FIRE NOTE

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COLD-FRONTAL BUSHFIRE WINDS AND COMPUTER FORECAST MODELS

This photo was taken from a Firebird 303 JetRanger helicopter over Lawloit, Victoria, just after a recent wildfire was hit by the downburst from a thunderstorm passing by to the south. The downburst from the thunderstorm turned the northerly flank into a headfire - with the typical pattern from a line of fire of about 5/6 headfire and 1/6 backing fire. The change in fire behaviour was very dramatic, and increased risks to ground crews who were positioned to the north of the fire. **Photo supplied by Steve Grant, DSE Fire Management Officer.**

ABOUT THIS PROJECT

Project A2.1: Fire Weather – Fire Danger is part of Bushfire CRC Program A: Safe Prevention, Preparation and Suppression

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Acknowledgments: The research team includes Dr Graham Mills (project leader), Xin-Mei Huang (Bushfire CRC researcher 2004-06), Yimin Ma (Bushfire CRC researcher 2007-09), and project collaborator Kevin Parkyn (Head, Severe Weather Forecast Section, Victoria).

For more information about this research, visit the Research page at www.bushfirecrc.com or contact Dr Graham Mills at g.mills@bom.gov.au

SUMMARY

This research has developed a new model to better forecast cold fronts – and outcome that will help better protect communities and firefighters. The work was completed through extensive study that has led to a better understanding of the complex phenomenon of cold fronts. This research has focused on understanding two things. Firstly, the physical processes that cause cold-frontal wind changes to be what they are – why sometimes they are abrupt, why sometimes more gradual, why some have sustained strong winds after the change (Ash Wednesday 1983) and some do not (Black Friday 1939). Secondly, how to verify forecasts of wind change timing at observation sites and from computer forecast models.

BACKGROUND

Wind change matters to fire managers. It can change bushfire activity in a moment, shifting the flank of the fire to the fire front, suddenly putting firefighters and communities at risk. A change in wind can also change the rate of fire spread, increase the quantity, distance and direction of downstream spotting, and change the safety status of residents and townships in a flash. There have been several notable disasters associated with wind changes, including:

- the Mann Gulch Fire in Montana in 1949
- the Ash Wednesday fires across south-eastern Australia in 1983
- the 1994 South Canyon fire in Colorado that killed 14 firefighters
- the 1998 Linton bushfires in Victoria, where five volunteer firefighters perished in their vehicle after being caught out by a sudden wind change
- the fires in Ku-ring-gai Chase National Park in 2000 that led to the deaths of four National Parks and Wildlife Service staff and the serious injury of three others when

