.2deg 07:14:24GMT
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**Figure 5: Plan radar reflectivity view (in dBZ) at 1.2° of elevation (upper panel) and vertical cross section (lower panel) looking south from Moree radar at 0714 UTC on 13 January. The horizontal coordinate in the lower panel is distance from the radar, with the curved yellow lines indicating height above the radar. The line of cross-section is indicated by a vertical white line in the upper panel, while the 1.2° elevation cone of the upper panel is indicated by the white line in the lower panel.**

Unfortunately, the fire plume near Coonabarabran is sufficiently distant from the two nearest radars (Namoi, around 90 km distant and Moree, around 200 km distant) as to be not well observed by the Bureau's weather-watch radar network.

# DISCUSSION

The ability to suppress fires is highly dependent on a number of weather features. These include air temperature and humidity, wind strength and variability, atmospheric stability, and the strength and timing of wind changes. It is therefore important that these basic meteorological properties be well modelled: this is also an essential ingredient for the successful prediction of fire intensity and spread.

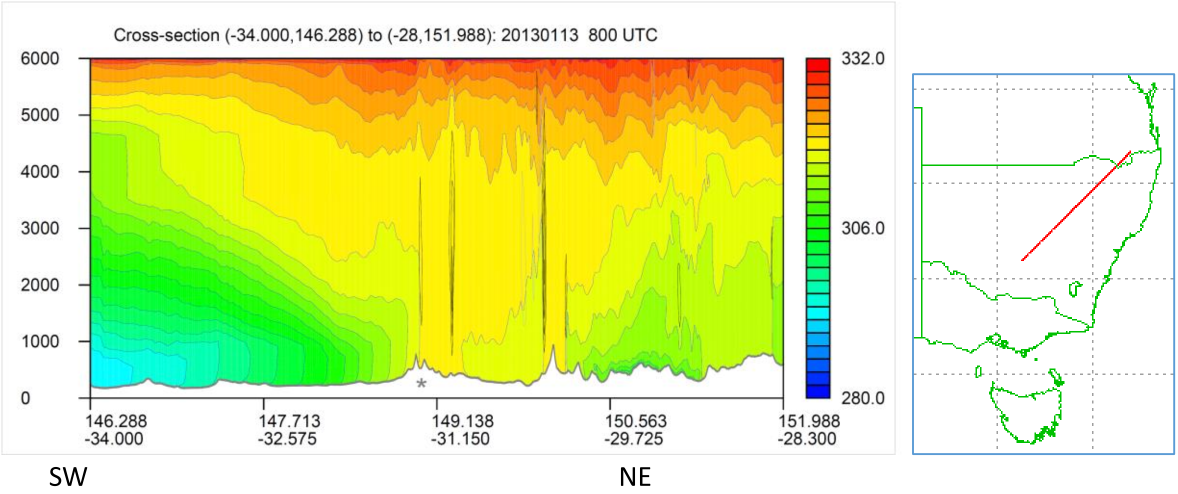

**Figure 6: Vertical cross-section (left) along the line shown in red in the map (right) at 0800 UTC (1900 EDT) on 13 January. This is approximately the time at which the primary wind change passes across the Warrumbungle National Park (indicated by the grey asterisk at around 149°E). The cross-section also passes near Mt Kaputar to the northeast. The colours denote potential temperature (in K), with the black (grey) contours denoting upwards (downwards) vertical velocity (in contour intervals of 1.5 m s$^{-1}$). The vertical coordinate is height (in metres) above mean sea level.**

The simulations show a complicated array of interacting features. As noted above, the primary feature is the passage of a trough moving northeast across the fireground in the afternoon on 13 January. This trough was accompanied by cooler temperatures (Figure 6) and a wind change. Added to that are the effects of sea breezes from the NSW coast, generated on the day together with the residues of those generated on the previous day.

