Nat. Hazards Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/nhess-2019-354-AC2, 2020
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Natural Hazards and Earth System Sciences
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Discussions

Interactive comment on “Evolution of an extreme Pyrocumulonimbus-driven wildfire event in Tasmania, Australia” *by* Mercy N. Ndalila et al.

Mercy N. Ndalila et al.

mercy.ndalila@utas.edu.au

Received and published: 21 March 2020

RC: The manuscript subject is the analysis of a pyroCb event in Tasmania, the first on record, that occurred in the Forcett-Dunalley on 2013. Its formation and evolution is related to fire danger and the C-Haines index, as well as with fire severity. I found the work solid and writing effective. The only issue of note is the role attributed to VLS (vorticity-driven lateral spread) by the authors. From the information and figures provided I really don’t see enough empirical evidence for it, so I think the text could be more cautious.

AC: We appreciate your comments on VLS. See the end of this response for details on VLS.

RC: See below specific comments addressing mostly minor concerns.

RC: L11. I am not sure whether pyroCb development can be called a fire characteristic.

AC: The development of a PyroCb is contingent on the presence of a fire of sufficient intensity, therefore PyroCb development is intrinsically linked to fire behaviour, and the drivers of that fire behaviour. The generation of local weather associated with PyroCb in turn generates a feedback that further alters fire behaviour, so the linkage between the two phenomena is clear, and we believe studying PyroCb as a characteristic aspect of fire is justified.

RC: L31. ‘energetically intense”. Fire intensity is energy by definition. Maybe rephrase to ‘high-intensity’ or similar.

AC: We have rephrased the sentence to “Anthropogenic climate change is increasing the occurrence of dangerous fire weather conditions globally, leading to high-intensity wildland fires”.

RC: L32. Shouldn’t it be ‘conducive to’?

AC: We have rephrased the sentence to “. . .climate projections suggest a pronounced increased risk of extreme fire events in Australia, with 15-70% increase in number of days conducive to extreme wildfire by 2050 in most locations. . .”

RC: L35. Check ‘;’, it’s breaking the sentence flow.

AC: The sentence has been revised, to also include suggestions by another reviewer.

It now reads: “While fire weather is most often understood as a surface phenomenon (for example, through surface temperature, wind speed and relative humidity), atmospheric processes such as instability, wind shear and mesoscale conditions can also drive extreme fire development.”

RC: L35-36. Temperature is essentially expressed through fuel dryness. So remove the former or remove the later and add relative humidity.

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AC: The near-surface fire danger (FFDI) is computed from temperature, RH, wind speed and fuel dryness. However, to avoid doubt and reduce the wording, we have replaced fuel dryness with relative humidity.

It now reads as follows: “While fire weather is most often understood as a surface phenomenon (for example, through surface temperature, wind speed and relative humidity), atmospheric processes such as instability, wind shear and mesoscale conditions can also drive extreme fire development”.

RC: L37. This is a narrow definition of an extreme fire, as deep flaming and atmosphere coupling are often absent. Better to rephrase to make more explicit what the authors consider extreme, i.e. a particular type or range of extreme fire behaviour.

AC: We have rephrased the sentence to: “Definitions of extreme wildfires vary (e.g. Sharples et al., 2016), but associated behaviour includes rapid spread (>50 m min-1), high fireline intensity (>10,000 kW m-1), long distance spotting, erratic behaviour, and impossibility of control, often with associated development of violent pyroconvection (Tedim et al., 2018). In some cases, violent pyroconvection can manifest as pyrocumulonimbus clouds (pyroCb), the tops of which can reach the upper troposphere and lower stratosphere, ...”.

RC: L46. ‘Near the pyroCb’ suggests it is near the surface.

AC: Agreed, it is both near the surface and in the vicinity of the pyroCb. Gust outflows could also endanger firefighters not immediately below the pyroCb. So, we prefer to keep the text as it is.

RC: L64. More accurately, the C-Haines index indicates the potential for large fire development.

