What conditions influence the occurrence of pyrocumulonimbus?

This research aims to better understand the environmental factors influencing the occurrence of pyrocumulonimbus (pyroCb), also known as firestorms. This will provide for better prediction and mitigation of the risks associated with these extreme wildfire events, which include dangerous escalations in fire behaviour and severe stratospheric pollution.

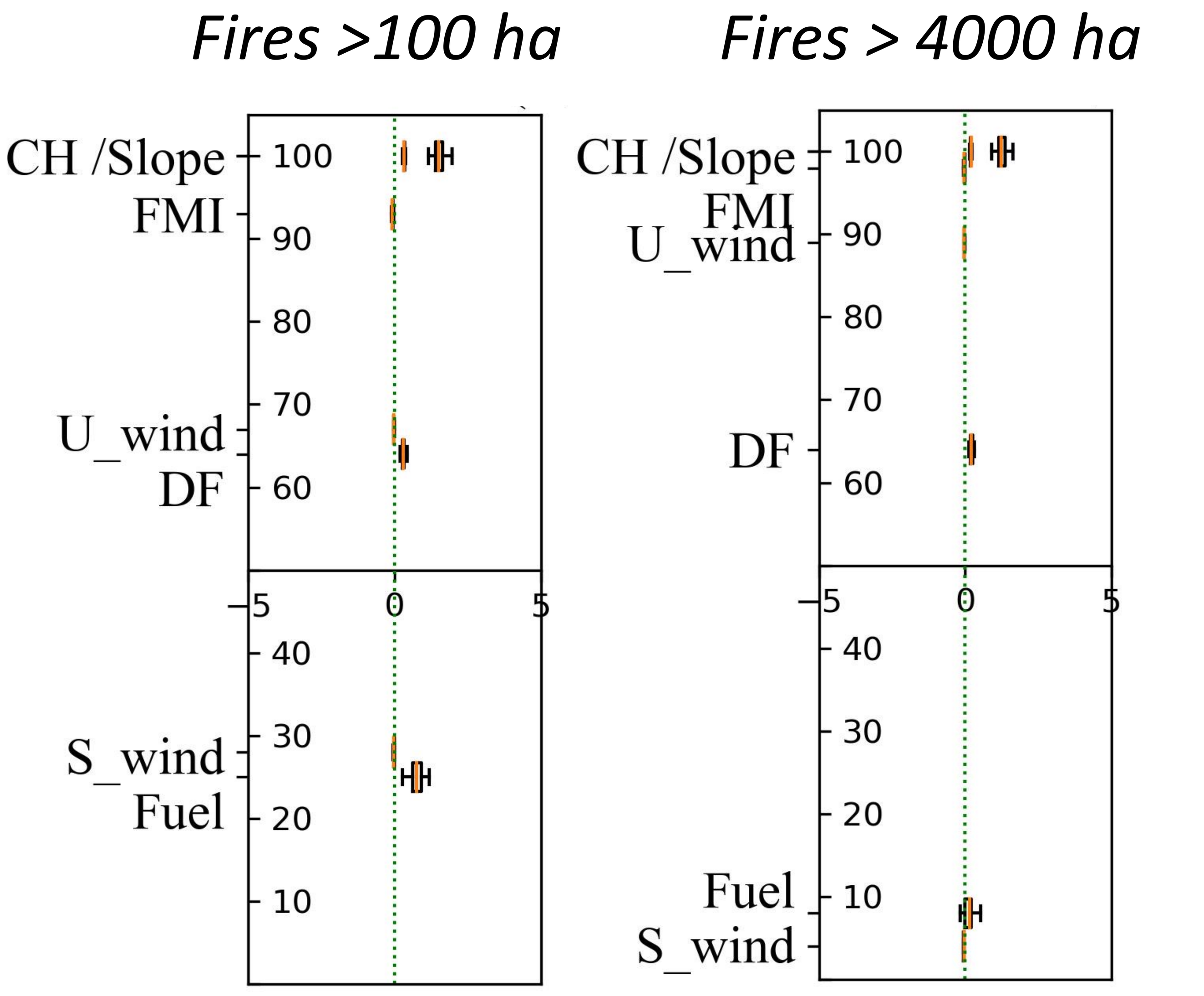

***Fig. 1**: Importance of various factors for pyroCb occurrence over SE Australia.*

Statistical models were used to assess the importance and contribution of environmental factors to pyroCb occurrence. These included:

