SCIENCE OF THE 2003 CANBERRA WILDFIRES

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UNSW Canberra
January, 2023.

Contents

PREAMBLE

As the Planning Officer in the Incident Management Team, I earned a number of years working with lawyers as the Coronial Enquiry rolled out. This incredibly adversarial inquest earned many lawyers a lot of money at the tax-payers expanse. Along the way were some highlights, such as this exchange:

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MR CRADDOCK: I object. We have been over and 20 over this.
THE CORONER: That is right. We want an answer. We haven't had
an answer. Don't throw your pen down, Mr Craddock. You did that
yesterday, and I am not going to tolerate it. Don't throw your
pen down in this court.
MR CRADDOCK: I didn't do it yesterday.
THE CORONER: You did. You threw your pen down.
I said to you the reason this question has been repeated, Mr
Craddock, is because it hasn't been answered.
MR CRADDOCK: That is not so, your Worship.
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"Crash" Craddock was my representative, and a very useful one.

Another highlight was a debate about the phrase "cause and origin" – is it two terms or is it one (an "*endiadis*")? A whole day in court from that one. I also got to think about the application of the Magna Carta in the workplace – not many get to do that.

While these shenanigans were going on, the scientists got up to speed. For a start, they need the data, and some of that was sequestered away by lawyers. Ultimately the science was critical.

It painted an entirely different picture of events.

McRae, R. (2011). Learning, Improving, Blaming: Science and Bushfires. Fire Australia, Spring, 2011, 48-50.

There was a conference paper given to an Australian Bushfire Research Conference in Adelaide not long after the fires. In it I started the understanding of what is now called VLS and is the most effective cause of catastrophic fire escalation in rugged landforms globally. That it had not been discovered previously speaks to the usefulness of multispectral linescans being flown over fires.

McRae, R. (2004). Breath of the dragon – observations of the January 2003 ACT Bushfires. Bushfire 2004 Conference, Adelaide.

This review does not aim to present the science, rather it gives an overview of the links between operations and the science.

There is so much to cover. I may update this report from time-to-time.

8 JANUARY 2003

This material was gathered during the fires by Rick McRae, then with the ACT Emergency Services Bureau.

The view from the north-west corner of Black Mountain. LEFT: 8 January 2003, with the dust storm obscuring any view of the ranges in the distance. The tree canopy is very thin due to the lead-up conditions. RIGHT: 7 January 2023, showing a clearer sky and a healthier forest.

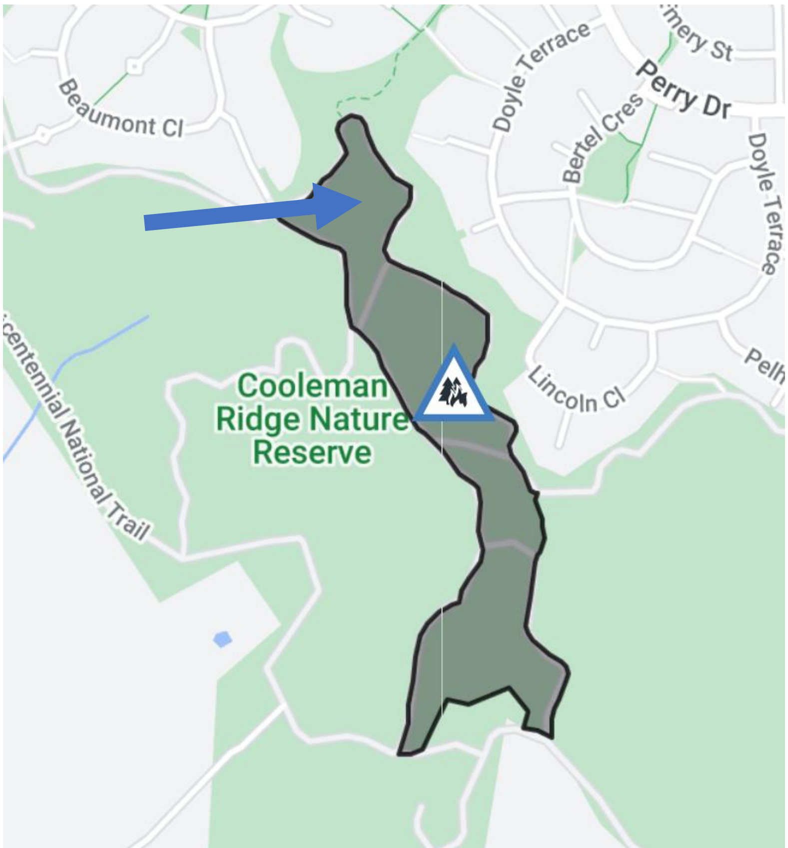
ABOVE: There was widespread arson in early January 2003 on that part of Black Mountain. It was fortunate that no fires arose from this during the bad fire danger days.

ABOVE: 8 January 2003: Understorey on Black Mountain, showing the effects of lead-up conditions.

BELOW: 7 January 2023: Understorey in a wet summer.

ABOVE: Helicopter view of a fire on Cooleman Ridge on 6 January 2003. This area was hot by the fire tornado 12 days later.

BELOW: In a nice irony, the first application of fire on Cooleman Ridge for some years was on 8 January 2023, adjacent to the 2003 fire seen above (blue arrow).



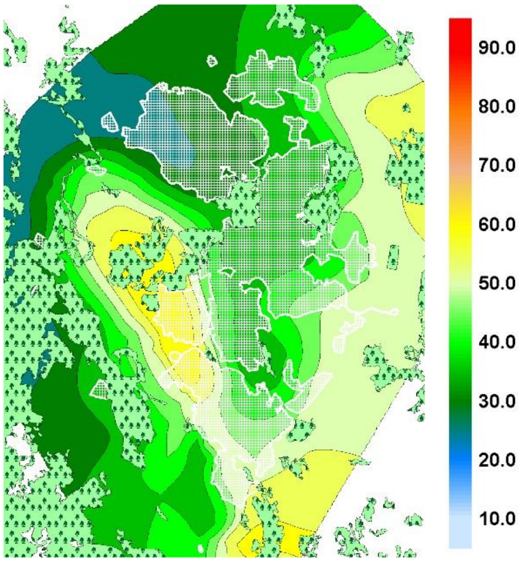
BELOW: The helicopter trip was to use an electronic fuel moisture meter to assess fuel flammability in the high country. The results, a day after a thunderstorm, showed that the underlying drought level was high.

A series of papers (not linked to the 2003 fires) have explored a simple fire danger index. The basic form is the fire danger is, simply, proportional to wind speed divided by fuel moisture content. Further FMC is ten minus a quarter of the difference between temperature and relative humidity, with a correction for Drought Factor (multiply by seven and divide by the actual DF). This is not the complex formula often used.

The end result is that you can go into the field and measure the FMC, T & RH. The only unknown, DF, can then be estimated.

LEFT: Applying the technique near the Cradle Mountain (Tasmania) wildfires, February 2016.

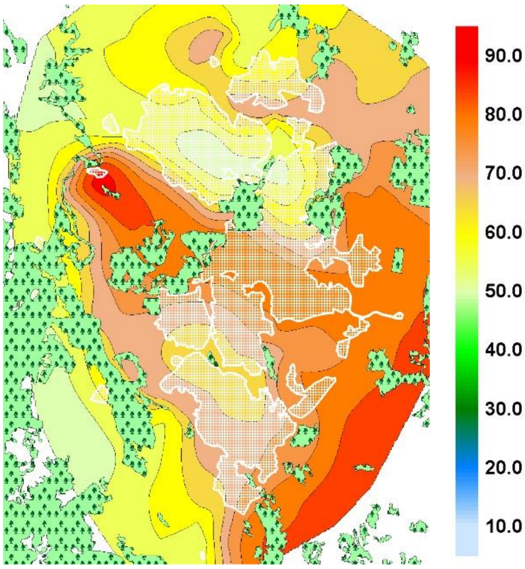
Due to a range of issues the “official” DF values did not match what the fires were doing. Field data allowed a critical re-calibration of Fire Danger Indices.



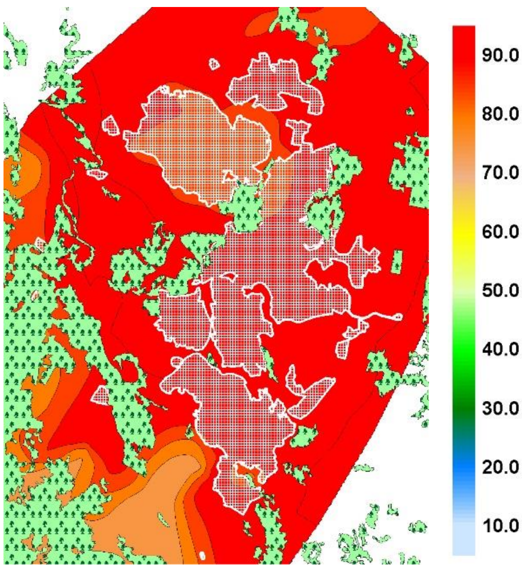
29 October 2002: Grassland curing around Canberra. The change from this point, over the next three weeks was and still is unprecedented.

The scale is curing in percent. At 0% the grass is green and non-flammable. Above 60% some flammability occurs. At 100% it is fully flammable.

This change coincides with the spike in drought level seen below.



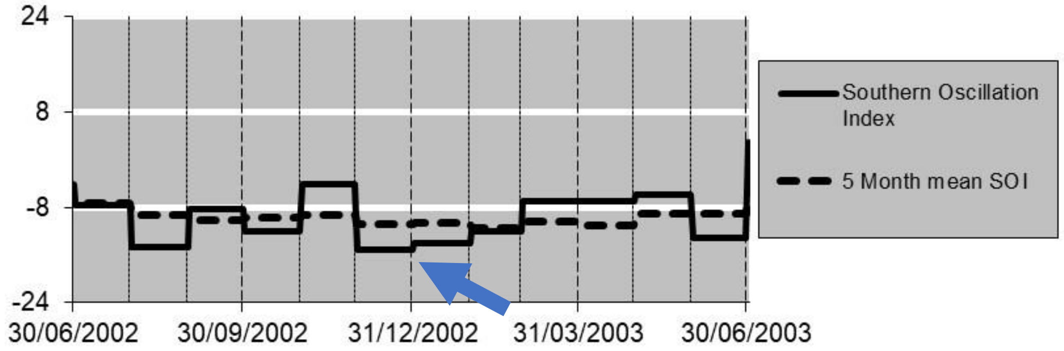
6 November 2002



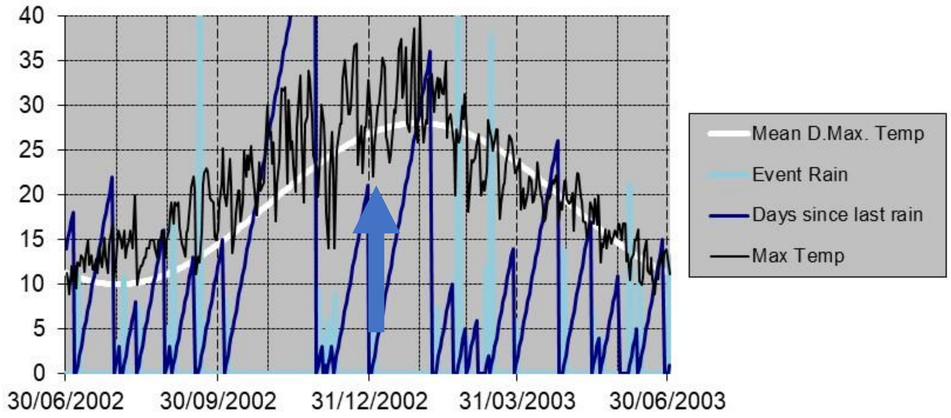
18 November 2002: The entire landscape is now flammable.

Change like this normally takes around 2 months.

The mapped data are from field surveys.



ABOVE: The Southern Oscillation Index clearly showed the impact of a long-running El Nino (shown by SOI below -8). The blue arrow points to 8 January.

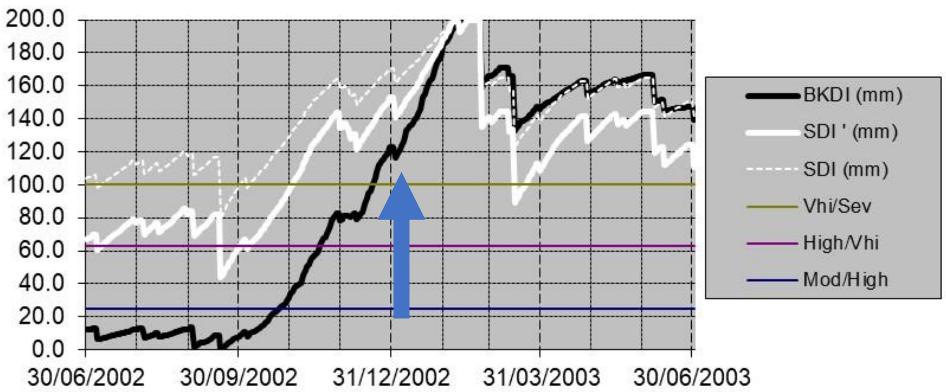


ABOVE: Bureau of Meteorology weather observations from Canberra Airport showed that:

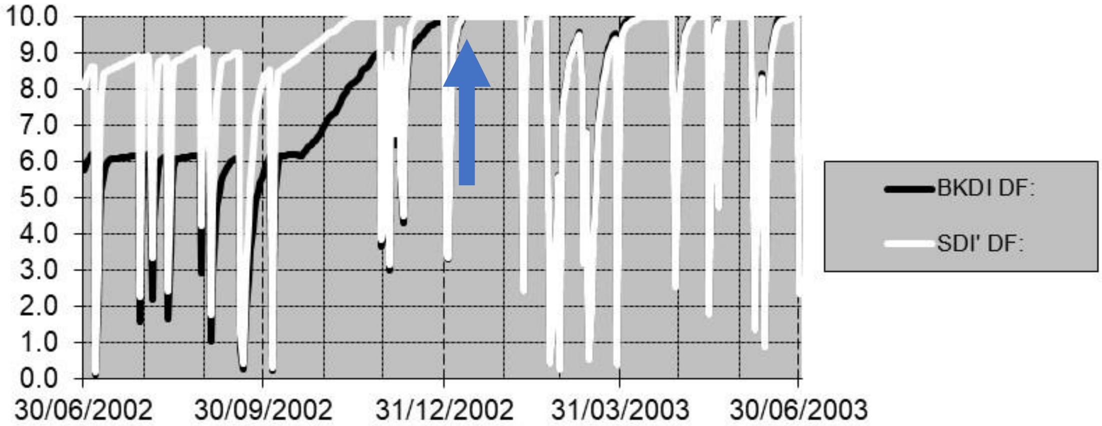
* Temperatures were running well above normal since July.

* There had been a major run without rainfall in October.

(It turned out that a second dry run had started.)



ABOVE: The drought Indices were all trending up from a low start in September, eventually maxing out. 0mm means very wet soil surface, 200mm means extremely dry soil surface.



ABOVE: The Drought Factor derived from the Drought Indices. Zero means wet surface fuels and no flammability, 10 means fully flammable surface fuels. Problems arise with DF exceeds 6. Forest Fire Danger is directly proportional to DF. Note the short relief from storms in early January.

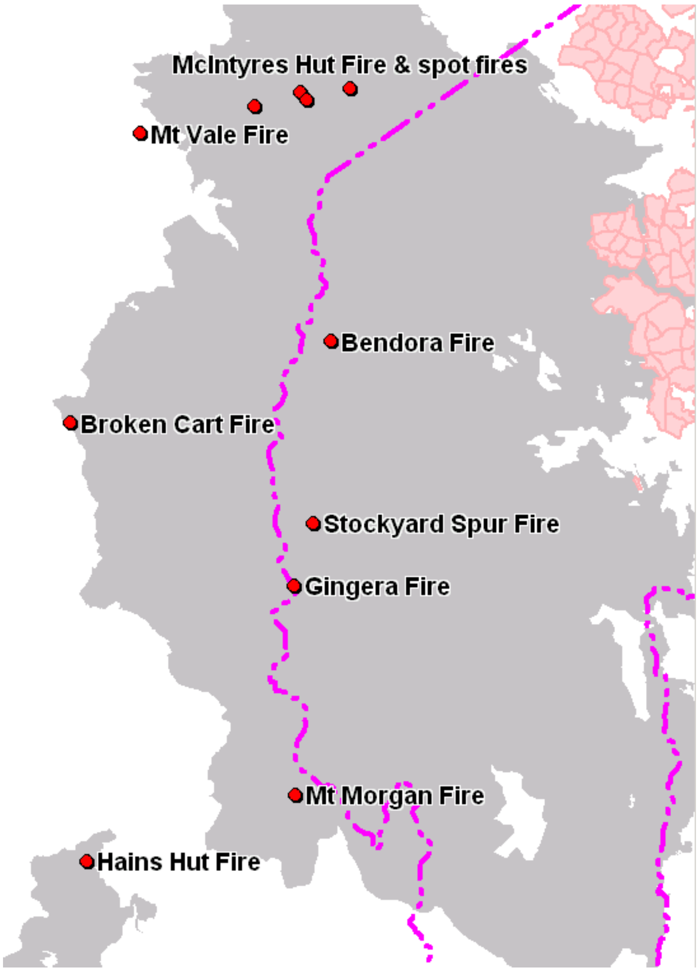
ABOVE: The drought severity is obvious in the low storage levels of Corin Dam, 6 January 2003.

THEN….

9 JANUARY 2003

This material was gathered during the fires by Rick McRae, then with the ACT Emergency Services Bureau.

It was critical that a full assessment of the situation was conducted.



ABOVE: This map shows the fire ignitions as assessed on the morning of 9 January.

From the helicopter, I took the photos below and made the assessments provided.

MT VALE FIRE, NSW

The Mt Vale Fire in the Brindabella Valley in NSW. This fire had containment lines around it and was quickly suppressed.

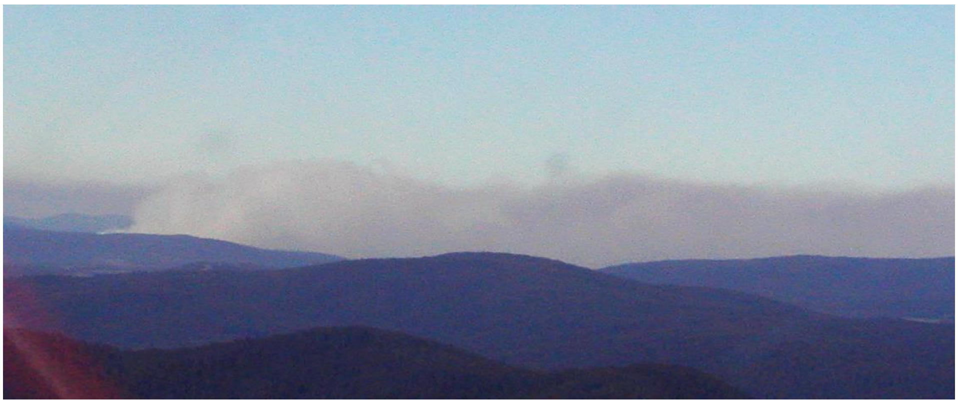
STOCKYARD SPUR FIRE, ACT

ABOVE and BELOW: The Stockyard Spur fire, covering 8ha, 18 hours after its ignition.

ASSESSMENT

FIRE #4 ACT	STOCKYARD SPUR FIRE @ GR 635 652; elevation: 1480 m
FUEL	Mixed forest
TERRAIN	Ridgeline
SIZE	8 ha growing
ACCESS	Dormant trail by foot
BEHAVIOUR	Backing, 0.5 m flames. 1 m on W flank. Escalating
THREATS	Cotter Catchment. Lots of large fallen timber.

FIRES IN KOSCIUSZKO NATIONAL PARK



ABOVE: Major fires in Kosciuszko National Park near Yarrangobilly.

ABOVE: The Hains Hut Fire in NSW, towards Kiandra.