AC: Agreed. However, our definition (‘C-Haines index provides a measure of the potential for erratic fire behaviour’) is also correct, similar to Potter (2018) below. So, we have decided to keep the text as it is. Potter, B. 2018. The Haines Index – it’s time to

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revise it or replace it. International Journal of Wildland Fire 27:437-440.

RC: L65. From 0 to 13?

AC: Theoretically, there is no upper bound on C-Haines, but realistic values of the input variables restrict its range. Mills & McCaw (2010) have reported the maximum as ∼13; Yeo et al. (2015) quote the upper bounds as 13.5 while Di Virgilio et al. (2019) report values such as 13.7. In this study, gridded CH for the period 2007-2016 reached 12.63.

The text now reads:" The C-Haines index provides a measure of the potential for erratic fire behaviour, based on air temperature lapse and moisture content between two lower-tropospheric levels, and typically ranges from 0-13, although values above 13 are possible (Yeo et al., 2015; Di Virgilio et al., 2019).

Yeo, C. S., J. D. Kepert, and R. Hicks. 2015. Fire danger indices: current limitations and a pathway to better indices., Bushfire & Natural Hazards CRC, Australia. Di Virgilio, G., J. P. Evans, S. A. P. Blake, M. Armstrong, A. J. Dowdy, J. Sharples, and R. McRae. 2019. Climate Change Increases the Potential for Extreme Wildfires. Geophys. Res. Lett. 46:8517-8526.

RC: L190. 'These thresholds were chosen to define an elevated fire weather day (95th percentile)' is confusing. Maybe 'to correspond' instead of 'to define'?

AC: We have revised the sentence to: "These thresholds were defined to correspond to an elevated fire weather day (95th percentile) based on weather conditions at Hobart Airport,. . ..".

L218. The figure would benefit from the inclusion of wind direction. Did it change noticeably during the fire duration and is there information about wind direction at different heights? This can be important in relation to the assumed/inferred VLS subsequently in the text. Changes in wind direction impact the fire plume and can change spotting patterns hence modifying fire growth rate and direction.

AC: We have now included text on and a time series plot of wind direction. The time

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series plot is now separated into two: one for wind variables, the other one for the other weather variables. See Fig. 1 in this supplement for details.

RC: L239 (Figure 3). So, fire severity distribution is for three periods? Wouldn't it be possible to partition those more? This would require fire growth isochrones or perhaps take advantage of the information provided by Jon Marsden-Smedley report? Also, to supplement fire severity and context, the text could indicate (possibly in the discussion) rates of spread of the wildfire for those periods, as they are available (at least in part, did not check) in said report.

AC: The fire severity progression is only for three periods as they represent the short period of erratic fire behaviour on 4 January. Two intermediate isochrones at around 14:30 and 17:30 on 4 Jan (on Jon Marsden- Smedley's report) were obtained from fire spread modelling and were not part of the official isochrones provided by Tasmania Fire Service (TFS). So, we excluded them in the previous fire severity paper as well as this one. There are other isochrones (representing the entire fire duration, 3-18 Jan) that were omitted as we were only interested in the period of erratic fire behaviour on 4 January.

We have now included info on the rate of spread during those three periods in the discussion as follows: "Mapping of the Forcett-Dunalley fire by Ndalila et al. (2018) showed that areas subjected to the highest fire intensities broadly aligned with undulating terrain and long unburnt dry Eucalyptus forest which under the influence of strong winds produced an ember storm that impacted the coastal township of Dunalley situated in the lee of the low hills. During this period (at 15:25 on 4 January), the rate of fire spread was reported to be around 50 m min-1 (or 3 km h-1), which then reduced to 1.9 km h-1 between 17:30 and 20:00, and by the time of the next fire isochrone, when fire severity and area burnt had significantly reduced (Fig. 3), the rate of spread was 1 km h-1 (Marsden-Smedley, 2014). It must be acknowledged that the role of downdrafts and mass spotting underneath the plume during the period of extreme fire behaviour is hard to infer without additional data sources on fire behaviour (such as infra-red/multispectral linescans) and high-resolution coupled fire-atmosphere modelling (Peace et al., 2015)”.

