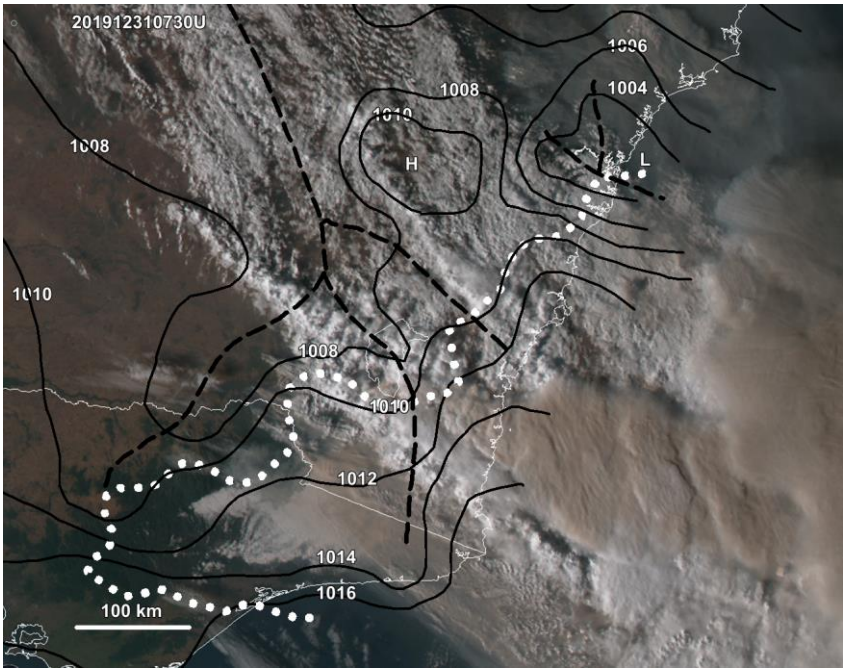
URGENTLY REVISITING PAST BUSHFIRE LESSONS



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UNSW CANBERRA

UNSW Bushfire

URGENTLY REVISITING PAST BUSHFIRE LESSONS

This report arises from scientific studies of bushfires over many years. During that time, numerous new scientific ideas about bushfire dynamics have become established. In a number of instances these new ideas have shed new light on why past fires have had catastrophic outcomes. The goal is to ensure that all lessons are learned and applied.

There have been delays in some of this new thinking being adopted operationally. This may be due to any of a number of causes:

- A lack of perceived need to change.
- Vested interests wishing to continue business-as-usual.
- An inability to discern the correct message in a flood of messages being constantly delivered. Who should be listened to?

In the case of accelerating impacts of climate change, it is essential that fire services adapt rapidly and correctly. They cannot afford repeats of past bad fires.

Unfortunately, on more than one occasion offers to present this material to national conferences have been rejected. That reinforces my key point. Thus, this material is being posted on-line.

You may care to read more about my views:

McRae, R. (2024). New Strategy Needed for Extreme Wildfires. *Wildfire Magazine*, Q3 2024, pp 28-32.

Contents

CONCEPT

Australia's fire services are, and have long been, very good at their job. Every now and then a fire in south-east Australia has such a catastrophic outcome that it is concluded that some parts of the fire services' operations were inadequate for the task.

Houses are lost; people die on the roads; people are killed by heat or smoke; fire crews are caught in a burn-over; - we all know the list. Remedy is sought by Governments – lessons have to be learned, and improvements demonstrably made.

This is achievable by one or more entities from a hierarchy of possibilities:

- Royal Commissions
- Parliamentary Inquries
- Coronial Inquests
- Operational Reviews
- In-house reviews
- After-action reviews

These focus on the elements of the basis for fire-fighting operations, which include:

- Training
- Communications
- Crewing levels
- Equipment levels
- Equipment maintenance
- Logistics
- Planning
- Prior risk mitigation
- Public awareness
- Again, we know the list.

Governments choose to accept all or most of the recommendations made. For the coming years there is an adjustment made to the funding levels to permit adoption of those accepted recommendations.
Training and procurement projects are implemented.

Even the magpie agrees.

The public is, overall, satisfied.
The typical sequence, in years, is this:

- 0 = fire event
- 0.5 = recovery phase winds down (sometimes longer)
- 1 = Enquiries start up, lawyers emerge
- 3 = Enquiries wind down with findings based on past wisdom
- 4 = Government implementation phase begins
- **4 = Science on the fire begins to be published.**

Can you see the problem?

The real issue addressed here is that scientific findings emerge after lessons have been learned. They often do not align with the findings produced by enquiries.

There is a reluctance to back-track on hard-earned changes because some academic says something (that is often incomprehensible) was missed.

