Mesoscale Numerical Weather Prediction And Extreme Fire Weather

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Abstract

Contemporary mesoscale numerical weather prediction (NWP) systems generate extremely accurate simulations of the complex and rapidly evolving small-scale circulations that usually accompany extreme weather events. I will discuss these capabilities and potential improved fire weather products in the context of two examples. The first will be a discussion of the temporal and spatial fluctuations of wind speed and gustiness, and of humidity, during the New South Wales bushfire event of the 2001/2002 summer, using the Bureau of Meteorology's operational mesoscale NWP model data. Important features in this case range over time periods from weeks (large-scale drying), days (episodes of abrupt atmospheric drying and increased wind speed and gustiness), to hours (rapid evolution of wind-shift lines and timing of cool changes). The second example is that of Ash Wednesday, 1983. In this case a hindcast, using archived analyses and current research versions of the Bureau's NWP system are used to demonstrate our current ability to forecast such an event, and to diagnose some of the mesoscale atmospheric features that made the day so unusual.

Introduction

Numerical weather prediction (NWP) models provide extremely valuable weather forecast guidance from time-scales of a few hours for the highest resolution mesoscale models to approaching a week for the most accurate medium-range global models. The current operational mesoscale NWP models frequently provide outstanding simulations of complex mesoscale circulation patterns (eg Mills 2002a, Mills and Pendlebury 2003), and, further, are able to predict extreme events (eg Mills 2002b). The application of mesoscale NWP systems to forecasting and understanding the meteorology of two significant Australian fire events will be demonstrated in this paper. The first is during the period of the 2001-2002 New South Wales bushfires, focussing on the longer-term (seasonal) drying of the soil over southern NSW, on the episodic nature of the extreme fire weather during the 2-3 week period of the fire event, and thirdly demonstrating the ability of the mesoscale models to resolve the complexity and rapid time evolution of the wind fields along the NSW coastline on a day when a wind change was moving northwards along the NSW coast. The second event is a hindcast of the cold front moving along the Victorian coastline on Ash Wednesday, 16 February 1983. In these examples the Bureau of Meteorology Research Centre limited area prediction system, LAPS, (Puri et al 1998) will be used to generate the mesoscale forecasts.

New South Wales – December 2001 / January 2002

The spring months over eastern NSW started with near-average rainfall, but by December the rainfall over much of the eastern half was well below average (Bureau of Meteorology 2001). The operational 0.125^{o} operational meso-LAPS model includes a land-surface scheme (Viterbo and Beljaars 1995), and so models the soil moisture content in four soil layers. As an example of the indications of long-term drying of the soil over a 500 km square east of Sydney, the mean a time-series of mean soil wetness from each mesoscale

NWP forecast through December/January 2001-2 is shown in Fig. 1. Apart from the peak around 8 December, following a small rain event, a generally downward trend in the already very low soil moistures is seen, indicating large-scale, relatively log-period drying prior to Christmas 2001.