ASSESSMENT FOR MT MORGAN FIRE

FIRE #5 NSW, 2 km from ACT	MOUNT MORGAN FIRE @ GR 620 450; elevation: 1550 m
FUEL	Snow gum
TERRAIN	Knoll above saddle, to NE of main peak.
SIZE	2 ha
ACCESS	4WD trail to 700m to NE
BEHAVIOUR	90% self-extinguished overnight. Hot spots on N, SW & SE corners.
THREATS	No direct threats.

GINGERA FIRE, NSW (adjacent to ACT border)

ABOVE: The Gingera Fire, covering 4ha, 18 hours after ignition. Note the terrain, access difficulties and dense vegetation.

ASSESSMENT

FIRE #3 ACT/NSW border	GINGERA FIRE @ GR 618 608; elevation: 1680 m
FUEL	Snow gum
TERRAIN	On main range, SSE of peak
SIZE	2 ha, growing
ACCESS	4WD trail 200 m downslope to E
BEHAVIOUR	0.5 m backing on flanks & heel; 1 m spreading around rocks on head to N
THREATS	Cotter Catchment. Could make a run onto peak.

BENDORA FIRE, ACT

ABOVE: The Bendora Fire, covering 22ha, 18 hours after ignition.

ASSESSMENT

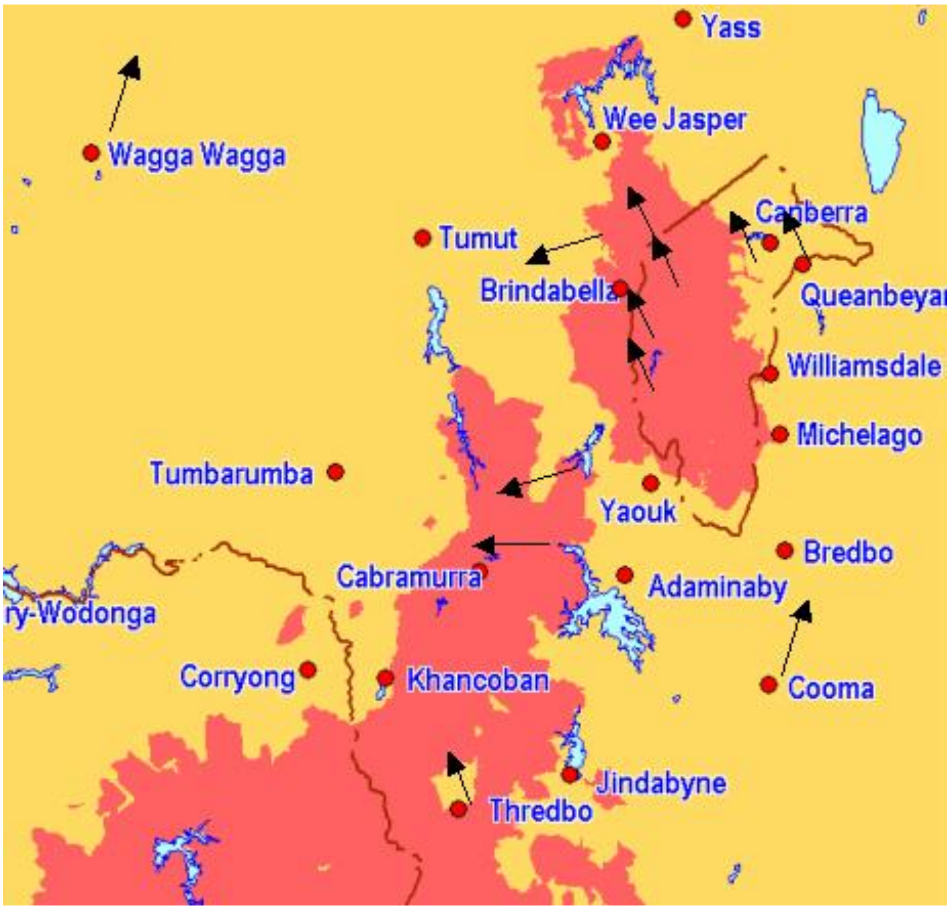
FIRE #1 -ACT	BENDORA FIRE @ GR 645 791 M; elevation: 1130 m
FUEL	Montane forest
TERRAIN	Ridgeline
SIZE	20ha, growing
ACCESS	Wombat Road, to SE
BEHAVIOUR	Backing with 1.5m flames to NW, NE; hot with 2m flames on SW; out on SE along road.
THREATS	Cotter Catchment

McINTYRES HUT FIRE, NSW

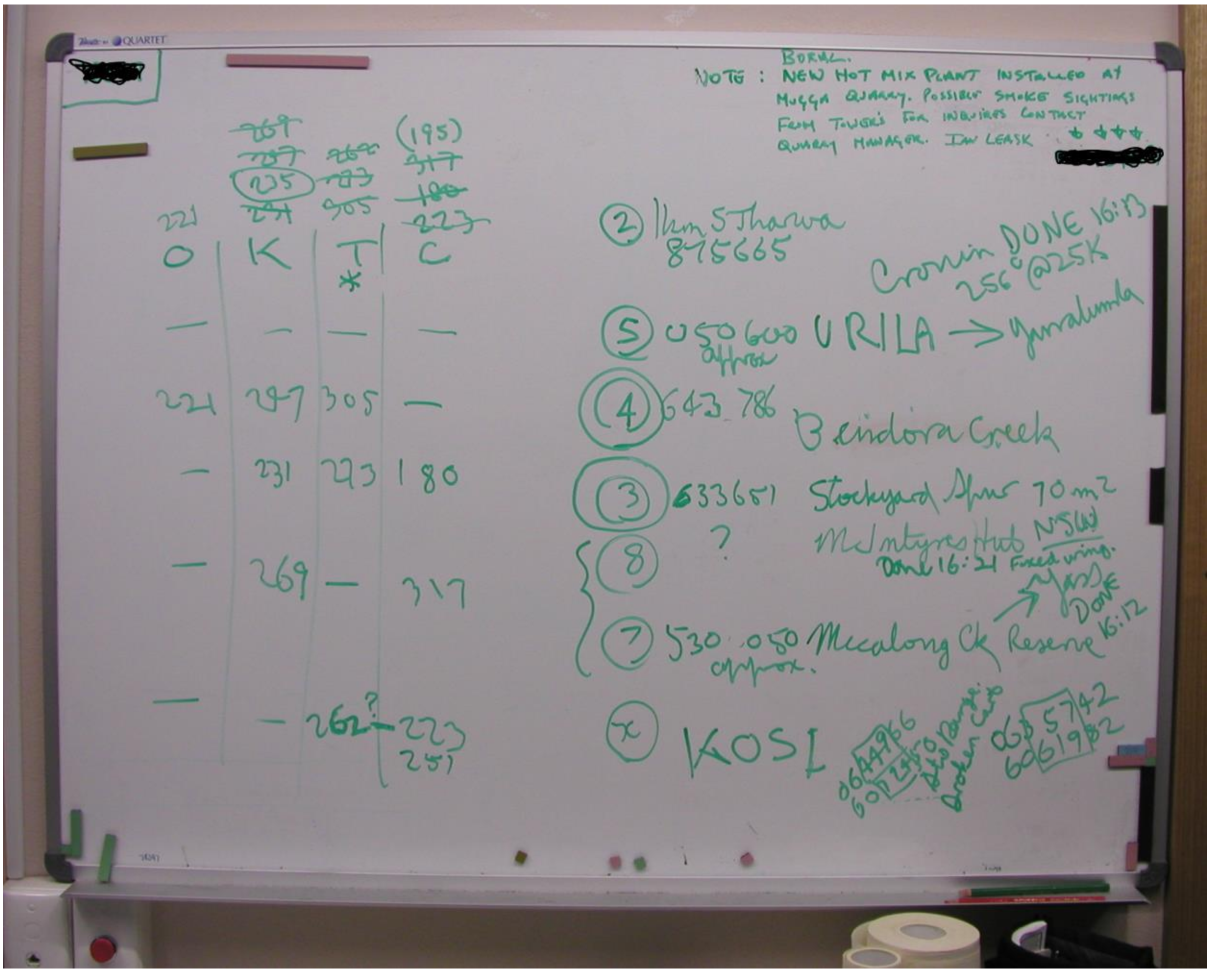
ABOVE: Smoke from the main part of the McIntyres Hut Fire, originally in NSW, seen from the south 18 hours after ignition. Note the low lying smoke, which hindered aerial operations. It was discovered that there were four spotfires in the smoke (later determined to be due to Vorticity-driven Lateral Spread).

ASSESSMENT

FIRE #2 - NSW, 5km from ACT	McINTYRES HUT FIRE
FUEL	Dry forest
TERRAIN	Steep dissected valleys
SIZE	Main fire: 300ha @ GR 590 965; elevation c. 800 m Dingi Dingi Ridge spotfire: 20 ha @ GR 630 965; elevation c. 1200 m Mountain Creek spotfire: 15 ha @ GR 623 975; elevation c. 1000 m Baldy Range spotfire: 20 ha @ GR 660 975; elevation c. 1050 m All fires growing
ACCESS	Off Two Sticks Road
BEHAVIOUR	Mostly backing, flames 0.5 to 1.5 m, some hot spots
THREATS	ACT, especially pines; private property; powerlines.



ABOVE: Somewhat alarmingly, weather data and the photos above showed that the fires had made runs driven by the overnight wind change in largely unprecedented directions. Red areas are the final burnt extent.



As the dust storm cleared, the fire towers began reporting smoke columns. This whiteboard shows the rather frantic effort to work out where we had new fire reports. As these were calculated they were phoned through to NSW fire control centres or responded to by ACT duty officers.

Tower operators are trained to report bearing and distance, but the hazy sky made distance estimates unusable. Bearings are relative to a standard tower north, which was somewhat different to actual magnetic north due to the age of the towers.

It was obvious that this was a regional effort, and a high-level meeting to synchronise efforts was held that night at Queanbeyan.

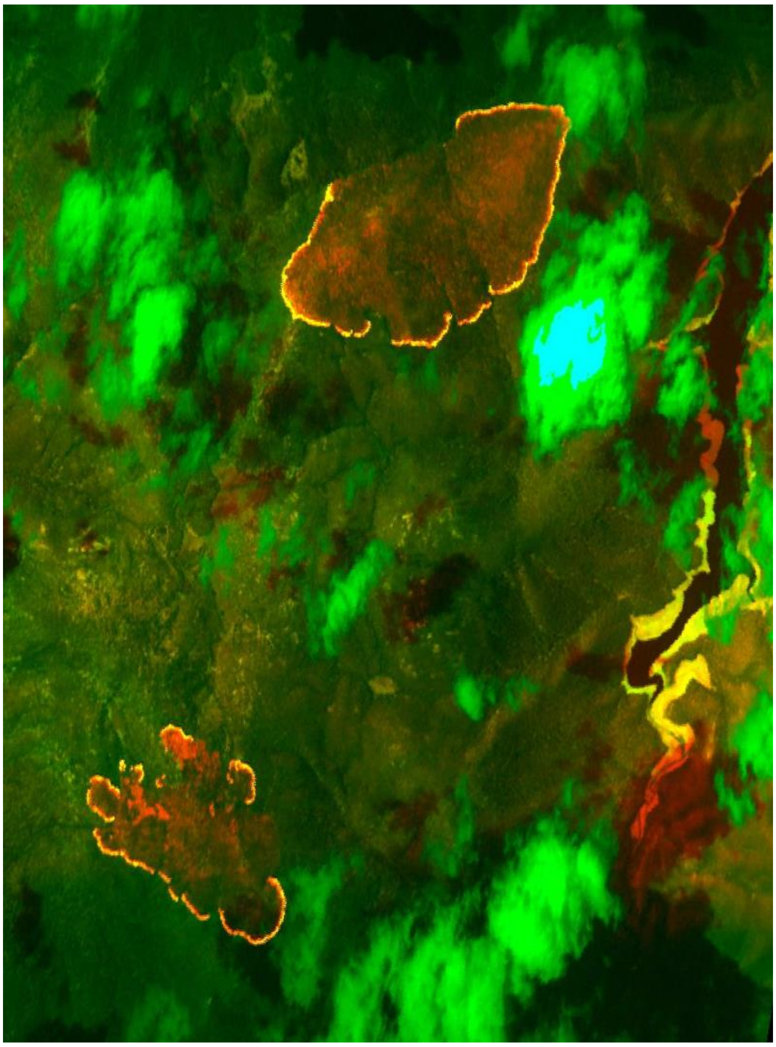
11 JANUARY 2003

This material was gathered during the fires by Rick McRae, then with the ACT Emergency Services Bureau.

Everyone was settled into an operational tempo, with a lot of work to be done, due to:

- A lot of ignitions in the area.
- An elevated level drought.
- The summer weather and higher elevations.

What turned out to be a major advance was the first linescans ever flown of an ACT fire by NSW Rural Fire Service.



ABOVE: Airborne linescan imagery of the Stockyard Spur Fire (top, 3 sq km with a 7km perimeter) and Gingera Fire (bottom, 2 sq km with an 8 km perimeter). Note the bare earth around the stored water behind Corin Dam.

Linescanner are satellite sensors adapted to work inside aircraft. The sensor continuously sweeps across the flight path of the aircraft, building up an image over time. The sensors include both visible bands (red, blue and green), but also a set of infrared bands. Visible and infrared can be brought together to form what is called a pseudo-color image that can be interpreted to reveal a lot about what the fire is doing.

It was this service by NSWRFS that allowed the subsequent scientific breakthroughs in wildfire science to occur. There is no other way to form and record a coherent overview for complex fire situations.

The two fires shown in the linescan above had, after three days, burnt 5 square kilometres with 15 km of perimeter – and just over 2km contained.

Below is that day’s morning Fire Weather Forecast from the Bureau of Meteorology.

For the area of these fires there is only High Fire Danger Rating. The key was the Drought Index being 130mm (out of a possible 200 mm) and the Drought Factor being 10 (out of 10).

BUREAU OF METEOROLOGY
CANBERRA METEOROLOGICAL OFFICE

ACT FIRE WEATHER FORECAST

Issued at 6:12am on Saturday the 11th of January 2003

FORECAST CONDITIONS			LOWLANDS			HIGHLANDS	
			Fairbairn	Tuggeranong	Tidbinbilla	Mt. Orroral	Corin Dam
Rain to 9am			0.0	0.0	0.0	0.0	0.0
Rain 9 - 3			0.0	0.0	0.0	0.0	0.0
Max T			27	27	26	24	24
Dew Pt.			6	5	6	6	6
RH%			26	26	28	31	31
Wind Speed at Max. T			20	20	20	20	20
Wind (Km)	Time Group	00/10	S/SE 10/20	S/SE 10/20	S/SE 10/20	S/SE 10/20	S/SE 10/20
		10/16	E 20	E 20	E 20	E 20	E 20
		10/20	E 30G45	E 30G45	E 30G45	E 30G45	E 30G45
Curing			95	95	95		
BKDI			112.4	115.1	144.0	130.0	120.0
DF			10	10	10	10	10
FDR	Grass Land		11	11	10		
	Forest		20	20	18	15	16

OTHER GENERAL FORECAST PARAMETERS

1500m wind			3000m wind			Turbulence		
Time Group	08/18	ESE 25-30	Time Group	06/18	S 30	Time Group	06/16	slight
							16/20	moderate
Cloud Amount			**Stability Class**			**Lightning Probability**		
Time Group	Night		Time Group	Night		Time Group	Night	
	am	5		Day	B-C		Day	0%
	pm	2						

Stability Class: A - very unstable, B - moderately unstable, C - slightly unstable, D - neutral, E - slightly stable, F - moderately stable, G - very stable

CANBERRA AIRPORT DATA at 6AM

TEMP	RH%	WIND	RAINFALL	BKDI	DF
11.2	79	Calm		110.7	10

WARNING CURRENT

FWW:	NO	TO BAN:	NO	SEV TS:	NO	SEV WX:	NO	GALE:	NO

FORECAST FOR ACT

Dry. Some patchy early cloud, otherwise mostly sunny. Light to moderate east to southeast winds becoming gusty in the afternoon and evening. UV: 13. Haines: 4.

THREE DAY OUTLOOK

Sunday	Dry, early cloud. Similar winds.
Max about:	27
Monday	Dry, early cloud. SE/NE 10/15 km/h, then gusty easterly later in the day.
Max about:	20
Tuesday	Dry, partly cloudy. SE/NE 10/15 km/h, then gusty easterly later in the day.

12 JANUARY 2003

This material was gathered during the fires by Rick McRae, then with the ACT Emergency Services Bureau.

The 12th was when it became clear that the fires were not making runs “in the usual manner”, but were just spreading over the landscape, often heading further inland. This created problems, as most assets that are useful for fire containment are designed for fires heading to the east, with a hot, dry north to north-west wind behind them.

Here is the Bureau of Meteorology Fire Weather Forecast:

BUREAU OF METEOROLOGY
CANBERRA METEOROLOGICAL OFFICE

ACT FIRE WEATHER FORECAST

Issued at 3:15pm on Saturday the 11th of January 2003

FORECAST CONDITIONS			LOWLANDS			HIGHLANDS	
			Fairbairn	Tuggeranong	Tidbinbilla	Mt. Orroral	Corin Dam
Rain to 9am			0.0	0.0	0.0	0.0	0.0
Rain 9 - 3			0.0	0.0	0.0	0.0	0.0
Max. T			25	25	24	22	22
Dew Pt.			9	9	9	8	8
RH%			38	38	38	41	41
Min. T			13	13	12	09	08
Dew Pt.			12	12	11	7	7
RH%			94	94	94	87	93
Wind Speed at Max. T			30	30	30	35	35
Wind (Km)	Time Group	16/22	E/SE 25/35	E/SE 25/35	E/SE 25/35	E/SE 25/35	E/SE 25/35
		22/10	E 20	E 20	E 20	E 20	E 20
		10/16	E 30G45	E 30G45	E 30G45	E 35G45	E 35G45
Curing			95	95	95		
BKDI			112.8	115.9	144.9	130.0	130.0
DF			10	10	10	10	10
FDR	Grass Land		16	16	15		
	Forest		17	17	15	14	14

OTHER GENERAL FORECAST PARAMETERS

1500m wind			3000m wind			Turbulence		
Time Group	16/18	ESE 25/30	Time Group	18/18	SE 30	Time Group	18/12	slight
							12/18	moderate

Cloud Amount			Stability Class			Lightning Probability		
Time Group	Night	7	Time Group	Night	D	Time Group	Night	0%
	am	5		Day	C		Day	0%
	pm	3						

Stability Class: A - very unstable, B - moderately unstable, C - slightly unstable, D - neutral,
E - slightly stable, F - moderately stable, G - very stable

CANBERRA AIRPORT DATA at 3PM

TEMP	RH%	WIND	RAINFALL	BKDI	DF
22.2	48	ESE 37		111.6	10

WARNING CURRENT

FWW:	NO	TO BAN:	NO	SEV TS:	NO	SEV WX:	NO	GALE:	NO

FORECAST FOR ACT FOR TONIGHT AND TOMORROW

Overnight and morning cloud with some possible drizzle, then a mix of sun and cloud. Moderate east to southeast winds becoming gusty afternoon and evening. UV Index=13 [ex] dropping to 9 [vh] under cloud. Haines Index = 4

THREE DAY OUTLOOK

Monday	Dry. Partly cloudy. E/SE winds
Max about:	28
Tuesday	Dry, partly cloudy. E/NE winds
Max about:	29
Wednesday	Partly cloudy. E/SE winds

High Fire Danger Rating, and winds from the coast.

Lannon Harley is a photojournalist who was doing work for the Canberra Times. He kindly provided access to some important fire behaviour photos that he had taken on a number of days.