Climate Change is rapidly changing the drivers of these fires, making long-adopted wisdom less relevant or even invalid. The "rule book" is being torn up and thrown out. We need to agree that we need a new one. We need to agree where it will come from.

And the world is full of people selling new rule books. Which one do we use?

[Graphics: McRae]

Without being so bold as to say "use this document as the rule-book", at the very least I offer this up as guidance on what might be needed.

DETAILS

Below are some key events from the last four decades that are related to this.

1983 EVENTS

9/1/1983 GRAYS POINT FIRE

This was a serious burnover event. Three volunteer firefighters from Heathcote Brigade were killed.
It was ascribed to a loss of situational awareness in what is now called the Dead-Man Zone.

RETHINK:

- The fire escalated in a VLS prone area, in conditions amenable to VLS occurring. The entrapment resulted from dense spotting.
- This erodes the basis of the Dead-Man Zone.

VLS generator (red line) upwind of burnover location. Analysis by Jason Sharples

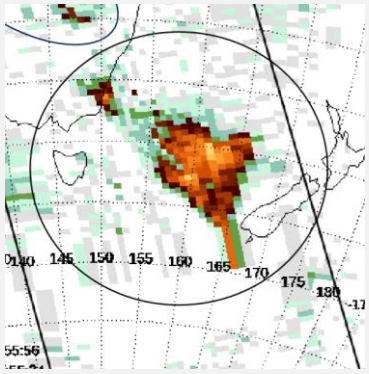
Cheney, P., Gould, J. & McCaw, L. (2000). The Dead-Man Zone – a neglected area of firefighter safety. Australian Forestry, 64(1), pp:45-50.

9/1/1983 GUDGENBY FIRE (pyroCb 1983c)

Operationally the usual suspects were wheeled out. It was seen as a call for more hazard reduction burning.

RETHINK:

1) This was an extreme wildfire, not responsive to fuel loads.
2) Hydrological studies produced still valid findings, largely ignored by fire services despite repeated validation and despite operational use in the ACT in the ’90s.



Upper atmospheric aerosol from the Gudgenby Fire. AI data: Nasa, map: Colin Seftor]

16/2/1983 ASH WEDNESDAY (pyroCbs 1983a & b)

Catastrophic fires in Victoria and South Australia killed 75 people.
Frequently used as a foundation for new fire spread theories, and for the calibration of most quasi-steady-state fire spread models in Australia.
It was used as a basis for building codes for bushfire-prone areas.

RETHINK:

Satellite imagery showed a Foehn Arch offshore from Lorne.
Satellite atmospheric data (Aerosol Index) showed two pyroCbs.

Comparison of plumes from Ash Wednesday 1983 and from Pacific Pallisades Fire, LA, 7 Jan 2025. [Images: AIDR & HPWREN]

The Ash Wednesday fires were dynamic fire events.

- Normal fire models calibrated off them are therefore to some extent invalidated, as they spread by dense spotting, not as firelines.
- Building Codes for Bushfire-Prone Lands may be incorrect.

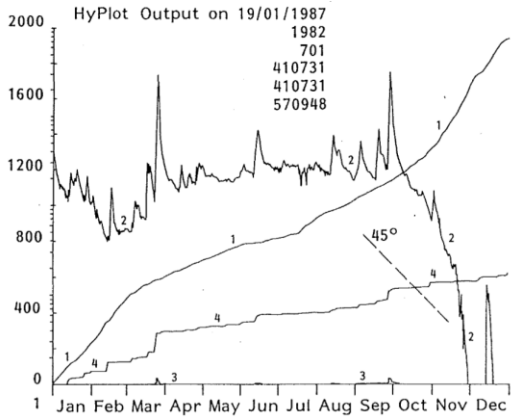
1990 SCIENCE

RIVER DRYINGS ISSUE DISCOVERED

A hydrological study found that when local rivers stop flowing, even large dead-and-down fuels can be fully flammable, which is a precursor for a blow-up fire event.

Kulik, V. (1990). Bushfire Hydrology: Runoff as an indicator of critical fire danger. Water Resources Development, 6, 44-54

This applied to the 1983 Gudgenby Fire – a 7 year lead-time. This predated a modern trend to use satellite imagery to sense fine fuel moisture levels.



