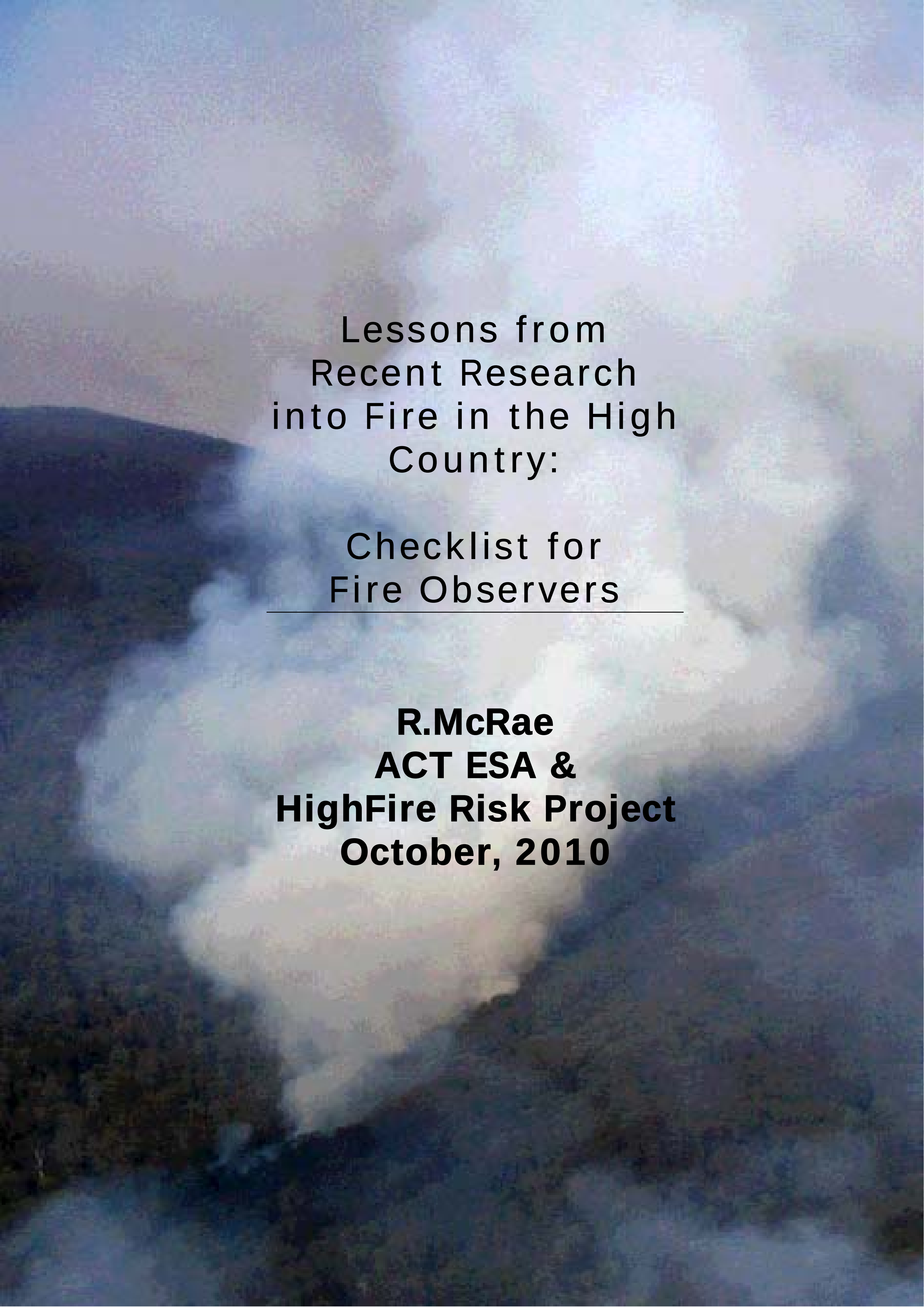


Lessons from Recent Research into Fire in the High Country:

Checklist for Fire Observers

R.McRae
ACT ESA &
HighFire Risk Project
October, 2010

CONTENTS

INTRODUCTION

New research undertaken as part of the HighFire Risk project (begun in the Bushfire Cooperative Research Centre) has given us fresh insights into the drivers of the catastrophic fires in the high country this decade. This has been linked into other research projects underway in Australia, Europe and North America to give a clarity that has in the past evaded us.
The research details are available elsewhere. This report seeks to define a process that links the act of observing a fire to gaining an understanding of what processes might be at work and then to altering the IMT so that they may adjust the IAP to react to those processes.
A number of events are described here so that observers may know what to look out for. An observation of an event is given an urgency rating:

1 Highly significant observation, requiring immediate reporting
2 Significant observation, requiring immediate reporting
3 Significant observation, requiring immediate verification and reporting
? Observation requiring verification

In reporting an event, an inferred phenomenon can also be noted:

- Fire channelling
- Deep flaming zone
- Violent pyro-convection
- Mountain wind waves
- Foehn winds
- Low-level jet
- Wind change at fire
- Nocturnal dew point depression event
- Abrupt surface drying
- Eruptive fire growth
- Thermal belt
- Convergence zone

The reporting of these phenomena may indicate that a Red Flag Warning is required:

1. Plume-driven fire
2. Conditions conducive to plume-driven fire
3. Passage of dry slot over fire
4. Thunderstorm
5. Wind change
6. Fire channelling event
7. Dew point depression event
8. Foehn wind
9. Unusual combustion
10. Intense spotting

Of these, 1 requires attention from the IMT as an absolute priority. 4, 5, 6 & 10 require treatment as a highest priority for the IMT, and the remainder are a high priority.

For this system to work effectively, all involved must understand the significance of an observation. The reaction from the IMT must be appropriate and timely. An observer must react with the correct level of urgency and must verify observations where necessary.

The scale of phemomena now known to operate is such that it is no longer possible to expect to see them directly. Rather, the goal is to see events that are evidence of them at work, and from those events draw conclusions of importance to the IMT.

If you see anything covered by this report – *PHOTOGRAPH IT!*

(as long as it is safe to do so)

USING THIS HANDBOOK

In the following pages each event is covered in turn. Where applicable, guidance is given for Air Observers, Field Observers or Situation Unit Analysts.

For each event its implications are given in tabular form. The Tables show three elements:

Firstly the inferred phenomena are listed, as in the example below:

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Fire Channelling		
Deep Flaming Zone		
Wind Change at Fire		
Convergence Zone		

Each phenomenon carries an urgency rating, shown by the number and the colour:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
	1	
	2	
	3	
	?	

1 Highly significant observation, requiring immediate reporting
2 Significant observation, requiring immediate reporting
3 Significant observation, requiring immediate verification and reporting
? Observation requiring verification

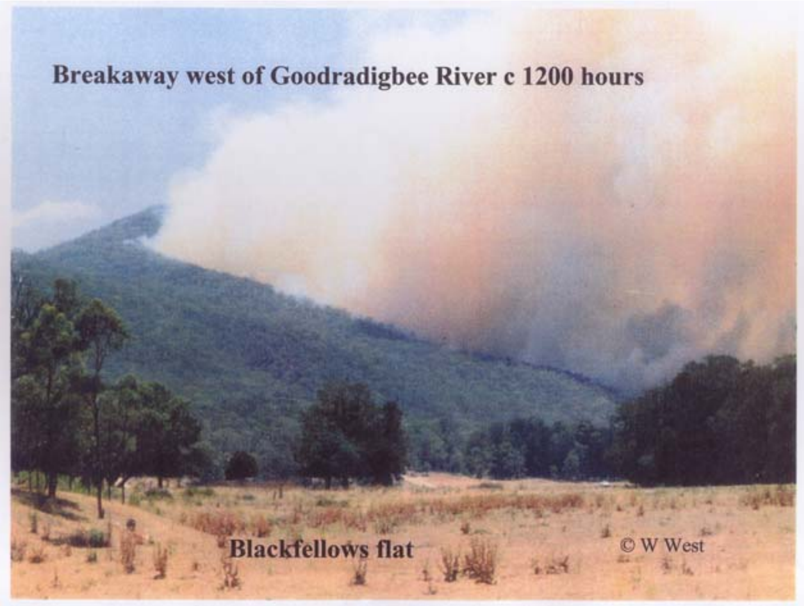
Then the required reaction by the IMT is indicated by the colour:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
		RFW of Absolute Priority
		RFW of Highest Priority
		RFW of High Priority
		RFW Uncertain

FIRE CHANNELLING PHENOMENA

Event (1): Hot fire on lee-side of hill, lee wind-field full of smoke.

AIR OBSERVER OR FIELD OBSERVER:



[1]

In this photograph taken on Blackfellows Flat on the Goodradigbee River, the wind is blowing strongly from the left to the right. Rather than moving downslope to the right, **the fire is circulating in the lee-slope eddy** and filling the entire slope up to the break-in-slope at the top. This is diagnostic.

Channelling is also dragging the entire system **towards the observer**. Note that in other circumstances channelling might push the fire laterally in the opposite direction, away from the observer. The leading "lateral edge" is characterised by **spotfires**, noticable in the photo from their dark grey smoke plumes. The main smoke is, by contrast, of a somewhat orange colour. This is diagnostic.

Fire is spotting onto the entire landscape downwind, to the right, for some kilometres.

This landscape-scale ignition pattern dictates that a field observer seeing this should immediately seek safe egress.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Fire Channelling	3	6) Fire channelling event

[1] Photo: Wayne West, tendered to ACT Coronial into the 2003 Fires.
148.74° -35.30° looking NNW at about 12:00 AEDST 18th January, 2003.

FIRE CHANNELLING PHENOMENA

Event (2): Fire flank follows dog-leg around lee-slope.

AIR OBSERVER:


[2]

In this photo the wind is blowing strongly away from the camera. The Blue Range is in the middle ground, with Uriarra Pine Plantation in the background. In the lee slope of the Blue Range a **fire channelling event is driving the fire to the right**. Note the intense convection there, compared with the more whispy smoke on the left-hand edge of the photo.

The fire edge moves away from the camera (in the lower-left corner), then makes a right-angle turn to move to the right, then makes another right-angle turn, to the left, to move away from the camera again. This dog-leg configuration is diagnostic.