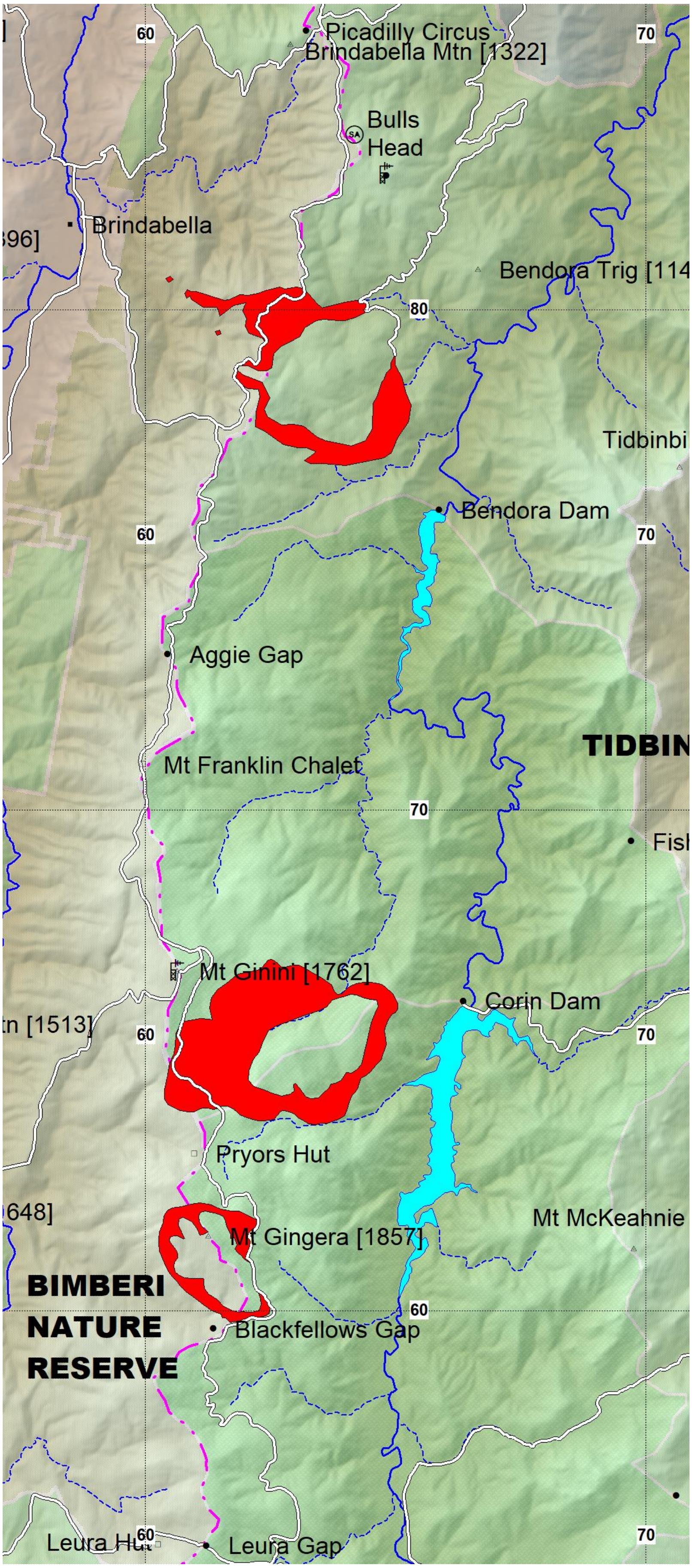
This aerial show looking south over Corin Dam shows the Stockyard Spur Fire. It is slowly spread down the spur, and not as headfire. Curiously, whatever the slope, the perimeter is uniform. It appears that the convection above the fire is causing some level of self-organising into a coherent fire edge.

You will also see how most of the smoke is heading westward.

Additional problems occurred at night-time when fire danger did not significantly abate, making burn-out operations challenging.

ABOVE: Over night burn-out underway on Bendora Fire. (Photo supplied by Dave Tunbridge, Molonlgo Brigade)

RIGHT: part of a daily progression map showing the day's spread in red. The Bendora Fire in the north has spotted over into the Brindabella Valley. Stockyard Spur Fire has spread into NSW near Pryor's Hut, and the Gingera Fire has continued spreading on the mountain top.



ABOVE: The scale of the fire should not be forgotten.

LESSONS LEARNED:

OVERNIGHT FLAMMABILITY:

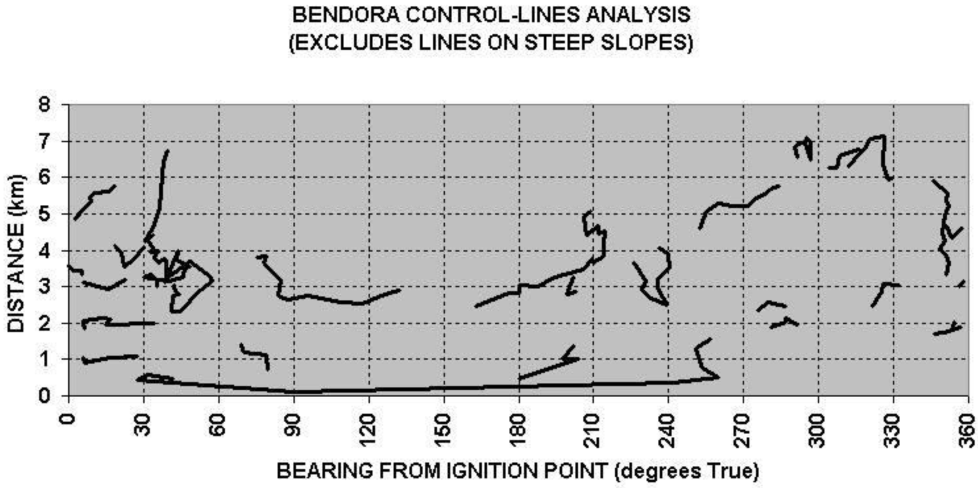
The overnight flammability lead to a published paper on the Thermal Belt in Australia:

McRae, R.H.D. & sharples, J.J. (2011). Modelling the Thermal Belt in an Australian Bushfire Context. Proceedings, MODSIM 2011.

https://www.mssanz.org.au/modsim2011/A2/mcrae.pdf

CONTROL OPTIONS FOR FIRE SPREADING IN UNUSUAL DIRECTIONS:

Bendora Fire

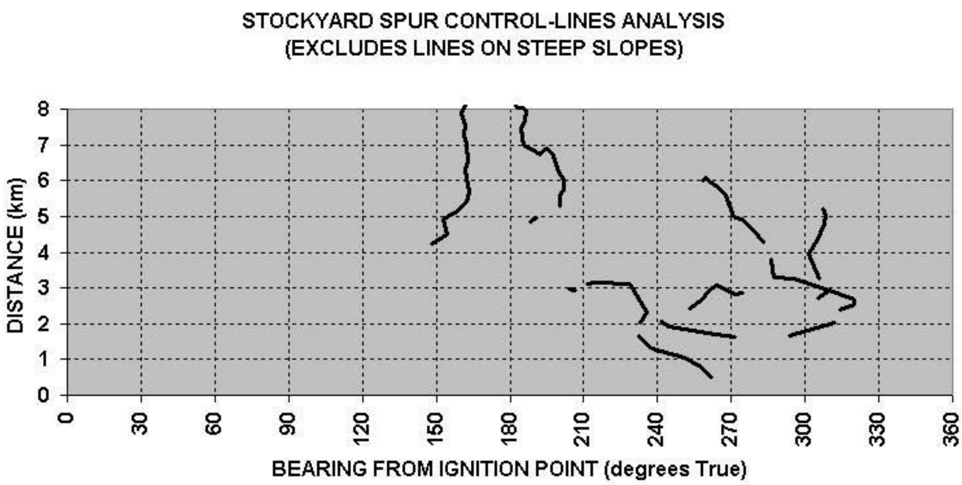


ABOVE: Polar plot of control options around the Bendora Fire, showing control options as a polar plot. These polar plots use distance and bearing (rather than X and Y coordinates) of nearby control features. In these plots, the ideal would be nearly horizontal lines right across the graph at around 1, 3 and 6km. These would give good control capability with fall-back options.

From this:

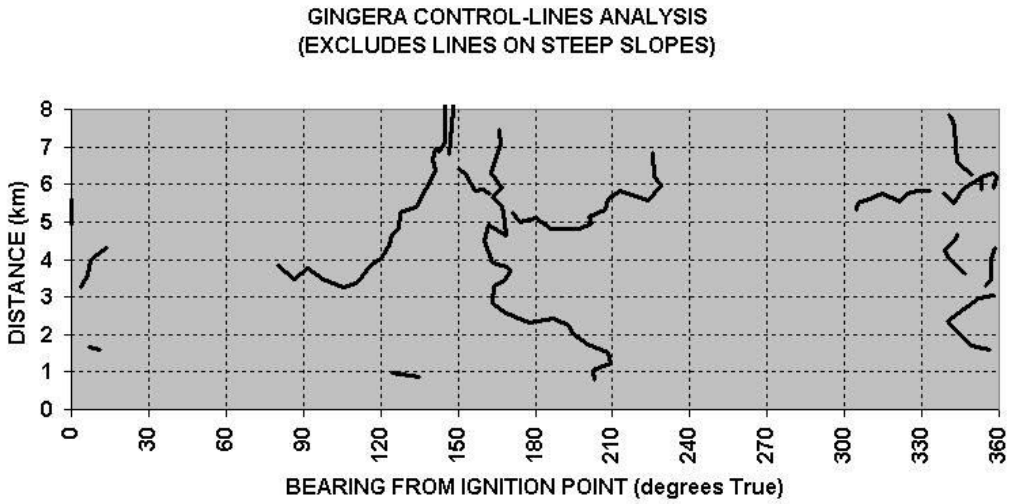
- Many parts of the fire had multiple control line options.
- Due to steep slopes, many of these were incomplete.
- The sector from 30 to 70 degrees at close range was held on the 8th and went cold.
- The sector from 80 to 210 degrees was the focus of considerable effort to build and hold a line for a burn-out at 3km.
- At 150 degrees, a breakout occurred due to VLS (more on this soon) out on the 18th [at 3km effective range over a newly constructed line] into the area around Bendora Dam.
- From 220 to 250 degrees, the first option, at close range, was jumped on the 11th.
- At 290 degrees, the fire jumped the last line into NSW, at 2km range, on the 12th.
- After this, the sector from 220 to 260 degrees was a NSW fire.

Stockyard Fire



ABOVE: Polar plot of control options around the Stockyard Spur Fire. **Error! Reference source not found.**This shows quite a different situation to the previous Figure. No control options exist from 320 to 150 degrees. Alternatives exist in the 230 to 320 degree sector, but anchoring these would always be problematic. A new line was evaluated in the 330 to 70 degree sector at 5 km range, but time ran out for constructing it.

Gingera Fire



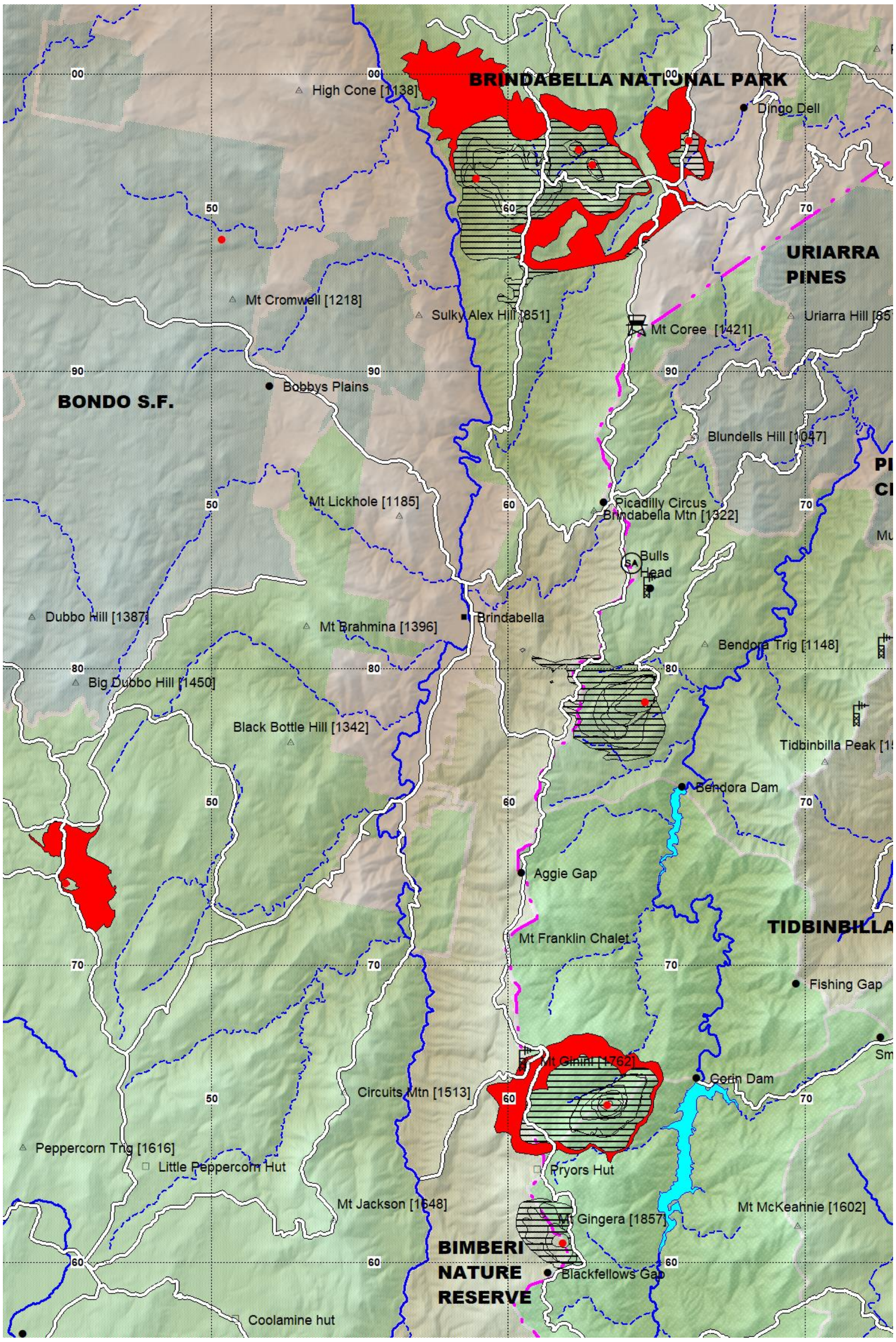
ABOVE: Polar plot of control options around the Gingera Fire. This is based on the same dataset as above, but from the perspective of the Gingera Fire. Options clearly exist in the 300 to 10 degree sector, but these are already of tactical importance to the Stockyard Spur Fire, in places using the opposite side of the road. In the 90 to 200 degree sector, there are also opportunities for control lines. Crews attempted to work on the lines in the 90 to 150 degree range, but were unsuccessful due to mishaps. Clearly there were issues with control in the 10 to 80 degree and 230 to 310 degree sectors, where no opportunities existed. A track on a steep sidecut held the fire in the former sector until the 15th. It was unlikely to hold back active fire during very high or extreme fire danger due to overlapping canopies and a dense understorey.

These graphs show that the best opportunities existed for the Bendora Fire, although these were going to be difficult to completely implement. The other two fires, in mountainous country, lacked control options, and could only be controlled with adequate time or a switch to moist weather.

13 JANUARY 2003

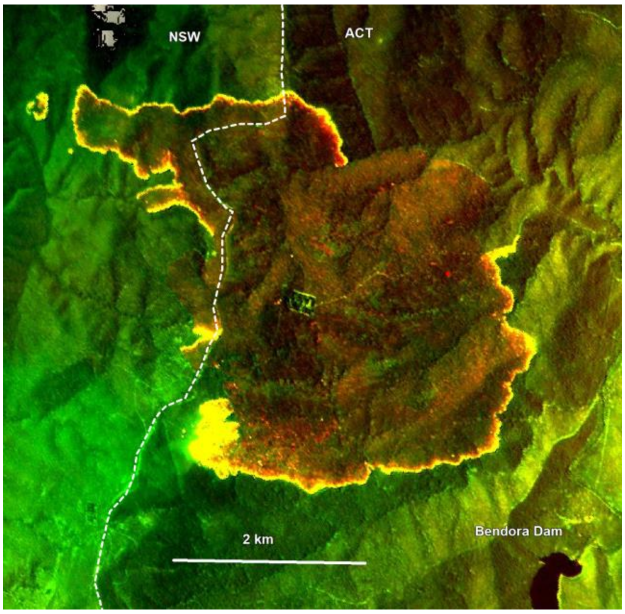
This material was gathered during the fires by Rick McRae, then with the ACT Emergency Services Bureau.

The fires continued to spread in the same manner as before.



Of note is the commencement of the ambitious burn-out block around the McIntyres Hut Fire. Also noteworthy is the Broken Cart Fire to the west of the ACT.

A later NSWRFS linescan of Bendora Fire showed more of the spread to the west in detail.



LESSONS LEARNED:

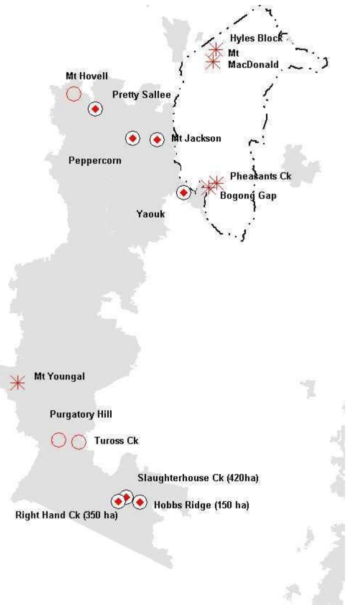
LIGHTNING IGNITIONS:

There was time now to analyse the distribution of the original lightning ignitions.

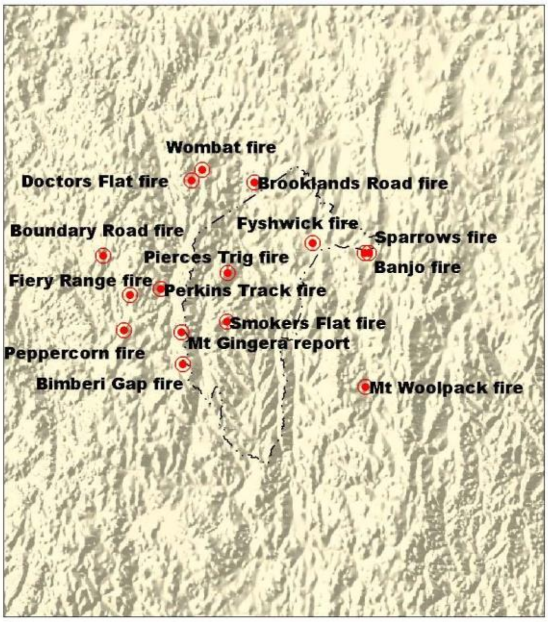
The police assigned ignition investigation to Taskforce Tronto, who searched for lightning-hit trees. Lightning is frequently hitting trees in the high country, but these only go on to become wildfires in certain places.

There had been other ignition swarms in recent years – see below – and previous swarms recorded in Kosciuszko National Park in 1964, 1977, 1978 & 1991.