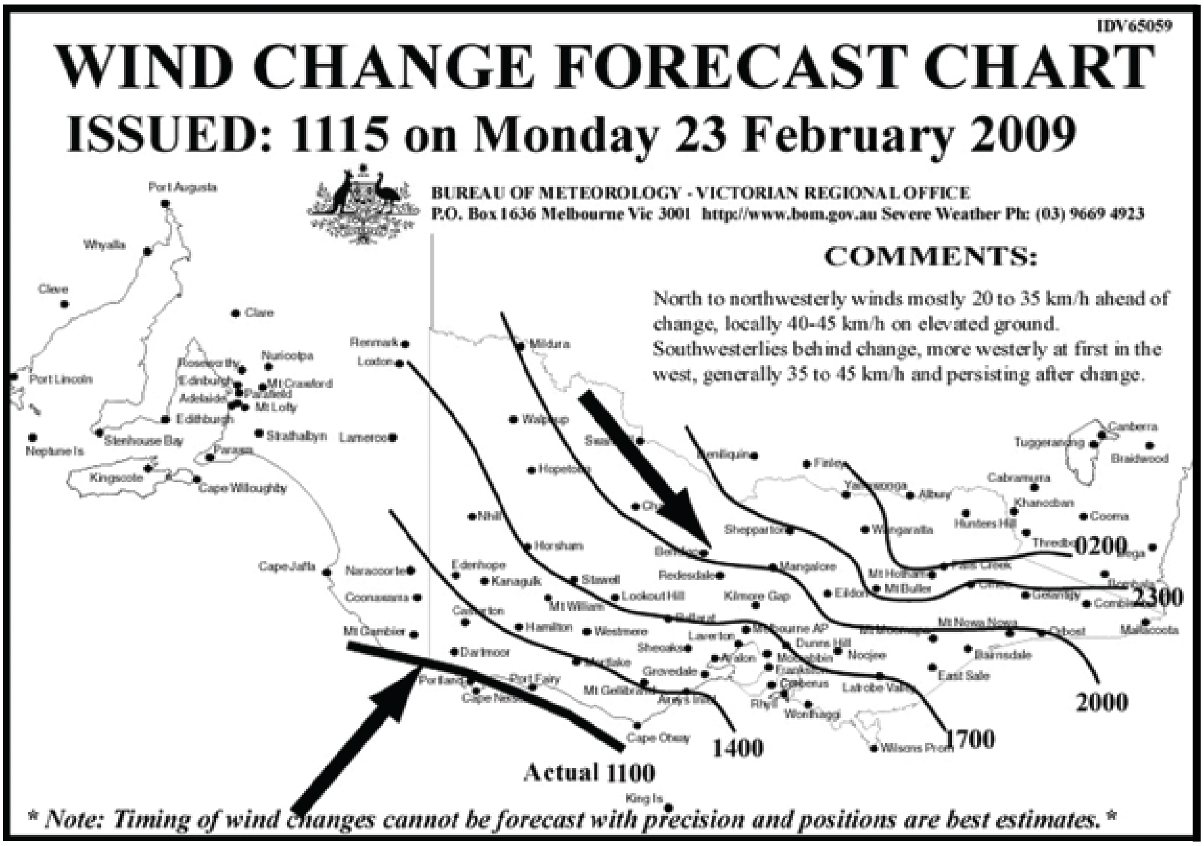


Figure 1: A wind change forecast chart.

a routine hazard reduction burn went wrong

- the 2005 fires on the Eyre Peninsula in South Australia that killed nine members of the public caught out by sudden changes in the bushfire behaviour
- the recent Black Saturday fires in Victoria in February 2009
- the deaths of several Spanish firefighters in July 2009.

BUSHFIRE CRC RESEARCH

Verifying wind change forecast charts

Due to the importance of wind change on fire behaviour, the Bureau of Meteorology offices in several Australian states have for many seasons issued Wind Change Forecast charts (Figure 1). Since 2000 the Bureau's Victorian Regional Forecast Centre has manually verified its wind change forecast charts at selected stations at the end of the fire season. This verification requires an experienced meteorologist who uses the time series of observations from the verification location, together with a series of detailed spatial analyses ('weather maps') to estimate a single wind change time, which is then compared with the forecasts. This process is demanding and time-consuming.

It was the aim of this research project to develop algorithms to automate this process – from the sequence of half-hourly observations at a site on a 'wind change day', to determine a single wind change time that, as far as possible, match the changes interpreted by the meteorologist's verification. This turned out to be a challenge, as wind changes differ widely in their intensity, even on the same day. The research developed a Wind Change Rate Index (WCRI), which represents the rate of change of wind direction with time.

However, because a wind change is more significant as the wind speed becomes stronger, the wind speed is included in the calculation of the WCRI. As wind speeds can be strong before and after the change, and as there is often a lull at the change time, these decisions were highly complex. By fine tuning the algorithm it was able to estimate times that compared favourably with the times estimated by the experienced meteorologists.

One of the by-products of this algorithm is that not only is a time of maximum wind change produced, but the algorithm also estimates a *change start time* and a *change end time*, which suggests that the concept of a *wind change period* may have some merit.

When subjective estimates from experienced meteorologists and objective times from the algorithm were compared, it showed that over four Victorian fire seasons the subjective and objective times were within half an hour on greater than 60 percent of occasions, and within 2.5 hours on greater than 85 percent of occasions. The subjective time was within the objective wind change period on greater than 95 percent of occasions.