If observed again in, say, ten minutes, the edge moving away from the camera would have **moved to the right**, while the upwind edge, at the top of lee slope, would still be anchored to the top of the slope.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Fire Channelling	3	6) Fire channelling event
Deep Flaming Zone	?	2) Conditions conducive to plume-driven fire

[2] Photo: Stephen Wilkes, Air Observer.
148.86°-35.30° looking ESE at about 3:00 AEDST on 18th January 2003.

FIRE CHANNELLING PHENOMENA

Event (3) Upwind edge of fire locked into break in slope

AIR OBSERVER:


[3]

In this photograph taken over Blackfellows Flat, the winds are blowing from right to left and somewhat towards the camera, over a plateau. A channelling event is underway in the incised valley of the Goodradigbee River. It is **filled with smoke** due to the circulation system set up by the channelling event. The **dense smoke seen stops at the break-in-slope**, hard against the wind. This is diagnostic. Note also the intense flaming on the upwind edge of the fire.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Fire Channelling	3	6) Fire channelling event
Deep Flaming Zone	?	2) Conditions conducive to plume-driven fire

[3] Photo: Stephen Wilkes, Air Observer.
148.73° -35.30° looking SW, at about 15:30 AEDST 18th January, 2003.

FIRE CHANNELLING PHENOMENA

Event (4) Dense "orange" plume of smoke on upwind corner of fire, at top of a lee slope

AIR OBSERVER:

[4]

This image is a mosaic of stills from an airborne FLIR system on a Customs Dash 8 aircraft over the northern Brindabella Ranges. The wind is blowing from right to left.
The closest part of the plume on the right can be seen to have an orange hue, and is denser than the smoke behind it. The fire channelling process is moving the base of this dense smoke towards the observer.
In the far right-hand of the image, the fire is held on its upwind edge on a break-in-slope. In the left-hand half, the fire channelling event is creating dense spotting, with some spotfires well established.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Fire Channelling	1	6) Fire channelling event
Deep Flaming Zone	?	2) Conditions conducive to plume-driven fire

[4] Photo mosaic from video footage taken by an Australian Government aircraft with a FLIR pod.
148.76° -35.14° looking SSE at about 3:00 AEDST 26th January, 2003.

FIRE CHANNELLING PHENOMENA

Event (5) Fire jetting out of lee-slope eddy away from main fire

AIR OBSERVER:

[5]

This photo of the Jesusita Fire in California shows two fire channelling events acting together to move the fire rapidly both downwind and cross wind. The right-hand edges of both events have dense smoke and active convection.
In both cases flames can be clearly seen emerging from the lee-slope eddy and "jetting" out. This is likely due to thermal expansion within the eddy, which also leads to ejection of embers which ignite the landscape downwind. Observation of jetting is diagnostic.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Fire Channelling	1	6) Fire channelling event
Deep Flaming Zone	?	2) Conditions conducive to plume-driven fire

[5] From an ABC TV News Bulletin, from a Calfornia news helicopter. 119.7° 34.4° looking N at about 18:00 PDT 5th May 2009.

FIRE CHANNELLING PHENOMENA

Event (6) Intense spotting on fire flank

AIR OBSERVER:


[6]

This photo looking from Uriarra Crossing to Pig Hill, shows a stable lateral edge of a smoke plume. A large number of spot fires can be seen under or just outside of the shadow of the plume. One of these spotfires was observed to become established and reach maximum rate-of-spread within three minutes of ignition, despite five helicopters arriving within that time. Note that documented fire channelling events were underway at the back of this flank (at Pig Hill) and in the lower-left corner of the image (at Uriarra Crossing).

[6] Photo: Stephen Wilkes, Air Observer.
148.96° -35.24° looking NW at about 15:00 AEDST, 18th January 2003.

FIELD OBSERVER:

[7]

This photo, taken in Eucumbene Drive in Duffy, shows the typical (!) situation downwind of a fire channelling event. The landscape is ignited by spotfires, which rapidly amalgamate. There is no headfire. The smaller headfires are being drawn toward established ones. The latter often have tall flames (over 90m has been confirmed), but little or no lean on the flames.
Also associated are ember storms, which require strong winds. It is likely that a sequence of events occurs, culminating in the spot fires.
Observer safety becomes the initial concern if this is seen, followed by reporting the observation.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Fire Channelling	2	6) Fire channelling event
Deep Flaming Zone	?	2) Conditions conducive to plume-driven fire
Violent Pyro-Convection	?	1) Plume-driven fire
Wind Change at Fire	?	5) Wind change
Convergence Zone	?	?

[7] This photo is a still from a WIN TV news video
149.03° -35.34° looking NW at about 16:00 AEDST on 18th January, 2003.

WIND WAVE PHENOMENA

Event (7) Lenticularis cloud in areas

AIR OBSERVER:


[8]

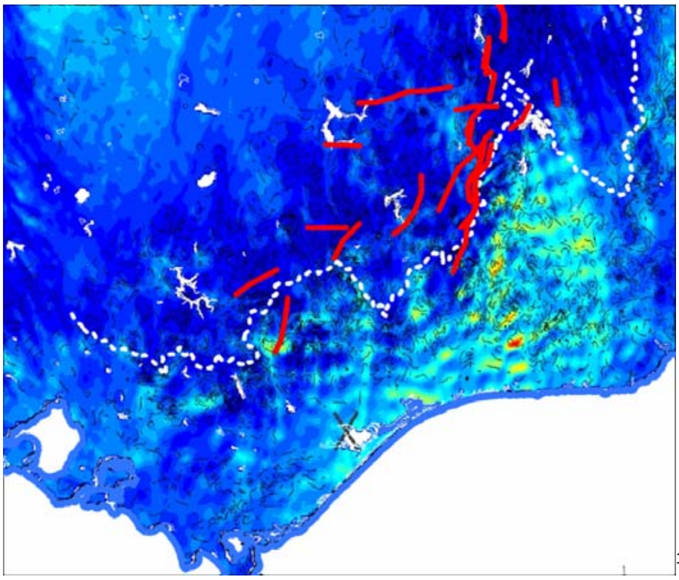
While air observers should note the material below for field observers, they should also recognise the potential for FLIR sensors to detect wind waves affecting fires. In the image above Looking to Thredbo from Yaouk, the heat from the fires is detected (white) three times: the lower glow is direct radiated heat from the fires; the middle glow is heat reflected off the smoke plumes, which include pyro-Cu clouds; and the upper glow is heat reflected off ice crystals in high-level lenticularis clouds. These clouds are in the crest of wind waves generated by the alps, and can be associated with extreme fire behaviour underneath.

[8] Photo taken from video footage from an Australian Government aircraft fitted with a FLIR pod.
148.79° -35.73° looking SSW atabout 15:00 AEDST 26th January, 2003.

FIELD OBSERVER:


[9]

This photo shows a characteristic lenticularis cloud ("lenny" or Standing *Altocumulus lenticularis*). This cloud is aligned generally across the prevailling wind direction, but parallel with the escarpment, somewhere upwind, that generated the wind wave. There may be other parallel lennies in the area, typically at 15km spacing downwind. Air moving into the wind wave crest is cooling and forms cloud, while air decending out of the crest is warming and losing cloud. Thus while the cloud elements may be moving rapidly, the cloud itself is stationary. This is diagnostic.


[10]

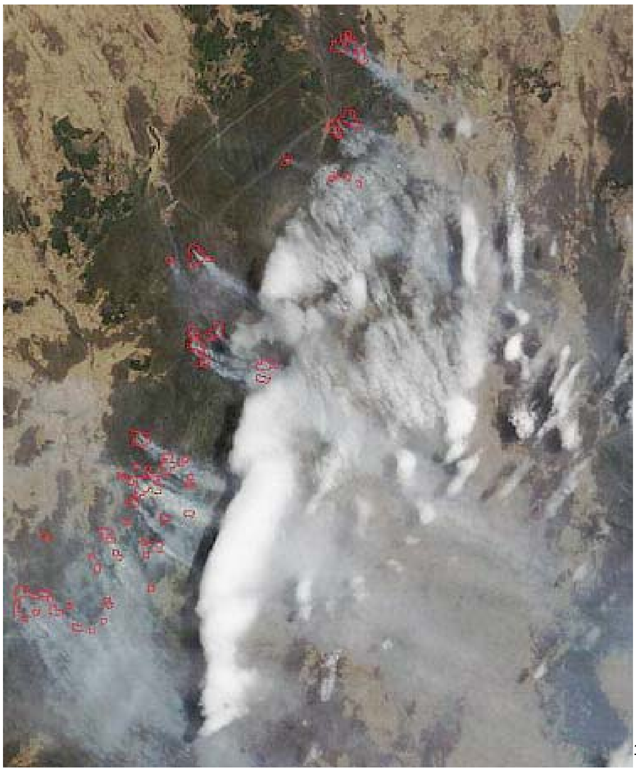
This map shows waves of elevated FDI downwind of known wind wave generating escarpments (red) and the Great Divide (white dotted line).

---

[9] Photo: McRae.
149.08° -35.33° looking S. 12:35 AEDST 21st November 2006.

[10] Computational Fluid Dynamics Map: Rachel Badlan, University of Melbourne.

SITUATION UNIT OFFICER:


[11]

This satellite image shows a field of lennies generated in a NW air flow by the escarpment on the western edge of the high country between Tumut and Khancoban. The rounded shape of the main upwind *lenticularis* is diagnostic.

Note the extended shadows.

Care must be taken when interpreting shadows in cross-path scanning satellite imagery. Sideways viewing angles will distort shadows in a way that cannot be remedied during rectification. Also visible here are commercial aircrafts' contrails, which can be used to calibrate shadow analysis. They typically fly at around 10km ASL, but this can equate to as little as 8km AGL over the alps.

Imagery will often show *lenticularis* fields extending downwind for around 100km, and they typically span the rugged landscape.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Mountain Wind Waves	3	?

[11] MODIS image spanning from Bombala to Tumut, rectified courtesy of Goddard Space Flight Center. 1pm AEDST 18 January 2003.