- Atmospheric instability and dryness (C-Haines index, CH)
- Topographic ruggedness (Slope)
- Fuel moisture content (FMI)
- Drought Factor (DF)
- Surface winds (S_wind) and Upper winds (U_wind)
- Vegetation type (forest or grass, Fuel)

Figure 1 indicates that **atmospheric instability was the most important driver of pyroCb occurrence** over southeast Australia, followed by topographic conditions and surface fuel moisture content, along with drought and upper winds.

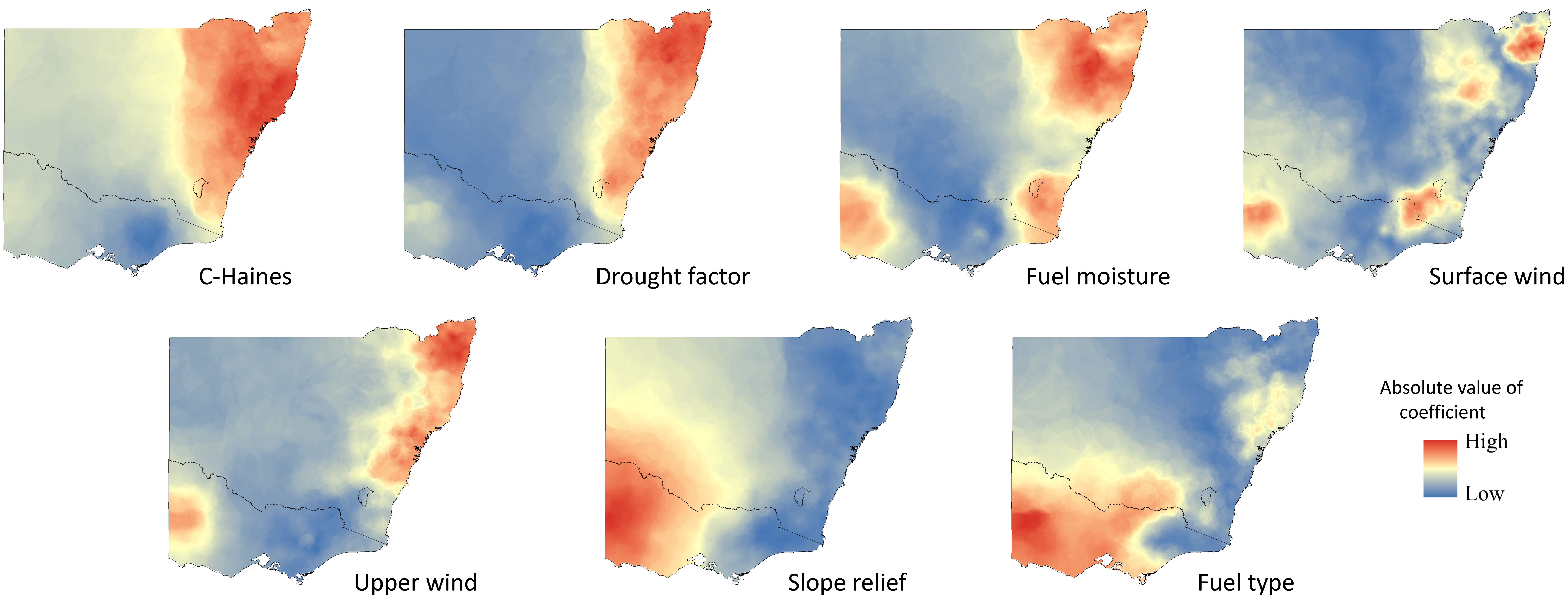

***Fig. 2**: Regional influences of environmental drivers of pyroCb occurrence over SE Australia. The higher the absolute value of the coefficient, the greater the impact on the probability of pyroCb occurrence.*

Figure 2 indicates that there are regional differences in the influence of pyroCb drivers over southeast Australia. Atmospheric instability (C-Haines), drought factor and fuel moisture content have a stronger influence in the northeast, while topography and fuel type are more influential in the southwest. Future work will consider the effect of climate change on pyroCb occurrence and how it may change the regional influence of the various environmental drivers.