20th Dec 2002

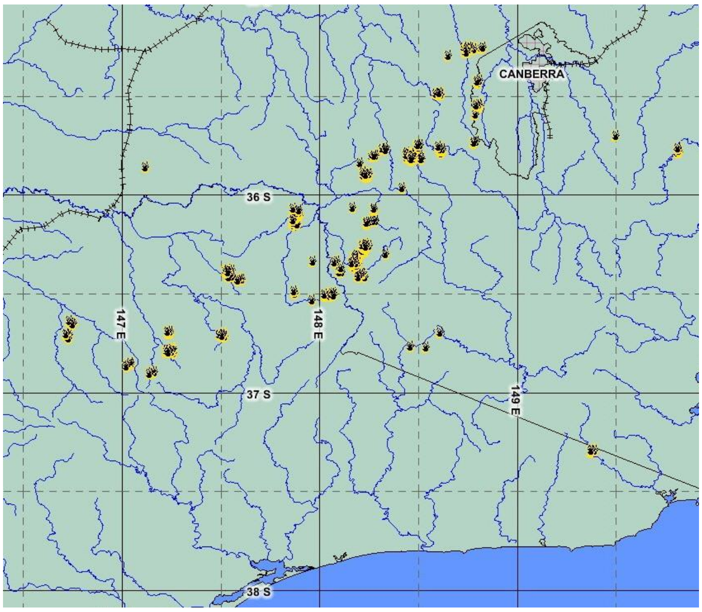


1st Dec 2001



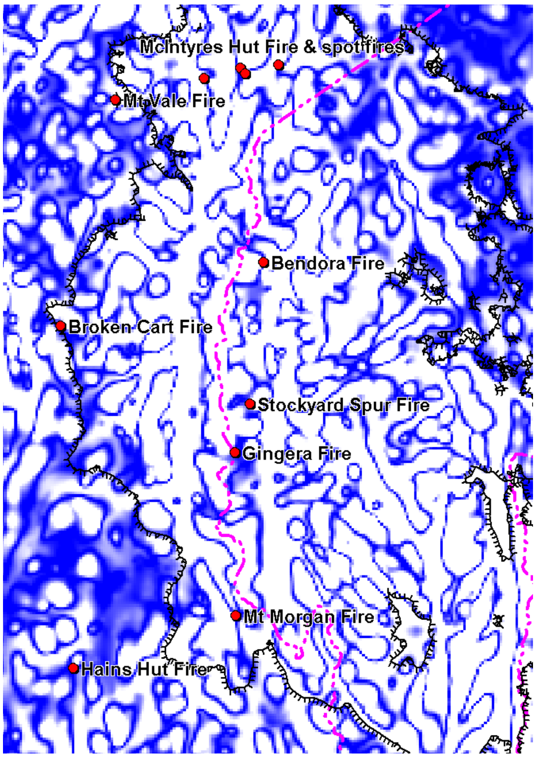
I had published the first effective predictive model for where lightning ignitions occur on the landscape: This was applied to the 2003 data, giving the results below.

McRae, R. (1992). Prediction of areas prone to lightning ignition. *International Journal of Wildland Fire* **2(3)**: 123-130.



ABOVE: Map of MODIS hotspots of 8 January 2003 ignitions, showing a clustering around the rugged high country of Victoria, NSW and the ACT. (SENTINEL data from before GeoScience Australia took on ownership.)

BELOW: Original map of ignitions near the ACT against output of lightning ignition prediction model (blue). Note that all of the red dots are on blue areas. For the spotfires near McIntyres Hut Fire this implies that they were separate lightning ignitions, not spotfires from the main fire.



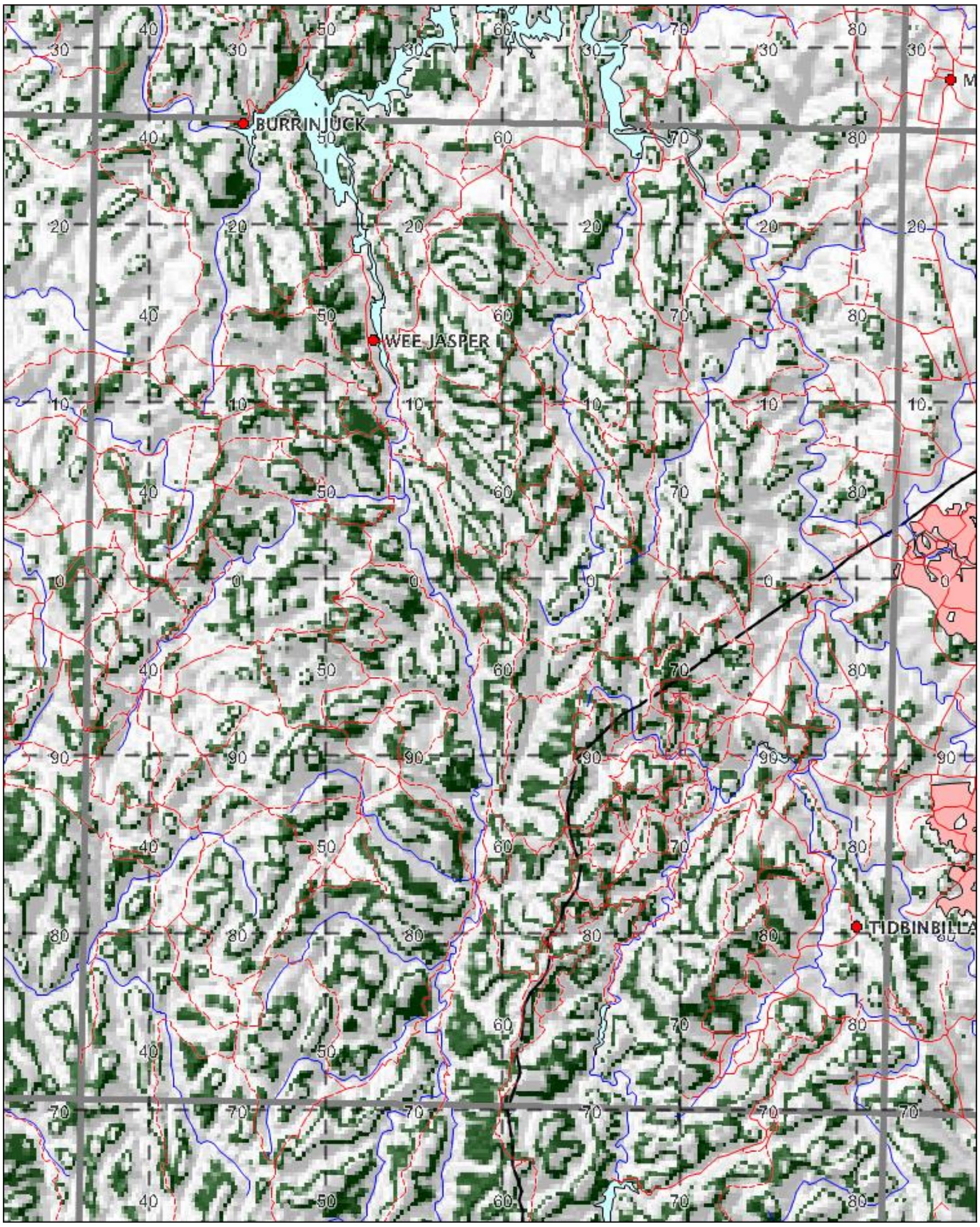
This clustering led to a reworking of the main model. The original model is based on a spatial analysis of a digital elevation model. The workings of this are explained on-line at:
http://www.highfirerisk.com.au/maps/terrain_explained.htm

To factor in the clustering around rugged terrain, the original output is multiplied by the slope of the smoothed terrain.

This has serious implications for fire crews. It says that lightning ignitions may cluster around places that are both difficult to access and difficult to work in. They also experience the most extreme weather events – upper-level winds, nocturnal low-level jets, dew point depression events, elevated solar UV levels, and so on. This can be factored into preparedness for such events.

BELOW: Map of updated model output (green areas) from

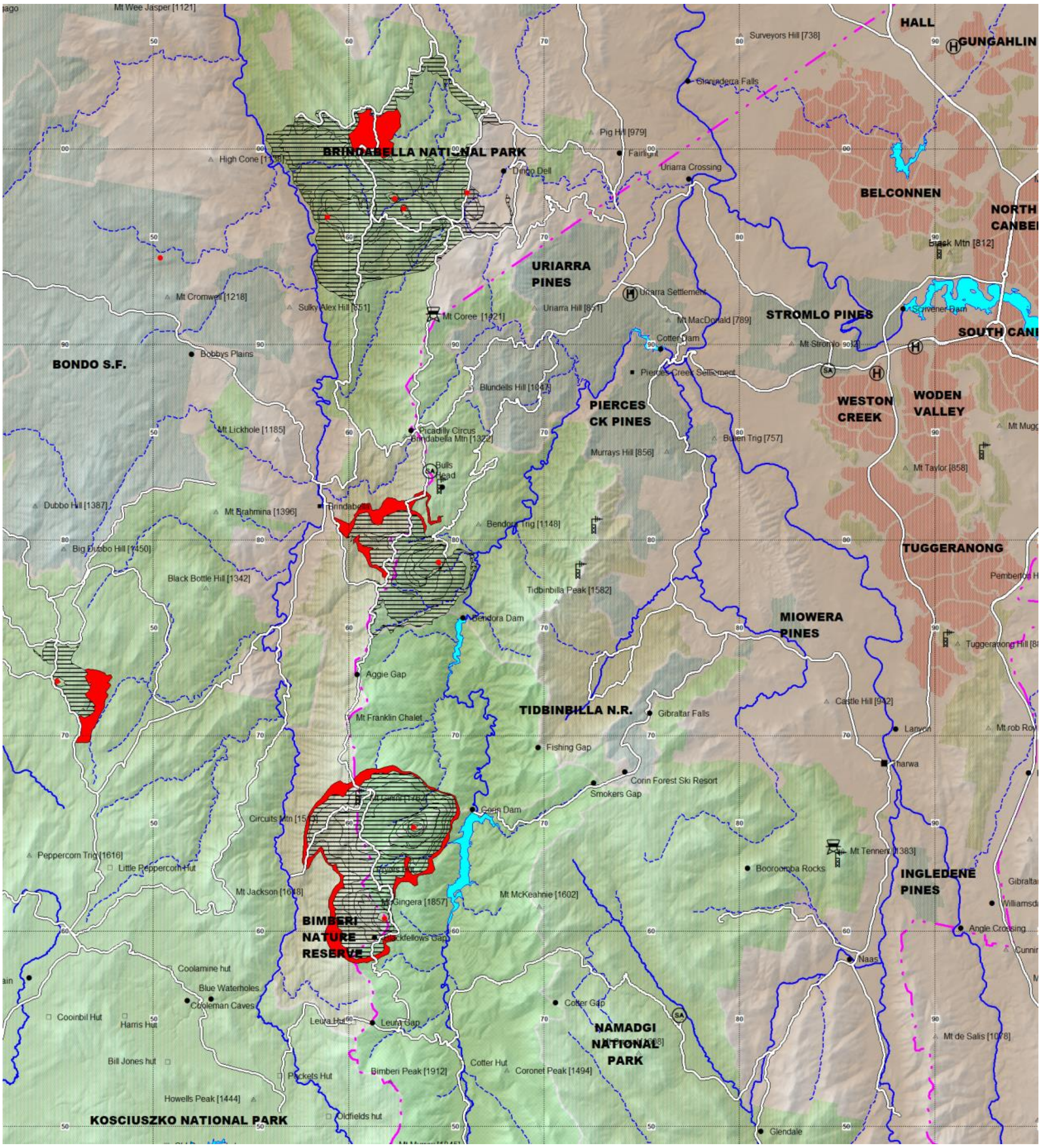
http://www.highfirerisk.com.au/maps/8627_nii.htm



17 JANUARY 2003

This material was gathered during and after the fires by Rick McRae, then with the ACT Emergency Services Bureau.

The fires continued to spread in the same manner as before.



Containment of McIntyres Hut Fire has progressed well, but some interior areas are yet to be burnt out. Broken Cart Fire escaped and needed a new line to the east. Bendora Fire has anew containment line being burnt out in the northern sectors.

The Fire weather forecasts for today were sitting around the junction between Very High and (the old definition of) Extreme Fire Danger Ratings. Similar FDRs are forecast for the 18th.

BUREAU OF METEOROLOGY
CANBERRA METEOROLOGICAL OFFICE

ACT FIRE WEATHER FORECAST

Issued at 6:06am on Friday the 17th of January 2003

FORECAST CONDITIONS			LOWLANDS			HIGHLANDS	
			Fairbairn	Tuggeranong	Tidbinbilla	Mt. Orroral	Corin Dam
Rain to 9am			0.0	0.0	0.0	0.0	0.0
Rain 9 - 3			0.0	0.0	0.0	0.0	0.0
Max. T			36	36	35	33	33
Dew Pt.			4	4	3	3	3
RH%			14	14	13	15	15
Wind Speed at Max. T			30	25	25	30	30
Wind (Km)	Time Group	06/10	VRB 15	VRB 15	VRB 15	NW 15	NW 15
		10/13	N/NW 20-25	N/NW 20	N/NW 15-25	NW 25	NW 25
		13/19	NW 30G45	NW 25G40	NW 25G40	NW 30G50	NW 30G50
Curing			95	95	95		
BKDI			119.2	121.8	150.7	130.0	130.0
DF			10	10	10	10	10
FDR	Grass Land		37	27	27		
	Forest		52	48	48	45	45

OTHER GENERAL FORECAST PARAMETERS

1500m wind			3000m wind			Turbulence		
Time Group	06/18	NW 35	Time Group	06/18	WNW 65	Time Group	06/10	slight
							10/18	moderate
Cloud Amount			**Stability Class**			**Lightning Probability**		
Time Group	Night		Time Group	Night		Time Group	Night	
	am	2		Day	C		Day	5%
	pm	3						

Stability Class: A - very unstable, B - moderately unstable, C - slightly unstable, D - neutral,
E - slightly stable, F - moderately stable, G - very stable

CANBERRA AIRPORT DATA at 6AM

TEMP	RH%	WIND	RAINFALL	BKDI	DF
15.1	81	Calm		115.6	10

WARNING CURRENT

FWW:	YES	TO BAN:	YES	SEV TS:	NO	SEV WX:	NO	GALE:	NO

FORECAST FOR ACT

Dry and hot. Areas of smoke haze at times. Light winds at first, tending moderate to occasionally fresh northwest by the afternoon. UV:13 lowering to 9 with haze, 5 with thick haze. Haines: 6. NOTE: Increase the highland winds 1hr early both time periods; i.e. 09-12, and 12-18 rather than 10-13 and 13-18.

THREE DAY OUTLOOK

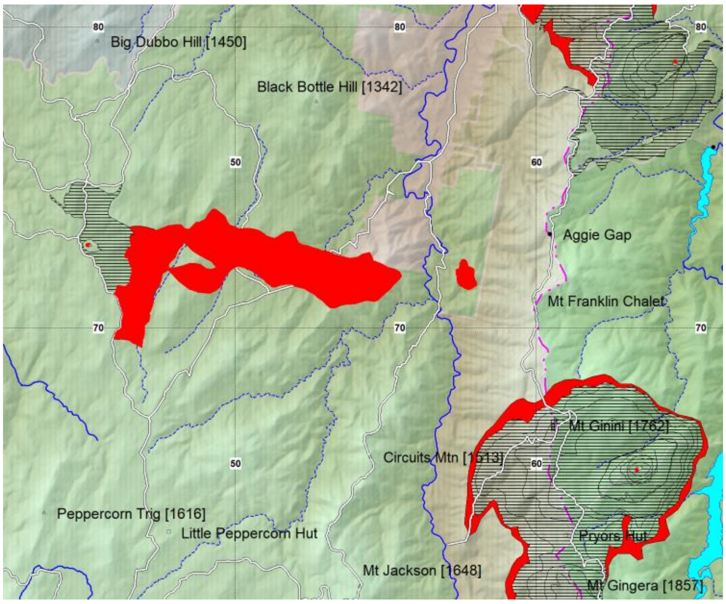
Saturday	Hot and hazy. Mostly dry. W/NW 25/35 km/h at times. E'ly change likely, but probably after sunset.
Max about:	37
Sunday	Dry. Slightly cooler. Light E'ly winds tending W/NW 20 km/h a'noon before late a'noon E'ly.
Max about:	32
Monday	Hot. Light winds tending NW late morning, reaching 20 to 30 km/h at times in a'noon.

This is now known to be sitting at a junction point: either it progresses with raised FDR or with dry fuels and instability, fires couple with the atmosphere and become blow-up fire events. At the time there were no predictive tools for this.

Late on the 17th, the latter occurred.

BROKEN CART FIRE:

Broken Cart broke containment and spread well to the east:



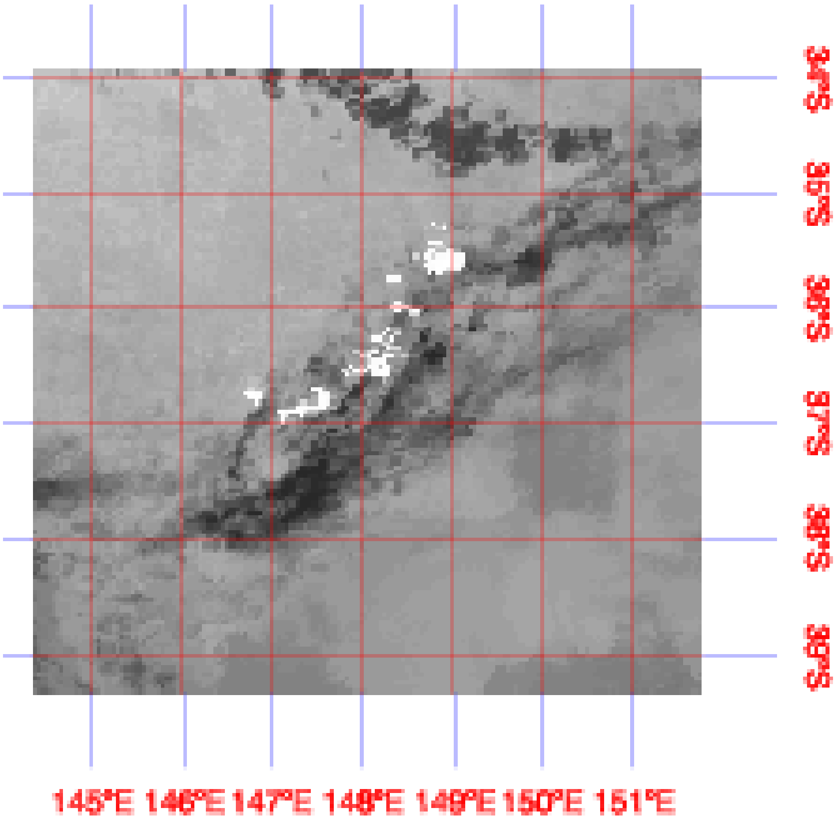
This developed VLS on four different ridgelines as it progressed, and a long-range spot east of the Goodradigbee River, on the lower slopes of the Brindabella Ranges. Worryingly this was aligned with the gap between the Bendora Fire and the Stockyard Complex. With darkness approaching and dense smoke blocking situation assessment, this was a poorly known scenario. It would not be a major event tomorrow.

BELOW: A photograph taken from Wanniassa near sunset on the 17th, showing smoke plumes: Bendora Fire on the right, Stockyard Complex in the centre, and Broken Cart Fire on the left. The high level cloud above Broken Cart suggests a pyroCb was underway. On this basis the spotfire east of the Goodradigbee River (above) may have been caused by pyrogenic lightning. [Photo: Jim Venn]

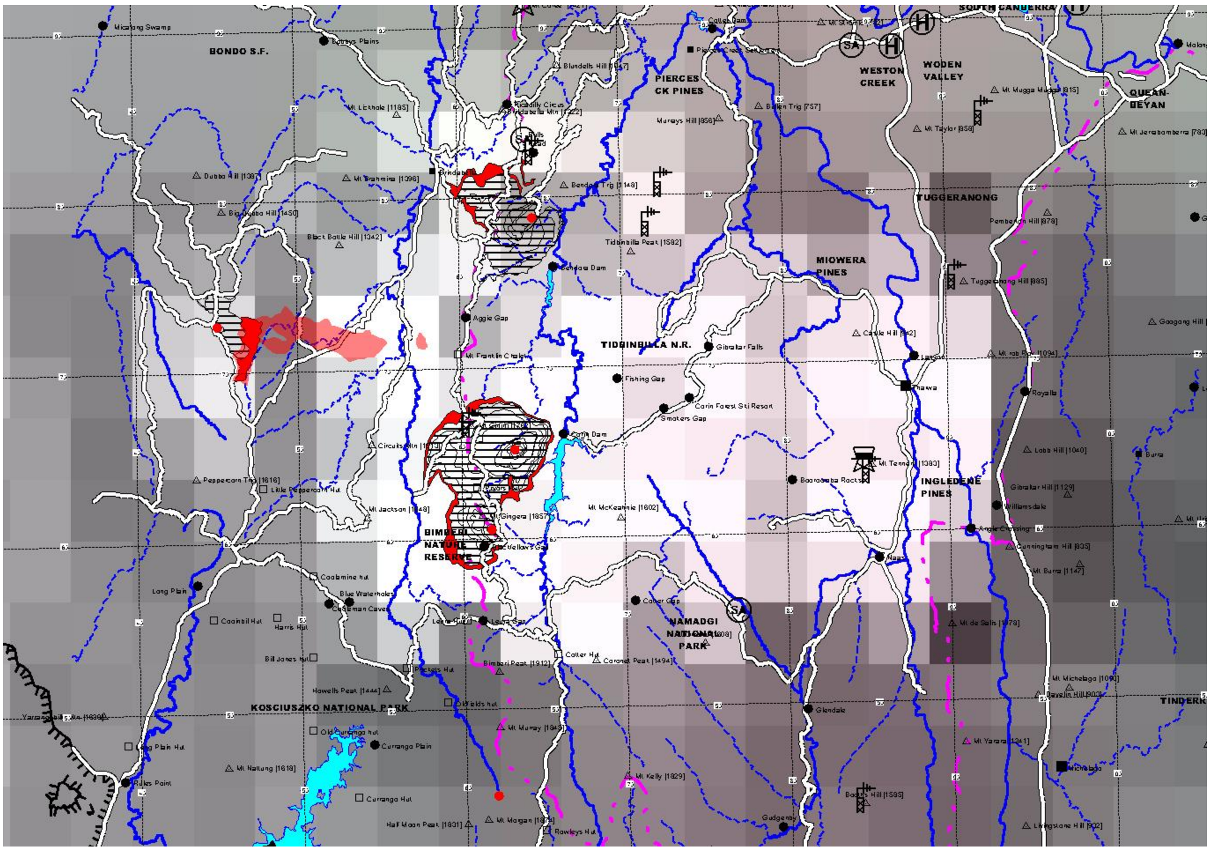
STOCKYARD COMPLEX:

Much of what happened on the night of the 17th remained a mystery for a long time.