RC: L255. I know it is given in another paper, but readers would benefit from additional information about fire severity in the Methods section.

AC: Noted. We have now included additional information in the methods section as follows: “The chronosequence of fire severity was derived from a previous study (Ndalila et al., 2018) from the intersection of fire severity map with fire progression isochrones within the fireground. Fire severity was based on differential normalised burn ratio (dNBR; Key and Benson, 2006) analysis of pre- and post-fire 30 m resolution Landsat 7 satellite images. A detailed description of fire severity assessments is provided by Ndalila et al. (2018)”.

RC: L256. See comment regarding L239.

AC: As aforementioned, we decided to only use isochrones that were provided by TFS. Our interpretation is therefore based on those isochrones.

RC: L291. 500 ha is not that high as a large fire size threshold. I would appreciate an enhancement of this figure where the green dots were attributed different colours corresponding to different fire size classes.

AC: We have now differentiated the fires into different fire size classes and represented them as different-sized dots, with larger dots in the graph corresponding to large fires sizes. See Fig. 2 in for details.

RC: L327. ‘satellite fires’?

AC: For clarity, we have rephased it to ‘new fires’.

RC: L425. And yet, Phoenix does not incorporate fire-atmosphere relationships, right?

AC: Yes. It only models fire behaviour on the surface (rate of fire spread, fire intensity, spotting etc). However, when the fire is coupled to the atmosphere, it fails to model the

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feedback, which needs more advanced modelling framework such as the atmospheric model Weather & Forecasting (WRF) which is coupled to a fire spread model. Peace et al. (2015) simulated fire behaviour in Kangaroo Island, south Australia using the mentioned modelling framework.

RC: L436. The interactions with terrain were suggested, rather than shown. From what I see in the supplementary material the VLS areas were quite small and fragmented in the landscape.

AC: We agree that the VLS-prone areas seem small, and their influence on pyroCb occurrence likely negligible based on these results, but we also caution that VLS likely occurred, but the effect may have been undermined by the limitations of the input data (DEM and wind direction layer). We have now rephrased the sentence in both the results and discussion sections to read:

In section 3.1.3 (Results): “Evidence of an effect of Vorticity-driven Lateral Spread on the fire behaviour was not strong. Analysis of the precursor terrain conditions only revealed small patches of VLS-prone areas near Dunalley township (Fig. S4). However, we are not able to rule out VLS occurrence on parts of the terrain that were not resolved by the DEM, and which may have played a part in the evolution of the plume. Indeed, the lateral development of the upwind edge of the plume in Fig. S4 suggests lateral development of the fire, similar to that associated with VLS in other fires (McRae et al. 2015).”

In the discussion: “this study did not find strong evidence of the effect of VLS on fire behaviour, as indicated by small patches of VLS-prone areas near Dunalley township (Figure S4). It is therefore possible that the pyroCb attained its maximum height without VLS. However, this interpretation should be taken with caution as VLS possibly occurred but data constraints (especially the spatial resolution of the DEM and wind direction) may have precluded accurate determination of VLS”.

RC: Enjoyed reading the manuscript.

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AC: Thanks!

