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THE SYDNEY 2014 FORECAST DEMONSTRATION PROJECT – A STEP FROM RESEARCH TO OPERATIONS

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INTRODUCTION

The tools available for predicting fire-weather conditions continue to evolve, due to recent advances in computer technology and greater scientific understanding of the meteorology surrounding and impacting fires. These have the potential to greatly benefit risk assessment at bushfires as well as predictions of how a bushfire will spread. This paper will discuss some of the recent advances in scientific understanding of meteorology influencing bushfires and the methods available to transition new knowledge into an operational framework, in particular through the use of Forecast Demonstration Projects (FDPs).

FDPs have provided valuable opportunities to expose recent research outcomes in a near-operational setting. During such exercises, operational forecasters and researchers work together each day over a period of weeks or months to trial new techniques and technologies in real-time forecasting situations. Researchers and new systems become better attuned to operational realities, and forecasters have an early look at, and a chance to shape, the tools that they will be using in the future. The Sydney 2014 FDP will be discussed here as an example of how new approaches to numerical weather prediction (NWP) modelling can be brought to bear on fire-weather services.

THE NEED FOR CHANGE

Fire-weather forecasts currently provided by the Bureau of Meteorology are underpinned by predictions of near-surface temperature and relative humidity and 10 m wind speed. These forecast values, combined with fuel information, provide the basis for fire danger ratings around the country and constitute the primary information in site-specific (spot) forecasts for planned and going fires. Importantly in an operational forecasting context, the near-surface parameters are quantifiable, easily extracted from NWP models and readily verified against observations from nearby weather stations.

Although official fire-weather forecasts are based on surface temperature, relative humidity and wind speed, there is (near-)universal acceptance by meteorologists and fire practitioners that this provides a limited description of the meteorology affecting a fire ground.

RECENT RESEARCH

Over the past decade, research into the meteorology surrounding bushfires has been active in Australia and much has been learnt about atmospheric processes with the potential to impact bushfires. The primary approach to fire-weather research has been case studies of significant events (e.g. Engel et al. (2013), Mills (2008a), Fawcett et al. (2013)). In particular, several studies examine the meteorology surrounding a fire in detail in order to identify dynamical atmospheric features that contributed to the observed fire activity. At many significant fires, three-dimensional and temporally evolving features of the atmosphere have been linked to the fire activity that occurred.

Examples include plume development processes and pyro-convective cloud (e.g. Fromm et al. (2006), McRae et al. (2013)), fire-modified winds (Coen et al. (2013)), mixing of dry slots (Mills 2008b), interactions between wind and topography (Sharples et al. (2013), Kepert et al. (2013)) and fire-atmosphere feedback processes (Peace et al. 2015). Broadly categorised, these studies relate the structure of the atmosphere in three dimensions and the dynamical interactions between the fire, atmosphere and terrain. They show that interactions between the different elements can be favourable for producing an environment that is conducive to non-steady-state fire activity.

The studies above identify phenomena that are distinctly different from the current focus in fire-weather forecasts in Australia.

FDP EXAMPLE – SYDNEY 2014

The Sydney FDP ran for 10 weeks from the end of September 2014 as a test bed for advances to the underlying science for extreme weather forecasting. It covered thunderstorm and rainfall prediction and fire-weather and air-quality services, and included forecasters outposted to the NSW Rural Fire Service as well as Regional-Office-based meteorologists. A centrepiece of the new techniques was a Rapid Update Cycle (RUC) NWP model, which produced a new forecast every hour at 1.5 km horizontal grid spacing, significantly finer than the most detailed operational predictions of around 4 km horizontal grid spacing.

Current operational NWP predictions update every 6 or 12 hours, and so in between model runs the predictions can be based on information about the state of the atmosphere which is at least 12 hours old. The hourly RUC predictions are able to incorporate the latest weather observations much more frequently (Dixon et al., 2009). The model run during the Sydney FDP, a version of the Australian Community Climate and Earth-System Simulator (ACCESS) NWP model (Puri et al., 2013), also incorporated rainfall and wind observations from Doppler weather radar, which are not currently used in operational NWP in Australia.