Months later Mike Fromm of the US Naval Research Laboratories in Washington DC asked me what was going on in this near-infrared band satellite image from an AVHRR satellite.

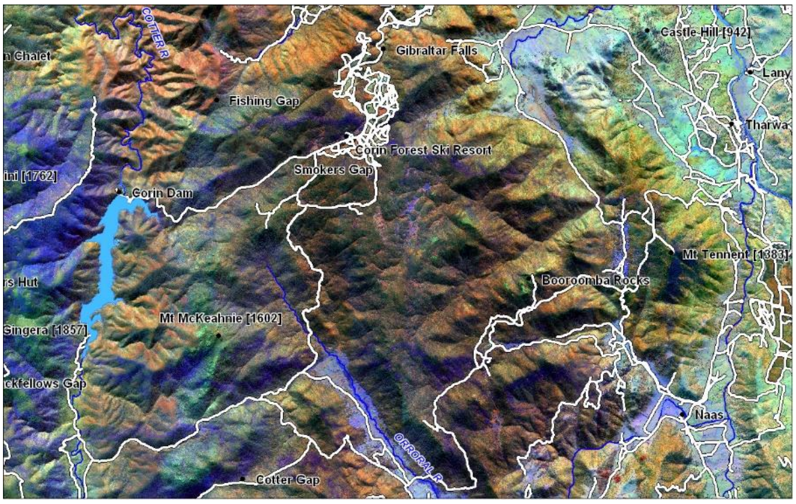


This can be put into some context:

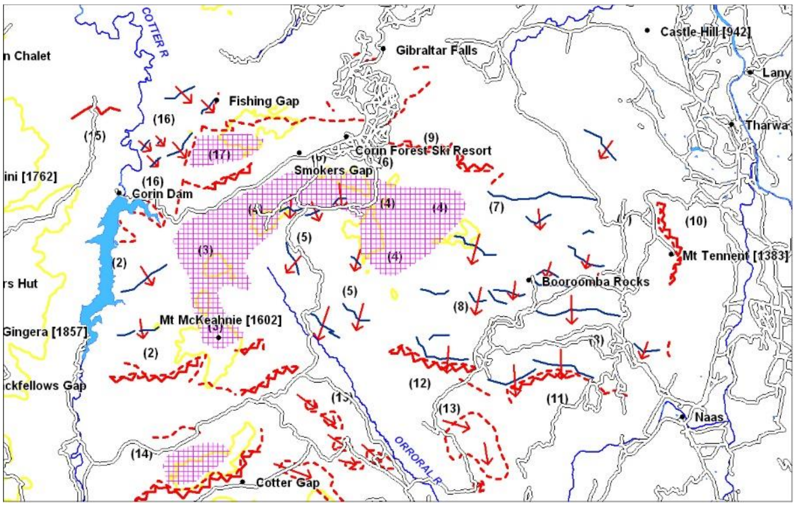


Detailed analysis of this showed that the eastern edge of the Stockyard Complex had developed a Blow-Up Fire Event at the image time, which was 10pm local time.

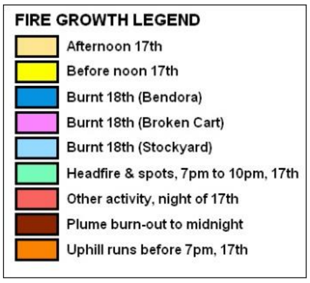
a) May 2003 multispectral linescan of the Corin Dam to Mt Tennent area. This was used to infer fire spread paths.

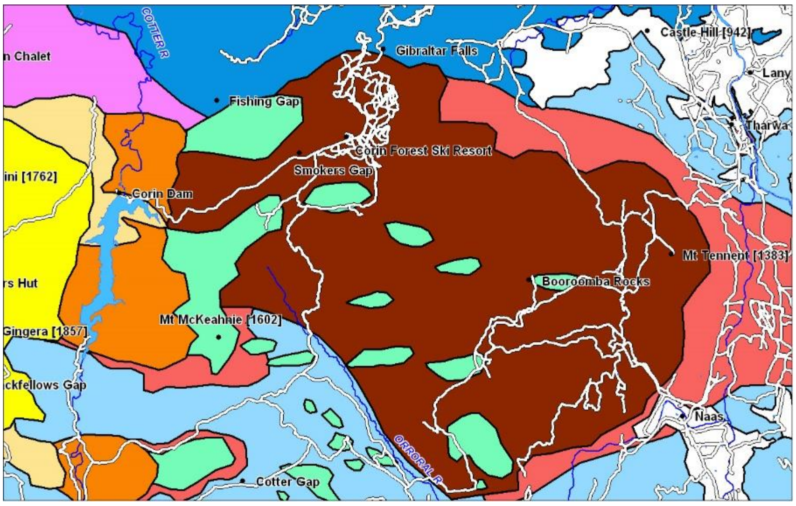


b) Inferred fire spread paths for that area late on the 17th. The yellow line is the 1400m contour, and the purple cross-hatched areas show the spectral signature of "normal" but intense fire behaviour – and perhaps indicate a subsidence inversion or nocturnal low-level jet was involved.



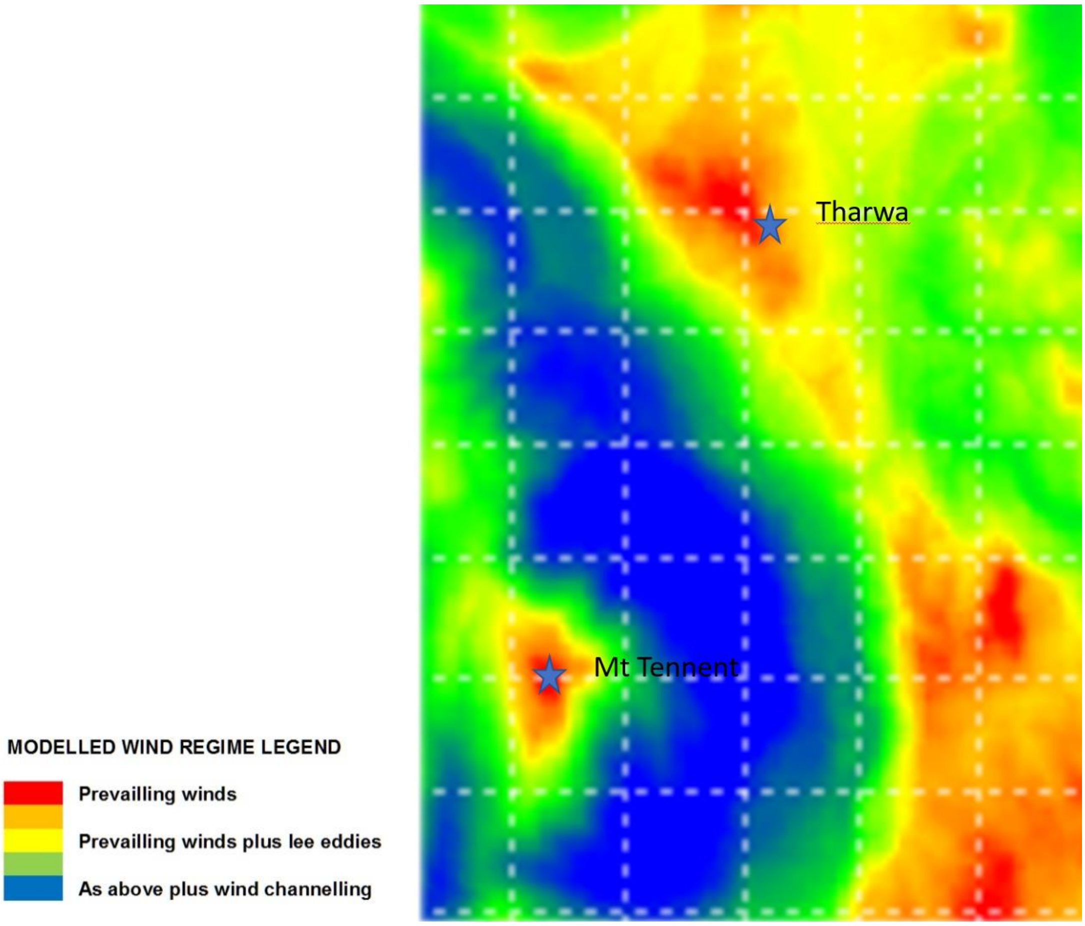
c) Inferred fire growth patterns, legend below.





The bottom line here is that just before midnight, above 1400m elevation, 20,000ha burnt and no-one knew about it, except the US Navy. There are similarities between this and events during Black Saturday in 2009 on the Kinglake Plateau north of Melbourne.

This event allowed a re-analysis of thinking about how wind flows over terrain. This became a research project funded as part of the HighFire Risk Project in the Bushfire Cooperative Research Centre. It involved deploying portable Automatic Weather Stations in rugged terrain in places where the forest canopy was burnt away. This produced a number of published research results.

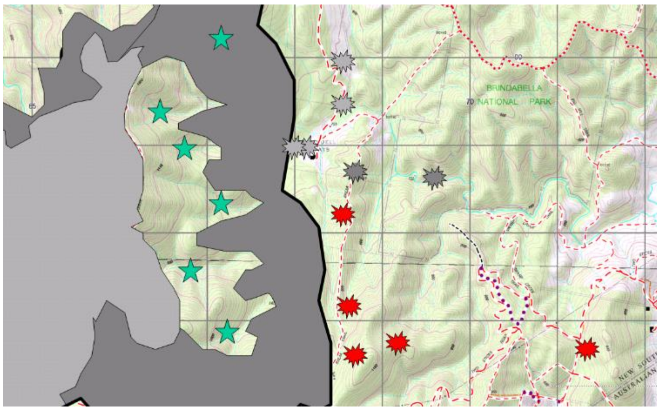


This shows that the lower slopes of Mt Tennent have very different wind regimes to those higher up. This makes it very difficult for a fire to spread off the hill onto the low country. The same happened in Black Summer with the Orroral Fire. The adjacent low country did burn in 2003, but due to back-burns intended to hold major fire runs of the sort now known to be unlikely. In fact, the model results show that over a few hundred metres there is a switch from a protective wind regime (blue) to a dangerous one (red). There are some major lessons for IMTs to be had from this.

Additionally, the AVHRR image shows infrared glow in areas downwind of the ultimate burnt area. This helped reach some key conclusions about infrared radiation in blow-up fire events. Depending on the band, IR can go right through smoke, be fully absorbed by smoke, be scattered by smoke, or absorbed and re-radiated by smoke. This suggests what is called radiative forcing of the plume base – it is being heated from below for up to a few kilometres above the ground, making the convection stronger, and increasing fire induced winds on the fire-ground. This is an additional entry into how “the fire makes its own weather”. More on this on later days.

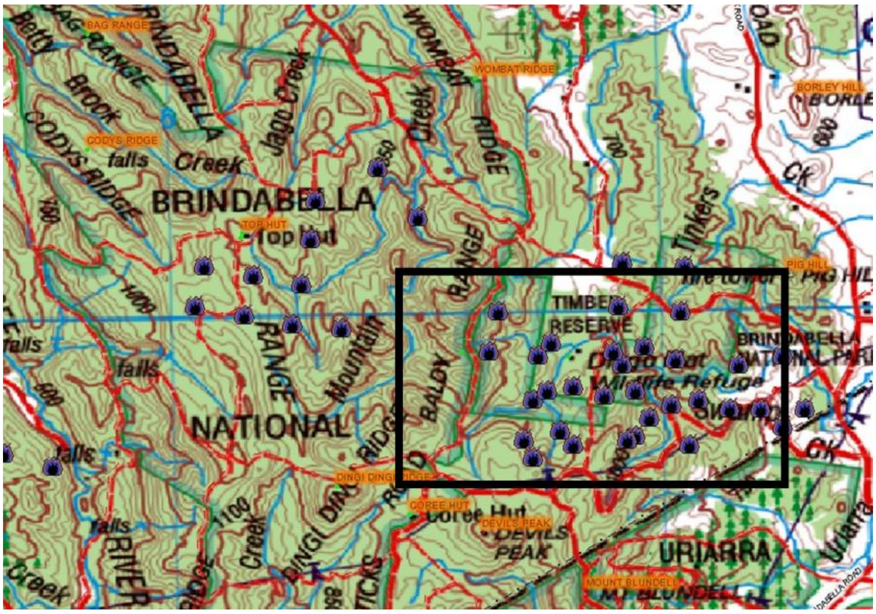
McINTYRES HUT FIRE

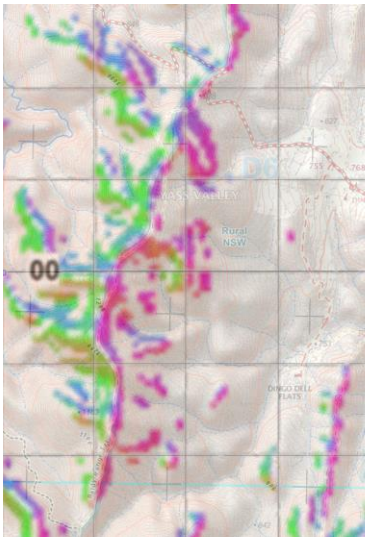
ABOVE: MODIS image of fire activity in the eastern part of the McIntyres Hut Fire. On the left is the main burn-out, and the right is burning-out of unburnt gullies on the east face of the Blady Range.



ABOVE: Spotfires, Uriarra area, late 17th. These are based on operational reports by NSWRFS crew (especially Matt Plucinski). Grey areas were previously burnt, green stars are actively burning gullies. The grey and red starts are initial and later spotfires (respectively). The correspondence between the gullies and the spotfires is clear.

BELOW: Sentinel hotspots for this event. The area in the map above is outlined.





ABOVE: Map showing VLS generator model for the Baldy Range. There is a clear potential. (See http://www.highfirerisk.com.au/maps/8627_vls.htm)

On the 17th, VLS was yet to be discovered. There is a clear operational safety issue. The containment of the perimeter of the fire included gullies that were initially too damp to burn, and which had VLS generators at their heads. The arrival of elevated fire weather would make spotting out of such gullies almost inevitable.

A lot was learned from the 17th in post-fire analyses. In real-time we made do with what was known – not much. Vorticty-driven Lateral Spread, pyroCbs, terrain-sensitive wind-regimes are all things that were learned – if not discovered – afterwards and because of these fires.

And then came the next day…

18 JANUARY 2003

This material was gathered during and after the fires by Rick McRae, then with the ACT Emergency Services Bureau.

This was the day that the bushfire textbook got rewritten.

New concepts that our industry sector was completely unaware of on the day that had significant impacts on the day's outcomes:

1. Vorticity-driven Lateral Spread
2. Lee-slope eddy winds
3. Fire thunderstorms
4. Pyrogenic lightning
5. Fire tornado
6. Foehn-effect (new for Australia)
7. Dry slots
8. Ember storms
9. Non-stoichiometric combustion

To be clear, none of these concepts appeared anywhere in the industry's training curriculum nor in its competency standards. This was because no-one knew that they were needed. Some researchers or meteorologists knew something about some of these topics. However, research dissemination is as important as the research itself. That is why the HighFire Risk website is what it is.

VORTICITY-DRIVEN LATERAL SPREAD (VLS)

Shortly after the fires I tried to understand what the linescans had revealed about fire spread on the 18th. It was a mystery. I realised that there was a novel interaction with terrain in play. I showed it to Tony Graham (who passed away 16/1/2023) and he became the second member of our species to know about what is now known to be the most important mechanism for massive fire escalation globally.

McRae, R. (2004). Breath of the dragon – observations of the January 2003 ACT Bushfires. Bushfire 2004 Conference, Adelaide.

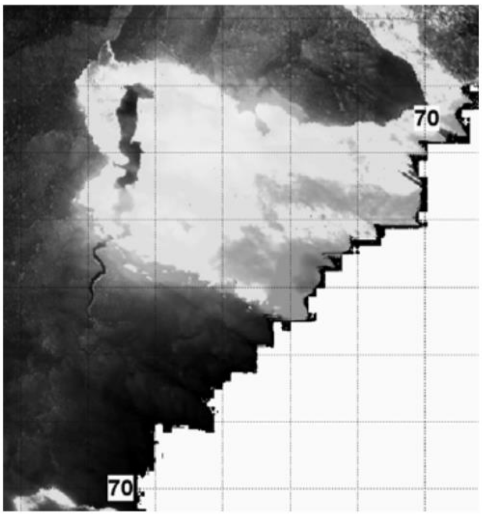
I originally linked it to a combination of lee-slope eddy winds and forced channelling of winds in valley. It is now known to be the result of interactions between fire-driven vorticity and its surroundings – thus the name change to VLS.

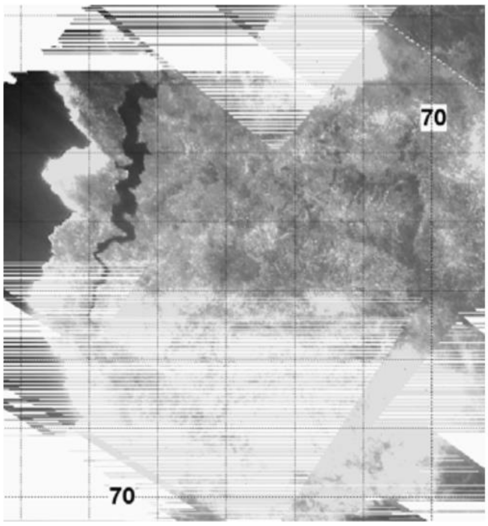
Sharples, J.J., McRae, R.H.D. & Wilkes, S.R. (2012). Wind–terrain effects on the propagation of wildfires in rugged terrain: fire channelling. International Journal of Wildland Fire, 21, 282-296

Sharples, J.J. (2009). An overview of mountain meteorological effects relevant to fire behaviour and bushfire risk. International Journal of Wildland Fire 18: 737-754.