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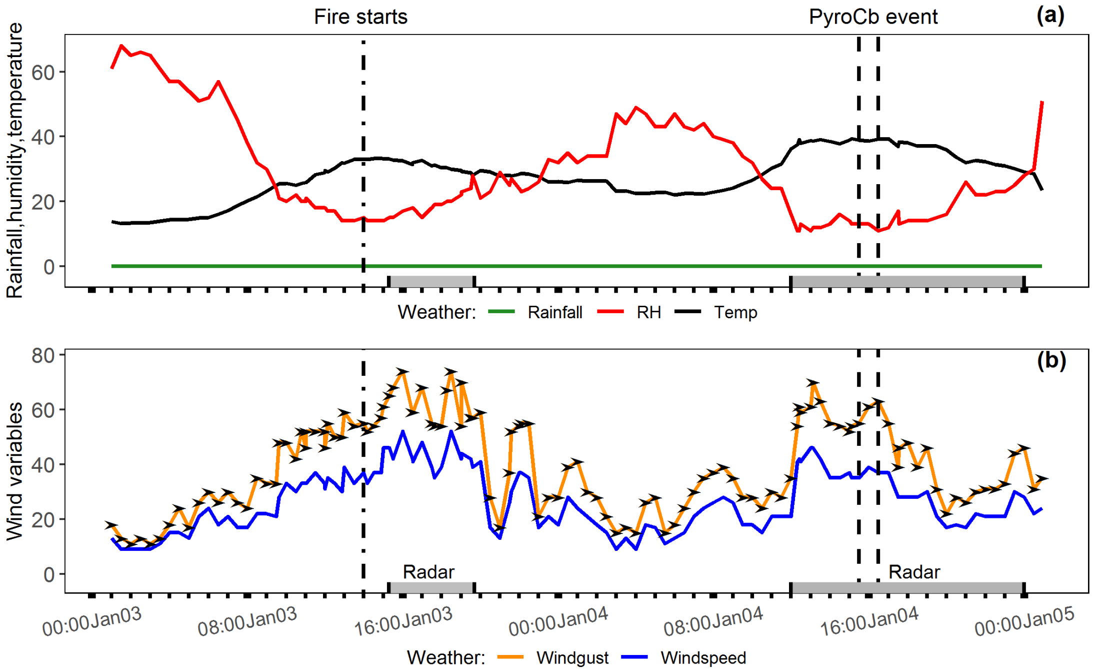

Fig. 1.

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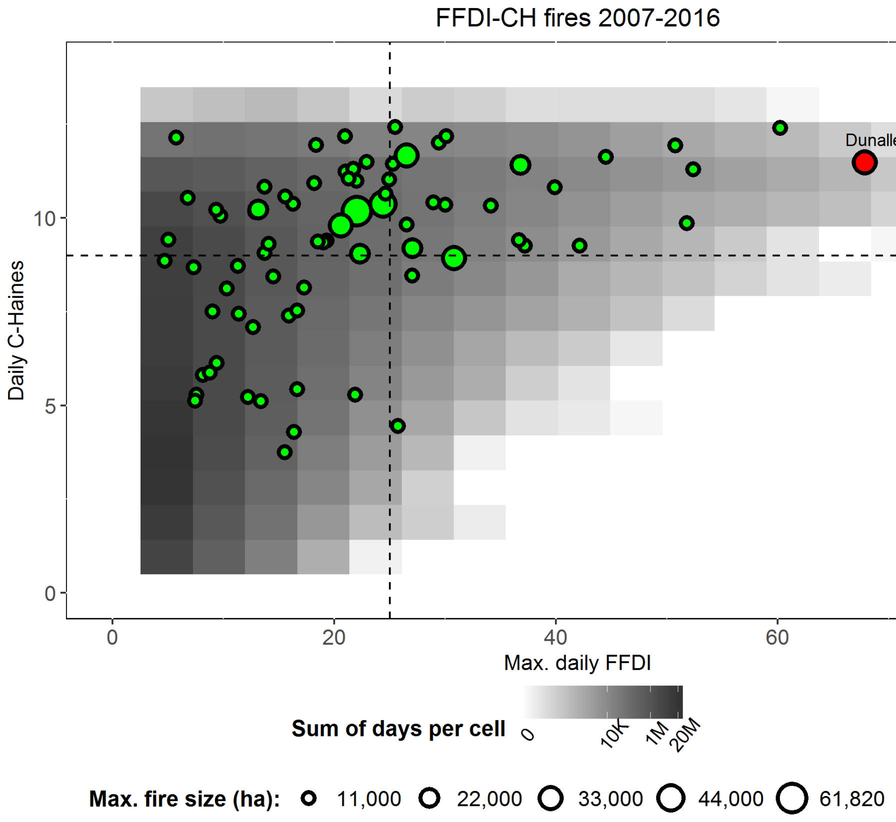

Fig. 2.

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