WIND WAVE PHENOMENA

Event (8) Parallel bands of clouds, transverse to prevailing wind direction

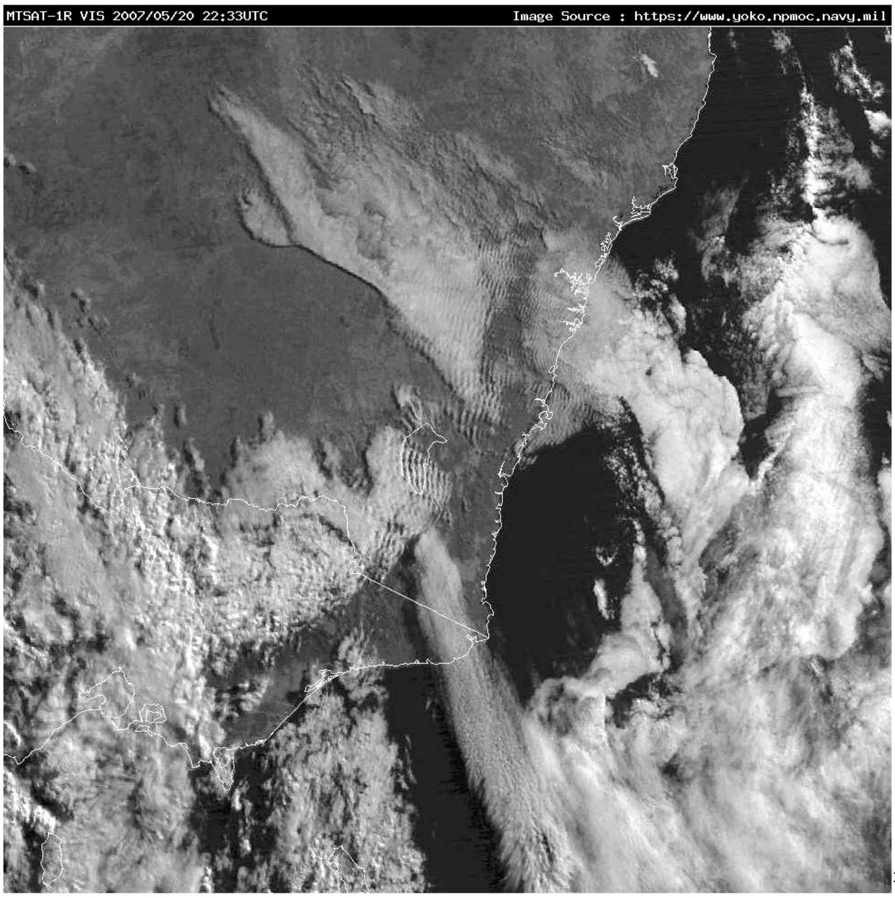
AIR OBSERVER OR FIELD OBSERVER:


[12]

In this photo the clouds bands can be seen to be parallel to the ranges upwind, on the horizon. These are clear indicators of vertical air flow within wind waves or rotors downwind of the ranges. Vertical air flow over fires can modify the stability with predictable effects on fire behaviour. Observers need to note whether or not the bands are geostationary, and whether there is any reversal of ground winds in the troughs of waves (which would indicate rotor formation). Expect rising air near the upwind edge of these cloud bands, and descending air on their downwind edge.

[12] Photo: McRae.
149.85° -35.28° looking SW, 31st March, 2008.

SITUATION UNIT OFFICER:



[13]

The image shows a complex weather pattern over south east Australia, which includes a Foehn-like event over Bombala. Centred around the ACT is a clear system of parallel wind-wave clouds being generated by the main range.
NE of the ACT there is not a main range, but wind-waves are also being generated there by the high ground around Crookwell and by the coastal escarpment around Nowra.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Mountain Wind Waves	3	?
Foehn Winds	?	8) Foehn wind

[13] MT-SAT visible satellite image.
08:33 AEST 21st May 2007

WIND WAVE PHENOMENA

Event (9) Geostationary clouds (forming on leading edge, decaying on trailing edge)

AIR OBSERVER OR FIELD OBSERVER:

[14]

In this photo the wind is blowing left to right. The cloud band that can be seen has formed on a wind wave crest.
Air moving into the crest from the left is cooling and forms cloud, while air decending out of the crest to the right is warming and losing cloud. Thus while the cloud elements may be moving rapidly, the cloud itself is stationary. This is diagnostic.
Expect rising air near the upwind edge of these cloud bands, and descending air on their downwind edge.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Mountain Wind Waves	3	?

[14] Photo: McRae.
149.07° -35.32° looking NNE. 17:00 AEDST 29th October 2003.

FOEHN WIND PHENOMENA

Event (10) Foehn Wall behind ranges

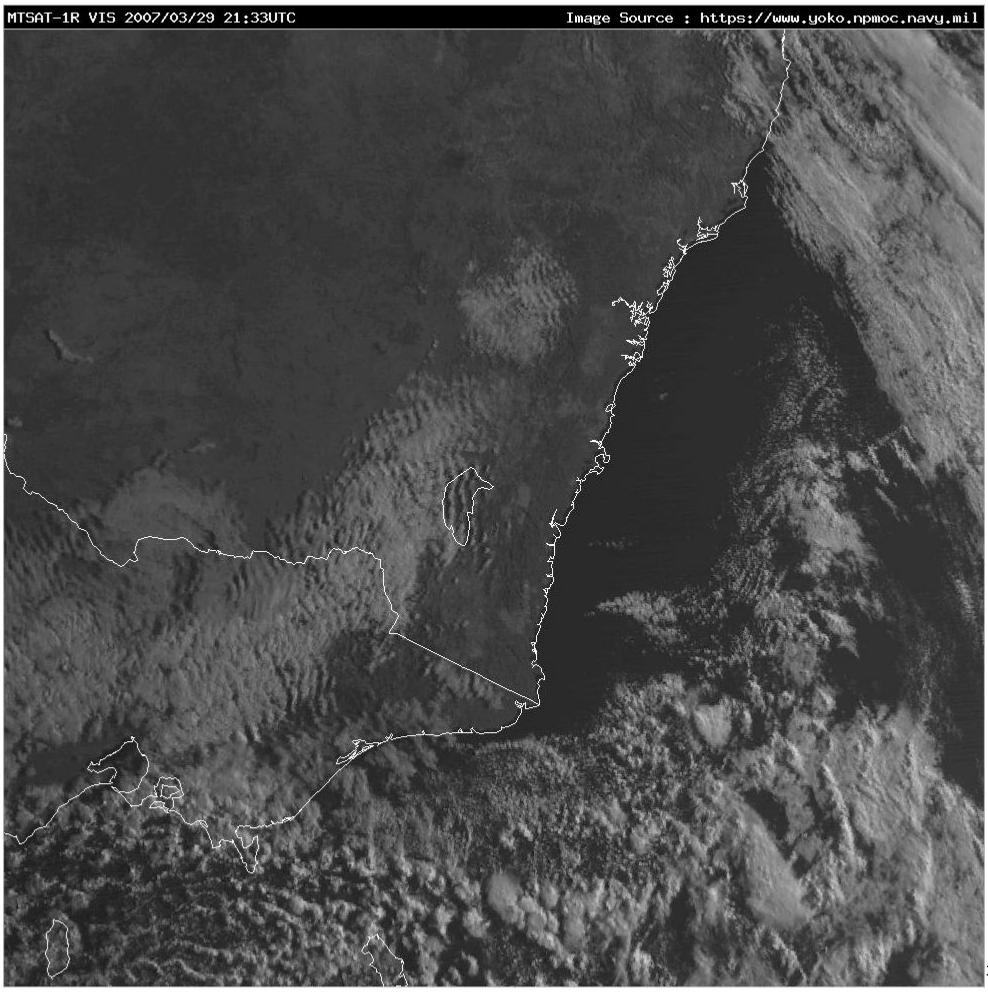
AIR OBSERVER OR FIELD OBSERVER:

[15]

This photo shows a Foehn Wall over the Liverpool Ranges in the upper Hunter Valley. Stratiform clouds on the far side of the ranges are just spilling over the top. The ranges are effectively damming the lower layer of moist air, allowing higher, dry air to flow over the top and the then descend towards the observer. Adiabatic warming produces marked difference in surface weather between the two sides of the ranges.

[15] Photo: McRae. 150.6° -32.0° looking NW. 1983.

SITUATION UNIT OFFICER:



[16]

The image shows striated, transverse cloud bands which are all upwind of the main range lines. Their upwind formation hints at them not being mountain wind waves. The downwind edge coincides with the main range and indicates a Foehn Wall.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Foehn Winds	3	8) Foehn wind

[16] MT-SAT visible satellite image.
08:33 AEDST 30th March 2007.

FOEHN WIND PHENOMENA

Event (11) Foehn Arch towards coast

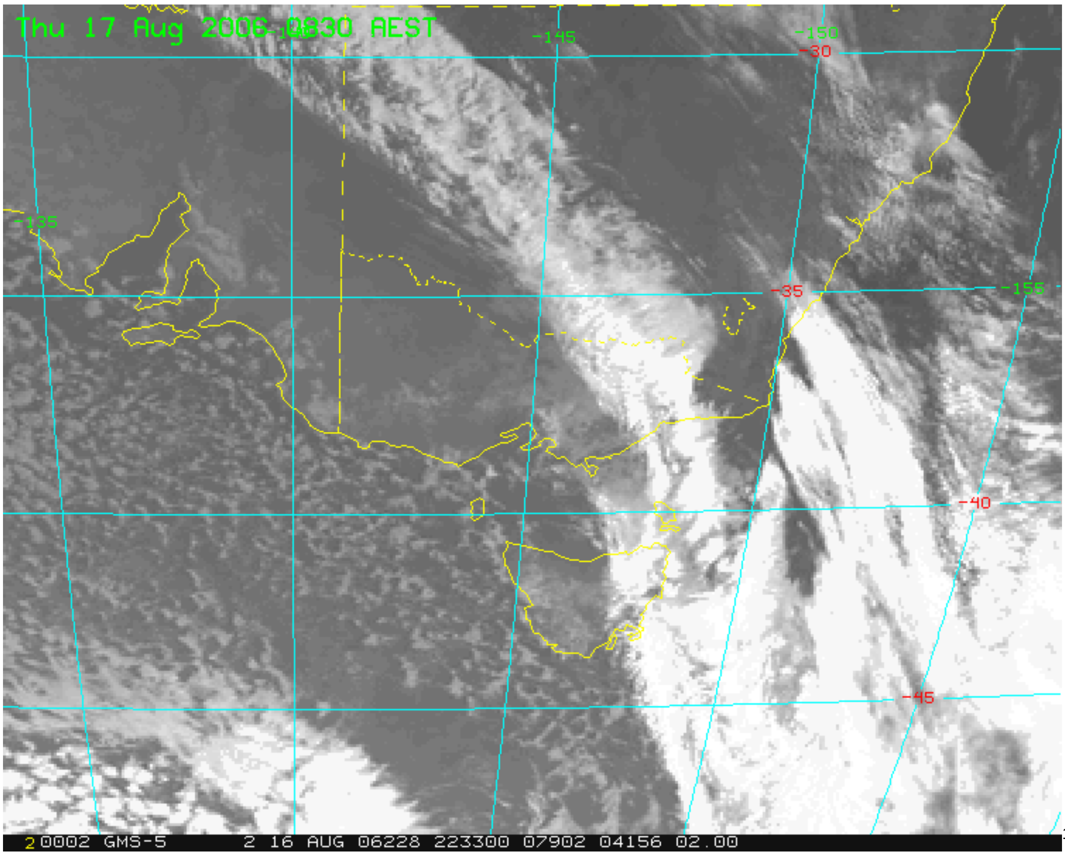
AIR OBSERVER OR FIELD OBSERVER:


[17]

This photo shows two processes. Winds are blowing from right-to-left. The low grey clouds to the right are geostationary *stratocumulus* bands at about 2km AGL in the Foehn Gap. The bright cloud to the left in the Foehn Arch, composed of a *cirrostratus* shelf at over 10km AGL with a geostationary upwind edge.