A river's flow depth drops rapidly indicating a dry landscape. [Graphic: Kulik, 1990]

1998 EVENTS

1/1/1998 WINGELLO FIRE

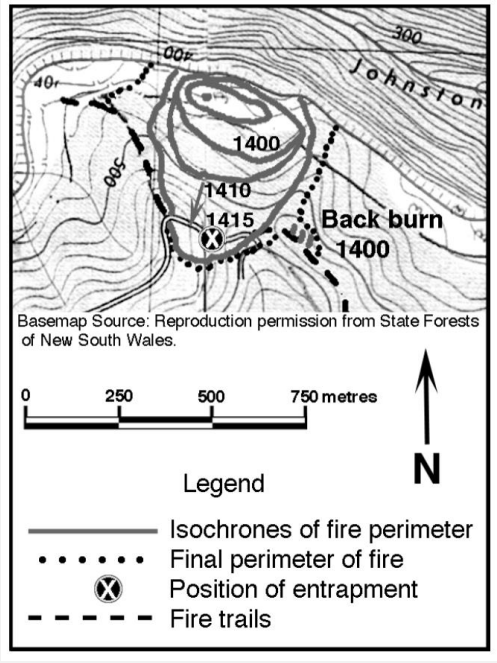
This was a significant burnover event, with one volunteer from Wingello Brigade killed and seven others injured.

It was used to describe loss of situational awareness in the Dead Mans Zone.

Post hoc analysis ascribed the situation to thunderstorm outflow winds in gorge country.

RETHINK:

- Fully compatible with Cliff-Top VLS.
- Erodes basis of Dead Man's Zone.



The Wingello Fire moved laterally above a cliff-top VLS generator. [Image: Cheney, et al., 2000]

2/12/1998 LINTON FIRE

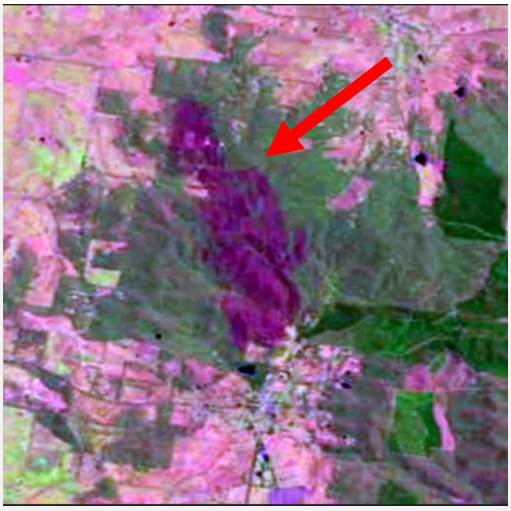
This was a significant burnover event, with five firefighters from Geelong killed. It was used as the basis for a focus on unexpected wind changes. It led to much stronger inter-service collaboration.

RETHINK:

The report into the fire described VLS without knowing what it was.

- VLS can be a major cause of fire crew burnovers.
- VLS can be suddenly activated by minor wind backing or veering.

Country Fire Authority, Victoria (1999). Reducing the Risk of Entrapment in Wildfires – A Case Study of the Linton Fire. CFA, July 1999.



The Linton Fire (purple) produced VLS (red arrow). [LandSat]

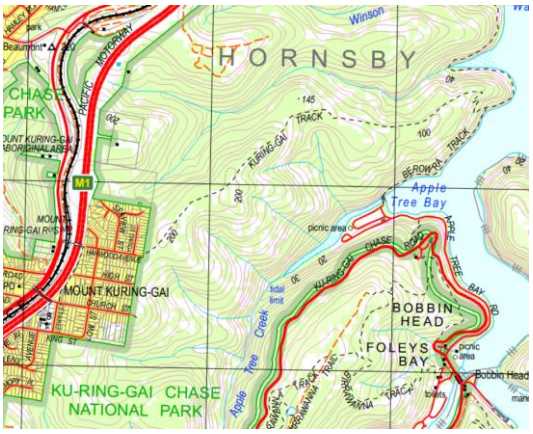
2000 EVENT

7/6/2000 MOUNT KU-RING-GAI FIRE

An unexpected flare-up during a hazard reduction burn killed four and injured three. It led to lessons on improving situational awareness and monitoring of conditions.

RETHINK:

This is a textbook case of eruptive fire growth. Specific, tailored watch-out arrangements are needed in cases such as these.



Gullies like these can be dangerous by allowing eruptive fire growth. [NSWLPI]

2003 EVENT

18/1/2003 CANBERRA FIRES (pyroCbs 2003d to h)

Driven by a complex trough, four major fires made VLS-driven runs, with major impacts in Canberra's suburbs. Four people were killed and hundreds injured. 512 houses were lost and a thousand saved.

Seen by Coroner as a case of poor management, and the usual suspects to fix this were wheeled out.

Expert advice given to Coroner was incorrect.

RETHINK:

- First major impact of climate change on an Australian capital city.

Violent pyro-convection approaching Canberra suburbs.