For more information contact:
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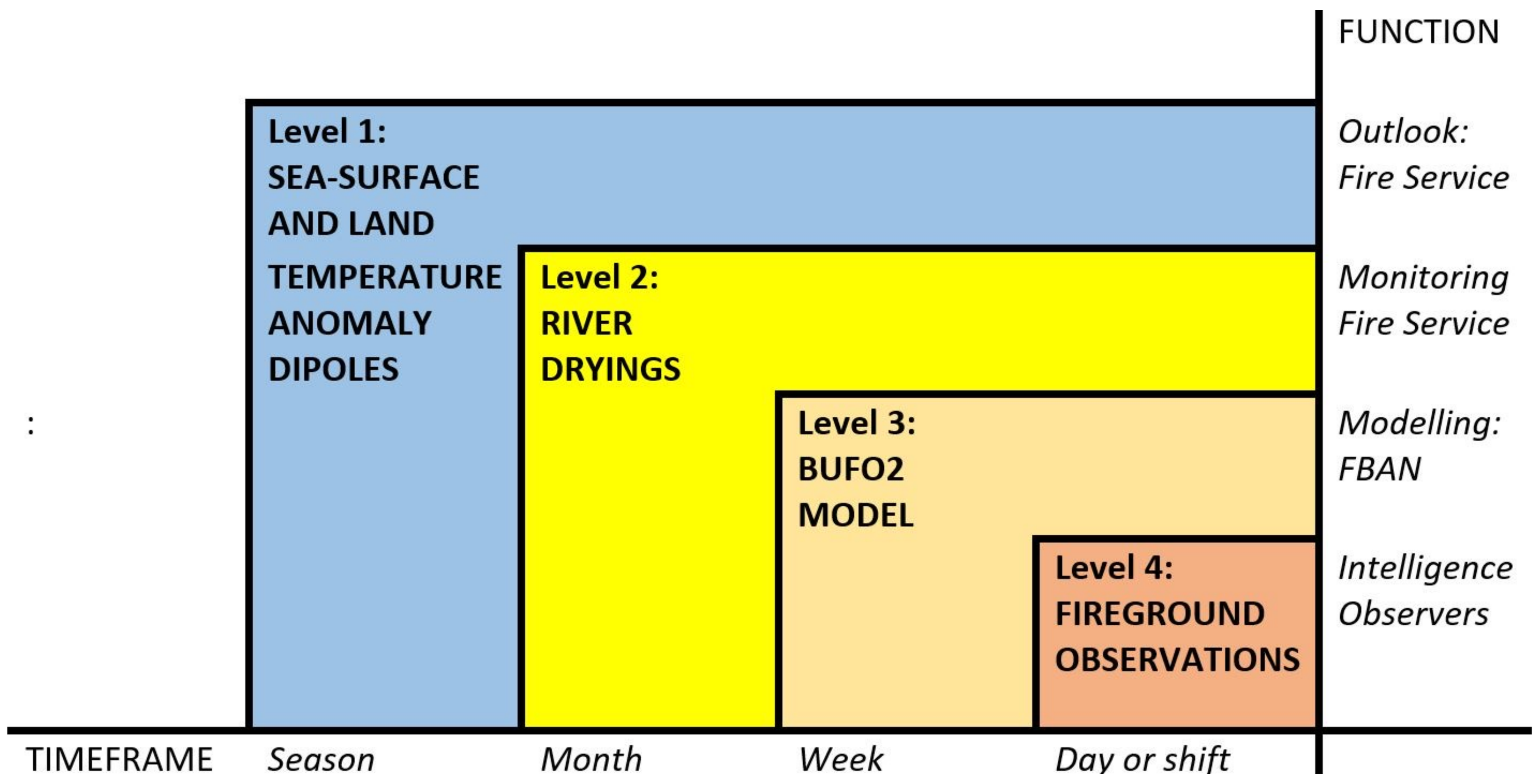
Watch my video