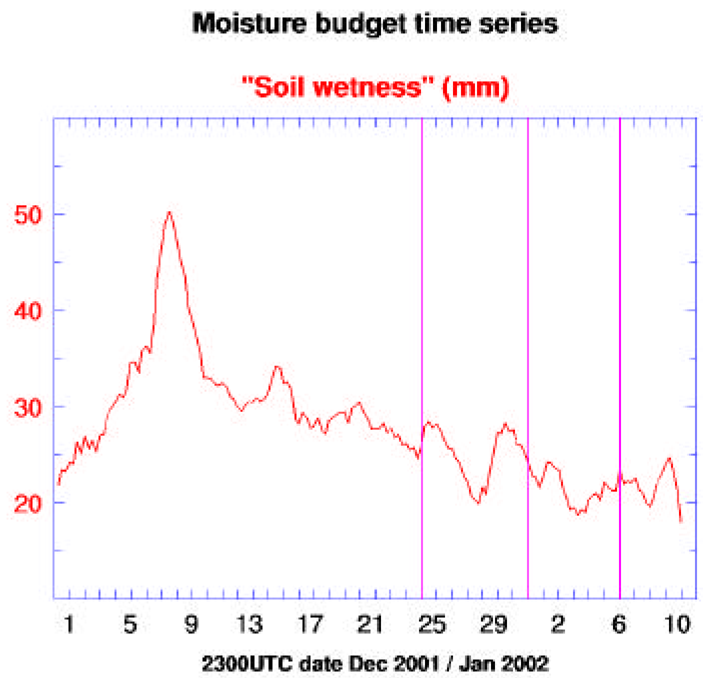

Figure 1. Time series of soil wetness (in mm) over a 500 km square east of Sydney from the meso-LAPS forecast model from 1 December 2001 to 10 January 2002. Field capacity is 150 mm, and the vertical lines mark the onset of the three periods of extreme fire danger described in the text.

The next aspect of this fire period to discuss are the three significant "peaks" in fire danger index (FDI) that occurred around 25 December, 1 January, and 7 January (although the rainfall that occurred over parts of NSW between 1 and 7 January did affect these values at different stations. Figure 2 shows time series of temperature and dewpoint from the Richmond (33.6 S 150.78 E) automatic weather station (AWS) and from successive 12- and 18-hour forecasts from the operational meso-LAPS NWP model. Particularly striking in the observations time-series are the three periods of abrupt drying marking the Christmas, New Year, and ~7 January peaks in fire danger index (FDI). It is clear that these drying episodes are a key component of the extreme FDI experienced during these periods, particularly given the sensitivity of FDI to extremely low humidities (McArthur, 1967, Noble et al al 1980). The time-series of model forecasts also shows the same three periods of extremely low humidities, and shows the model's ability to provide very useful short-term guidance on the onset and cessation of such events.

The third aspect of the 2001/2002 NSW fire period to discuss are the complex small-scale and evolving wind patterns that must be forecast and understood. The 2nd of January 2002 was a day providing such an example of complex flow patterns and evolution, and Fig. 3 shows the nwp model's forecasts over the southern and central NSW coast at 2-hour intervals on that day. At 0000 UTC, the model is forecasting strong westerly winds over the Blue Mountains and central highlands of NSW. There are two vortices forecast just off the coastline, one south and one northeast of Sydney, and these lead to onshore flow north and south of Sydney, while a southwesterly change is just passing Cape Howe, on the

Victorian/NSW border. Two hours later, the cool change has passed Cape Howe, and a southerly change is moving up the southern NSW coastline, there is still light onshore flow north of this change and north of Sydney, but there are stronger westerlies reaching the coastline near Sydney and farther north, towards Pt. Macquarie. The final two panels, valid at 0200 and 0400 UTC, show the southerly change moving northwards towards Sydney, the band of strong westerlies near Sydney extending offshore, but still with onshore northeasterlies north of Sydney. It is of interest that as the day wears on, the zone of weaker onshore winds between the southerly change and the offshore westerlies near Sydney becomes smaller, and by the final panel indicates that an abrupt change from strong westerlies to strong south-southeasterlies is likely near the coast.