NWP models are crucial to forecasting dangerous fire-weather conditions. They provide input to the Graphical Forecast Editor (GFE), which is used by the Bureau of Meteorology to provide gridded and text forecast services including fire-weather products. The RUC guidance was a key aspect of the Sydney 2014 FDP and a particularly important aspect of the project was its use in the GFE, where forecasters had to manage the increased volume of information and apply the higher-resolution model to spot fire forecasts.

APPLICATION OF RUC GUIDANCE TO GRIDDED FIRE FORECASTS

Fire-weather forecasts in the operational GFE are initialised with NWP guidance. Forecasters then use manual editing tools to enhance the NWP and produce their gridded forecasts of near-surface temperature, humidity and wind. Tools are run which use these forecast inputs, together with gridded information on fuel state to calculate the traditional forest and grassland fire danger indices (Noble *et al.* 1980). The tools also produce a grid of 'fire-weather hazards' which indicate the grid cells which have met or exceeded the fire danger index thresholds for severe, extreme or catastrophic fire danger ratings at some time of the day.

An important aspect of the use of RUC in the Sydney FDP was bringing it into the GFE and using it as the input for automatic pre-calculation of forest and grassland fire danger indices and resulting fire-weather hazards in the GFE. The forecaster was supplied with a new hazard comparison tool, which enabled a rapid graphical overview (see **Figure 1**) of hazard outcomes for the day for different NWP runs or between NWP guidance and the existing GFE forecast. These comparisons were the basis for generating automated alerts for the forecaster on arrival of the latest RUC guidance. This enabled forecasters to assess changes from the previous forecast, without going through all the forecast steps to determine the implications for fire weather of each hourly RUC run.

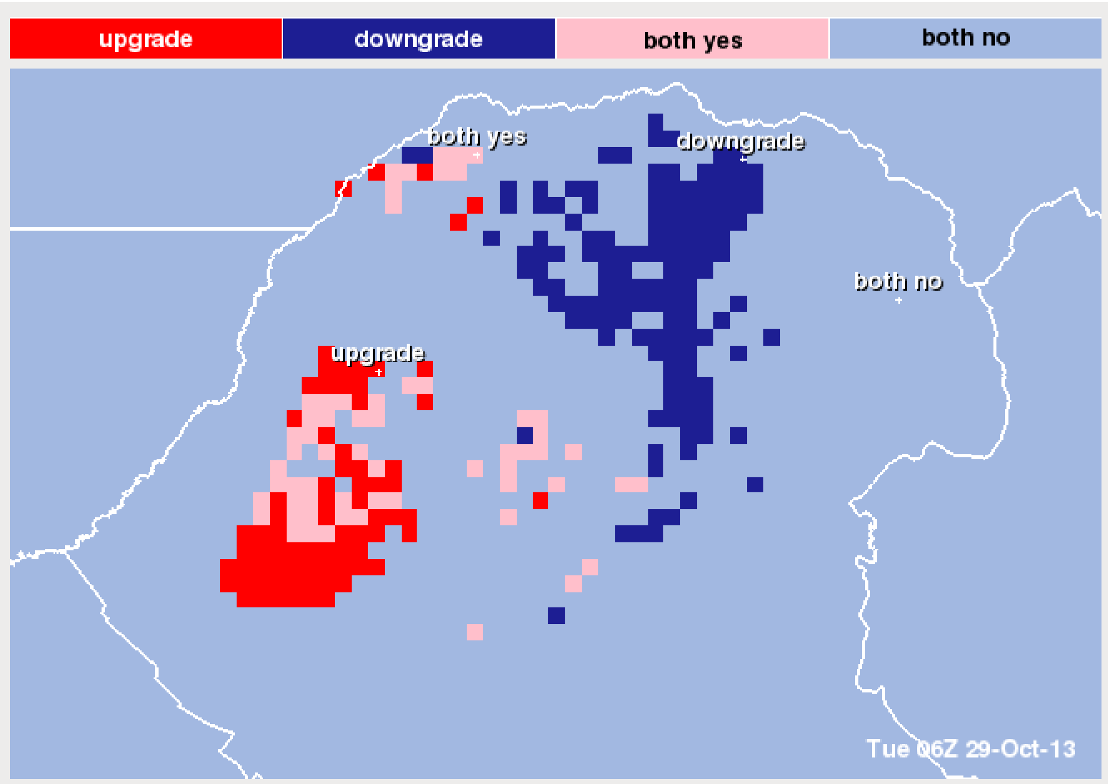

Figure 1. Comparison between the at-least-severe fire-weather hazard area for two NWP runs. Models agree where 'both yes' and 'both no'. Points labelled 'upgrade' show where the later model has the hazard while the earlier model does not, and vice versa for 'downgrade'.