Predicting extreme wildfires

This research involves ongoing development of tools to forecast extreme wildfires, which are key drivers of bushfire risk to communities. These tools augment existing operational systems, such as fire danger rating systems.

Studies of significant wildfire events, such as the 2003 Canberra fires, have provided valuable insights into dynamic fire behaviour and extreme wildfire development. These insights have informed development of **extreme wildfire forecasting** tools. The Black Summer fires confirmed the fundamental ideas and concepts behind these tools and provided new information that facilitated further development of extreme wildfire prediction models. This has culminated in the current **Hierarchical Predictive Framework** (HPF).



Some key science elements

HPF operates on a range of time scales. Each one has a different function and different key users. It draws upon correlations between river flows and historical extreme fire activity. Interestingly, this sort of information was used operationally by the ACT Bushfire Service and the ACT Government hydrology agency for many years.

Recent work with US colleagues used HPF to assist in detection of two pyrocumulonimbus events in Ash Wednesday and possibly one at Gudgenby, also in 1983.

More recent extreme wildfire activity, since about 1997, indicates that El Nino events are having less of an influence in driving bad bushfire events. Smaller-scale effects, such as used here, become critical.

HPF is now being run as an operational trial. We welcome feedback from partners!

BLOW-UP FIRE EVENT (BUFE) OUTLOOK SOUTH-EAST AUSTRALIA

This page shows current Alerts for Blow-Up Fire Event potential.

ISSUE DATE: END OF MAY 2023.

This is an Operational Trial.
It is intended to be an intelligence product to aid in informed decision making, and should not be used in any other way.

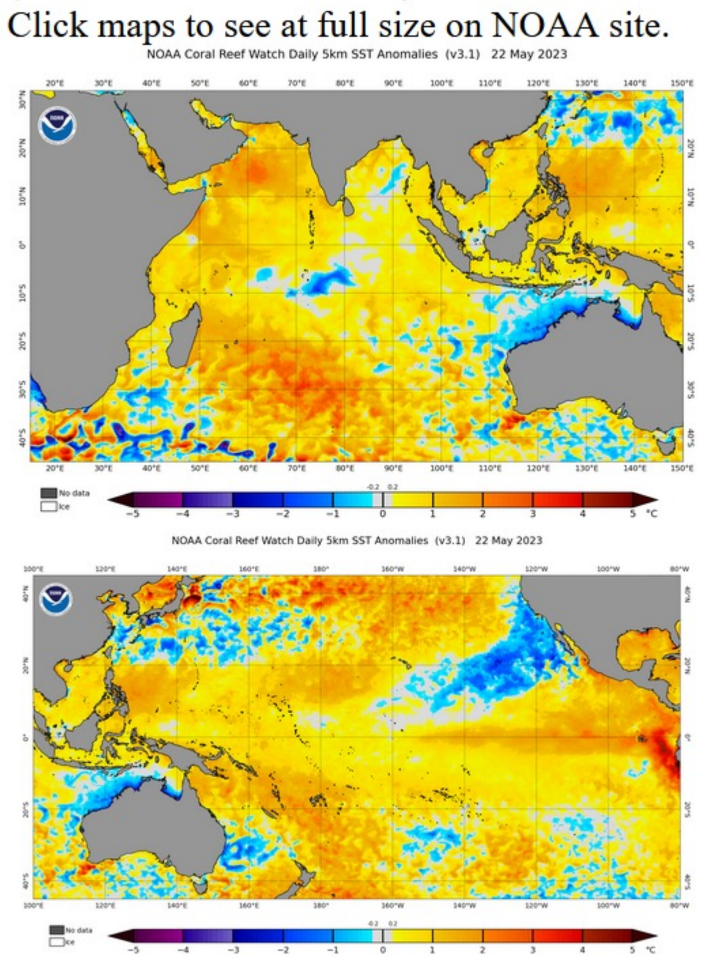
A REQUEST

If anyone uses this draft model operationally, can they please send their results to the author:

UNSW CANBERRA

Rick McRae

Current SSTA charts
(NOAA Coral Reef Watch)
Click maps to see at full size on NOAA site.



