bushfire CRC afac

FIRE NOTE

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FOEHN WINDS AND FIRE DANGER ANOMALIES OVER S.E. AUSTRALIA

CONTEXT

This research aimed to identify regions of southeastern Australia that are prone to foehn occurrence and to quantify the changes in fire danger rating that can be expected under foehn conditions. It also aimed to understand the meteorological mechanisms that result in foehn occurrence so as to provide better guidelines for issuing warnings about imminent severe fire weather.

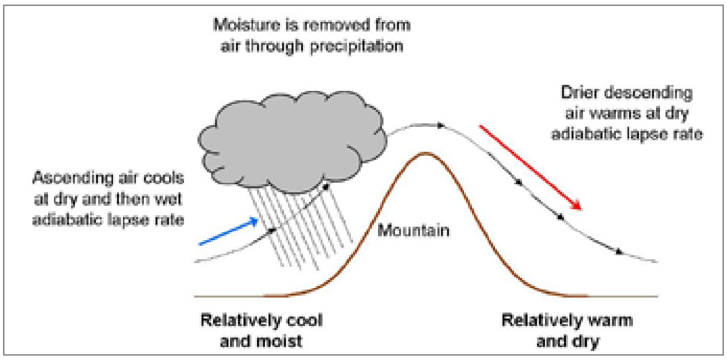
BACKGROUND

Foehn winds are warm, dry winds found in the lee of many mountain ranges. Examples include the Santa Ana and Chinook winds of North America and the Canterbury Northwester in New Zealand. Foehn occurrence has often been linked with increased wildfire risk and is attributed to two main mechanisms.

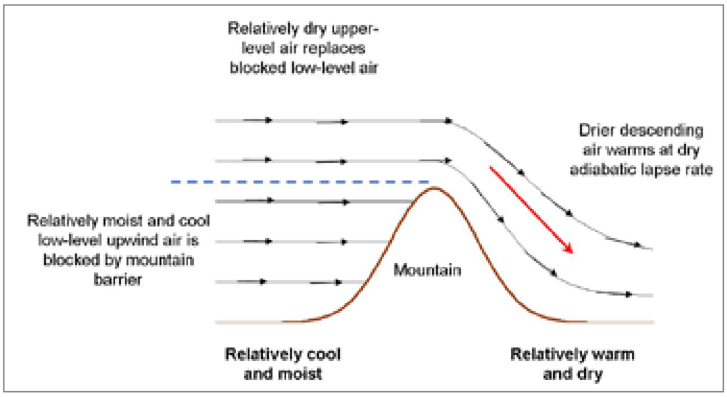
1. Thermodynamic Foehn: Moist air is lifted over a mountain barrier. As the moist air rises, it cools. The cooling of the air ultimately results in condensation and precipitation. The precipitation removes moisture from the air mass and the latent heat of condensation raises the temperature of the air. The drier air is then warmed further as it descends the lee slopes due to compression. See figure 2.
2. Blocking Foehn: Moist lower-level air is blocked by a mountain barrier. Drier upper-level air then flows down to replace it in the lee of the mountains. As the drier air from above descends it is warmed by compression. See figure 3. It is typical for this type of foehn to occur in association with a vertically propagating lee mountain wave.

In either mechanism, the end result is that conditions on the upwind side of the mountains will be relatively moist and cool while conditions in the lee will be relatively warm and dry.

▲ **Figure 1:** The Lone Pine Fire, Southern ACT May 2005. Note the (westerly) downslope flow in the smoke column. This fire was observed crowning at night while rain was recorded 10 km to the west. Photo taken by Rick McRae, ACT Emergency Services Agency.



► **Figure 2:** Schematic illustrating the thermodynamic foehn mechanism.



► **Figure 3:** Schematic illustrating the blocking foehn mechanism.

SUMMARY

In southeastern Australia severe fire weather is often associated with dry cool changes or coastally modified cold fronts. Less well known, however, are synoptic events that occur in connection with the topography of the region, which can also lead to abrupt changes in fire weather variables. Foehn winds provide an example of such an event.