- First major pyroCb event in populated Australia.
- Discovery of VLS.
- First confirmed pyro-tornadogenesis.
- Discovery of Extreme Wildfire concept.
- Nuclear Winter Hypothesis validated.

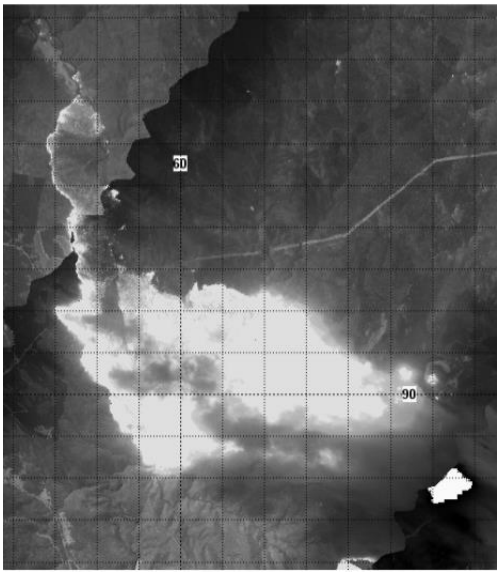
2003 OPERATIONS

Analysis of the 2003 fires showed that unexpected fire behaviour occurred. Terrain analysis showed that there was a new mechanism in play.

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

Near real-time weather data from BoM showed that extreme fire behaviour was linked to complex trough systems.

Real-time air observer reports indicated a fire tornado.



A NSWRFS linescan showing the first proof of unexpected fire behaviour. [NSWRFS]

2005 SCIENCE

ERUPTIVE WILDFIRE SPREAD DISCOVERED

Viegas, D.X., Pita, L.P., Ribeiro, L. & Palheiro, P. (2005). Eruptive Fire Behaviour in Past Fatal Fire Accidents. Eighth International Wildland Fire Safety Summit, Missoula, MT.

A fire in an escalator of an underground railway station in London turned catastrophic. This led to an understanding of flame attachment in trench shaped features. This applies to steep gullies.

Fennell, D. (1988). Investigation into the King's Cross Underground Fire. The Department of Transport, London.

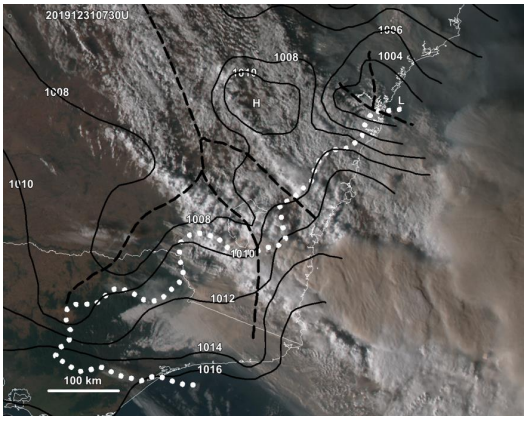
Flames attaching to a model of an escalator trench and jetting out of the top. [Fennell, 1988]

2005 SCIENCE

MESO-SCALE CIRCULATION SYSTEMS PROVEN

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.

Applies to 2003 Canberra Fires and to Black Summer fires.
Standard wisdom about post-change weather can be wrong.

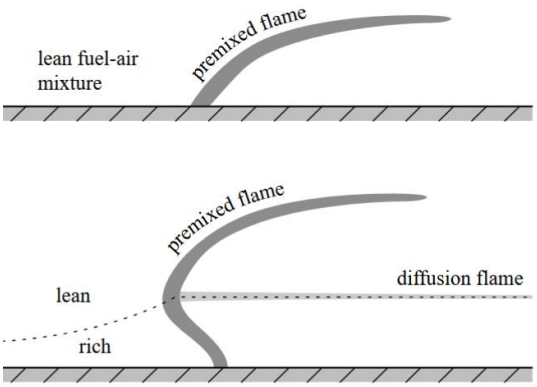


Branched trough, Black Summer. [Image: H8, Data: BoM; Analysis: McRae]

2005 OPERATIONS

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.

Applies to 2003 Canberra Fires.
Non-stoichiometric combustion and ember storms are still poorly understood threats during BUFEs.



Combustion chemistry is complex. [Dold, et al., 2005)

2006 EVENT

16/12/2006 MANSFIELD BURNOVER

A near-miss for NZ crews when fire entered a trench-shaped gully.
Insufficient consideration was given to the slope and unburnt fuel present. The failure to establish an appropriate anchor point and escape route may have been an outcome of this underestimation.

NZ fire crews escaping from the eruptive spread event.