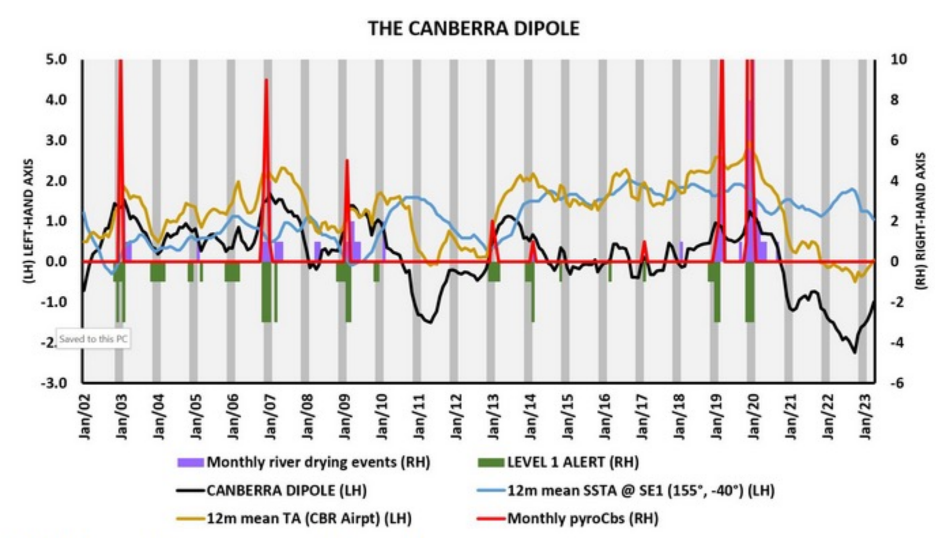
Current Alert Status:

NO ALERTS, BUT MONITORING REQUIRED.

LEVEL 1 CANBERRA DIPOLE

This reflects interactions between land and sea that influence synoptic patterns conducive to wildfires (or rain).

Data:
SSTAs - NOAA Coral Reef Watch;
TAs & River flows - Bureau of Meteorology;
PyroCbs - Australian pyroCb Register.



[Click on image to enlarge.]

ANALYSIS: (Changed from last month.) While the current value is negative, indicating continued rain events across some of Eastern Australia, this is changing rapidly. There is no BUFE potential likely until positive values return and other critieria are met. This is not likely until, at least, next summer. This may cause alerts during next summer.
NOTE: The land TA ran at record values during Black Summer, and its recent minimum was at levels once considered quite warm. The key factor is the remarkable warm SSTA run of ten years. Recently a cool SSTA area has formed offshore from Sydney. That run may have broken. The cool pool needs to become persistent for positive dipole values to form - remembering that it uses 12-month averaged TA values.

See the HPF outlook online.

Collaborators:
This is derived from operational work in Black Summer, and discussions with the international pyroCb working group.

For more information contact:
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Watch my video

The effect of fire geometry on extreme wildfire development

UNSW CANBERRA

This research examines how the expanse and shape of a wildfire influences its chances of developing into a fire thunderstorm. The higher a wildfire's plume can reach into the atmosphere, the more likely it will generate its own storm-like characteristics.

Fig. 1: *Pyrocumulonimbus over the Carr fire, California 2018..*

Extreme wildfires reach high into the atmosphere where fire-generated and entrained moisture can condense and form clouds. This process also releases latent heat, which can drive a wildfire plume deeper into the atmosphere and result in the formation of a thunderstorm within the fire's plume – this is called a ***pyrocumulonimbus*** (pyroCb).