[17] Photo: McRae.
149.08° -35.32° looking S. 2nd May 2007 at about 18:00 AEST.

SITUATION UNIT OFFICER:



[18]

Visible satellite image showing a Foehn event. West and South of the ACT is the Foehn Wall along the top of the main range. Near the coast is the Foehn Arch, the nearly linear western edge of the high altitude cloud shelf. In between is the Foehn Gap, sparsely populated with clouds. Note how the Gap is a significant break in an extensive band of frontal cloud. The effect of terrain remains somewhat stationary as the cloud band moves overhead.

IMPLICATIONS:

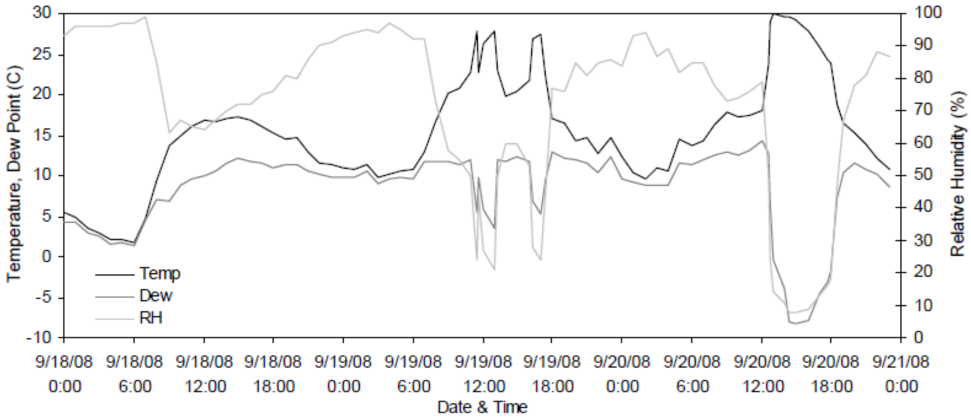
PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Foehn Winds	3	8) Foehn wind

[18] BoM visible satellite image.
08:30 AEST 17th August 2006.

FOEHN WIND PHENOMENA

Event (12) Sudden non-diurnal rise in temperature and fall in DP

FIELD OBSERVER OR SITUATION UNIT OFFICER:



The graph above shows a temperature, relative humidity and dew point time series for Moruya, 18th September – 21st September 2008. By reference to the event on the far right, note how the temperature rises, the dew point falls and the relative humidity falls in a synchronised fashion.
This is a Foehn event that was characterised by switching of the wind direction to from the ranges when the non-diurnal weather occurred. There can be up to a twenty-fold increase in fire danger in half an hour. This cannot be detected unless observations are taken on a regular basis.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Foehn Winds	3	8) Foehn wind

LOW-LEVEL JET

Event (13) Low-level clouds & smoke moving much faster than indicated by surface wind speed

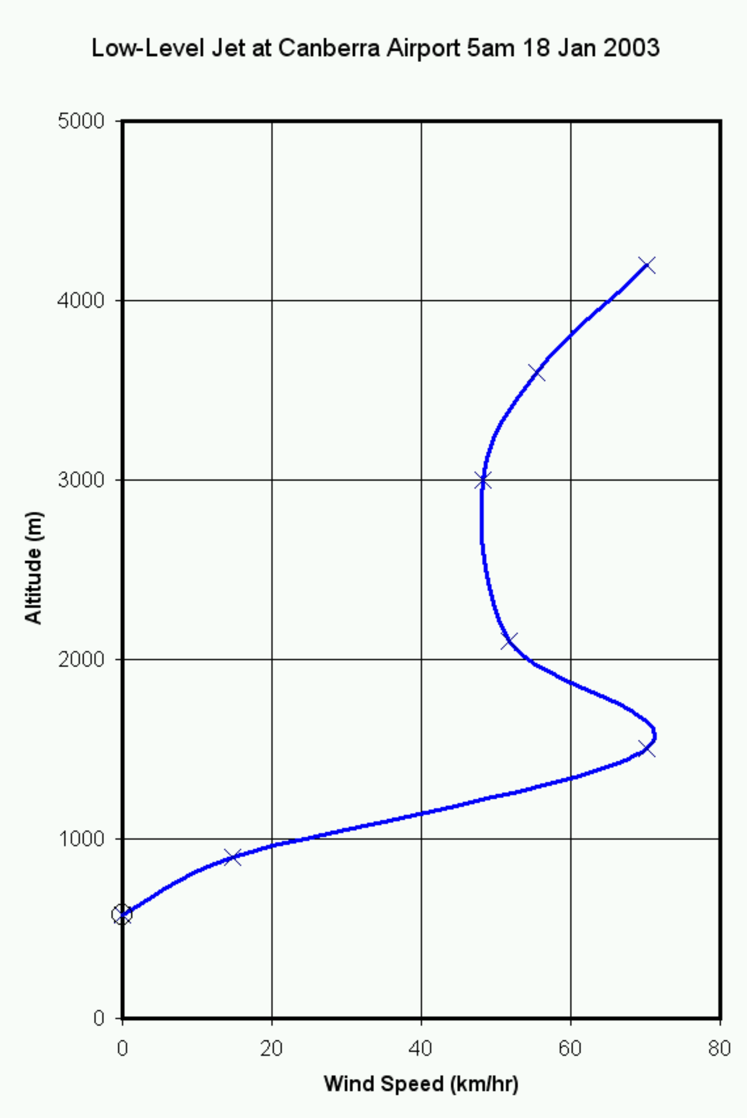
AIR OBSERVER:


[19]

This photo shows the effect of a low-level jet on a smoke plume. Note the extreme stretching, by the wind gradient, of the plume top on the left.

[19] Photo: Lannon Harley,
148.91° -35.32° looking SSE. 09:27 AEDST 18th January 2003.

SITUATION UNIT OFFICER:



[20]

The graph above shows a wind profile during a low-level jet event. Note the maximum wind speed at 1500m.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Low-Level Jet	3	?

[20] Data supplied by BoM.

PYRO-CONVECTION PHENOMENA

Event (14) Cloud Forms in convection column

AIR OBSERVER:


[21]

This photo shows a sylvicultural prescribed burn under way (hidden behind Mt Stromlo). A number of key points can be seen as the convection column rises above the fire.

1. The smoke initially rises and mixes with the surrounding air.
2. At the LCL, a cloud forms, but leaves behind a large fraction of the smoke. Note that the LCL there reflects the DP within the plume, which incorporates moisture generated during biomass combustion. In the photo the cloud base within the plume is thus well below that in the surrounding air.
3. The smoke spreads out in a layer at the LCL.
4. The pyro-Cu cloud rises for a considerable distance above the LCL.

[21] Photo: McRae.
149.07° -35.32° looking W. 15th May 2006, 14:00 AEST.

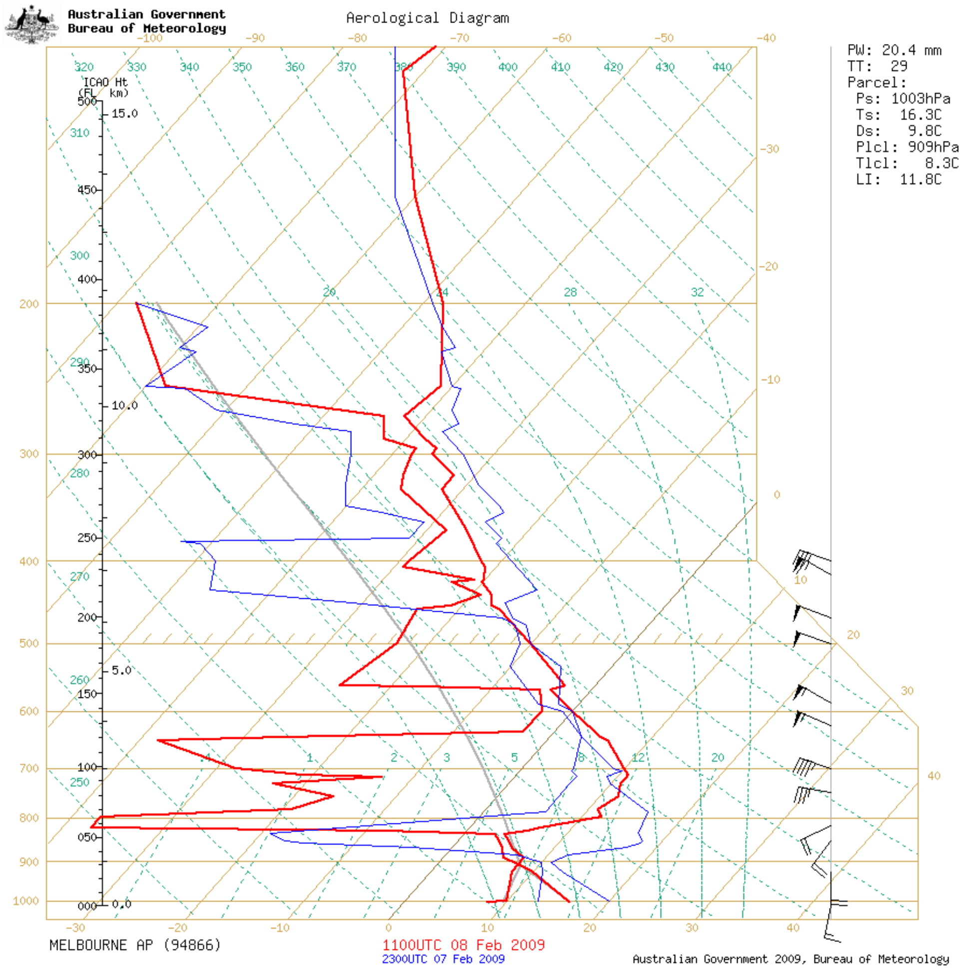
FIELD OBSERVER:

[22]

This photo shows cloud base over a slash burn. It indicates how the cloud base can be lowered over the convection column. While not a problem for a slash burn, in a wildfire it should be cause for further reconnaissance.