OUTCOMES FROM THE FORECAST DEMONSTRATION PROJECT

During the Sydney FDP, the RUC guidance and new tools in the GFE were trialled on days of increased fire-weather risk by using the new guidance as the basis for gridded fire-weather products, as well as in production of 12-hour-long spot fire-weather forecasts. Automated alerts were then used for monitoring of the forecasts. **Figure 2** shows an example of a fire danger rating map produced with RUC guidance during the FDP, in which the extra detail provided by the high-resolution model can be seen.

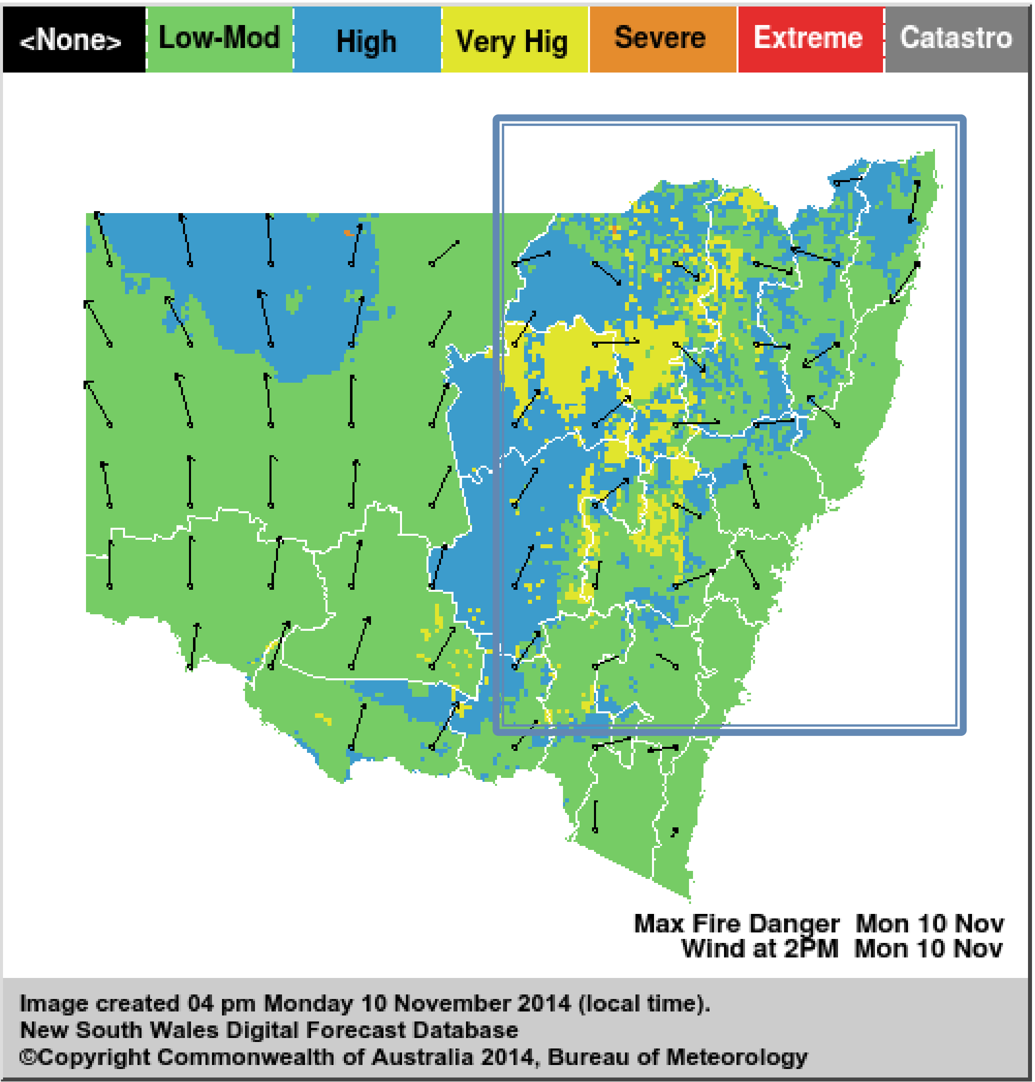

Figure 2. Fire danger rating (colour scale) and wind (arrows) prepared for the FDP using RUC data blended into lower resolution ACCESS-R data. The domain covered by the RUC data is indicated by the blue rectangle. Note that the spacing of the wind arrows does not reflect the spatial resolution of the wind data.