Several factors are known to affect the chances of a wildfire forming a pyroCb, including surface weather (hot, dry, windy), low fuel moisture content, atmospheric instability and rugged terrain. However, less attention has been given to how the expanse and shape of the fire influences the likelihood of a wildfire penetrating deep into the atmosphere.

Low fuel moisture content combined with dynamic processes such as spotting can produce large expanses of active flaming during extreme conditions. Coupled fire-atmosphere models were used to investigate how the geometry of the flaming region influences plume development. Various geometric configurations were considered, ranging from a circular region to a thin rectangular fire line. The plumes from thin fire lines were found to not reach as high into the atmosphere as those from more expansive flaming zones (see Figure 2). These results indicate that the formation of large areal flaming zones can trigger pyroCb development.

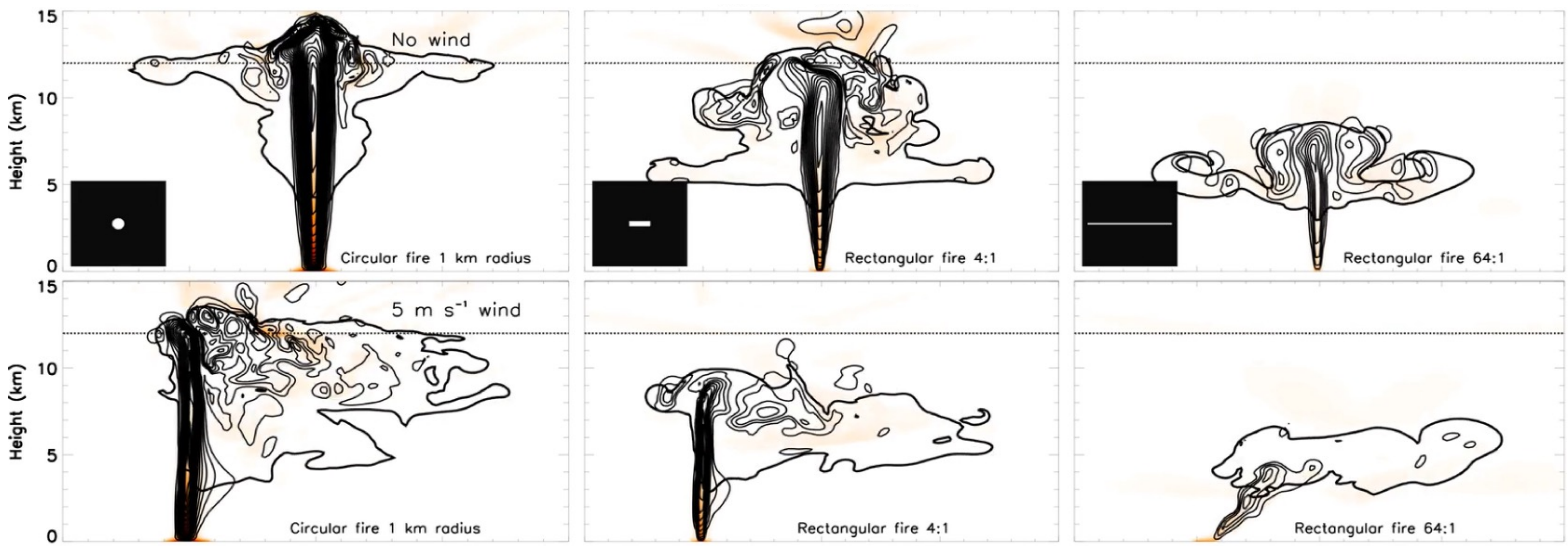

Fig. 2: *Coupled fire-atmosphere simulation results for fires of different geometric configurations (depicted in inset of top row) burning under the influence of two different wind speeds: 0 m/s (top row) and 5 m/s (bottom row).*

Collaborator:
Los Alamos National Laboratory

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Find out more

UNSW CANBERRA

Meteorological drivers of pyrocumulonimbus in Australia

This research is examining how meteorological features, such as cold fronts and troughs, influence the development of severe bushfire-generated thunderstorms known as pyrocumulonimbus (pyroCb). PyroCbs can produce extreme spotting, rapid fire spread, dry lightning, destructive winds and fire tornadoes. They are a significant hazard to those nearby!

