Mesoscale Features Related to the Blue Mountains Fires of 17 October 2013 Revealed by High Resolution Numerical Weather Prediction (NWP) Modelling

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Introduction
In October 2013, a number of significant fires broke out in New South Wales, Australia. The most intensive fire activities occurred between 13 and 26 October, when there were 627 incidents and an estimated area of 164,054 ha burnt. The afternoon of 17 October turned out to be the most destructive when the Blue Mountains was heavily affected with more than 200 houses damaged, although, thankfully, no lives were lost (New South Wales Rural Fire Services 2014).

Progression of Fires
The fires in the Blue Mountains region fires include the State Mine Fire and the Mount York Road Fire. The State Mine Fire was ignited on 16 October and spread to the south-east during the night and the morning of 17 October. Later, the fire spread rapidly to the east from about noon, with the estimated area burnt increased from 1036 ha at 11:56 am to 12,436 ha by 9:46 pm Australian Eastern Daylight Time (AEDT, 11 hours ahead of UTC). The Mount York Road Fire was ignited on the afternoon of 17 October. While not as extensive when compared with the State Mine Fire, it had an estimated burnt area of 482 ha by 7:46 am on 18 October (Figure 1).

The areal extension of the State Mine Fire during the afternoon of 17 October was phenomenal – a 12 times increase in burnt area in less than 10 hours (Table 1). It is of both practical and academic interest to investigate if the meteorological conditions had been conducive to the rapid spread of the fire during that day; if so, what were those meteorological conditions? We have tried to answer this question by performing a simulation using a Numerical Weather Prediction (NWP) model with a similar setup for operational purposes but with much higher resolution exceeding operational computing constraints, and have identified several mesoscale features that are of interest.

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Figure 1: The progression of the perimeters of the State Mine Fire and the Mount York Road Fire. The times are in Australian Eastern Daylight Time (AEDT). Location of Mount Boyce AWS is shown by the red dot.

**Meteorological Conditions**

*Lead Up Conditions*

The several months leading up to October 2013 had been quite dry about the Blue Mountains area. The rainfall recorded at Mount Boyce, a hill in the Blue Mountains area with an Automatic Weather Station (AWS) which is closest to the Blue Mountains fire grounds (Figure 1), had been significantly below average from July to October with a total of 81.8 mm against the climatological average of 213.5 mm. The soil dryness from the Australian Water Resources Assessment System (AWRA) (Vase et al. 2013) analysis also shows that it was exceptionally dry about the Blue Mountains area in the lead up to the fires (Table 1). The drought factor at Mount Boyce, interpolated from Bureau of Meteorology's national gridded analysis (Finkele et al. 2006), was 8.66.

Table 1: Various measures indicating dryness in the Blue Mountains area in October 2013 and the lead up period. All entries are values at Mount Boyce interpolated from the AWRA L4.5 database at 0.25° horizontal resolution, for October 2013 (unless otherwise stated) against previous and subsequent Octobers. **Effective Rainfall is the difference between rainfall and evapotranspiration.**

<table>
<thead>
<tr>
<th>Dryness Measure</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Layer (0 cm to 10 cm) Soil Moisture</td>
<td>4.29 percentile</td>
</tr>
<tr>
<td>Top Layer (10 cm to 100 cm) Soil Moisture</td>
<td>2.88 percentile</td>
</tr>
<tr>
<td>Rainfall</td>
<td>7.31 percentile</td>
</tr>
<tr>
<td>Mid Layer (10 cm to 100 cm) Soil Moisture Anomaly</td>
<td>−41.49 mm</td>
</tr>
<tr>
<td>Effective Rainfall Anomaly</td>
<td>−41.55 mm</td>
</tr>
<tr>
<td>Effective Rainfall Anomaly August to October 2013</td>
<td>−92.75 mm</td>
</tr>
</tbody>
</table>
Weather of the Day
A cold front passed through New South Wales on 17 October. The wind change accompanying the cold front was a complex one, manifested in the Blue Mountains area as several small abrupt directional changes, embedded within the general trend of north-westerlies gradually backing to south-westerlies throughout the day (Figure 2).

The weather conditions at Mount Boyce on 17 October were characterized by a maximum temperature of 22.5 °C, very dry conditions with dew point temperatures dipping to −7.6 °C around 03 UTC (2 pm AEDT), and windy conditions with one-minute wind speeds reaching 20.6 m s⁻¹ and gusts reaching 28.3 m s⁻¹ during the afternoon.