Report of the investigation of the Mansfield burnover incident on Saturday 16th December 2006. Conducted by a joint Department of Sustainability and Environment, Country Fire Authority and New Zealand National Rural Fire Authority Investigation Team. 22 May 2007

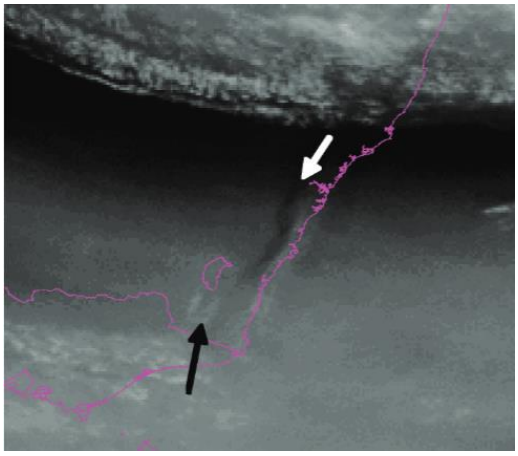
RETHINK:
Field assessment of risks from trench-shaped gullies must be mandatory.

2007 SCIENCE

DRY SLOTS FORMALISED

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

This links back to the 2003 Canberra Fires.
A hot fire run can cause the mixing down of dry air aloft, dropping fuel moisture and causing a feedback loop.



Satellite image of dry slot. [Mills, 2007]

2009 EVENT

7/2/2009 BLACK SATURDAY (pyroCbs 2009a to e)

Major loss of life. Large area burned. "Usual suspects" rolled out in post-enquiries.
Long distance spotting claimed.

RETHINK:

- A cluster of extreme wildfires poses major problems.
- Suppression intentions shown to be unachievable.
- Severity due to dynamic fire behaviour, not to elevated fire danger. The "Catastrophic" FFDR was incorrectly based.

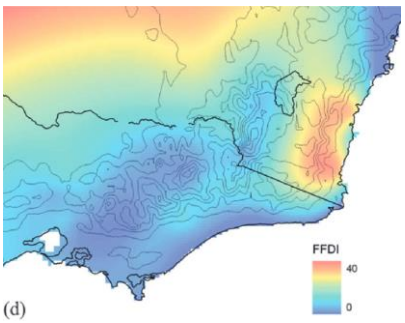
BUFEs during Black Saturday left widespread, uniform levels of significant impacts. [ACTESA]

2010 SCIENCE

FOEHN WIND DRIVEN FIRES IN AUSTRALIA SHOWN

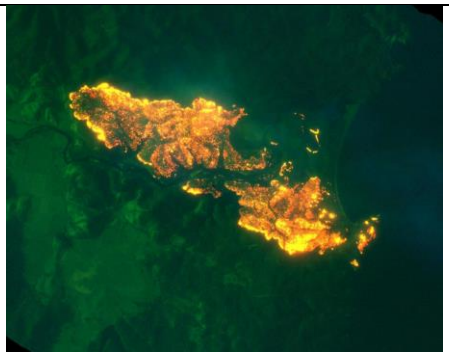
Sharples, J.J., Mills, G.A., McRae, R.H.D. & Weber, R.O. (2010). Foehn-like Winds and Elevated fire Danger Conditions in Southeastern Australia. Journal of Applied Meteorology and Climatology, 49, 1067-1095.

This links back to the 1983 fires, and to the 1967 Hobart Fires.



Modelled FFDI over SE Australia, 27 October, 2008, showing elevated FDI in lee of ranges near the coast. [Sharples, et al., 2010]

Now known to be a growing problem. Adaptation will require international collaboration. Significant training requirement.



The Tathra Fire 18 March 2018, crossed hazard-reduced areas, the estuary and the town by dense spotting. [NSWRFS linescan].

2012 SCIENCE

VLS PROVEN

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

A growing body of scientific literature has shown how dangerous VLS can be. This links back to the 2003 Canberra Fires, but is now known to have been involved in earlier fires.
A complex range of wind-terrain interactions are now understood:

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.