Figure 6 hints at the complexity of the meteorological situation. On the left hand side of the plot (i.e., southwest of the WNP), the cooler temperatures associated with the approaching cool change are clearly evident. Just ahead of the change (i.e., over the WNP itself) is a band of air which is well-mixed to around 4000 metres (yellow shades). This is typical of a hot summer day, but strikingly it is very different from the air masses to the southwest and northeast at this point in the afternoon (the well-mixed layer covered a much broader area earlier in the day). Either side of this band are two updrafts. The left (i.e., southwest) one is associated with the wind change, but the other appears to be associated with a simulated convective downdraft whose northeastern flank causes the third indicated updraft from the left. On the right hand side of the plot the air is also relatively cool, due to (evaporatively cooled) convective downdrafts.

The cool change as it impinges upon the WNP is around 1 km deep and generates updrafts to around 5 m s$^{-1}$ in the G12 simulation. In comparison, analogous simulations of the Black Saturday (7 February 2009) change over Victoria (Fawcett et al. 2012) modelled a slightly shallower depth but significantly stronger updrafts to around 10 m s$^{-1}$, while analogous simulations of the Eyre Peninsula (11 January 2005) change (Fawcett et al. 2013) showed updrafts in excess of 6 m s$^{-1}$. Following the change, the modelling indicated the presence of mountain waves over the WNP from around 0900 UTC (2000 EDT) on the 13th until around 2100 UTC (0800 EDT on the 14th). The modelled waves were at their strongest from around 1030 UTC until around 1230 UTC (Figure 7). Such waves could be the cause of strong winds and increased gustiness at the surface, with consequent significance for a going fire underneath them (see for example Kepert and Fawcett 2013). Night-time mountain waves of smaller amplitude were also simulated for the previous night.

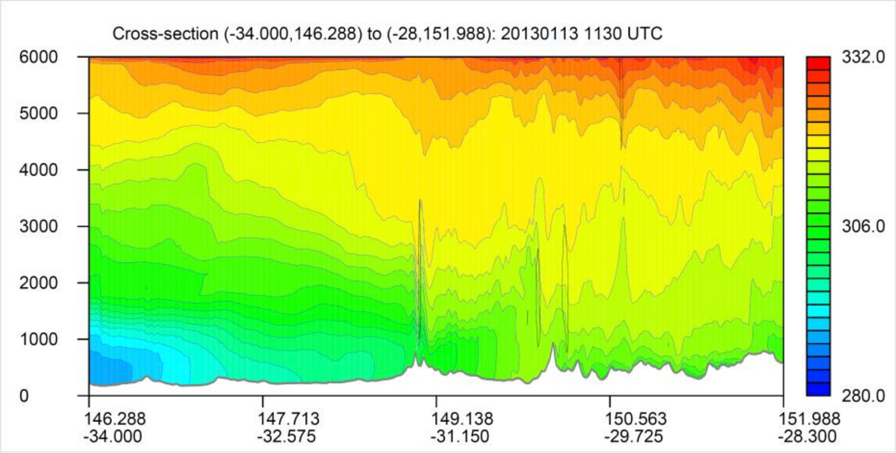

**Figure 7: As per Figure 6 but at 1130 UTC (2230 EDT). Mountain waves with updrafts (black contours) and downdrafts (grey contours) in excess of 1.5 m s$^{-1}$ are modelled over the WNP around this time.**

Lastly the model simulates many convective cells, with their attendant wind changes. The simulations suggest a range of features seen in analogous Black Saturday simulations: pre-change boundary-layer rolls (R; see also Figure 9) and cellular convection (C), and small vortices embedded in the primary wind change (P). Some of these features can be seen in Figure 8, which shows notional instantaneous Forest Fire Danger Index values (Mark 5; computed using the technique of Noble et al. 1980) some hours before the change reaches Coonabarabran. The incursion of maritime air into the region is indicated by the letter 'M'.