Sharples, J.J., Viegas, D.X., McRae, R.H.D., Raposo, J.R.N. & Farinha, H.A.S. (2011). Lateral bushfire propagation driven by the interaction of wind, terrain and fire 19th International Congress on Modelling and Simulation, Perth, Australia, 12–16 December 2011, pp. 235-241

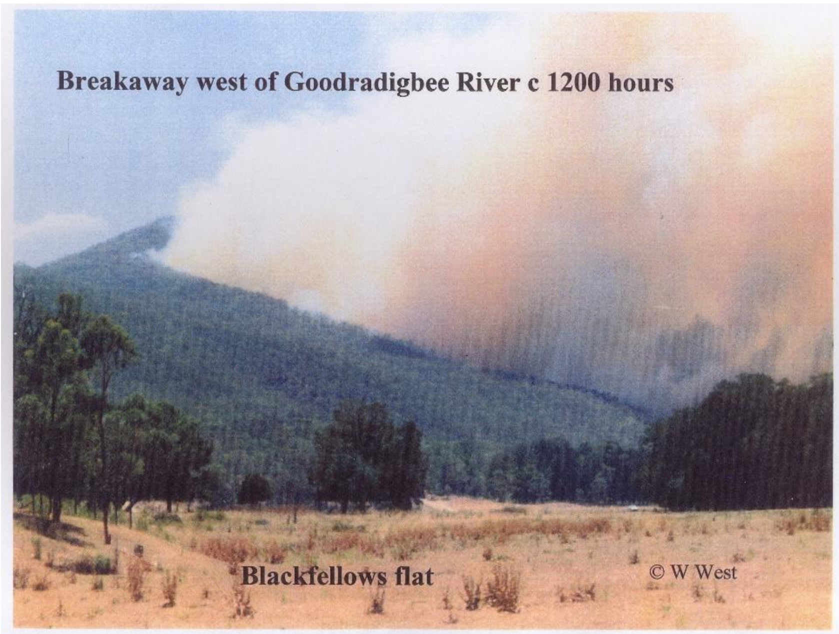
Simpson, C.C., Sharples, J.J. & Evans, J.P. (2014). Resolving vorticity-driven lateral fire spread using the WRF-Fire coupled atmosphere-fire numericla model. Nat. Hazards Earth Syst. Sci., 14, 2359-2371.





ABOVE: VLS: Bendora Fire 18/1/03. In the first linescan extract, taken about 14:50 the origin of the event is seen in its northwest corner, indicating less than 2 hours for the evolution of the flaming zone 3km north to south and in excess of 5km west to east. In the second, taken about 15:40 the flaming zone has moved generally southwards as a block for 4km. This indicates flank expansion of nearly 5km/hr. The left-hand edge is aligned with the top of the main slope out of the Goodradigbee River valley. [Linescans NSWRFS]

BELOW: A photograph looking north of the leading edge of a related event further north. It is moving south towards the camera as well as spotting to the right. Note the link to the top of the slope, which drove further scientific studies in wind tunnels and computer models. [Photo: Wayne West]



It did take some time for the science to be worked up. A series of alternative explanations had to be ruled out. This takes a lot more time than lawyers do.

LEE-SLOPE EDDY WINDS

Our understanding of these was triggered by the VLS work, so is also anchored on 18 January events.

World Meteorological Organisation rules dictate where weather stations can – and cannot - be sited. So in Australia they are on prominent hilltops and on valley floors away from terrain (such as at airports). This works really well for meteorologists preparing weather forecasts. It does not work well for firefighters sweating away half way up a mountain-side.

A weather station needs to measure wind – which is done with a sensor on top of a ten metre mast, sited well away from anything that could affect the wind flow in that site. You cannot put one up under a forest canopy and expect useful data. Unless a hot fire has removed the canopy over a large area. Which happened in 2003. So the very fire that identified the problem provided the solution: take the opportunity over the next few years to put up weather stations in unusual places to see how the winds flow in rugged terrain. We did, as a funded study in the Bushfire CRC HighFire Project.

We purchased a set of weather stations and hiked onto mountain-sides to deploy them. They were solar powered with data-loggers. Afterwards the data were analysed and some surprising results obtained.

In a deep valley, the wind often flows aligned with the valley – called forced channelling - a well understood process in countries like New Zealand, but less well know in Australia.

On a ridgetop or other high, exposed ground, the prevailing winds are experienced.

On side-slopes winds can be either upslope or downslope. Light winds are always a variant of the prevailing winds. But when they exceed 25 to 30 km/hr, you get lee-slope eddy winds. As the upslope winds hit the ridgetop they keep rising, separating from the lee-slope. Underneath a rotor forms, producing an upslope wind underneath. Thus both sides of the ridgetop have upslope winds. There is a line on the ridgetop where the two flow meet.

If fire gets into this line and fuels are dry (FFMC below 5%) then you can get a VLS event.

ABOVE: extracting data from a weather station on Stockyard Spur.

Sharples, J.J., McRae, R.H.D. & Weber, R.O. (2010). Wind characteristics over complex terrain with implications for bushfire risk management. Environmental Modelling and Software 25: 1099-1120.

Sharples, J.J., McRae, R.H.D. & Wilkes, S.R. (2012). Wind–terrain effects on the propagation of wildfires in rugged terrain: fire channelling International Journal of Wildland Fire, 21, 282-296

Sharples, J.J., McRae, R.H.D., Simpson, C.C., Fox-Hughes, P. & Clements, C.B. (2017). Terrain-Controlled Airflows. Fire Management Today, 75 (1): 20-24.

FIRE THUNDERSTORMS (pyroCbs)

Wildfires can form thunderstorms. Before 2003 this was seen in Australia in the following situations:

- 1995 (25 Feb) Vic: Berringa, during a wildfire, and reported on by Bureau of Meteorology and fire researchers. The threat of downburst winds was the main thing reported on.
- 1998 (02 Feb) Vic: Caledonia River, where a fire plume was shown in satellite to have formed a storm which put the fire out.

It turned out that researchers in the US had monitored some other events in remote places:

- 1994 (23 Jan) WA: WSW Kalgoorlie
- 2001 (18 Jan) WA: Splinter Rock
- 2002 (17 Dec) Vic: Big Desert

Satellite imagery seen during global monitoring had shown these events. The global monitoring was focussed on civil aviation threats from volcanic ash and some other sources of aerosol in the stratosphere. They had seen events that could not be explained and checked for fire smoke. The Chisholm Fire in Alberta confirmed that major wildfires can produce intense thunderstorms.

Then came 2003 in the ACT elsewhere in the high country. This really got the attention of atmospheric scientists across the globe.

- 2003 (17 Jan) ACT: Stockyard Spur
- 2003 (17 Jan) NSW: Cabramurra
- 2003 (17 Jan) NSW: Thredbo
- 2003 (18 Jan) NSW: Broken Cart Fire
- 2003 (18 Jan) ACT: Stockyard Complex
- 2003 (18 Jan) ACT: Stockyard Complex
- 2003 (18 Jan) NSW: McIntyres Hut Fire
- 2003 (18 Jan) NSW: Tumut River
- 2003 (26 Jan) NSW: Alpine Complex
- 2003 (30 Jan) NSW: Alpine Complex

There was even another event in WA:

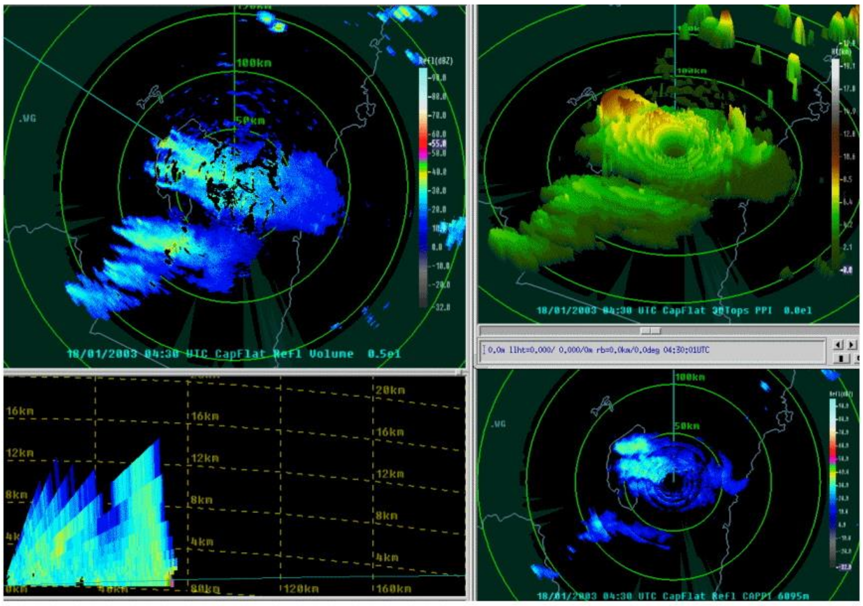
- 2003 (10 Jan) WA: Mount Cooke

So the extraordinary events that hit us on the ground were being monitored around the globe by atmospheric scientists. The Australian scientist in the International Volcano Watch project got them toy contact me to find out what had occurred on the ground.

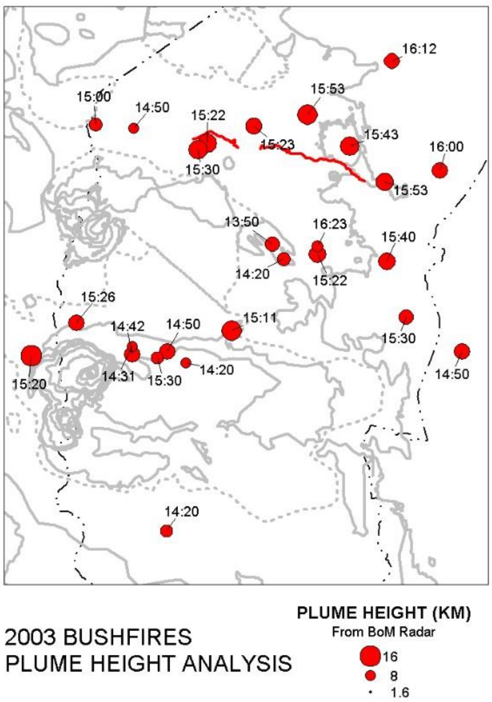
At the same time BoM was looking at the radar data. We had been lobbying BoM for nearly two decades for a Canberra weather radar. It was commissioned in November 2002!

ABOVE: The radome near Captains Flat.

Being nearby, it collected a treasure trove of data on the fire's convective systems.



ABOVE: 3d data from BoM's Captains Flat weather radar from 3:30pm on 18 January.
Top left: normal view; Top right: perspective view; Lower left: A slice through the plumes to the north-west; Lower right: A horizontal slice through the plumes 6km up. These allowed us to derived plume heights – which were up to 16km!



Fromm. M, Tupper, A, Rosenfeld, D, Servrancx, R & McRae, R, (2006). Violent pyro-convective storm devastates Australia's capital and pollutes the stratosphere. Geophys. Res. Lett. 33, L05815.

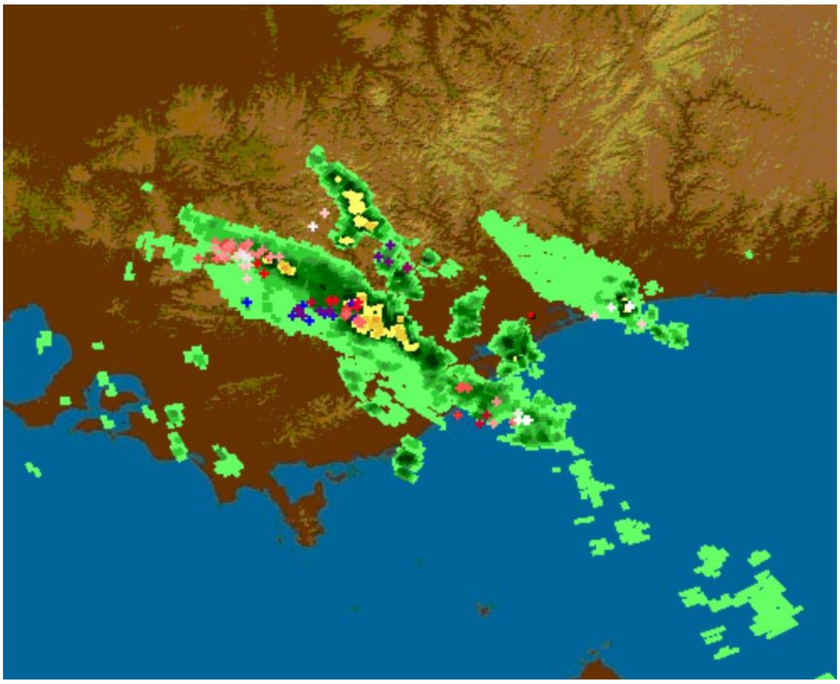
Fromm, M., Lindsey, D.T., Servranckx, R., Yue, G., Trickl,, T., Sica, R., Doucet, P. & Godin-Beekmann, S. (2010). The Untold Story of Pyrocumulonimbus. Bulletin of the American Meteorological Society. September 2010, pp 1193 - 1209.

PYROGENIC LIGHTNING

Thunderstorms can generate lightning if their cloudtops get to below about -40°C. Fire thunderstorms are the same. If conditions are right for a bad wildfire, then they are likely to also be like that downwind of the fire. So pyrogenic lightning is well placed to cause new fire ignitions.

This did not happen in 2003, but has happened in Victoria and NSW on a few occasions. A couple of years ago the fires in British Columbia associated with the heat dome at the town of Lytton spat out pyrogenic lightning for many kilometres downwind caused tens of new fires.

I only learnt that pyrogenic lightning occurred in 2003 by talking to one of the air ops guys while flying to the wildfires in BC in 2017. Every validated observation of this is scientifically useful while we learn more about it.



ABOVE: radar data overlaid with lightning data during Black Saturday in 2009.

PYRO-TORNADOGENESIS

This was perhaps the biggest surprise in real-time. Steven Wilkes was an air observer tasked by NSWRFS to work our fires from a helicopter. At one point the pilot told him that there was no air flow outside the door. Normally it is blowing a gale. They were being sucked into the tornado, and it took full power to escape. After this – and settling down – the damage path was mapped and photographed through the Uriarra Pine Plantation.

Bushfire experts called in that night expressed doubt about the report.

By collecting a full set of data and observations the proof of the world's first ever confirmed pyro-tornado was obtained. Two additional inputs were essential. A science paper published on numerical modelling of the plume produced a large vortex in just the right place.

Cunningham, P. & Reeder, M.J. (2009) Severe convective storms initiated by intense wildfires: Numerical simulations of pyro-convection and pyro-tornadogenesis. Geophys. Res. Lett. 36 L12812.

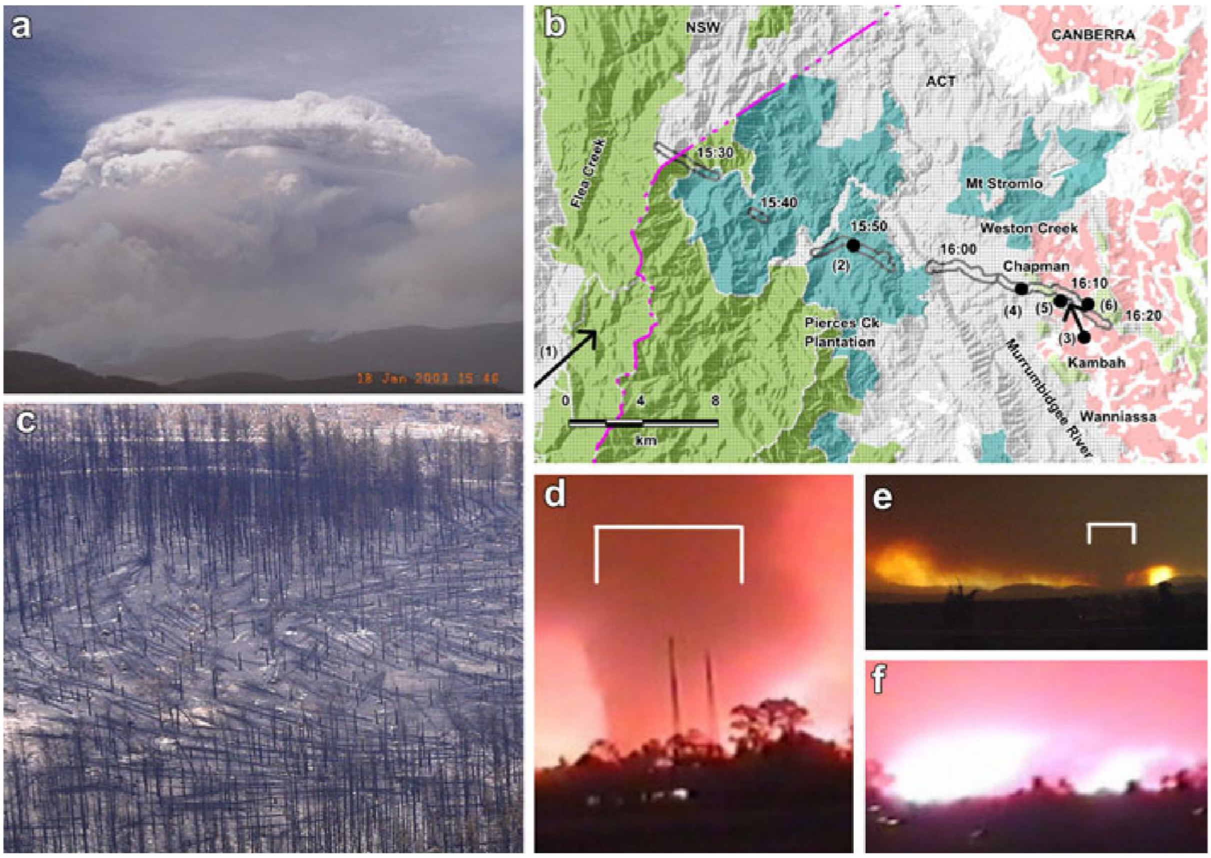
Tom Bates, a Kambah resident, was out on a walk and took a video of the tornado passing Mt Arawang. Such is the perversity of an adversarial Coronial enquiry that I first saw the video when shown it by John Dold, a combustion scientist from Manchester University.

So we got a paper published that showed that we experienced an F2 tornado. A few things need to be noted:

- Fire whirls are attached to hot ground, and have killed many people.
- Fire tornadoes (if they are indeed pural) are attached to the base of a pyroCb and can lift off the ground and re-attach downwind.
- Many media reports, even today, say that the damage in Chapman was due to the fire, but a lot of it was due to the tornado.
- Had the steering winds been one degree different, we would be talking about the tornado of 18 January 2003 (which had bad fires associated with it).

McRae, R., Sharples, J., Wilkes, S. & Walker, A. (2012). An Australian pyro-tornadogenesis event Natural Hazards, 65,1801–1811

BELOW: Here is a figure from the paper, with its caption.



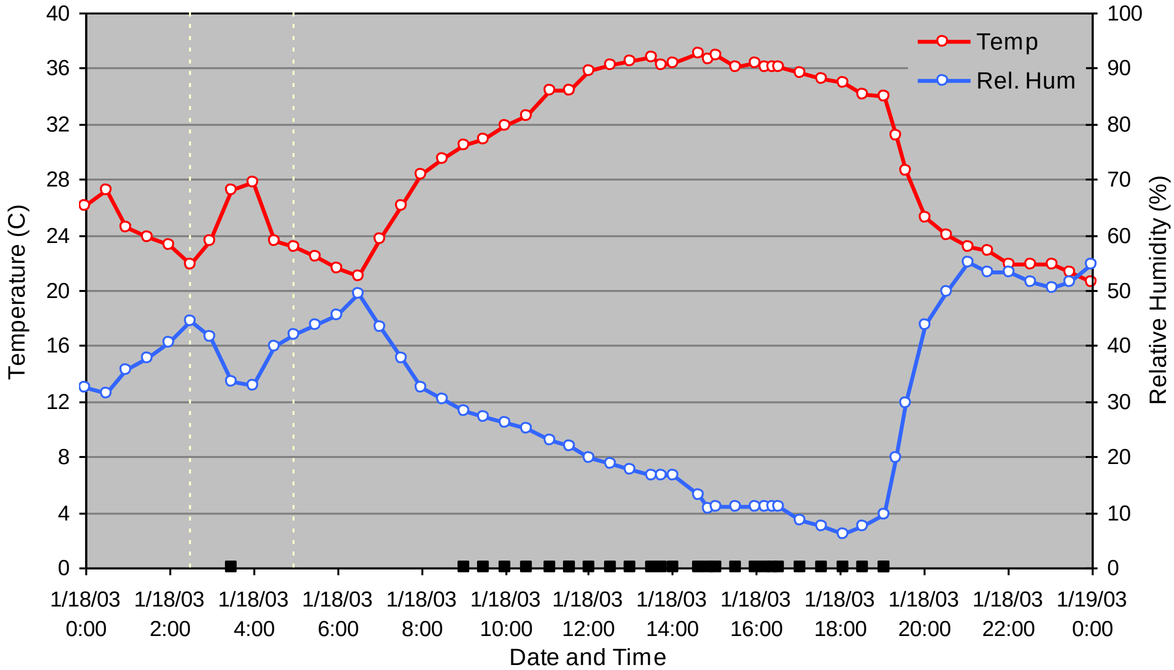
(a) The pyroCb seen from the SW, above Cooleman Creek. (b) Track map of the tornado, showing estimated timing of its progression, national parks in green, pine plantations in blue and the burnt area in grey. (c) Tornado damage in the Pierces Creek Pine Plantation. (d) The tornado passing the suburb of Kambah. E The tornado approaching the suburb of Chapman. I A landscape-scale flashover on Mt Arawang as the tornado passes. The brackets in d and e indicate the vortex

FOEHN EFFECT

The foehn effect is well known in some parts of the world – foehn translates to "fire" after all.