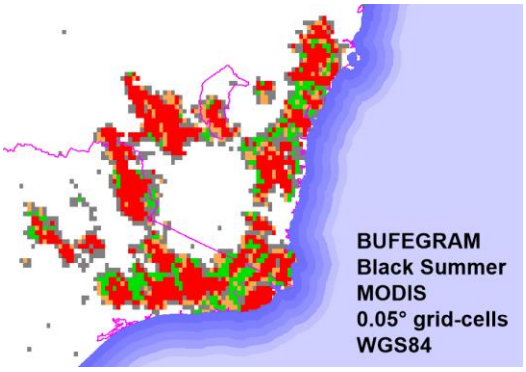
VLS underway, Airport Fire, Santiago Peak, CA, 9 September 2024. While winds are creating dense spotting way from the camera to the left, VLS is pushing the fire towards the camera under the ridge crest. [HPWREN video image]

2016 SCIENCE

EXTREME WILDFIRES FORMALISED

Sharples, J.J., Cary, G.J., Fox-Hughes, P. et al. (2016). Natural hazards in Australia: extreme bushfire. Climatic Change, DOI 10.1007/s10584-016-1811-1

Most events listed here are extreme wildfires, and thus to dynamic fire behaviour. There is a major training requirement to allow extreme fires to be properly anticipated.



Red areas burnt during Black Summer as dynamic fire behaviour. Green areas burnt over multiple days, orange on one day only. [Analysis: McRae]

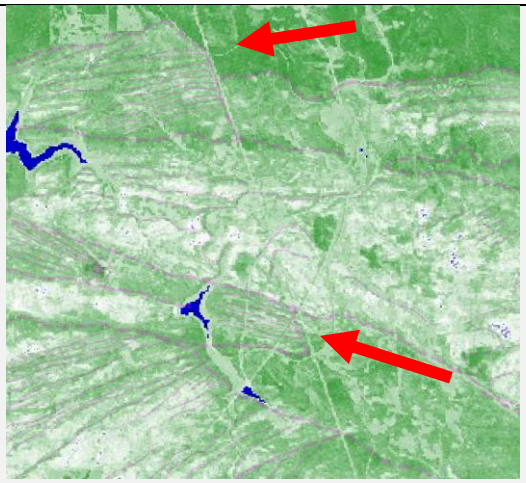
2016 EVENT

7/1/2016 WAROONA FIRE (WA) (pyroCbs 2016 a to c)

Fire Services were out of their comfort zone with this fire (as was the community).
Their explanation involved a pyroCb, but was not in accord with the detailed satellite data.

RETHINK:

- Need to include an involvement of VLS;
- There is a serious need to limit burn-out strategies in such events.



Satellite imagery shows fire edges following fire tracks.

2017 SCIENCE

2017 ERUPTIVE BURNOVERS FORMALISED

Lahaye, S., Sharples, J., Matthews, S., Heemstra, S., Price, O., and Badlan, R. (2018). How do weather and terrain contribute to firefighter entrapments in Australia? International Journal of Wildland Fire, 27:85-98.

Eruptive spread is known to be a key cause of major burn-over events.

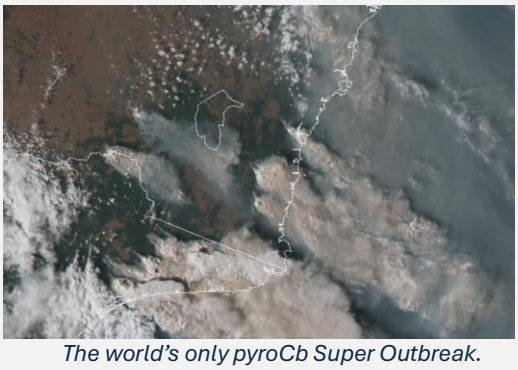
2019-2020 EVENTS

BLACK SUMMER (pyroCbs 2019a to 2019ax and 2020a to e and 2020k & l)

Unprecedented in every respect.

RETHINK:

- Fuel loads had no role.
- Suppression often not possible.
- Use of drip-torches created some of the hottest fires ever seen.
- Haines Index not relevant.
- Climate change is altering synoptic systems, making fires worse.
- Fires can alter the world's climate patterns.
- General predictive systems are seriously inadequate.



The world's only pyroCb Super Outbreak.

Violent pyroconvection was widespread during Black Summer.

CURRENT SCIENCE

PREDICTING BLOW-UP FIRE EVENTS

Predicting Blow-Up Fire Events using the Hierarchical Predictive Framework.
https://highfirerisk.com.au/hpf/

ADAPTATION

A lot of the key lessons are still in the pipeline...
We are getting faster, but are still slower than the Royal Commissions, etc.
This is benefiting from comparisons with Canada 2023 fires, Lahaina Fire, recent Californian fires, etc, but more collaboration is needed.

HPWREN video of the Airport Fire at Santiago Peak (10 September 2024). It has been enhanced to show the terrain-following ember storm (black streaks). The spotfire in upper right burnt 5ha in 2 minutes.

THE DILEMMA

What do we expect fire services to do when the immediate and the scientific lessons differ?

- Ignore the new: "We've done this for decades..."
- Choose one to use: "King Solomon is a volunteer firefighter, eh?"
- Train on both: "We ain't got the time for this, sport."