[22] Photo: McRae.
149.06° -35.33° looking NW and up. 12:38 AEST, 10th October 2002.

SITUATION UNIT OFFICER:



[23]

In this Aerological Diagram it is seen that the LCL is at 909hPa, or about 1km ASL. If enough heat was the plume it would punch through that and reach the major inversion at 840 hPa or 1.5km ASL. The amount of biomass being consumed (and thus moisture released) could not be directly assessed remotely. Satellite imagery would indicate cumulus formation potential.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Deep Flaming Zone	?	2) Conditions conducive to plume-driven fire
Violent Pyro-Convection	?	1) Plume-driven fire
Mountain Wind Waves	?	?

[23] BoM.

PYRO-CONVECTION PHENOMENA

Event (15) Cloud forms while convection column still resisting mixing.

AIR OBSERVER OR FIELD OBSERVER:


[24]

This photo shows a major pyro-Cu forming in the plume on the southern edge of the Stockyard Fire. A smoke ring is visible at the LCL, and smoke below that is dark coloured and dense. While the smoke plume is clearly wind-driven, the pyro-Cu exhibits strong vertical development above that.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Violent Pyro-Convection	2	1) Plume-driven fire

[24] Photo: NSW NPWS from Long Plain, Kosciuszko National Park. 148.7° -35.7°, looking E at about 14:00 AEDST 18th January 2003.

PYRO-CONVECTION PHENOMENA

Event (16) Cloud in convection column collapses

AIR OBSERVER:

[25]

Collapse of a towering pyro-Cu cloud. The photos were taken from the NSWRFS linescan aircraft at FL70 and show three views of a distinct convective event that formed over the Flea Creek Fire while that fire was in its early stages of escalation. The views are (A) at 15:04:21 with an apparent height of at least 9 km; (B) the cell dropping (top left) at 15:05:31 to 7 km; and (C) the cell has dropped to 4 km above ground and lost its cloud (just above photo centre) at 15:06:44. Analysis of these photos suggests that a cloud of volume c. 50 km^3 descended at over 150 km/hr. The impact the resultant downburst on fire behaviour would be spectacular – but in this case was unobserved. Note the upwards movement of a large cell in the background, at similar speeds.

[25] Photography: Air Target Services, Pty Ltd.
148.71° -35.43° looking NE at about 15:40 AEDST 18th January 2003.

FIELD OBSERVER:

[26]

This photo shows key features of the collapse of a pyro-Cu.
From time-to-time variations in the fire's intensity remove the buoyancy driving the pyro-Cu's development, and it partially collapses. The same effect can occur if winds aloft push the pyro-Cu away from its heat source. The collapse leaves behind residual smoke above the LCL, visible above and to the right, reflecting upper winds. A cloud remnant (pyro-fractocumulus) is seen surrounded by a halo of its smoke.
Analysis of a photo sequence shows that this was a cloud tower 2.5 minutes previously, indicating a descent velocity of the order of 50km/hr.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Deep Flaming Zone	?	2) Conditions conducive to plume-driven fire
Wind Change at Fire	?	5) Wind change

[26] Photo: McRae.
149.07° -35.32° looking W at about 14:00 AEST 15th May 2006.

PYRO-CONVECTION PHENOMENA

Event (17) Cloud in convection column attains cauliflower texture

AIR OBSERVER:


[27]

In this photo, taken from linescanning aircraft at FL70, a violent pyro-convective event is seen. The plume in the centre of the image has the "cauliflower" texture that is diagnostic of violent pyro-convection. Note also the layer of dense smoke, which has separated out at the LCL.

Above the LCL, the latent heat of condensation released can contribute up to three times the energy of the fire. The expansion of the plume here is so vigorous that it is resisting mixing with the surrounding air. Below the LCL, there is usually so much smoke that it is difficult to see a clear pattern.

[27] Photo: Target Air Services Pty Ltd. Over Uriarra area.
148.7° -35.4° looking E. at about 15:30 AEDST 18th January 2003.

FIELD OBSERVER:

[28]

When pyro-Cbs are created the view from afar is often the clearest. Above the smoke layer at the LCL, the cauliflower texture is clear even from 60km distance. This photo, from a helicopter near Tumut, looking towards Canberra, is the upwind face of the plume. An anvil may be just seen moving downwind away from the camera.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Violent Pyro-Convection	1	1) Plume-driven fire

[28] Photo: Stephen Wilkes, Air Observer.
148.5° -35.3° looking E at 15:50 AEDST 18th January 2003.

PYRO-CONVECTION PHENOMENA

Event (18) Cloud in convection column forms an anvil

AIR OBSERVER OR FIELD OBSERVER:

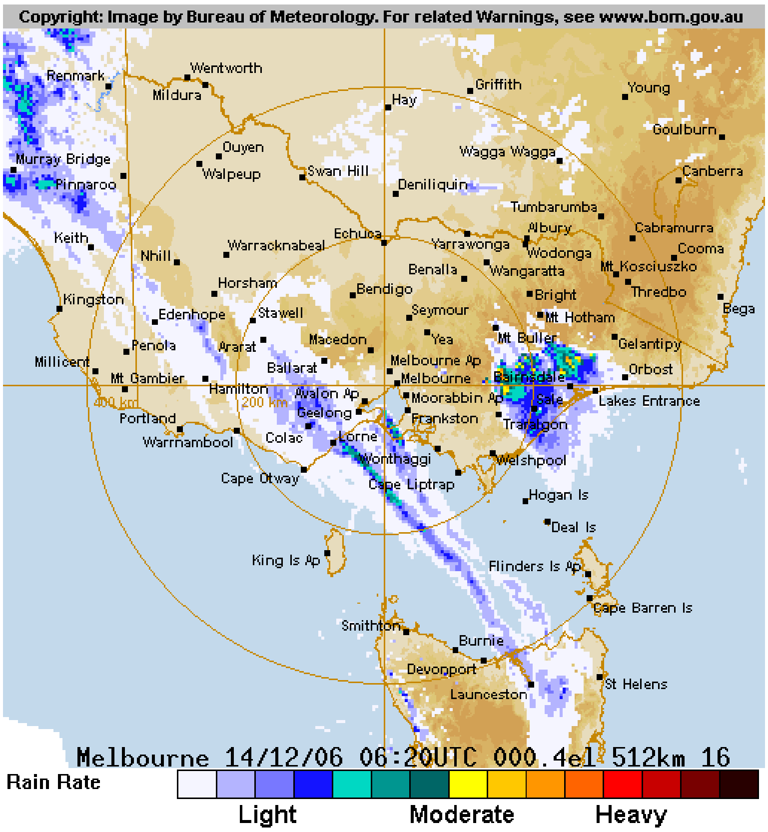

[29]


[30]

The upper photo shows an anvil (*incus*) forming in a smoke plume, seen from a distance of 80km. The lower photo shows detail of *mammatus* forming on the underside of the anvil.

[29] Photo: McRae. View of Billo Road Fire, 15:30 AEDST 11 December 2006.
[30] Photo: McRae. View of Billo Road Fire, 15:30 AEDST 11 December 2006. 149.07° -35.32° looking W.

SITUATION UNIT OFFICER:



[31]

This image shows a major event underway. A large wildfire complex is burning in the Victorian high country, and a cold front is approaching from the west, as shown by the NW-SE oriented cloud band. Three anvils are seen in the radar, to the NE of Traralgon.

IMPLICATIONS:

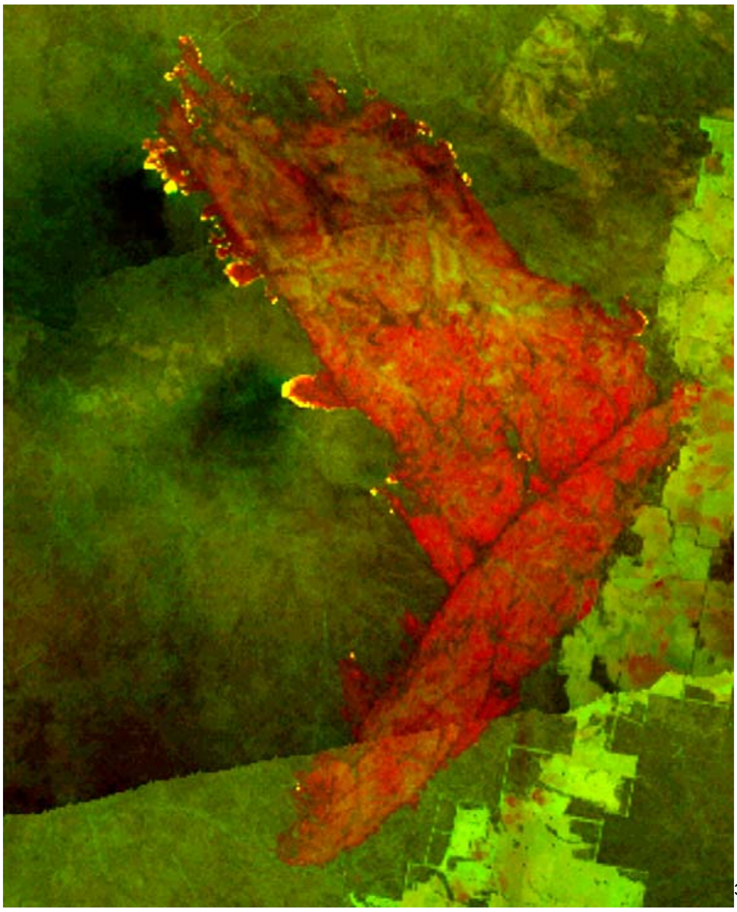
PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Violent Pyro-Convection	1	1) Plume-driven fire

[31] BoM Melbourne Weather Watch Radar image from 5:20pm AEDST 14 December 2006.