Many are familiar with the names of foehn winds – Chinook, Santa Ana, Mistral. They were not part of the standard wisdom in Australia.

BELOW: Graph of weather data for Canberra Airport on 18 January 2003. After midnight, the temperature rises for a few hours by six degrees while the relative humidity falls – inother words fire danger spikes in the early hours. This got us thinking about just what was going on.



It was fortunate that we were thinking about this. A wildfire started in southern Namadgi NP in May 2004 – almost winter in the high country. It defied suppression and became a crown fire at times. It was raining upwind in NSW. Coroner Doogan and her team dropped in to see how we were managing this fire, and failed to pick up any clues. The Lone Pine Fire was a foehn fire.

Sharples, J.J., Mills, G.A., McRae, R.H.D., & Weber, R.O. (2009). Fire danger anomalies associated with foehn-like winds in southeastern Australia. 18th World IMACS/MODSIM Congress, Cairns.

Sharples, J.J., Mills, G.A., McRae, R.H.D. & Weber, R.O. (2010). Foehn-like Winds and Elevated fire Danger Conditions in Southeastern Australia. Journal of Applied Meteorology and Climatology, 49, 1067-1095.

ABOVE: I especially liked the descending air flow shown by the smoke plume. Note the vehicle staging area in the lower left for scale. This area did not burn in 2003.

So we had enough to do the science on this, and got a paper published on it. It showed that when prevailing winds align at right angles to the terrain there can be a sudden spike in fire danger, and dry upper air is dragged down from the windward side of the ranges, through a well known process called isentropic drawdown. Well known to meteorologists at least. It was not in the bushfire literature at all. We gave a talk no this for the Bushfire CRC in Albury and some senior firefighters from the Gippsland said that they had named their foehn winds the "Autumn Equinoctial Gales" because no-one else knew about them.

We searched for more foehn affected fires after that, and found only a handful (Tathra and Holsworthy being the most notable). Black Summer added more than fifty to the list. Climate Change is making foehn affected fire a dominant driver of wildfire risk in south-east Australia. And it was first noticed on 18 January 2003.

DRY SLOTS

Graham Mills from the BoM head office was a keen analyst of wildfire weather. He wrote about what satellite imagery showed was related to the blow-up events in 2003.

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.

His detailed study showed that it is too simple to say that a fire “blow up ahead of the cold front”, as there are detailed and complex processes underway across the profile ahead of a front. He also showed how satellite infrared bands called “water vapor” band can show dry slots in the atmosphere, often ahead of troughs and fronts. An intense fire causes a lot of air to rise in its plume, and in some conditions this air from aloft is dragged down to replace what is going up (for example in deep valleys). This raises fire intensity and can forma feedback loop.

With the later advent of the Japanese Himawari-8 satellite, water vapor imagery has become a standard tool for intelligence generation.

Below: A key figure from Graham’s paper. The black diagonal band is the dry slot, As it passes Canberra the pyroCbs form and are the white areas.

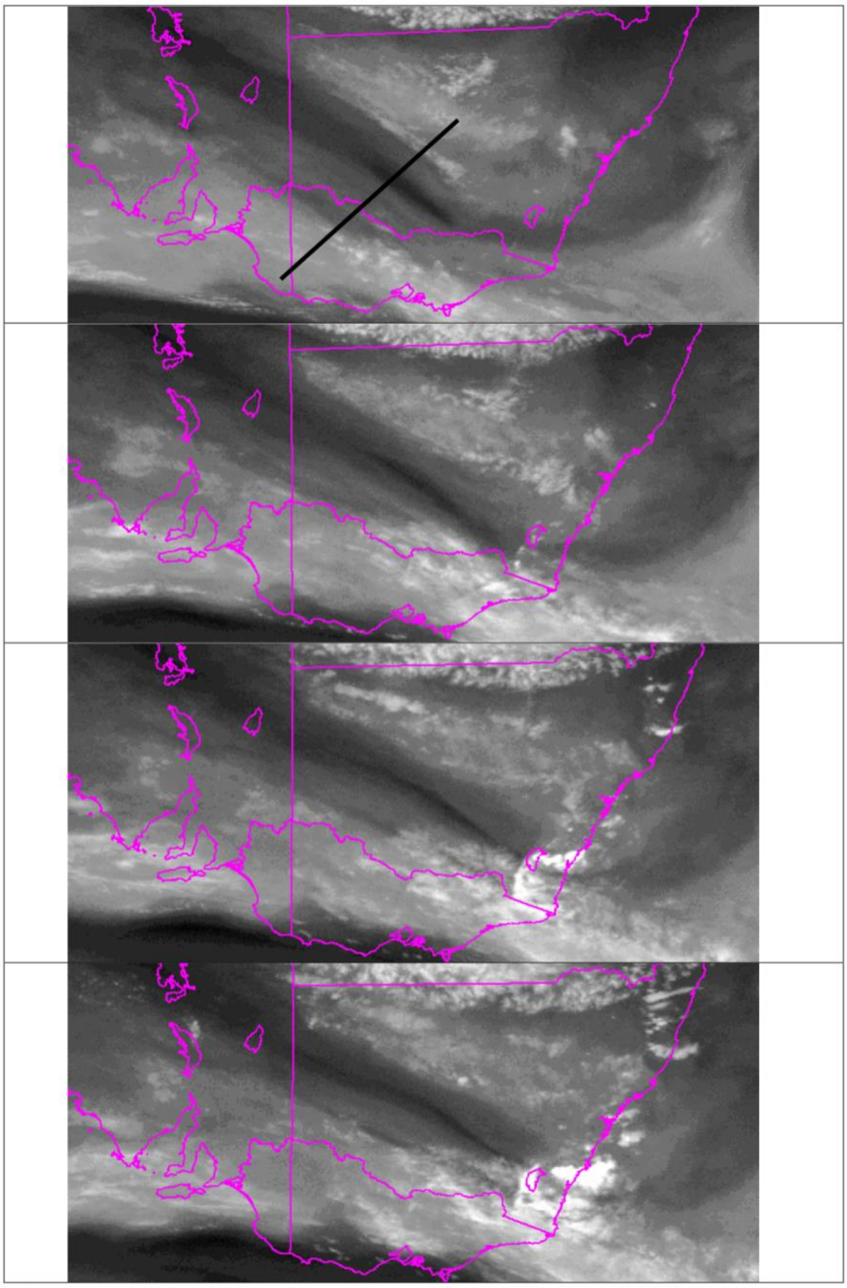


Figure 10. Enhanced Water-Vapour channel (6-7 µm) imagery from the GMS-5 satellite at 2330 UTC 17 January, and 0230, 0430, and 0530 UTC 18 January. The line in the upper panel marks the location of the cross-section in Fig. 11.

EMBER STORMS

A Channel Nine News Cameraman, Richard Moran, was forced to hop into an ACT Fire Brigade Command vehicle driven by Darrell Thornthwaite (Shadow). The footage is memorable for many reasons. At times Shadow drove through ember storms.

Most thinking about embers is in two models:

1) Ember showers occur when flames get inside the crown of a dry pine tree amd chimney up the trunk. The updraft drags a shower embers up into free air and they then settle some distance away and spread the fire.
2) Ember attack occurs when fragments of burning vegetation are lofted upwards as still burning firebrands. These follow a ballistic trajectory. There is a limit to how long they stay alight and how far they are propelled before they fall out of the plume downwind of the fire.

BELOW: The 2003 video showed something entirely different.

Pea-sized embers are blowing along parallel to the ground, like a fluid flow. It is thought that a low-oxygen environment contributes to this. It is also possible that, as is well known by bulk materials handlers (such as wheat silos) there can be static charge build-up as the particles collide off each other. Overhead is a large pyroCb, known to be forming pyrogenic lightning, possibly creating a large electric field.

As vegetation was ignited, it formed new embers, adding to the event.

The fluid flow follows the path-of-least-resistance, explaining why some houses were lost while other were unscathed. This poses serious questions for asset protection zone design.

Ember storms have since been seen invideos from other blow-up fire events, such as the Fort McMurray fire in Alberta, Canada, in May 2016, and even from Ash Wednesday in 2003.

NON-STOICHIOMETRIC COMBUSTION

As a fire plume forms, it contracts into a single column. As it does so it is trying to rise through the surrounding air. Friction causes it to mix-out with fresh air, diluting its buoyancy. However if a plume is rising above deep flaming caused by VLS, it is of a massive scale, with enormous energy embedded in it. It forms what could colloquially be called an event horizon as it resists mixing with its surroundings. The base of a pyroCb often looks like a cauliflower head.

What this means is that there may not be a ready inflow of oxygen to replace that used in combustion. This can manifest at a range of scales. Decades ago all fire trucks switched to diesel to avoid oxygen starvation.

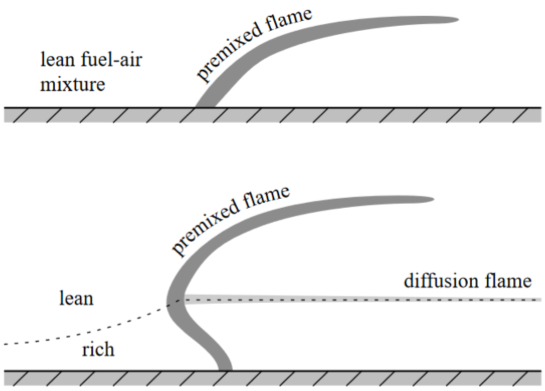
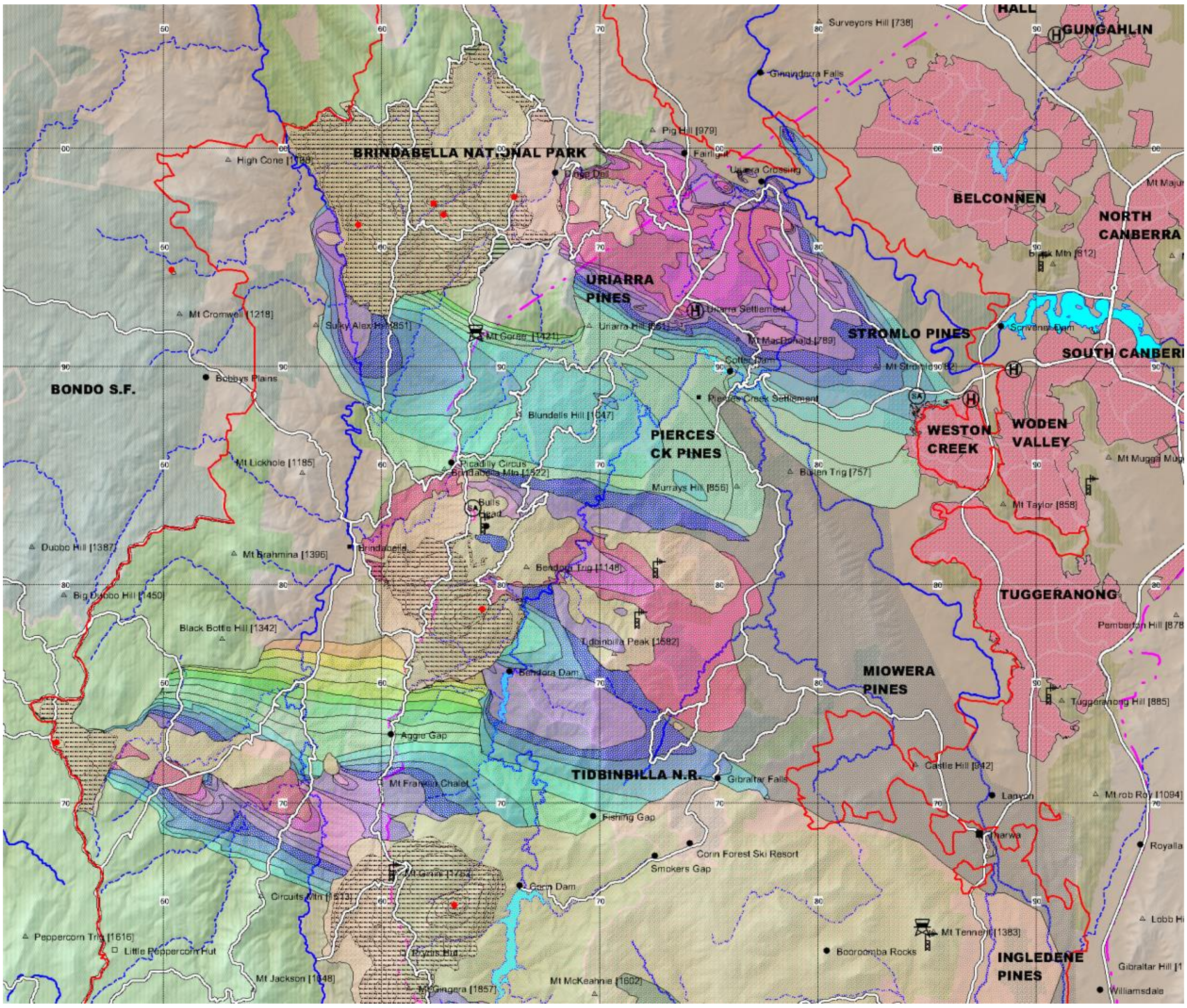


Figure 7: Sketches of flames travelling through a nonuniform mixture of fuel above ground. If the mixture is fuel-rich near the ground (lower diagram) a diffusion flame forms along the path of stoichiometry after the passage of the lean and rich premixed flame branches.

ABOVE: A figure from the paper on unusual combustion in 2003.

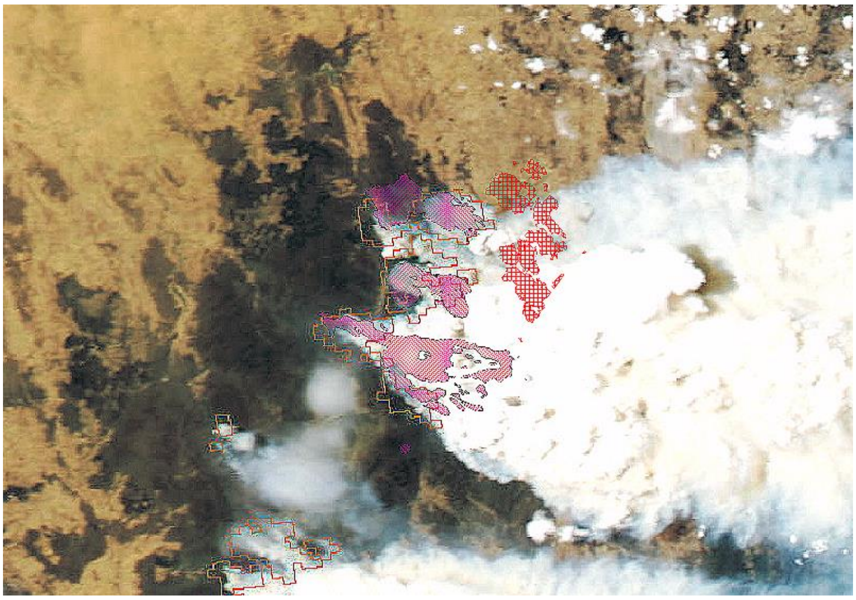
Dold, J, Weber, R, Gill, M, Ellis, P, McRae, R & Cooper, N. (2005). Unusual Phenomena in an Extreme Bushfire. 5th Asia-Pacific Conference on Combustion, The University of Adelaide.

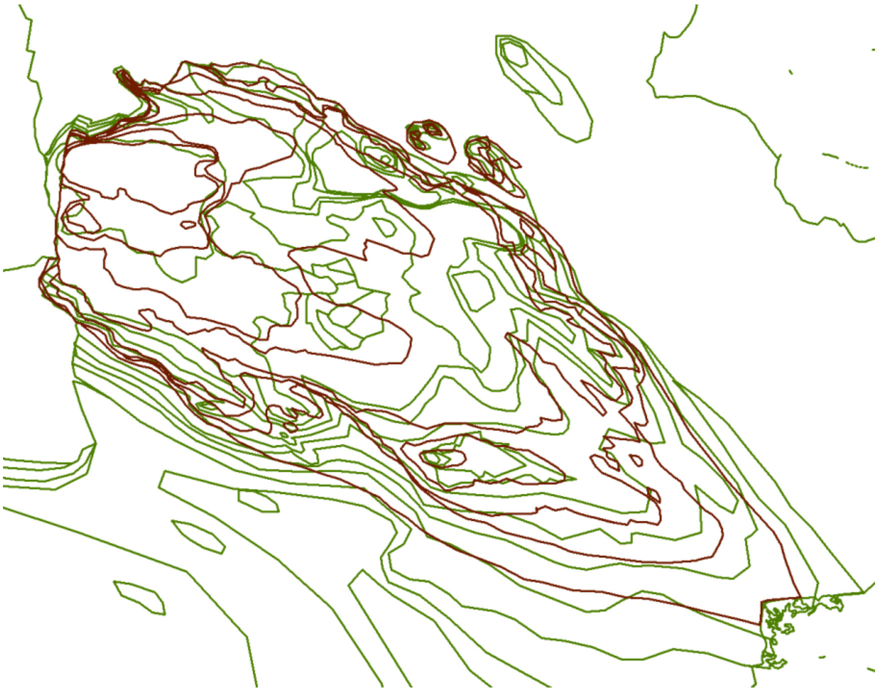
BELOW: John Dold trying to explain combustion physics.



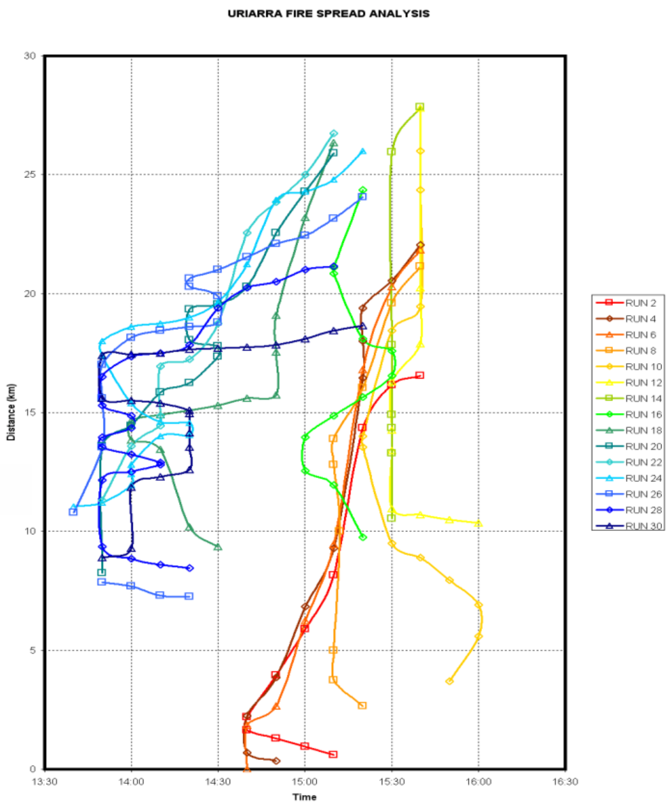
ABOVE: Fire progression map. Beige = burnt before 18 January; various colours = 10 minute spread increments; red line = final burnt area. The grid has 10km increments.