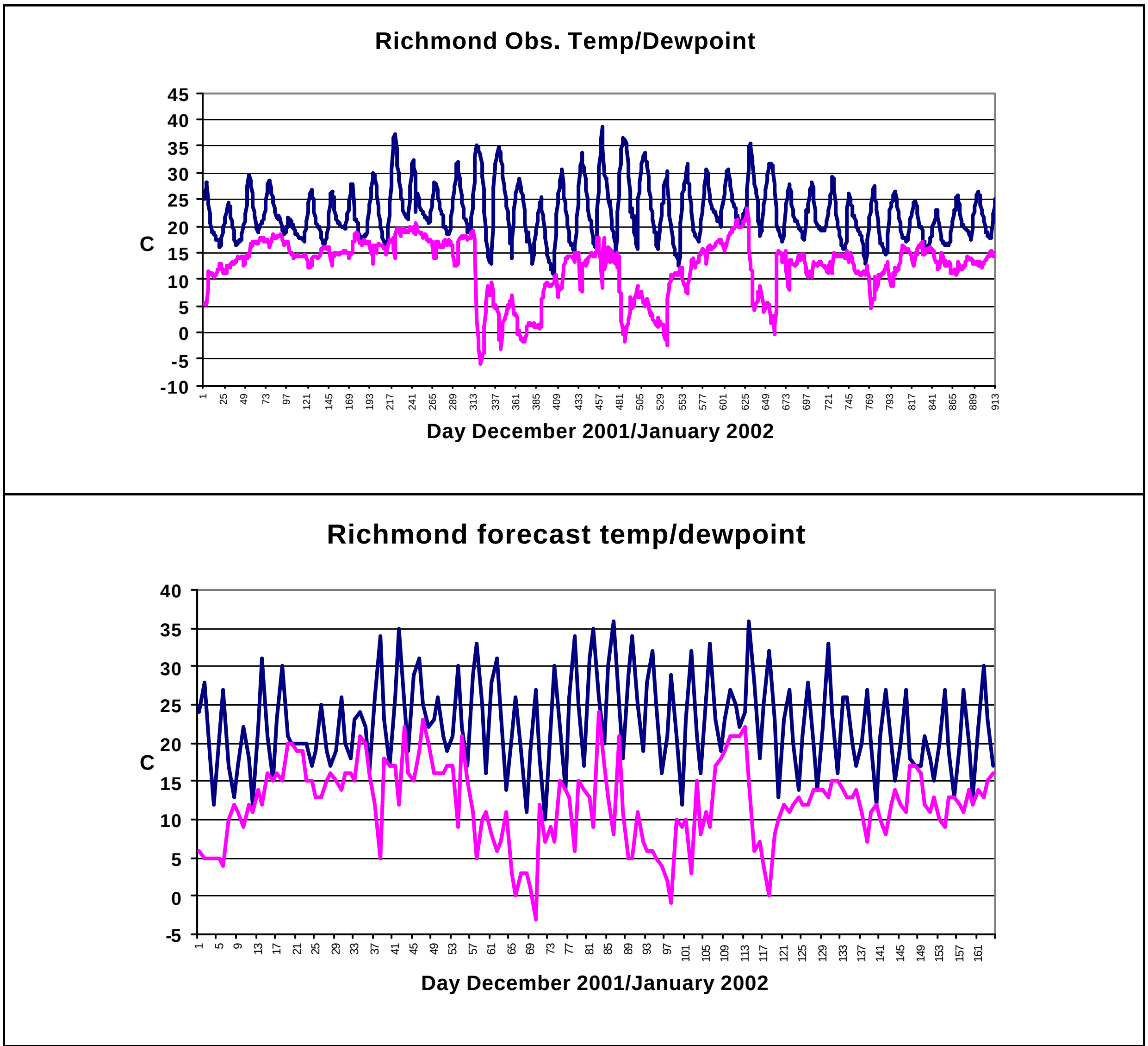

Figure 2. Time series of temperature (upper line) and dewpoint (lower line) hourly observations (upper panel) and 6-hourly forecasts (lower panel) from 0000 UTC 10 December 2001 to 0000 UTC 19 January 2001. The tick marks on the ordinate are at 1-day intervals.