The passage of cold fronts and troughs across southern Australia can have a significant influence on the behaviour of bushfires. Cold fronts and the low-pressure troughs that precede them provide atmospheric lift that can help in the development of pyroCbs (see Figure 1). The passage of a front/trough results in abrupt changes in surface and atmospheric conditions.

Initial work has shown that atmospheric stability and dryness and the moisture content of fuels differ significantly between pyroCb and non-pyroCb bushfire environments (see Figure 2), though questions remain about the role and source of atmospheric moisture in pyroCb formation.

***Fig. 1**: PyroCb initiation less than 10 minutes after the passage of a pre-frontal trough.*

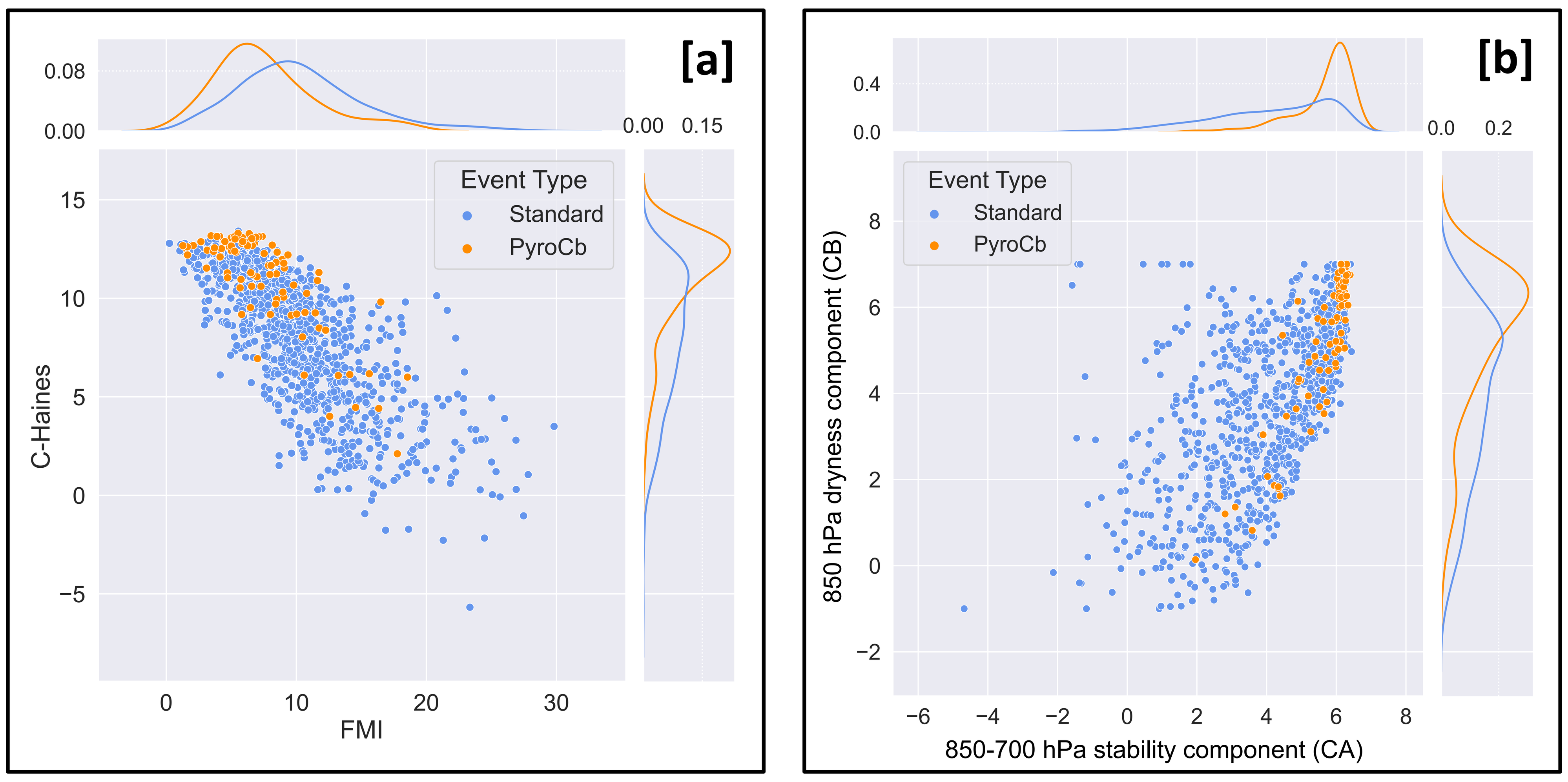


***Fig. 2**: Distributions of [a] Combined atmospheric stability and dryness (C-Haines) v. fuel moisture (FMI); [b] atmospheric dryness (CB) v. atmospheric stability (CA), for pyroCb and non-pyroCb (standard) events.*

Key research questions/objectives:

- What combinations of meteorological and fire conditions are required for the plume to overcome the temperature inversion?
- Does the moisture necessary for pyroCb formation in Australia originate in the mid-troposphere (like in western USA), at the surface (due to front/trough passage), or from combustion of fuels, and how much moisture is required?