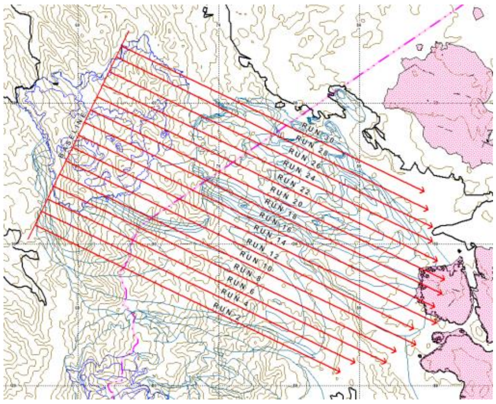
BELOW: MODIS image from 14:30 with Canberra and fire spread overlaid. [GSFC, NASA]





ABOVE: Reconstructions of fire spread through the Uriarra Pine Plantation. Brown lines are produced using steady-state fire theory (Phil Cheney, from ACT Coroner's Court); Green lines are produced using dynamic fire theory. Both were anchored off NSWRFS linescans, but were interpolated differently.





ABOVE: A set of transects along which fire spread rates were estimated. LEFT: Those spread rates. Continuous spread rates of over 20 km/hr result. Spotfires jumping ahead produce discontinuities.

POST 18 JANUARY 2003

This material was gathered during and after the fires by Rick McRae, then with the ACT Emergency Services Bureau.

After we were altered to what could be thrown at us on the 18th, we were looking harder for new evidence.

20 January weather

On about the 16th meteorologist warned me over the phone about the potential for extraordinary weather on the 20th – even compared to what happened on the 18th. This was based on the modelled temperature at 850hPa. If the lower air well mixed, then the surface temperature reflects this value plus about an extra ten degrees for every kilometre of descent. At the coast than is an extra 15 degrees, on the Brindabella Ranges – well you are there already.

The trick was that the 18th put dense smoke right across that layer. It was no longer well mixed, and the outlying surface temperatures did not occur.

This had a lot of relevance.

Firstly, there was a paper on this:

Mitchell, R.M., O'Brien, D.M. and Campbell, S.K. (2006). Characteristics and radiative impact of the aerosol generated by the Canberra firestorm of January 2003. Journal of Geophysical Research 2006 Vol 111 D02204

They showed that a cooling of around 3 degrees and a drop of wind speed of around 10 km/hr occurred.

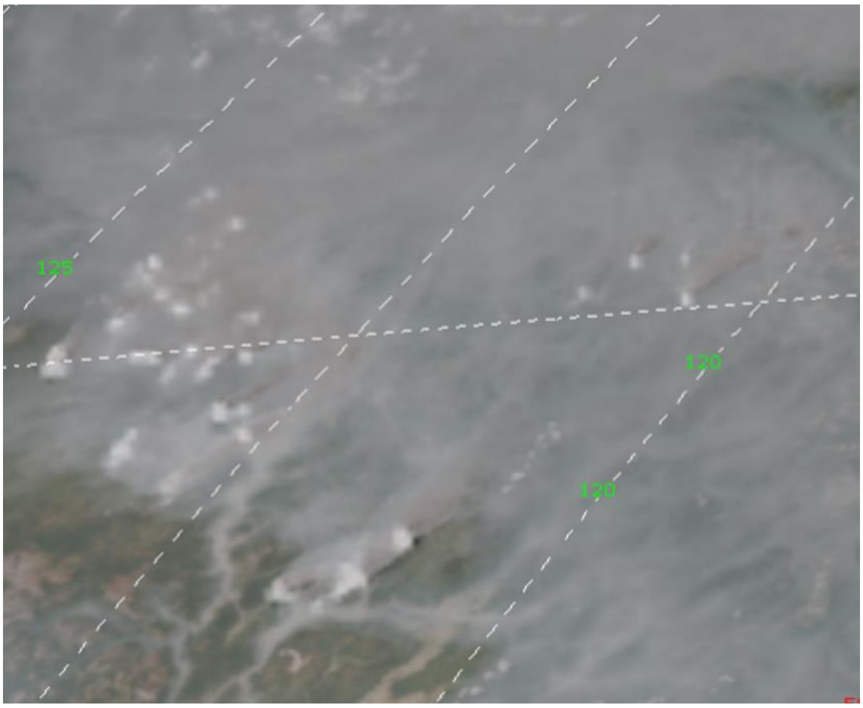
Secondly, it was involved in the validation of the Nuclear Winter Hypothesis in another paper:

Fromm. M, Tupper, A, Rosenfeld, D, Servrancx, R & McRae, R, (2006). Violent pyro-convective storm devastates Australia's capital and pollutes the stratosphere. Geophys. Res. Lett. 33, L05815.

Thirdly, it led to a reverse hypothesis:

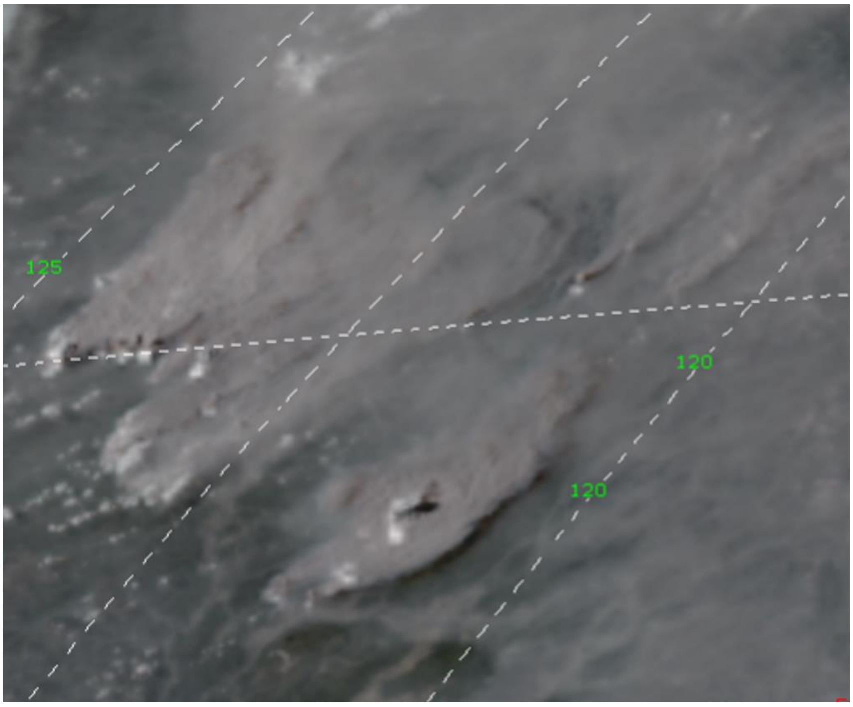
If dense low-level smoke is preventing dry, well mixed surface layer air forming, then the smoke's removal can cause dangerous fire conditions to suddenly appear.

This has been seen operationally since then. The fire crew safety implications are quite serious.



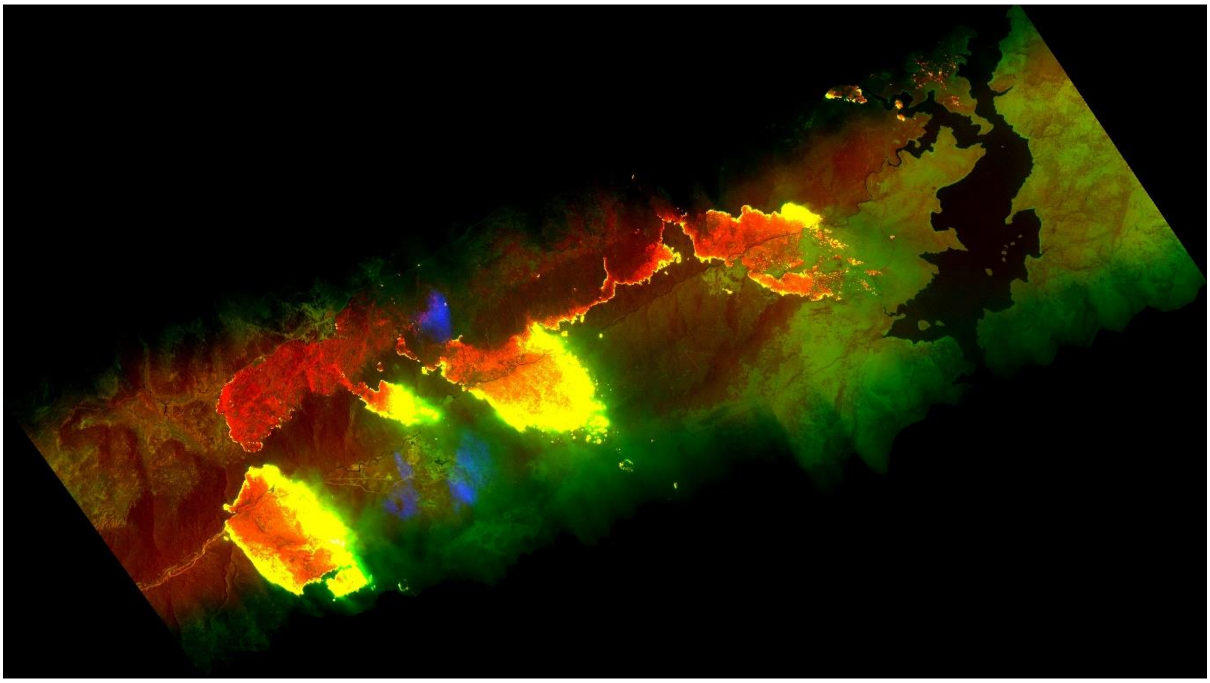
ABOVE: Satellite view of the British Columbia fires on the evening of the 17th July, 2017. Note the smoke layer across the region, clearing from the south-west (lower-left) as a cold front approaches. A number of pyroCu clouds can be seen. Note the denser, brown smoke forming on the lowest fires as clear air arrives. The map grid has two and a half degrees spacing [Images: GOES 16, SSEC].

BELOW: The same area about one hour later. As the smoke has cleared from the south-west large smoke shields have formed as the fires have escalated, and the initial steps of (then) the worst pyroCb outbreak ever recorded are seen. It must be noted that this was ahead of the frontal arrival. The smoke escalation indicates fire behaviour escalation that is at least as serious. Note also that the new pyroclouds are not near the surface.



FORWARD-LOOKING INFRA-RED

Some days after the 18th, and Australian Government aircraft with a FLIR pod fitted was made available for some reconnaissance flights. This proved to be of enormous scientific value.



ABOVE: NSWRFS Linescan of the Thredbo Valley on the 26th January. Fire was well established on the plateau, and four large fire-runs are seen heading into the valley from the north-west. Interpretation of such a complex fire pattern was challenging.

BELOW: Australian Government FLIR image of the same event. Looking to the north-east showing the intense upwind edge of a VLS event. This confirmed what happened.

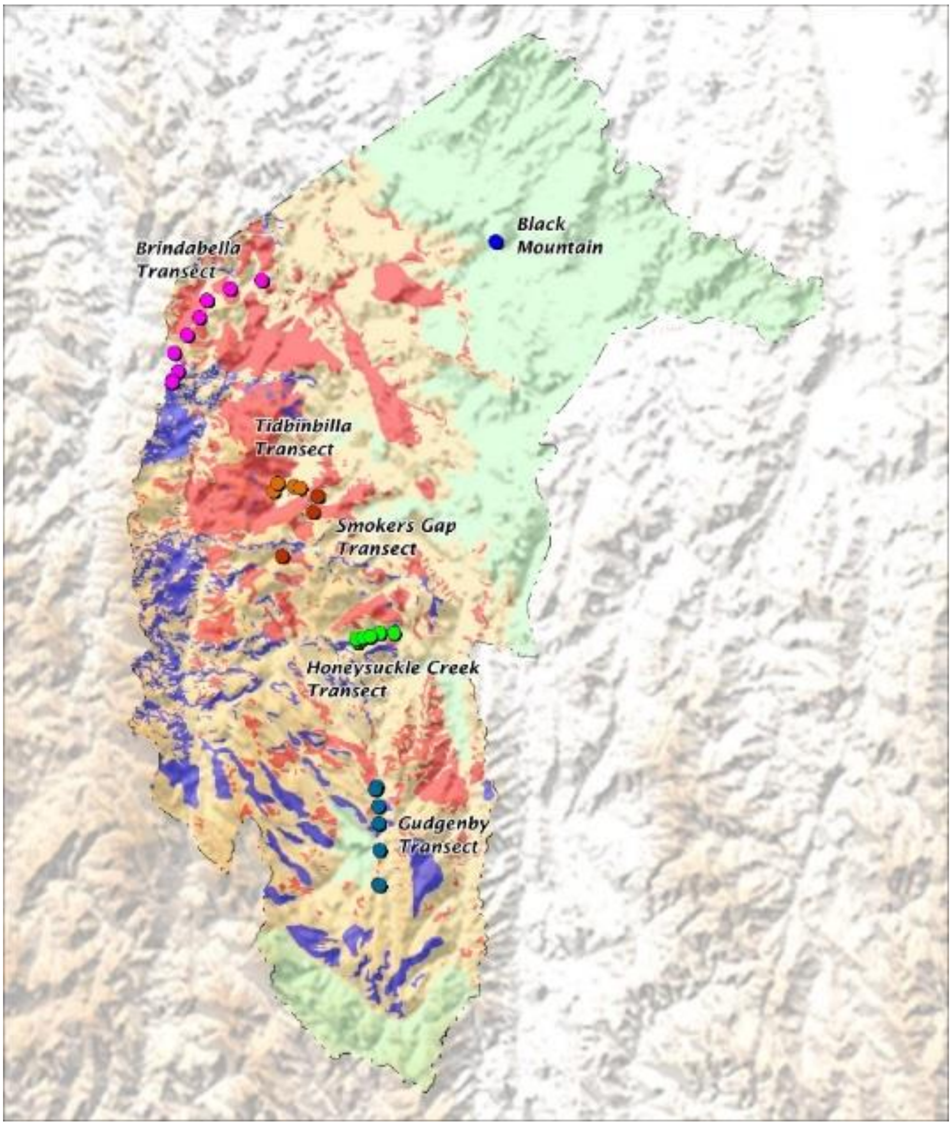
ABOVE: Fire crews on the north-west edge of a VLS run, where it crossed the valley flood highway. It a good thing that the theory of VLS formation shows that if the terrain element the generated the VLS ends, the fire stops spreading laterally.

BELOW: Well to the north on the same day, this large gathering of fire vehicles (image lower edge, centre) was equally fortunate.

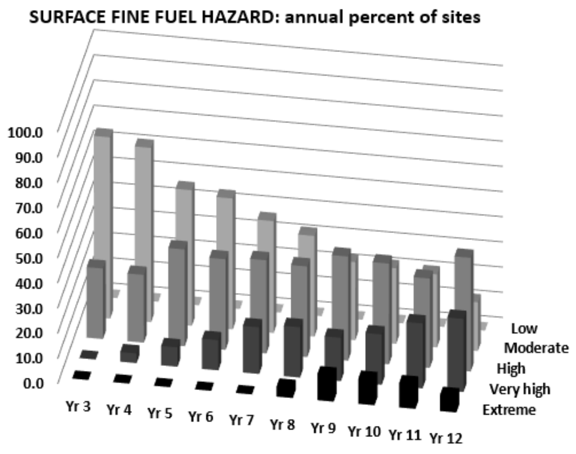
REGENERATION

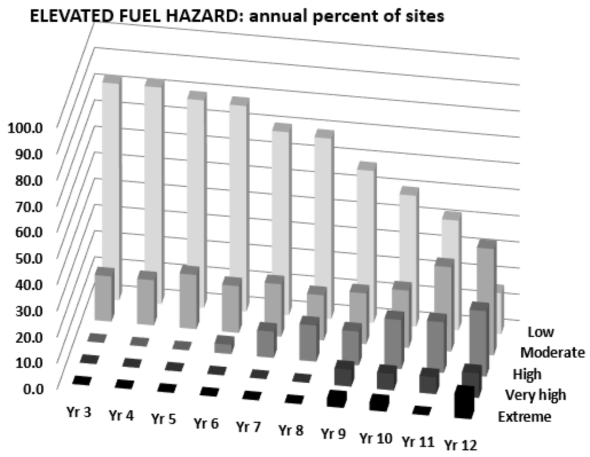
A long-term survey of how the forests regenerated after the 2003 fires was commenced when it had become safe to enter the fire affected stands.

BELOW: Sample site transects, with burn intensity: green = unburnt; blue = mild burn; yellow = hot burn; red = extreme intensity.



A series of key dynamics of stand recovery were recorded, reflecting both the forest type and the burn intensity. A cool burnt dry sclerophyll forest regenerated within five years, while an intensely burnt Alpine Ash forest is still regenerating.





ABOVE: Many fire behaviour models now refer to fuel hazard levels. The graphs shows the recovery trends for two key hazards.

TIMELINE OF SCIENCE PAPERS

2004

McRae, R. (2004). Breath of the dragon – observations of the January 2003 ACT Bushfires. Bushfire 2004 Conference, Adelaide.

2005

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.

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.

2006

Mitchell, R.M., O'Brien, D.M. and Campbell, S.K. (2006). Characteristics and radiative impact of the aerosol generated by the Canberra firestorm of January 2003. Journal of Geophysical Research 2006 Vol 111 D02204

Fromm. M, Tupper, A, Rosenfeld, D, Servrancx, R & McRae, R, (2006). Violent pyro-convective storm devastates Australia's capital and pollutes the stratosphere. Geophys. Res. Lett. 33, L05815.

2009

Sharples, J.J. (2009). An overview of mountain meteorological effects relevant to fire behaviour and bushfire risk. International Journal of Wildland Fire 18: 737-754.

Cunningham, P. & Reeder, M.J. (2009) Severe convective storms initiated by intense wildfires: Numerical simulations of pyro-convection and pyro-tornadogenesis. Geophys. Res. Lett. 36 L12812.

Sharples, J.J., Mills, G.A., McRae, R.H.D., & Weber, R.O. (2009). Fire danger anomalies associated with foehn-like winds in southeastern Australia. 18th World IMACS/MODSIM Congress, Cairns.

2010

Sharples, J.J., McRae, R.H.D. & Weber, R.O. (2010). Wind characteristics over complex terrain with implications for bushfire risk management. Environmental Modelling and Software 25: 1099-1120.

Sharples, J.J., Mills, G.A., McRae, R.H.D. & Weber, R.O. (2010). Foehn-like Winds and Elevated fire Danger Conditions in Southeastern Australia. Journal of Applied Meteorology and Climatology, 49, 1067-1095.

2011

Sharples, J.J., Viegas, D.X., McRae, R.H.D., Raposo, J.R.N. & Farinha, H.A.S. (2011). Lateral bushfire propagation driven by the interaction of wind, terrain and fire 19th International Congress on Modelling and Simulation, Perth, Australia, 12–16 December 2011, pp. 235-241

McRae, R.H.D. & sharples, J.J. (2011). Modelling the Thermal Belt in an Australian Bushfire Context. Proceedings, MODSIM 2011.

2012

Sharples, J.J., McRae, R.H.D. & Wilkes, S.R. (2012). Wind–terrain effects on the propagation of wildfires in rugged terrain: fire channelling. International Journal of Wildland Fire, 21, 282-296

McRae, R., Sharples, J., Wilkes, S. & Walker, A. (2012). An Australian pyro-tornadogenesis event Natural Hazards, 65,1801–1811

2014

Simpson, C.C., Sharples, J.J. & Evans, J.P. (2014). Resolving vorticity-driven lateral fire spread using the WRF-Fire coupled atmosphere-fire numericla model. Nat. Hazards Earth Syst. Sci., 14, 2359-2371.