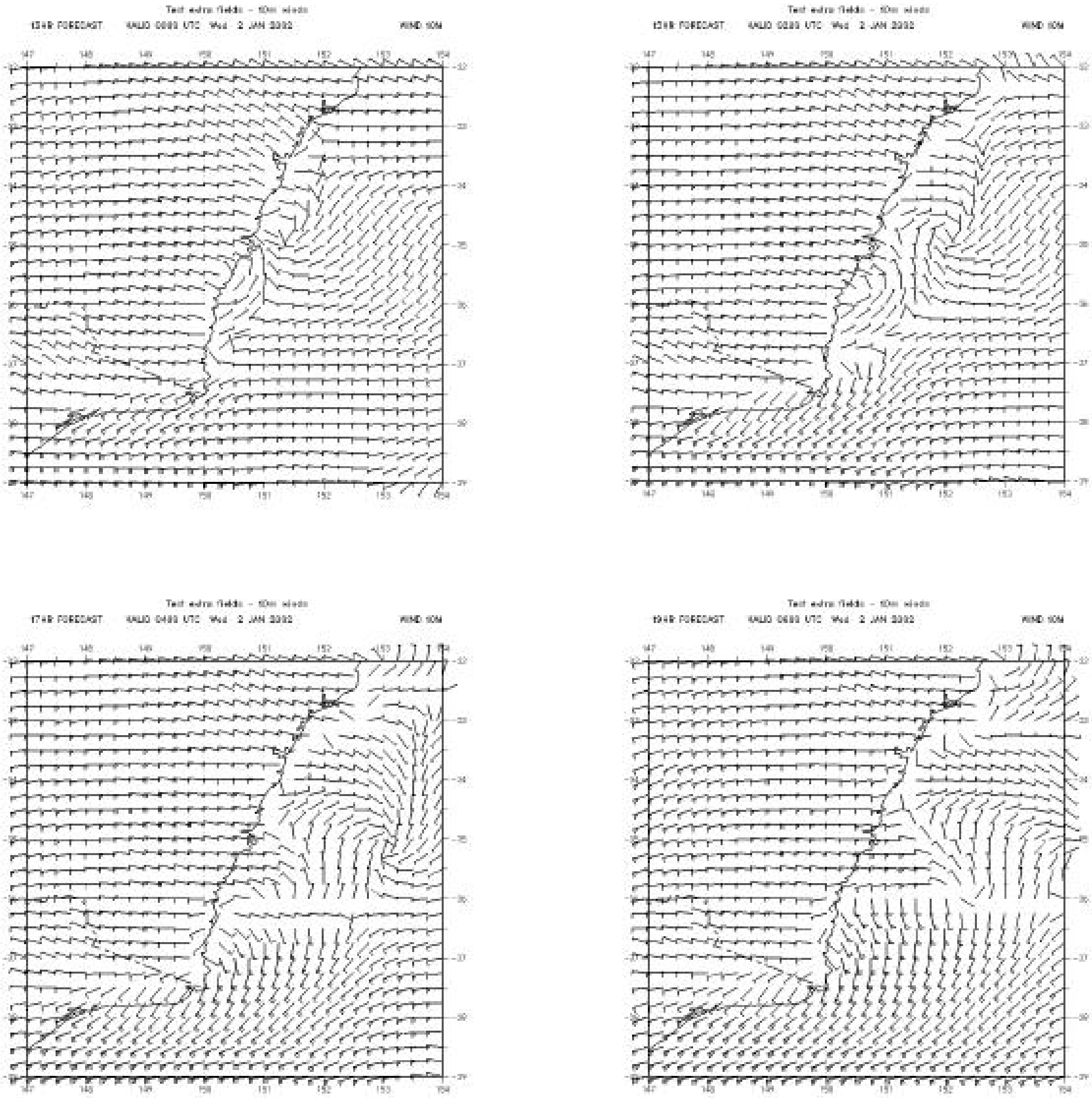

Figure 3. Forecast 10m wind fields from the meso-LAPS forecast model based 1100 UTC 1 January 2002, and valid 0000, 0200, 0400 and 0600 UTC 2 January 2002. The symbols have their usual meteorological meaning, with a long barb indicating 10 knots.