Subjective feedback was obtained from operational forecasters involved in the trial. The alerting and visualization of changes in hazard areas were considered to be useful for monitoring forecasts, in particular through comparing the latest version of guidance to that which had been used to prepare the forecast. The detailed depiction of wind features such as sea breezes interacting with topography at the 1.5 km grid spacing of the RUC helped forecasters build better understanding of meteorological processes significant for spot fire forecasts.

Limitations identified with the RUC guidance in its current form included problems with representation of late-afternoon surface dewpoint temperatures (a known problem with the ACCESS suite of models) and the lack of change in successive hourly runs of the model, except when the run of the 'parent' model supplying data at the edges of the model domain was updated. An area needing improvement in the model-based alerting in the GFE was accounting for the fact that the RUC runs were of various different lengths and could have different amounts of coverage of the peak fire-weather period of the day.

The Sydney 2014 FDP showed how new approaches to NWP modelling can be brought to bear on fire-weather services, but it stayed within the existing paradigm of fire-weather services, which focus on near-surface meteorological conditions. The past decade of research into the meteorology surrounding bushfires includes studies that have explored the structure of the atmosphere in three dimensions and the dynamical interactions between the fire, atmosphere and terrain. The challenge is how to formally incorporate what has been learnt in research into operational weather forecasts. Objective metrics are needed together with knowledge of significant thresholds, implying the need to extend case studies into more systematic research. A particular challenge is how to modify the current quantitative measures of fire risk, to include processes which are currently subjectively assessed. Future forecast demonstration projects would offer a vehicle by which researchers and operational practitioners could take up the challenge of transitioning such research outcomes into the operational sphere.

FIRE MODELS

A related challenge for the appropriate meteorological inputs in fire risk assessment lies in the increasing use of fire simulation models by fire agencies in Australia. The simulation models currently in operational use predict the evolution of a fire perimeter across a two-dimensional landscape in a particular fuel. The meteorological inputs of wind speed and direction are critical in these models, and small variations in wind inputs can produce substantial variation in simulation results. Fire models are generally run at grid spacings of tens of metres, whereas the highest resolution operational meteorological model in Australia runs at 4 km grid spacing. The variation in wind at the two spatial scales, particularly in mountainous areas, can be significant, and certainly affects the results from fire models. Compounding the complexity of the challenge of appropriate wind inputs is the knowledge that the energy released by the fire modifies the surrounding meteorological environment. It is the fire-modified winds, not the environmental winds, that propagate the fire front and in certain circumstances the difference between the two can be substantial (e.g. Peace et al. (2015)).

An additional challenge to establishing meteorological inputs to fire simulation models is that the near-surface winds only tell part of the story. Detailed, high-resolution gridded wind forecasts such as the RUC guidance from the Sydney FDP have the potential to improve wind inputs to fire simulation models. However, research shows that vertical structure of temperature and dewpoint, temperature inversions, atmospheric stability, as well as wind speed, direction and shear above the surface can all impact the evolution of a fire. Therefore, a simple wind-driven two-dimensional fire spread model will give a limited depiction of likely fire activity, and other meteorological processes need to be considered in order to anticipate how a fire will evolve.

FROM RESEARCH TO OPERATIONS

The Sydney 2015 Forecast Demonstration Project has already led to operational availability of higher-resolution NWP guidance in the GFE and is shaping plans for future meteorological guidance and models of operation for short-term forecasting.

The following questions have not yet been resolved: how do we best include the knowledge from recent research (which is mostly subjective), into a reasonably objective forecast process; and how do we establish the appropriate inputs to fire simulation models, with the aim of enabling safer, more effective and more efficient fire operations?

A forecast demonstration project bringing researchers together with fire-weather meteorologists, fire behaviour modellers and operational emergency services practitioners, in a near-operational context, would provide one way of exploring how new forecast guidance, conceptual models and service formats can connect in practice to allow better understanding and management of fire risks.

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