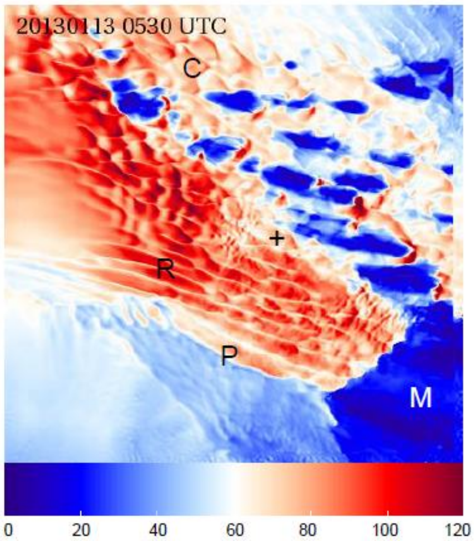

**Figure 8: Notional instantaneous FFDI values for 0530 UTC (1630 EDT) on 13 January, in the G075 simulation. A drought factor of +10 has been assumed across the entire domain: conditions as observed at Coonabarabran and Coonamble were this dry (M Logan pers. comm.). The region plotted in the figure is that indicated by the blue box in Figure 2. The black cross indicates the location of Coonabarabran Airport. The fire is located in the middle of the plot, a little to the west of the cross.**

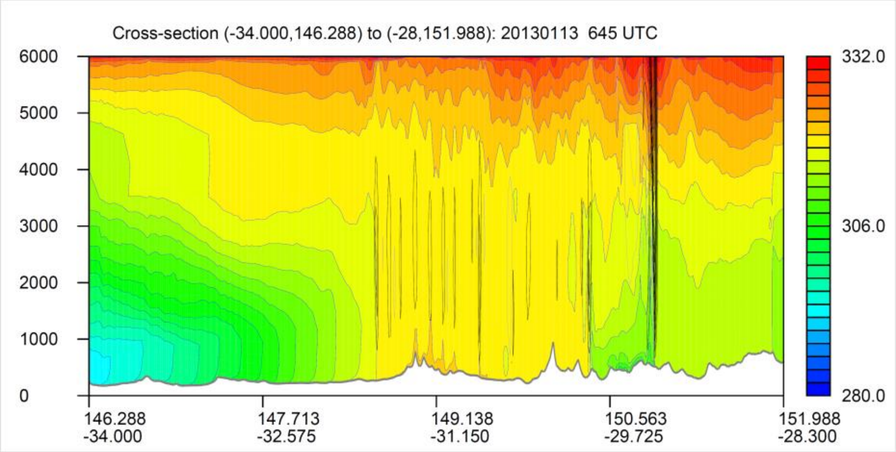

**Figure 9: As per Figure 6 but at 0645 UTC (1745 EDT). The regularly spaced updrafts in the middle of the plot suggest the presence of boundary-layer rolls in the pre-change air mass.**

# CONCLUDING REMARKS

The simulations for 13 January 2013 described in this paper contain many meteorological features which could have a significant impact on a going fire. Apart from the general conditions of a hot summer day, there is a significant synoptic cool change with its attendant wind change. Ahead of the change there are indications of boundary-layer rolls which are associated with increased short-term wind direction variability. There are afternoon convective downdrafts proceeding in different directions on shorter spatial scales. After the change, there are suggestions of mountain wave activity over the Warrumbungle National Park. On the larger scale, there is the typical summer sea-breeze proceeding inland from the New South Wales coast, oriented approximately perpendicular to the synoptic change. Such meteorological complexity could pose a significant communication challenge for weather forecasters attempting to convey the relevant details to fire agencies and their staff, and likewise for the fire agencies to make appropriate use of that information while fighting a going fire.

# ACKNOWLEDGEMENTS

This work was partially funded by the Bushfire Cooperative Research Centre, through its Fire Impact and Risk Evaluation – Decision Support Tool (FIRE-DST) project. The assistance of colleagues within The Centre for Australian Weather and Climate Research for their assistance in setting up the ACCESS simulations is also gratefully acknowledged.

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