WIND CHANGE PHENOMENA

Event (19) Flank becomes headfire

AIR OBSERVER & FIELD OBSERVER:


[32]

This image shows the eastern fire of the Pilliga Complex 30 November 2006 at noon. After long, narrow run to the NE, it has been hit by a SE wind change, and run for a similar distance in the new direction before decaying into fingers. Note the automatic headfire widening after the wind change. Note also some minor flank outbreaks near the origin.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Dynamic Channelling	?	6) Channelling event
Deep Flaming Zone	?	2) Conditions conducive to plume-driven fire
Wind Change at Fire	1	5) Wind change
Convergence Zone	?	?

[32] Image: Daedalus linescan, NSWRFS & Air Target Services Pty Ltd.

WIND CHANGE PHENOMENA

Event (20) Two convection columns converge

AIR OBSERVER:

FIELD OBSERVER:

[33]

This photo shows two major smoke plumes converging. It is taken from downwind. Not the bend in the right-hand plume, where it is clearly being drawn towards the other, larger plume. There is an obvious blue-sky gap between the two plumes.
The photographer, along with a number of other firefighters, was forced to take shelter during a burnover situation that closely followed this observation.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Deep Flaming Zone	?	2) Conditions conducive to plume-driven fire
Wind Change at Fire	?	5) Wind change
Convergence Zone	3	?

[33] Photo: Kaz Gorrie.
148.96° -35.33° looking NW at 10:30 AEDST, 18th January 2003.

WIND CHANGE PHENOMENA

Event (21) Convection column changes direction as it rises

AIR OBSERVER OR FIELD OBSERVER:

Smoke from a bushfire near Mirboo North in the south Gippsland area of Victoria billows skyward. (User submitted: Wayne Cornelius) (ABC) [34]

This photo shows a major smoke plume in the 2009 Black Saturday events. Up to around 2.5km AGL the smoke is moving right-to-left, above that it is moving left-to-right.
The inferrence is that the upper flow is in the pre-frontal continental air mass (NW), while the lower flow is in the post-frontal maritime air mass (SW).
While this particular event was expected, it clearly demonstrates a pattern that observers must watch for. The timing of arrival of wind changes has been a long-term concern and basis for research. However accurate wind change prediction may become, actual observations of the arrival remain critical for safety.

IMPLICATIONS:

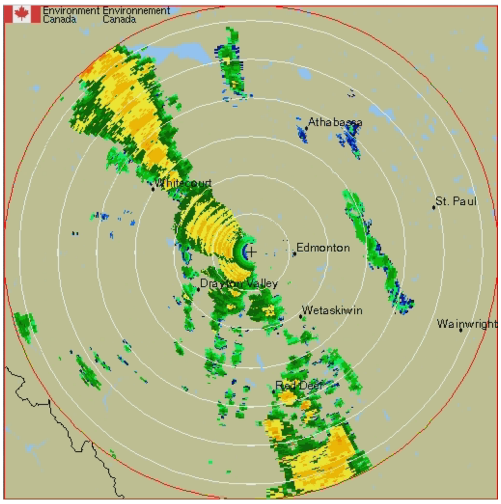
PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Wind Change at Fire	?	5) Wind change

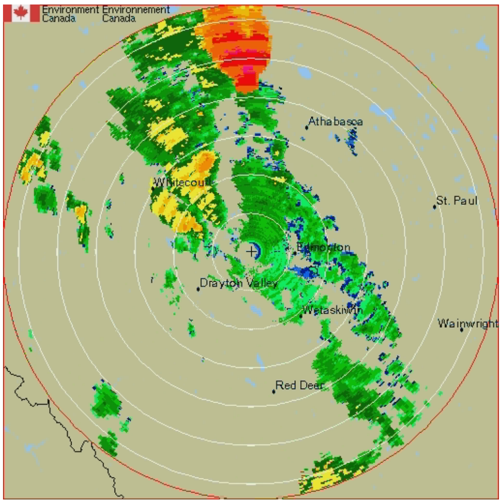
[34] Photo from ABC News website, submitted by Wayne Cornelius.
146.2 -38.4 looking E. 7th February 2009.

WIND CHANGE PHENOMENA

Event (22) Thunderstorm(s) approach fire

AIR OBSERVER OR FIELD OBSERVER:



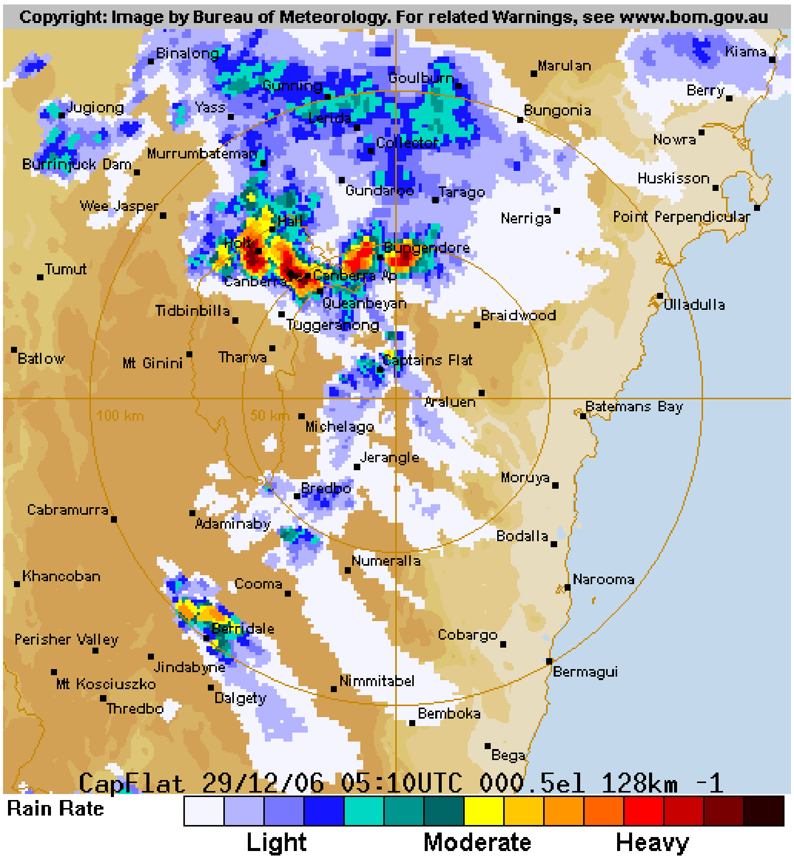


These images are radar plots of the Chisholm Fire in Alberta, Canada on 28th May 2001 (from 23:20 UTC and 02:10 UTC respectively). In these the fire is seen burning in the top centre, and a diagonal band of storms is approaching from the south. The explosive growth of the fire plume as the cloudband arrives is clearly seen. This fire is the most powerful ever recorded.

Many believe, correctly, that thunderstorms cause problems as a result of the local air flows that they generate. We now know that, additionally, a band of instability - made visible by the thunderstorms that it causes - can drive drive catastrophic fire escalation. It is aslo clear that under other conditions there may be no storms present as visible markers.

Observers should learn to scan the horizon for approaching bands of storm cells. Stationary storms that develop over high ground may be due to convective heating, and are not relevant here.

Situation Unit Officer:



[35]

This image is from the BoM Weather Watch radar at Captains Flat. It shows how thunderstorm activity can be ordered into bands that may move across the region. In this instance an E-W bands of intense cells was moving to the south, while a NE-SW oriented bands was forming on a sea breeze front moving slowly to the west. All anvils are showing that upper winds are NW.
Complex patterns like these can be a challenge for fire IMTs.
The web tools provided by BoM should be used to estimate arrival times. Care should be taken to account for storm cell life-cycles. Also a watch for pyro-Cbs is essential, as the instability needed is guaranteed if there are already Cbs in the region.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Deep Flaming Zone	?	2) Conditions conducive to plume-driven fire
Wind change at fire	?	4) Thunderstorm 5) Wind change

[35] Image from BoM

VORTEX PHENOMENA

Event (23) Tornado (attached to base of cloud)

AIR OBSERVER OR FIELD OBSERVER:


[36]

This photo shows a remarkable close-up of an F2 tornado generated by a violent pyro-Cb event. Note the intensity of fire activity close to the base of the tornado, where evidence suggested wind speeds in excess of 200 km/hr.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Violent Pyro-Convection	2	1) Plume-driven fire

[36] Photo: Still from a video taken by Tom Bates in Kambah.
149.06° -35.38° looking NW. 15:30 AEDST on 18th January, 2003.

VORTEX PHENOMENA

Event (24) Fire whirl (attached to ground)

AIR OBSERVER OR FIELD OBSERVER:


[37]

The photo shows a fuel reduction burn west of Mount Stromlo reaching the crest of a hill and spawning a large fire whirl. Note the base of the whirl, where large flames are visible and other smoke plumes are becoming entrained.