EXAMPLES OF THE LESSONS DILEMMA IN ACTION

THE YARNELL HILL FIRE, NEVADA, USA, 30 JUNE 2013.

This was the most serious burnover event of recent decades. It was the basis of the movie "Only the Brave".

OLD LESSON: Thunderstorm outflow winds from the north caused the burn-over.

SCIENCE: Smoke punched through the thunderstorm anvil. C. 12km up.

NEW LESSON: VLS to the south, ahead of the outflow winds, caused the burn-over.

NECESSARY COMPROMISE: Lookouts in VLS prone terrain need to be trained to look in all directions, not just where the flames are.

The red "x" in the satellite image below shows smoke filled cloud above the fire ground punching through the leading anvils of the storm line approaching from the north.

(The new lesson serves to increase the significance of the Granite Mountain Hotshots' sacrifice.)

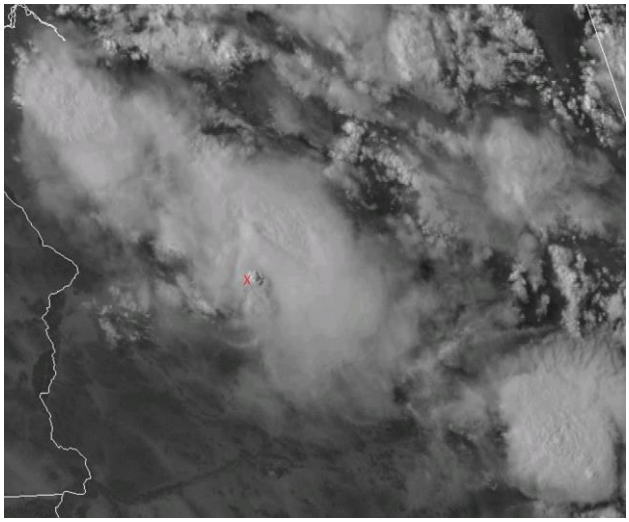


Figure 1. NOAA satellite image of the Yarnell Hill Fire underway.

07/02/1967 HOBART FIRES

The Hobart Fires have been used to evaluate MANY long-established fire spread models.

Below is an extract from yet another early report of VLS in what we now know to be a VLS-prone landscape. The official report into the fire weather said:

"...aerial observation of the fire areas appears to confirm that local channelling of the surface wind played a significant part at the Cascades, Waterworks Road and a section of Taroona...

"...turbulent eddies on the leeward side mountain region led to fires burning against the general wind direction, up the leeward slopes..."

Bond, H.G, Mackinnon, K. & Noar, P.F. (1967). Report on the meteorological aspects of the catastrophic bushfires in south-east Tasmania on 7 February 1967. Bureau of Meteorology, Melbourne.

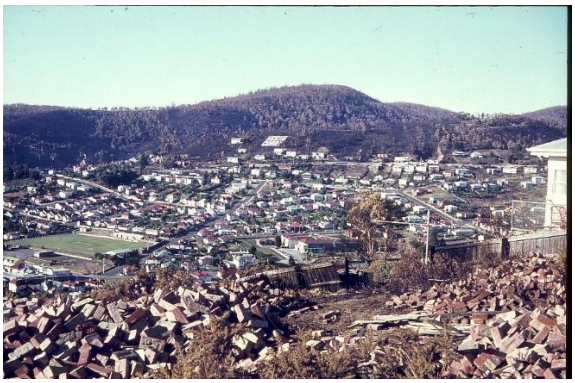


Figure 2. Suburban areas burnt in the 1967 fire. Note similarities to recent Californian urban impacts. [Photo: ACT Bush Fire Council]

The blue areas in the map below are prone to forced wind channelling.

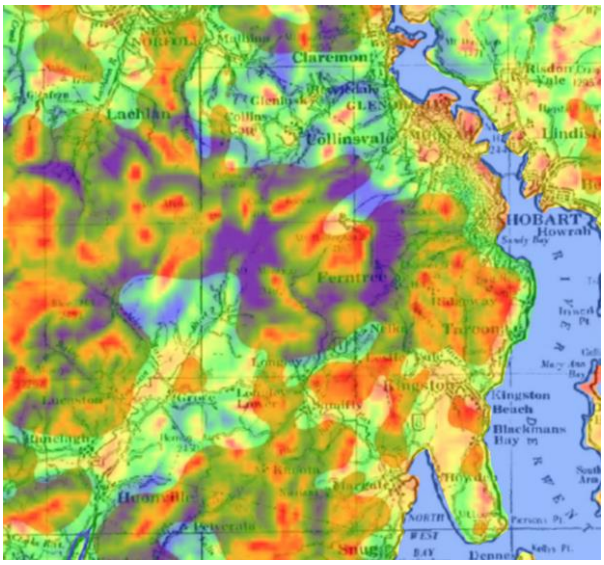


Figure 3. Terrain analysis of the Hobart hinterland. Terrain position is shown: red = exposed, bue = entrenched, green = mid-slope. Dark blue highlights the local areas burnt in the 1967 fire.