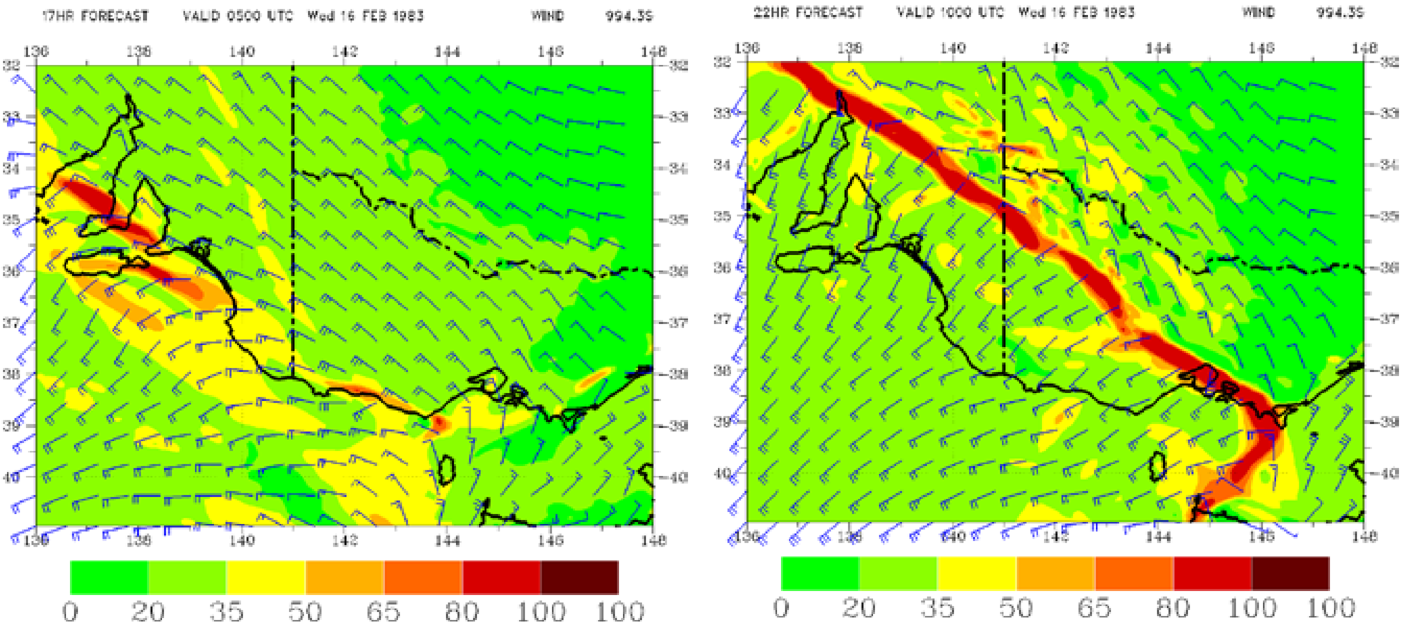
Applying the model

Very high resolution computer model forecasts (mesoscale numerical weather prediction (NWP) models) have been developed at the Bureau of Meteorology and provide vital guidance to forecasters.

These models predict the wind speed and direction, temperature, humidity, and pressure at every gridpoint (a regular lattice approximately every five kilometres) every hour. If these forecasts are considered as a time series of observations, then a WCRI can be calculated at every gridpoint every hour. This has two applications:

- The time of maximum wind change can be estimated at a gridpoint closest to an observation site and the numerical forecasts of wind change time verified.
- A spatial field of WCRI can be generated, and animated in time to provide a powerful visual display of the wind change and the way it develops, as it is forecast to move across a region.

Such a spatial field of WCRI is illustrated in Figures 2A and 2B, which show a simulation of the cool change on Ash Wednesday 1983. In these panels the barbs show the direction and speed of the 10m wind, while the shading shows the WCRI, with increasingly dark colours indicating a stronger wind change in terms of change in direction and higher speeds. The first panel shows the simulation for 4pm EDST (3:30pm CDST), with the frontal wind change approaching Adelaide,



▲ **Figure 2A & 2B:** Ash Wednesday cool change simulation, according to the Wind Change Rate Index.

and just beginning to intensify along the western Victorian coastline. The second panel shows the situation five hours later with a much more intense change approaching Melbourne.

When forecasters use NWP model guidance they have to decide whether to "go" with the guidance, or whether to make some allowance for possible error. Knowing the biases and error characteristics of the model forecasts helps this decision. The verifications of this research show that the issued forecasts are largely unbiased with time (neither too slow nor too fast on average), and that more than 60 percent are within 2.5 hours, for forecast lead times between nine and 36 hours.

Cool changes and bad fire days

A further aspect of the study was to understand how cool changes in disastrous fire event days differentiate from cool changes on more regular fire weather days. The re-examination of the Ash Wednesday fire event revealed that a characteristic of the most extreme days, and those on which the majority of bushfire deaths in south-eastern Australia in the past 45 years have occurred, is the strength of the front at around 1.5 km above the land surface. Many of summertime cool changes are relatively shallow, but those such as that of Ash Wednesday, the day of the Hobart fires in 1967, the Streatham fires in western Victoria, 1977, the fires on Lower Eyre Peninsula in South Australia in 2005, and the Victorian Black Saturday fires in February 2009 are characterised by strong temperature gradients and high temperatures at 1.5 km elevation ahead of the front. This indicates a deep strong front that tends to have strong winds both before and after the wind change.