- What is the role of dynamic fire behaviour?
- Coupled fire-atmosphere modelling case studies will be performed.

Before front/trough passage

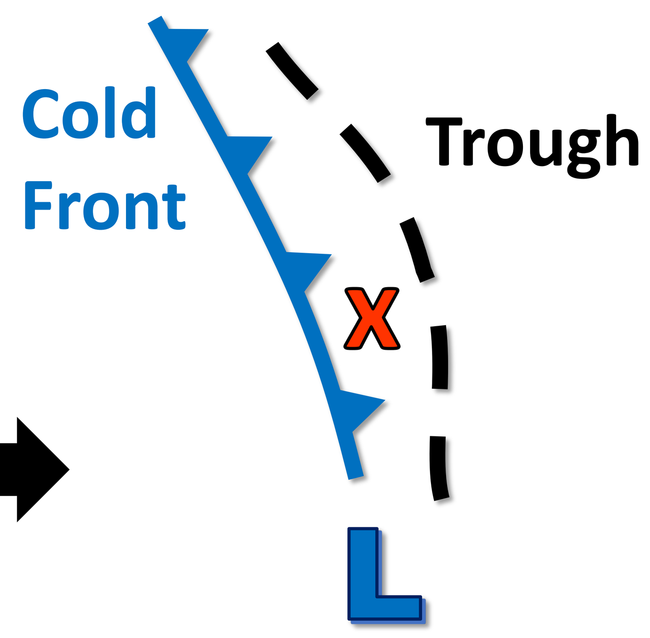
Mid-to-upper-troposphere

- Cooler temperatures
- Potential instability
- Atmospheric moisture?

Temperature inversion prevents pyroCb

At/near the surface

- Hot, dry, windy—very dry fuels
- Ongoing intense fire
- Widespread flaming



Front/trough passes over bushfire location (x)

Provides lift that helps the fire's plume overcome the temperature inversion and access the unstable atmosphere above

After front/trough passage

Mid-to-upper-troposphere

- Explosive pyroCb growth
- Cooler temperatures; instability
- Atmospheric moisture?

At/near the surface

- Cooler but with high winds
- Increased moisture/ instability
- Rapid fire growth on wind change; enhanced spotting and increases in intense, widespread flaming
- Large, powerful updrafts from fire maintain pyroCb growth

Collaborator:
Bureau of Meteorology

For more information contact:
Caleb Wilson, Jason Sharples or Jason Evans
<bushfire.research@unsw.edu.au>

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