Foehn winds are characteristically warm and dry and are found in the lee of significant topography such as the Australian Alps. While some knowledge about Australian foehn winds does exist, it has not been widely disseminated and generally stems from brief accounts that are based on experience rather than detailed scientific studies.

This note summarises the first detailed scientific study into the occurrence and characteristics of foehn-like winds over southeast Australian and the implications of foehn occurrence for bushfire risk management in the high-country and its surrounds.

BUSHFIRE CRC RESEARCH

The highest levels of bushfire risk are often associated with extreme weather events (for example, January 18 2003, 7 February 2009). Taking drought as a background state, foehn winds thus serve as episodic drivers of potential fire disaster. The uncertainties associated with anthropogenic climate change further complicate the problem faced by fire and emergency managers tasked with optimising the resilience and capacity of society to respond to such catastrophic events.

To address the shortcomings of our understanding of foehn winds over southeastern Australia and their impact on fire danger levels and bushfire risk, our research was conducted as follows:

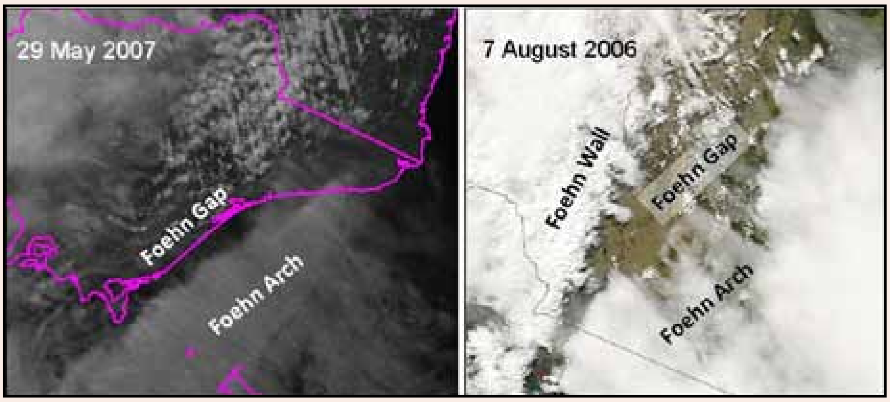
Meteorological observations, in particular wind, temperature and relative humidity, were studied, and a number of foehn-like occurrences (that is, relatively cool and moist upwind of mountains and relatively warm and dry in the lee) were identified. Satellite imagery was also used in the identification of likely foehn occurrence (see 'Foehn Clouds' box above). A subset of eight candidate events was selected for more detailed analyses.

The observations surrounding the candidate events were subject to spatio-temporal analyses and combined to produce maps representing McArthur Mark 5 Forest Fire Danger Rating (FFDR) over southeastern Australia for each of the candidate events. Examples of FFDR maps for the foehn events on 19 and 20 September 2008 can be seen in figure 5. FFDR at a particular location and time of year was deemed anomalous if it was at or above the 95th percentile for the place and time, when compared to climatological values (Dowdy et al., 2009). As indicated in figure 5, foehn conditions produced anomalous FFDR on 19 and 20 September 2008. FFDR on 20 September was in fact above the 99th percentile at Bega on the south coast of NSW. Figures 6 and 7 illustrate the abrupt temporal changes in surface conditions experienced at Moruya and Bega during foehn occurrence.

A mesoscale (approx. 5km) numerical weather prediction (NWP) model was used to investigate the structure of the atmosphere surrounding the candidate foehn-like occurrences. Figure 8 indicates the presence of a vertically-propagating gravity wave over the Gippsland region. Figure 8a shows strong subsidence in the lee of the ranges, while the streamlines in figure 8b indicate partial orographic blocking of low-level upwind air. Similar atmospheric structures were also evident in the NWP model diagnoses for the other candidate events.