IMPLICATIONS:

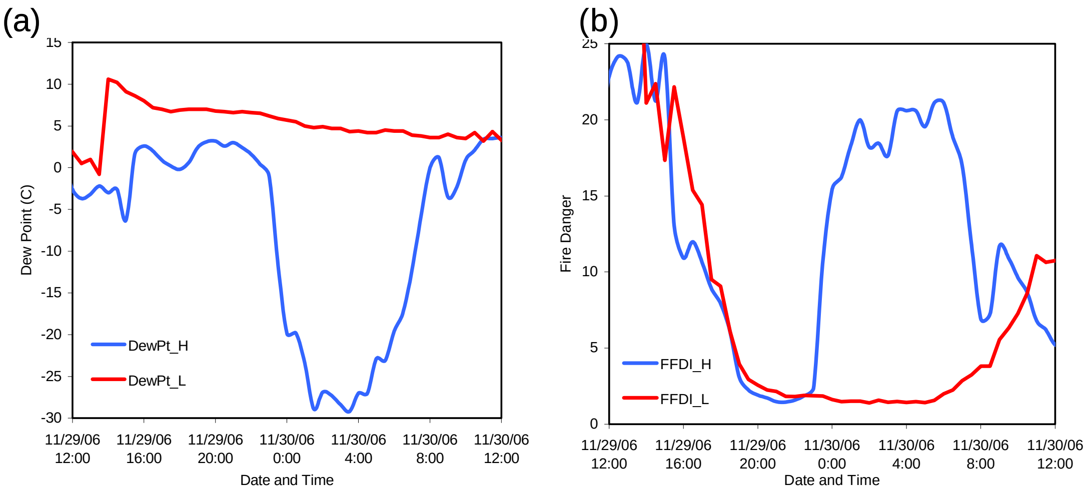
PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Deep Flaming Zone	?	2) Conditions conducive to plume-driven fire

[37] Photo: McRae.
149°00 -35.30° looking SSE at 14:36 AEST 18th May 2006.

NON-DIURNAL WEATHER PHENOMENA

Event (25) Fall in DP in second half of night at high altitudes

FIELD OBSERVER OR SITUATION UNIT OFFICER:



(a) Dew point at Mt Ginini (blue) and Canberra (red). (b) corresponding forest fire danger at Mt Ginini (blue) and Canberra (red).

On one night in seven, on average, an event like this will occur in parts of the high country. The graphs compare conditions at an alpine site and a lowland site. The latter shows a typical diurnal cycle, while the former occasionally does. However, a strong anomaly is evident between 00:00 and 04:00 on 30/11/06. This causes a major spike in FFDI, of concern to crew leaders involved in tasks such as overnight burn-outs.

Detection of such events relies on access to AWS data or to data from hand-held instruments.

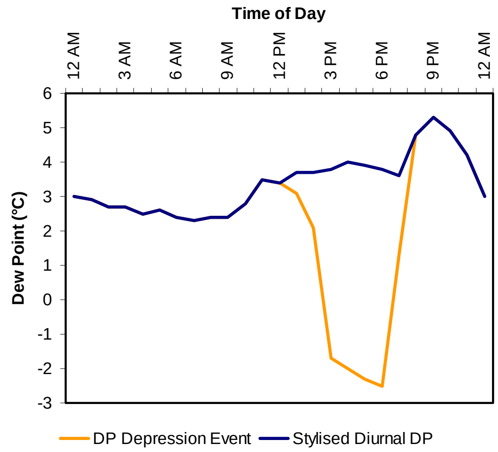
IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Nocturnal DP Depression Event	3	7) Dew point depression event

NON-DIURNAL WEATHER PHENOMENA

Event (26) Sudden non-diurnal fall in DP mid-afternoon

FIELD OBSERVER OR SITUATION UNIT OFFICER:



The graph above shows a stylised DP depression event, and compares a typical diurnal trace with that of a typical event.
Detection of such events relies on access to AWS data or to data from hand-held instruments. Observations must be on a regular basis to detect these events.
In general these are due to the advection of dry upper air over the site, and are not accompanied by changes in wind direction, and even the temperature trends may continue on the diurnal cycle.

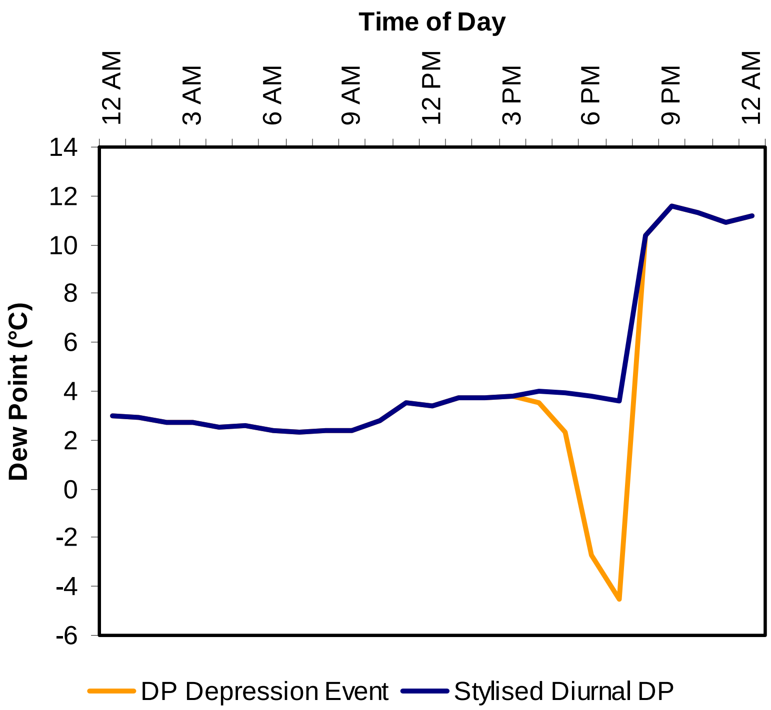
IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Abrupt Surface Drying	2	3) Passage of dry slot over fire 7) Dew point depression event

NON-DIURNAL WEATHER PHENOMENA

Event (27) Sudden non-diurnal fall in DP ahead of sea-breeze front

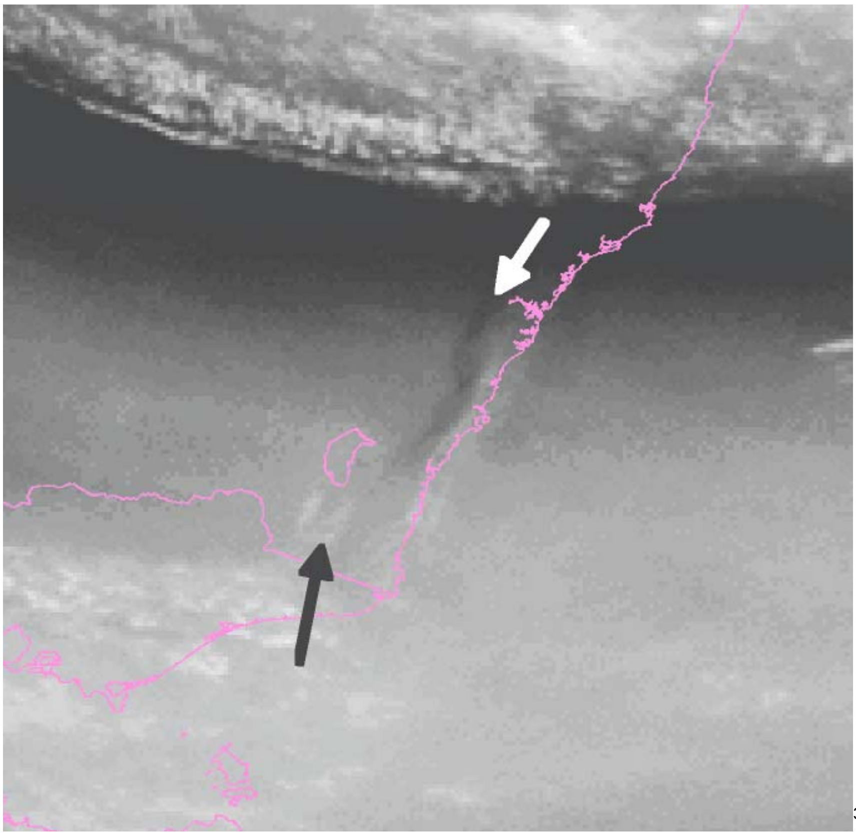
FIELD OBSERVER:



The graph above shows a stylised DP depression event, and compares a typical diurnal trace that includes a sea breeze arrival with that of a typical event.

Detection of such events relies on access to AWS data or to data from hand-held instruments.

SITUATION UNIT OFFICER:


[38]

This graphic shows a “dry slot” or abrupt surface drying event moving inland ahead of a sea breeze front. The dry air shows up as a dark stripe on water vapour imagery such as this. Reference to AWS Data, visual imagery or infrared imagery would confirm the presence of a sea breeze.
Examniation of AWS data may confirm the DP drop-out.

IMPLICATIONS:

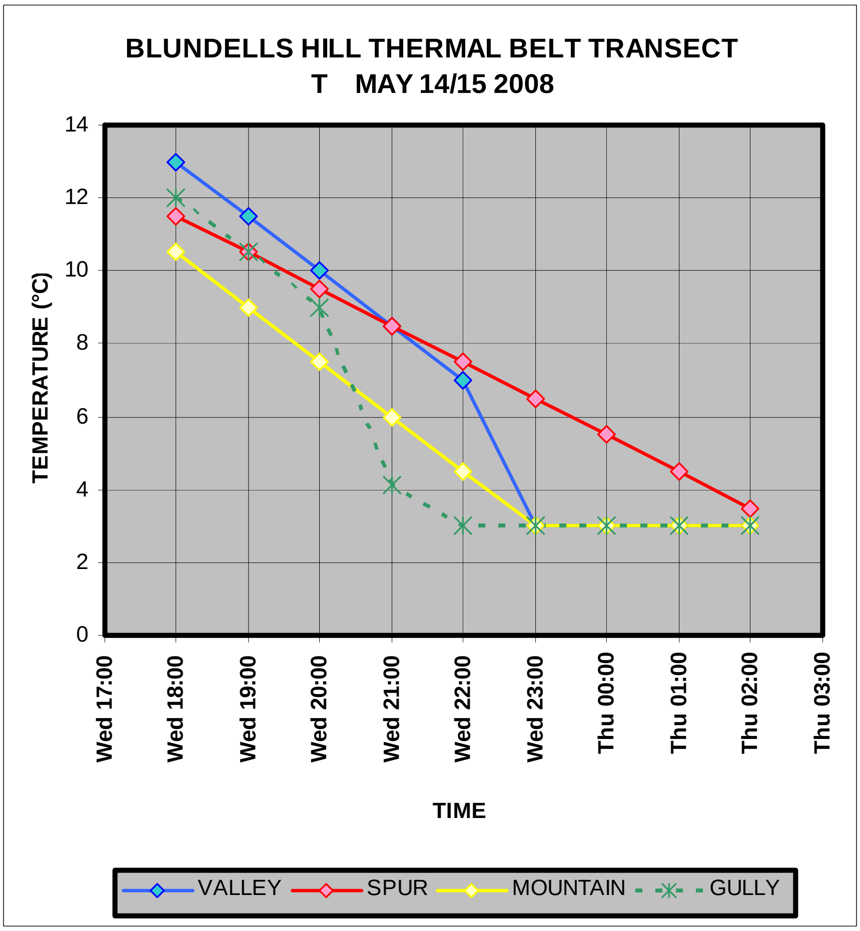
PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Abrupt Surface Drying	2	3) Passage of dry slot over fire 7) Dew point depression event

[38] BoM

NON-DIURNAL WEATHER PHENOMENA

Event (28) Clear night, continental air mass

FIELD OBSERVER OR SITUATION UNIT OFFICER:



[39]

This graph shows a model of the formation of a thermal belt in a mountain valley west of Canberra. The curves fitted to observational data taken on representative places in the landform.
The key point is that late in the night, even though the spurs are cooling, they become the warmest parts of the landscape.
Corresponding models for DP and FFDI show that the spurs can support unexpectedly high fire behaviour. Note that base camps and observation sites are rarely placed on spurs. The thermal belt may be missed unless deliberate observations are made.
Observers should note the clear skies, light winds and a continental air mass are considered prerequisites for a thermal belt to develop.