END USER STATEMENT

"Sudden wind changes and associated increase in bushfire behaviour has contributed to the deaths or serious long-term injury to those living in bushfire prone environments as well as firefighters. The scientific research undertaken in this project provides the scientists and fire managers with an understanding of this form of complex weather phenomena influencing fire behaviour. The research developed a Wind Change Rate Index (WCRI). The accurate forecasting of wind changes together with the WCRI will provide fire managers with critical information for the planning and execution of the most appropriate strategy and tactical resourcing for firefighter and community safety."

– Russell Rees, Chief Officer, Country Fire Authority (Victoria)

A diagnostic tool that allows the strength of any front to be put in historical context has been developed by this project. This is illustrated in Figure 3, which shows a scatterplot of twice-daily summertime values at 1.5 km of temperature gradient and highest temperature in a box over south-eastern Australia over 46 years. The major events such as Ash Wednesday (1983), Black Saturday (2009), and Hobart (1967) are highlighted, and indicate the meteorological rarity and the significance of these events – they lie in the outer fringes of the total distribution.

RESEARCH OUTCOMES/ADOPTION

The project team has run the software at the end of the past two fire seasons (2007-08 and 2008-09) and provided objective verification data to the Victorian Regional Forecast Centre. These have been used in its end-of-season forecast verification.

The spatial WCRI forecasts have been made available to forecasters since the 2006-07 fire season, and form important part of the fire weather guidance. The project has received enthusiastic endorsement of this form of forecast guidance and the product has been included in the Bureau's new Graphical Forecast Editor system that was implemented in the Victorian Regional Forecast Centre in late 2008.

A software package has been developed that will allow the verification of the fire weather forecaster's wind change forecast to be run by the Bureau's regional offices. This package, which runs on the Bureau's workstations, takes a tabulated set of forecast wind change times at a set of observing stations, extracts observational data at those stations from the Bureau's archives, extracts numerical weather prediction model data from another archive, and computer verification statistics for both the official forecasts and for the corresponding numerical forecasts. It takes less than an hour to install and set up. A user's guide is being finalised.

This study has provided a better understanding on how fronts intensify on the Victorian coastline and then surge along the coast. This understanding has been included in training sessions for US fire weather forecasters, and also in an Advanced Forecaster Workshop attended by forecasters from all states.

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Download at www.bushfirecrc.com/publications/fire_note.html

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Issue 42: Observing Teamwork in Emergency Management. This research project focused on understanding information flows and incident management team effectiveness.

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Issue 46: Fires drive major shifts in CO2 emissions from sub-alpine woodlands and grasslands. Summary of a scientific paper currently in press for the journal *Global Change Biology*.

Issue 47: Plants and fire: survival in the bush. This research investigates the composition of plants with different fire response traits across a mountainous region of south-eastern Australia, and the role fire plays in these patterns.

Issue 48: Historical patterns of bushfire in southern Western Australia. Understanding historical variation in bushfire patterns in southern Western Australia, to provide a baseline for future fire regime comparison.

Issue 49: Forest Flammability – How fire works and what it means for fuel control. Forest Flammability is a next-generation fire behaviour model that reveals the complex links between fire behaviour and forest ecology.

Issue 50: Effectiveness and efficiency of aerial fire fighting in Australia. Bushfire CRC research examining the practical effectiveness and economic efficiency of aerial firefighting in Australia.

Issue 51: Assessing Grassland Curing by Satellite. To improve the assessment of grassland curing in Australia and NZ, this research developed an improved algorithm using Moderate Resolution Imaging Spectroradiometer satellite data.

Issue 52: Bushfire Safety for People with Special Needs. This study looked at how households with special needs prepared for and met the challenge of a fire event, and how community education programs could improve their preparedness.

Issue 53: Determining grassland fire danger with plant models. This project addresses the rate of natural die-off in common grass species and provides a way to adapt agricultural modelling to predict curing rates across temperate grasslands.

Fire Note is published jointly by the Bushfire Cooperative Research Centre (Bushfire CRC) and the Australasian Fire and Emergency Service Authorities Council (AFAC).

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