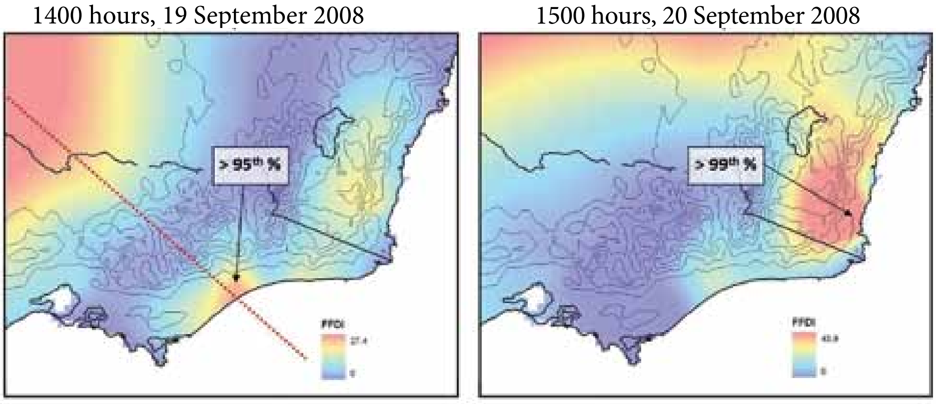
FOEHN CLOUDS

Foehn occurrences are often accompanied by distinctive cloud formations. The *foehn wall* is an orographic cloud band that forms along the ridge tops of mountain ranges due to condensation of moisture as the air is lifted up the windward slopes, while the *foehn arch* is an extensive layer of altostratus cloud that forms downwind of the mountains in the rising portion of a lee mountain wave. Typically, a band of clear air called the *foehn gap* can be observed between the wall and arch clouds.



▲ **Figure 4:** Examples of foehn clouds over southeastern Australia.

1400 hours, 19 September 2008 | 1500 hours, 20 September 2008



▲ **Figure 5: FFDR maps showing foehn effects on 19 and 20 September 2008.**

ABOUT THIS PROJECT

Project B6.3 Managing the risk of fire in the high-country (HighFire Risk)

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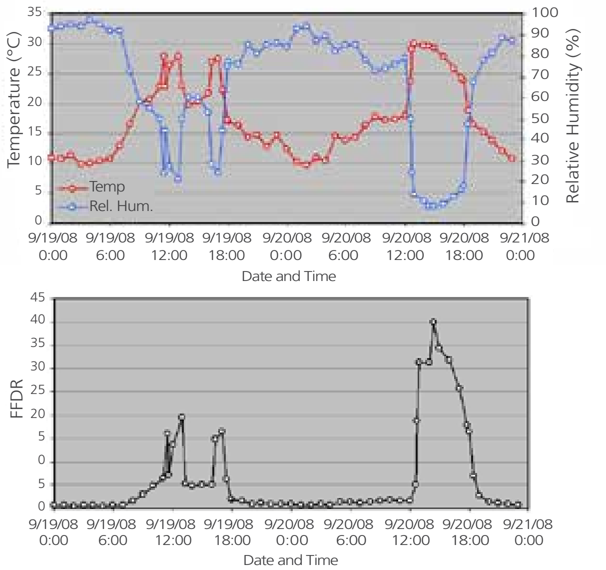
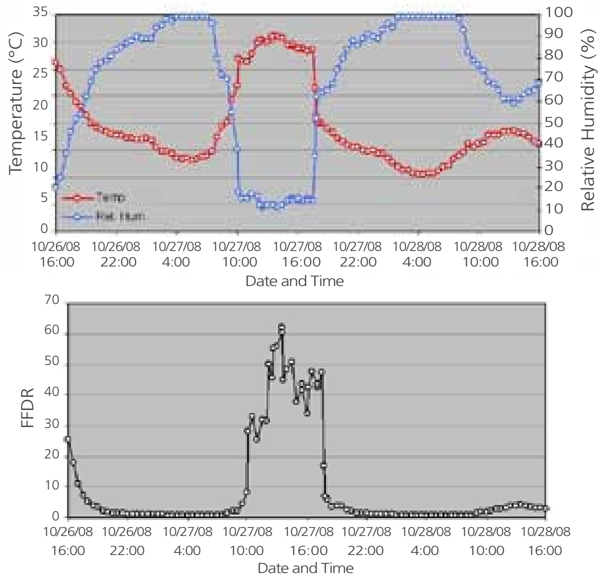


▲ **Figure 6:** Time series of temperature, relative humidity and FFDR at Moruya, NSW.



▲ **Figure 7:** Time series of temperature, relative humidity and FFDR at Bega, NSW.