IMPLICATIONS:

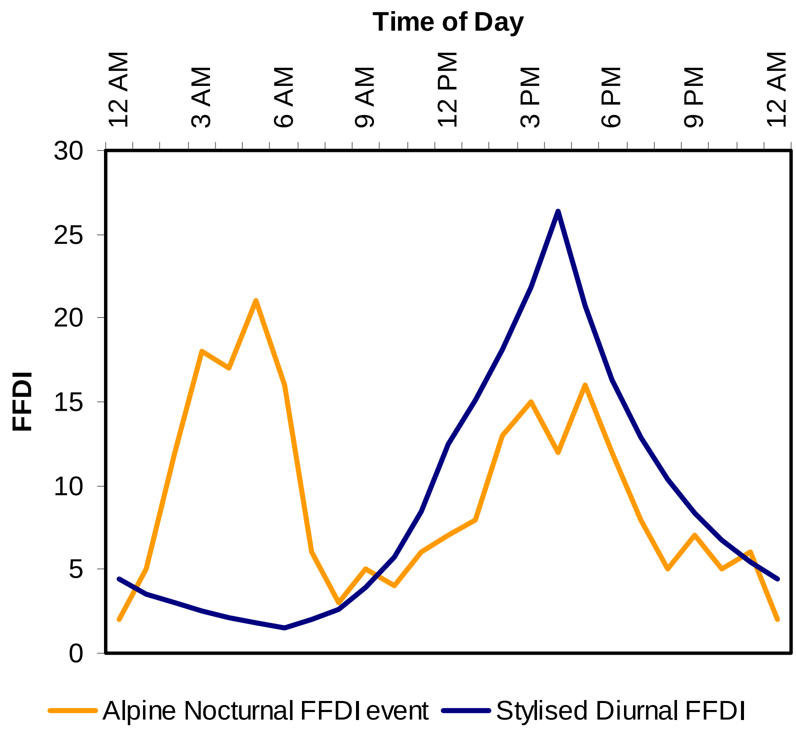
PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Thermal Belt	3	- - -

[39] Data from HighFire Risk experimental work. Note that no observation were below 3°C, the then current DP.

NON-DIURNAL WEATHER PHENOMENA

Event (29) Non-diurnal overnight escalation of fire behaviour, not linked to wind

FIELD OBSERVER:



The graph above compares a stylised diurnal cycle for FFDI with a typical noctural FFDI escalation event. This is typically related to a fall in DP between midnight and sunrise, arising from events such as subsidence inversions or low-level jets. These events tend to affect sites over 1500m elevation, and may be spatially discontinuous. Careful observation is thus essential. Note the rapid onset after midnight.
Detection of such events relies on access to AWS data or to data from hand-held instruments. Note that readings must be taken regular, otherwise the onset may be missed.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Nocturnal DP Depression Event	3	7) Dew point depression event
Thermal Belt	?	- - -

UNUSUAL COMBUSTION PHENOMENA

Event (30) Burnt area reburns as a crown fire or similar

FIELD OBSERVER:

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Violent Pyro-Convection	?	1) Plume-driven fire
Eruptive Fire Growth	2	?

UNUSUAL COMBUSTION PHENOMENA

Event (31) Fire continues to accelerate up a canyon or gully

AIR OBSERVER:

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Eruptive Fire Growth	?	2) Conditions conducive to plume-driven fire

UNUSUAL COMBUSTION PHENOMENA

Event (32) Elongated flames stay underneath canopy on steep slope

AIR OBSERVER:


[40]

This photo shows flames being entrained onto the slope to the west of Mount Franklin. The forest is a thirty-metre high Mountain Gum mixed montane type. The slope is a minimum of 35°. In this example of the Trench Effect, the flames run for a considerable distance upslope before any smoke or flames breech the canopy. The effect can occur if the slope exceeds 27°.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING
Eruptive Fire Growth	?	9) Unusual combustion

Eruptive fire growth is a known fire crew killer. Any crews operating between the fire and the top of the ridge are at risk. Air Observers should initially liaise directly with Sector Leaders to ensure crew safety.

[40] Photo: Stephen Wilkes.
148.76° -35.48° looking S at about 1500 AEDST 18 January 2003.

UNUSUAL COMBUSTION PHENOMENA

Event (33) Ember storm

FIELD OBSERVER:


[41]

These photos of Eucumbene Drive Duffy, stills from a TV news video, show a spectacular ember storm in progress. Gale force winds are causing embers to be pulled off burning pine slash. These are then blowing downwind following ballistic trajectories. Their weight is keeping them low to the ground, but it is suspected that frequent collisions have made them electrically charged. Charge repulsion might be responsible for keeping the layer elevated to about one metre off the ground. Any vertical object within that zone is heavily affected by ember attack.
While the observer is not threatened by the ember storm, great care is needed to monitor threats to safety from the fire event upwind.

IMPLICATIONS:

PHENOMENON	URGENCY	INDICATED RED FLAG WARNING INDICATED RED FLAG WARNING
Dynamic channelling	2	6) Channelling event
Violent pyro-convection	1	1) Plume-driven fire

[41] Photo from WIN TV News footage.
149.03° 35.33° looking N at about 16:00 AEDST, 18th January 2003.

RESOURCES

Sharples, J.J. (2009) An overview of mountain meteorological effects relevant to fire behaviour and bushfire risk. *International Journal of Wildland Fire*, in press.

PLUME-DRIVEN FIRE

Fromm, M., Tupper, A., Rosenfeld, D., Servranckx, R. & McRae, R. (2006). Violent pyro-convective storm devastates Australia's capital and pollutes the stratosphere, *Geophysical Research Letters,* Vol. **33**, L05815, doi:10.1029/2005GL025161

CONDITIONS CONDUCIVE TO PLUME-DRIVEN FIRE

Weber, R.O. & Dold, J.W. (2006). Linking landscape fires and local meteorology – a short review. *Japan Society of Mechanical Engineers International Journal* Series **B**, Vol. **49**, No **3**, 590-593.

PASSAGE OF DRY SLOT OVER FIRE

Mills, G.A. (2005) On the sub-synoptic scale meteorology of two extreme fire weather days during the Eastern Australian fires of January 2003. *Australian Meteorological Magazine* **V54**, pp: 265-290.

Mills, G.A. (2007). On easterly changes over elevated terrain in Australia's southeast. *Aust. Met. Mag.* **56**: 177-190.

THUNDERSTORM

WIND CHANGE

Sharples, J.J., McRae, R.H.D., Weber, R.O. (2009) Wind characteristics over complex terrain with implications for bushfire risk management. To be submitted to *Agricultural and Forest Meteorology*.

Sharples, J.J., R.H.D. McRae, and R.O. Weber (2009). An empirical probabilistic study of wind direction over complex terrain. In Anderssen, R.S., R.D. Braddock and L.T.H. Newham (eds) 18th World IMACS Congress and MODSIM09 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand and International Association for Mathematics and Computers in Simulation, July 2009, pp. 4446-4452. ISBN: 978-0-9758400-7-8.

CHANNELLING EVENT

DEW POINT DEPRESSION EVENT

Sharples, J.J., McRae, R.H.D., Weber, R.O. & Gill, A.M. (2008). A simple index for assessing fuel moisture content, *Environ. Model. Softw.*, doi:10.1016/j.envsoft.2008.10.012

FOEHN WIND

Sharples, J.J., Mills, G.A., McRae, R.H.D. & Weber, R.O. (Submitted). Elevated fire danger conditions associated with foehn-like winds in southeastern Australia. Submitted to *Journal of Applied Meteorology and Climatology*.

Sharples, J.J., G.A. Mills, R.H.D. McRae, and R.O. Weber (2009). Fire danger anomalies associated with foehn-like winds in southeastern Australia. In Anderssen, R.S., R.D. Braddock and L.T.H. Newham (eds) *18th World IMACS Congress and MODSIM09 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand and International Association for Mathematics and Computers in Simulation*, July 2009, pp. 268-274. ISBN: 978-0-9758400-7-8.

UNUSUAL COMBUSTION

Dold, J, Weber, R, Gill, M, Ellis, P, McRae, R & Cooper, N. (2005). Unusual Phenomena in an Extreme Bushfire. *5th Asia-Pacific Conference on Combustion*, The University of Adelaide.

INTENSE SPOTTING

McRae, R.H.D., Sharples, J.J., Mills, G.A. & Weber, R.O. (In prepn). The thermal belt in an Australian bushfire context.

Sharples, J.J., McRae, R.H.D., Weber, R.O., Gill, A.M. (2009a) A simple index for assessing fuel moisture content. *Environmental Modelling and Software* doi:10.1016/j.envsoft.2008.10.012 (online publication: 2 Dec 2008)

Sharples, J.J., McRae, R.H.D., Weber, R.O., Gill, A.M. (2009b) A simple index for assessing fire danger rating. *Environmental Modelling and Software* doi:10.1016/j.envsoft.2008.11.004 (online publication: 20 Dec 2008)