BERRINGA FIRE (pyroCb 1995a)

The Berringa Fire was the first in Australia to have open discussion of an associated thunderstorm. Arising from the official fire weather review was:

"Reports from the USA indicate that downbursts of air from similar clouds, have driven fires across control lines endangering personnel. **No evidence has been found of downburst activity from this cloud**, however possible mechanisms which may produce downbursts from fire-generated clouds are investigated."

Andrew Treloar, Regional Forecasting Centre, Bureau of Meteorology, Melbourne. Meteorological Study of a Bushfire Smoke Plume and Associated Convective Cloud in South East Australia. *Proceedings, The Sixth Fire Weather Workshop*: 18 - 22 June 1995, Hochstens at Hahndorf, South Australia

However, ever since then fire services and BoM have repeatedly stated that there is a risk of downburst winds on the fire ground.

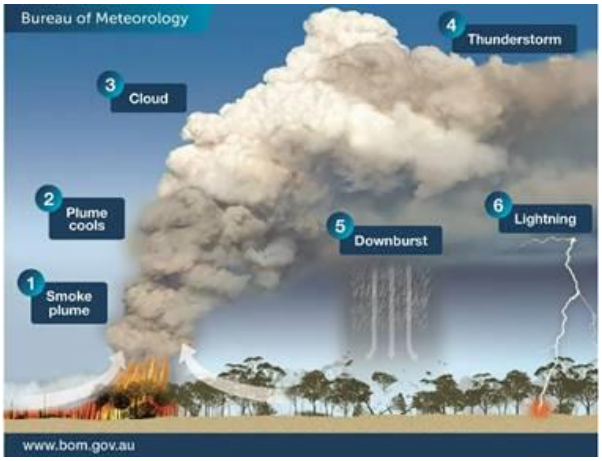


Figure 4. BoM graphic suggesting the presence of a downburst risk on the fireground.

BoM uses the graphic above for public information, and it includes downburst despite no case yet being recorded in Australia.

THE RETHINK

If you are from eastern Australia, think of a list of landmark lesson-learning fires – the ones that drove changes in how your fire services does its business.

Then cross-off from your list the following events, which need a rethink:

Hobart 1962;
Grays Point 1983;
Gudgenby 1983;
Ash Wednesday 1983;
Berringa 1995;
Wingello 1998;
Linton 1998;
Ku-ring-gai 2000;
Canberra 2003;
Mansfield burnover 2006;
Black Saturday 2009;
Black Summer 2019-2020.

What is left on your list? How much of your business model might have shaky foundations?

Then consider how the mismatch can be addressed. Is it a national problem or a local one? Who owns the problem? What can you do?

Early in this report, I presented the usual list of the things that can be improved to reduce future wildfire impacts. Unfortunately, many of these are ineffective against dynamic fire behaviour. We need to develop a new list for such fires, to be implemented alongside the usual one.

CLOSING REMARKS

It is important to honour what the people involved in these fires went through, and it is significant that we can still learn from their experiences.

I often refer to scientifically useful photos of the 2003 fires from space, and mention that the photographer died during their space shuttle's re-entry.

An extreme case of this: it now seems that there was a pyroCb formed from the urban mass fire after the Hiroshima Atomic Bomb. It had previously been confused with the mushroom cloud. We must continue to learn from these events, but the toll behind them can be challenging...

GLOSSARY

BUFE: A Blow-Up Fire Event (BUFE) occurs when part of a fire forms deep flaming, and develops dynamic fire behaviour.

Deep flaming: Deep flaming is a switch from line-fire propagation of the fire to a large area flaming at the one time. This alters the base of the fire plume and alters the air flow around the fire ground.

Dynamic fire behaviour: Dynamic fire behaviour is when the fire stops responding to the typical set of drivers (terrain, surface weather and fuel) and instead reflects the terrain, the atmospheric profile and the fire itself. The fire ground risk profile radically alters when this transition occurs.

Extreme wildfire: An extreme wildfire is one that, on one or more occasions, forms a BUFE in part of its perimeter.

Quasi-Steady-State fire behaviour: This is the "normal" form of fire behaviour, where (with some exceptions) terrain, fuel, and weather determine the behaviour of fire.