RESEARCH OUTCOMES

This research has confirmed that foehn winds do indeed occur in connection with the Australian Alps and has highlighted the role that they play in exacerbating FFDR on a regional level. In particular, the research shows that foehn winds can result in abrupt localised changes in FFDR, which can reach anomalous levels (that is, above the 95th percentile of climatological values). In some instances these changes can increase the fire danger levels by a factor of ten or more within an hour. This in turn can lead to loss of containment, abrupt changes in rate of fire spread and the entrapment of fire-fighters.

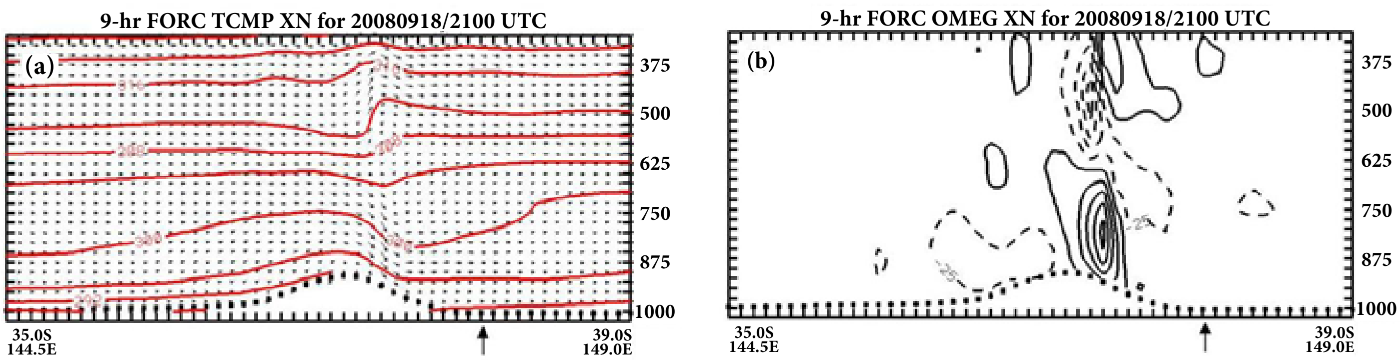
Regions shown to be significantly affected by foehn winds include the Sydney Basin, the south coast of New South Wales and the Gippsland region of Victoria, though similar effects could be expected at other regions located in the lee of topography. This includes many of the densely populated coastal regions of southeast Australia. See box 'Foehn-like Event At Wilson's Prom' on page 4.

NWP modelling indicated an association between foehn conditions and partial orographic blocking of relatively moist low-level air on the upwind side of the mountains and subsidence of drier upper-level air in their lee. The NWP analyses also indicated the presence of topographically-induced vertically propagating gravity waves in connection with foehn conditions. As such, the foehn occurrences considered in the study were mostly of the 'blocking foehn' type described above. However, it was not possible to completely discount the thermodynamic foehn mechanism in some foehn occurrences.

All of the foehn events considered occurred in connection with the passage of low pressure cells or synoptic fronts across the Great Australian Bight and southeastern Australia, which cause strong winds to align almost perpendicular to certain parts of the Great Dividing Range. Thus, at least at the synoptic level, there is good potential for forecasting foehn occurrence. In particular, the research conducted so far could be used to issue red flag warnings about the potential for anomalous FFDR levels in the lee of mountainous regions.

The problem of determining whether foehn conditions will actually be experienced at a particular location on the ground is more complicated, and is the subject of ongoing research. Progress in this respect will rely on gaining a better understanding of the interaction of foehn flows with local atmospheric structures, such as inversions. For example, the conditions at Moruya on 19 September 2008 (Figure 6) illustrate the intermittent impact of foehn conditions at the surface due to the presence of a marine inversion.