Ash Wednesday, 16 February 1983

On the evening of 15 February 1983 a trough and associated surface cool change was approaching southeastern Australia. Given the pre-existing drought conditions (Bureau of Meteorology, 1984, hereafter BM84), extreme fire danger was expected with that change and fire bans were issued, although the extremity, timing, and details of the mesoscale meteorology of the event would be moot. A significant aspect of the change was the very strong winds behind the cool change. The difference between the anemographs for Melbourne for the 1983 Ash Wednesday and the 1939 Black Friday cool changes is striking (see BM84, Figs. 77, 91), with wind speeds decreasing after the change in 1939, but increasing in 1983. It is difficult to identify a dynamic reason for this behaviour from the synoptic-scale historic analyses: however, mesoscale NWP modelling can provide some insights. Using NCEP reanalyses (Kalnay et al. 1996), radiosonde data were re-assimilated over a 12-hour period from 1100 UTC 15 February 1983, and a 0.05 degree grid meso-LAPS forecast was prepared, using the re-assimilated analysis as initial conditions, and NCEP analyses as lateral boundary conditions. The 5-hour near-surface wind forecast over the Victorian "surf coast" is shown in Fig. 4. While the change is forecast to be further east than observed at that time, the wind structure is perhaps instructive. Strong northwesterly winds ahead of the front are seen, with a shear line extending almost west-east through Bass Strait. Interestingly, a small area of gale-force southerly winds is seen on the western flank of the vortex (mesoscale low) just off the coast. Whether this scenario represents the real atmospheric structure on Ash Wednesday is as yet unverified (and may be unverifiable), but it does provide a realistic hypothesis for why such strong southwesterly winds were experienced along the surf coast in the wake of the cool change. The recently available revision of the NCEP reanalyses (Kanamitsu et al 2002), and the archive of the Bureau's objective analyses, METANAL (Seaman et al 1977) do make it possible to test the sensitivity of these results to the initial state, and thus may allow more robust conclusions than allowed by a single model forecast.

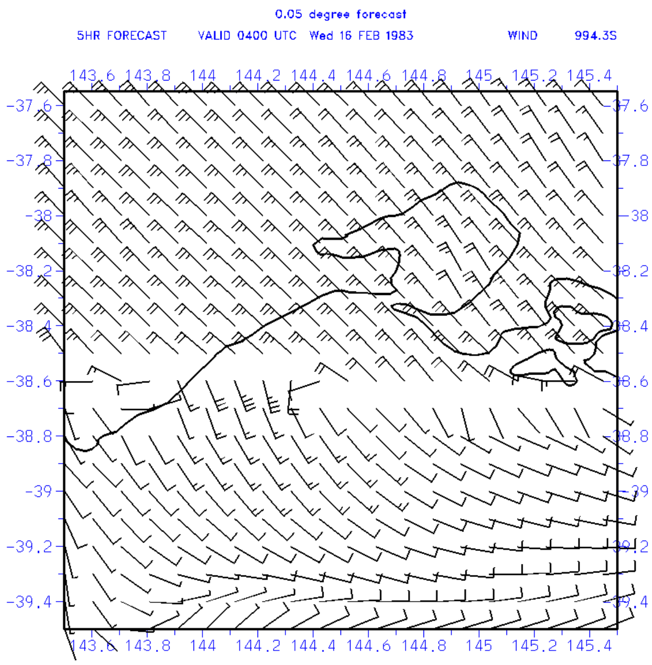

Figure 4. Five-hour forecast from a 0.05^{o} 29 level LAPS model forecast based at 2300 UTC 15 February 1983. A long barb indicates 10 knots.

Concluding remarks

These few examples presented in this paper show the power of mesoscale NWP models to assist the prediction and understanding of the complex mesoscale meteorology that is frequently associated with extreme fire weather events. There is great potential to extend and enhance these capabilities, and some of these opportunities will be developed in a series of projects within the new Bushfire Cooperative Research Centre. Particular foci in the first years of these projects will be the development of verification strategies and verification statistics for the wind change forecasts from NWP models, an understanding of the wind structure ahead of and after wind changes, the relation between flow features and major dry episodes, and the potential for seasonal fire danger outlook.

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