Figure 2: Meteogram of 2-metre temperature (black), 2-metre dew point (red), 10-metre wind direction (gryish yellow), 10-metre wind speed (green) and 10-metre wind gust (cyan) at Mount Boyce from 03 UTC 16 October 2013 to 09 UTC 18 October 2013. Solid dots in the foreground are NWP simulation data (STAGE5 nest). Fainter dots in the background are AWS observations.
NWP Model Configuration
In this study, the simulation was performed using the Australian Community Climate and Earth-System Simulator (ACCESS). The atmospheric component is version 8.5 of the Unified Model developed at the UK Met Office, as implemented at the Bureau of Meteorology. The initial condition was the Bureau's operational global analysis valid at 03 UTC on 16 October 2013, and was run at successively finer nests, beginning with an approximately 40-km mesh on a global domain, down to 4.0 km (STAGE3), 1.3 km (STAGE4) and 440 m (STAGE5) on progressively smaller domains, all with 70 hybrid vertical levels. The global model had a model top of 80 km, with nested models having a model top of 40 km.

Mesoscale Features
Mountain Waves and Downslope Winds
Vertical cross-section from the simulation showed a marked downward extension of the stronger winds aloft in the general vicinity of the fire ground (Figure 3). Examination of the vertical velocity showed a clear mountain wave signature. This pattern persisted from about 23 UTC 17 October to 07 UTC 17 October, which coincided with the rapid fire spread period. This appears to be the cause of the enhanced surface winds and associated gustiness seen in the observational data.

![Figure 3. Left: Vertical cross-section of horizontal wind speed along a line through Mount Boyce at 02 UTC 17 October (STAGE4 nest). Positive (negative) values indicate flow from left (right) to right (left). Arrows indicate three-dimensional wind directions projected onto the cross-sectional plane. The figures 0 to 12 along the horizontal axis are position markers 50 km apart. Mount Boyce is located at the position marker 6. Right: Model terrain height and orientation of the cross-section.](image)

The potential for mountain waves to escalate fire behaviour was discussed by Sharples (2009), and they were shown to be responsible for overnight escalations in fires at Margaret River (Kepert and Fawcett 2013) and Aberfeldy (Wells et al., 2014). This case is of particular interest because the phenomenon occurred during the day, rather than at night when the nocturnal inversion provided near-surface conditions favourable for downslope winds.

Dry Slot
Though not reaching the observed Mount Boyce −7.6 °C dew point, a marked northwest-southeast orientated dry slot was present in the simulation from about 23 UTC 16 October to 07 UTC 17 October which passed through the Blue Mountains area around 02 UTC 17 October (Figure 4). The magnitude of the dryness and arrival timing was well represented apart from less abrupt change from drying to moistening than observed. However, a secondary, less marked
drying period observed at Mount Boyce AWS around 0630 UTC was not captured by the simulation (Figure 2).

Figure 4. NWP simulated 2-metre specific humidity at 01:45 UTC 17 October 2013 (STAGE4 nest).

Figure 5 shows the vertical cross-section of the dry slot in the simulation. While there was vertical motion in the vicinity of the dry slot, the simulation did not clearly reveal a secondary cross-frontal circulation associated with the dry slot as described by Mills (2005, 2008). Further analysis suggests the dry slot was actually a dry nose of a cooler and otherwise moist airmass spreading from the southwest. Later during the afternoon, the dry slot was dissipated in an interaction with convective activities in the north as it moved into northeastern New South Wales.

Figure 5: As in Figure 3 but for specific humidity at 01:45 UTC 17 October 2013.

Undular Bore

The formation of the dry nose which acted as a precursor of the dry slot mentioned in the previous section turned out to be related to an undular bore formed upstream the night before when the moist cool change slid into the shallow nocturnal layer over inland Victoria and New South Wales. The passage of the bore raised the leading shallow layer of nocturnally cooled dry
air, to a depth of about 2000 m (Figure 6), which formed the cold, dry nose of the cool change. The AWS observations at Kilmore Gap and Yarrawonga were supportive of the revelation by the simulation.

Figure 6: Vertical cross section of potential temperature (top) and specific humidity (bottom) at 11:30 UTC (left) and 16:30 UTC (right). The vertical cross sections are 120 km across, orientated southwest (left) to northeast (right), centred at the undular bore (marked by the faint circle) over a region southwest of the Blue Mountains. The figures 0 to 12 along the horizontal axis are position markers 10 km apart.

References