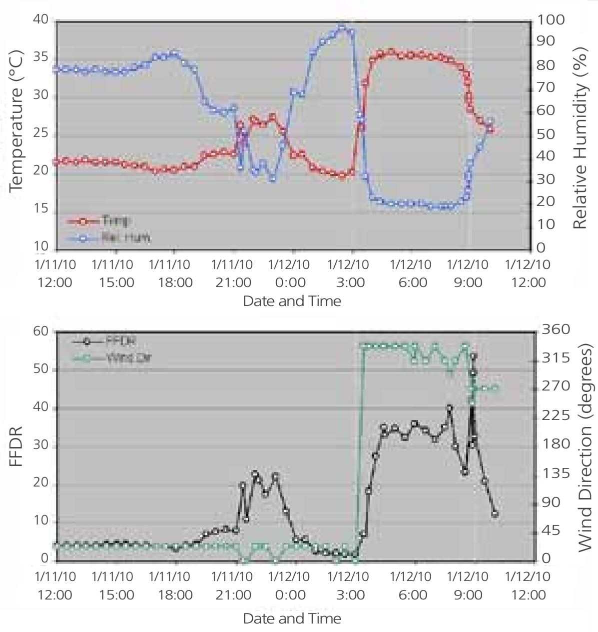
This research challenges current best practice in the sense that it highlights a significant driver of bushfire risk that has hitherto been poorly understood in the Australian context. At present, the possibility of foehn winds and the impact that they can have on FFDR are not formally accounted for in any bushfire risk management system used in Australia. The research also has a number of implications for fire suppression operations and fire crew safety. For example, hourly



▲ **Figure 8:** NWP model diagnoses (a) Streamlines and projected wind vector, (b) vertical motion of the air: solid lines represent downward moving air and broken lines represent upward moving air. The arrow below each panel indicates the approximate position of the coast. The cross section is shown in plan view in figure 5.

THE FOEHN-LIKE EVENT AT WILSONS PROMONTORY, 12 JAN 2010

On 12 January 2010, conditions conducive to foehn occurrence manifested over southeastern Australia. Between 3am and 4am observations at Wilson's Promontory were consistent with foehn conditions. Figure 9 shows that at 3am temperature and relative humidity were 20.2°C and 95%, respectively, and FFDR was 1.7. Immediately after 3am a wind change to the NNW was recorded. Coincident with the wind change, temperature and relative humidity began to change rapidly. Twenty-five minutes later the temperature was 27.8°C and relative humidity was 59%. By 4am temperature and relative humidity were 34.9°C and 23%, respectively, and FFDR was 27.5 – an increase in fire danger rating by a factor of sixteen within an hour, and at a time when fire behaviour would normally be expected to be mild.



▲ **Figure 9:** Time series of temperature, relative humidity, FFDR and wind direction at Wilson's Promontory, Victoria.

updates of weather variables by personnel in the field may be insufficient given that foehn occurrence can cause significant changes in FFDR over sub-hourly time intervals (for example, in Bega 27/10/08: FFDR changed from 'Low-Moderate' to 'Very High' within 36 minutes).

FUTURE DIRECTIONS

Future research will use finer-scale NWP models in connection with finer-scale sampling of meteorological variables, using portable automatic weather stations, to better understand the interaction of synoptic-scale foehn flows with local atmospheric and topographic structures.

The researchers have had discussions with the Bureau of Meteorology about incorporating the research findings into improved fire weather training material. They are also seeking to engage personnel from the Bureau's Severe Weather Section to work together on developing a framework that can be used to determine if a foehn warning should be issued.

The effect of anthropogenic climate change on the extent and frequency of foehn conditions over southeast Australia is also an open problem that will be pursued in further research.

REFERENCES / FURTHER READING

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END USER STATEMENT

Many experienced fire fighters have, at some point in their careers, witnessed fire weather or fire behaviour that they cannot explain. It is pleasing to see researchers developing detailed explanations for some of these causes of those events.

While fire fighters are acutely aware of the impact of hot, dry and windy conditions on fire behaviour and spread, there is less awareness about certain processes that can cause these conditions.

This research has highlighted a significant, yet poorly understood, weather phenomenon that can have catastrophic consequences for fire management in and around the mountains of southeast Australia.

The challenge for fire managers and fire weather forecasters is to support the capacity to anticipate and predict potential increases in fire behaviour, rather than observing the consequences. This research will help in this respect by underpinning improvements in fire weather forecasts and warnings.

As has happened elsewhere around the world, there are clear benefits to be gained from increased awareness of foehn winds by fire fighters and the community.

– Andrew Stark
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