Nat. Hazards Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/nhess-2019-354-AC4, 2020

Natural Hazards and Earth System Sciences
Open Access
Discussions

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

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Received and published: 21 March 2020

RC: This paper provides an analysis of a significant pyroCb event in Tasmania (January 2013). The evolution of the plume is assessed using weather radar. Analysis of meteorology is largely based on the lower troposphere using the C-Haines index and FFDI. Fire severity maps are also included. The manuscript is generally well-organized and easy to read. Results are relevant to several research communities. The pyroCb phenomenon has been gaining significant attention in recent years. However, a few aspects of the paper require some clarification prior to publication.

RC: Please see my comments below.

RC: Abstract line 18: "highly unstable atmosphere" do you mean "highly unstable lower

troposphere" since you are referencing C-Haines?

AC: We meant highly unstable lower atmosphere i.e both the lower troposphere (C-Haines) and the low-mid- tropospheric instability (850-500 hPa in Fig. S2). We have now rephrased the sentence to: "The pyroCb was associated with a highly unstable lower atmosphere (C-Haines 10-11) . . ."

RC: Lines 65-70: lapse rate in lower-troposphere, mid-levels, or both?

AC: The C-Haines is calculated from two lower-tropospheric levels. We have now rephrased the sentence as follows: "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)".

RC: Line 139: "10 hPa". . ..what are these high altitude data used for? C-Haines is only based on the lower troposphere?

AC: We were just indicating up to which atmospheric height the BARRA data were available, although we calculated up to the 150 hPa level (see the BARRA soundings in Fig. S2). We also, in Fig. S3, determined air temperature lapse rate at the 850-500 hPa, in addition to C-Haines (for 850-700 hPa height).

We have rephrased the sentence to: "We extracted hourly air temperature and dew-point temperature at different air pressure levels (1000 hPa at the surface to 150 hPa in the lower stratosphere), as well as pre-calculated hourly McArthur FFDI for the period of the fire and the period of BARRA data available at the time of the study (January 2007-October 2016)".

RC: Line 181: is there a reference for "typically happens at or near the start of fires"?

AC: We have included an example of a fire whose major run was at the start of the fire. The sentence now reads:

“A total of 77 fires, of varying ignition sources, were identified in the Tasmania Fire Service fire history database as being >500 ha in size, and having a known ignition date. Of these, 18 did not have recorded end dates, and these were operationally specified as being four weeks later, an arbitrary cut-off to capture the most likely major growth (or ‘run’) of the fire that typically happens at or near the start of fires (e.g. the 2009 Victorian fires; Cruz et al., 2012). The assumption is that these runs result in peak fire intensities that most likely drive strong convections”.

RC: Line 195: please replace “was always higher than” with a specific range of values.

AC: The sentence now reads: “It is worth noting that maximum daily FFDI calculated at the Hobart Airport station was always higher than daily gridded FFDI extracted from the BARRA product (compare maximum FFDI of 92 recorded at the station with FFDI of 68.7 from the BARRA model on 4 January)”.

RC: Section 3.1: In addition to surface fire weather, pyroCb are driven by the full 3-D structure of the troposphere. This discussion can be improved. The supplement provides thermodynamic profiles. Can you quantify the LCL and highlight the pressure levels that are used to calculate C-Haines? Was there any CAPE in these profiles? Please also provide a couple sentences describing the synoptic weather pattern that set the stage for this event.

AC: We agree with your observations that both surface fire weather and 3D troposphere influence pyroCb development. We have captured the role of these fire weather aspects in the introduction and discussion sections. In the results section, the atmospheric aspect has been described in the section on pyroCb development (Section 3.1.3), and the section on spatio-temporal variation of C-Haines. We have now included in Section 3.1.2 information about synoptic weather as per your suggestions, to further expound on the tropospheric processes associated with the event.

1. Regarding quantifying the Lifted Condensation Level, the values are now in the aerological profiles in Fig. 1 attached to this response.

2. The pressure levels used to calculate C-Haines are 850 and 700 hPa, and are shown in Equations 1-3. Full description of the variables are provided immediately below the equations.

3. CAPE is now available in the profiles. The value was zero, suggesting lower potential for thunderstorm development, with the energy to lift the air parcel and produce the pyroCb coming from the fire rather than the unmodified atmosphere. That information is provided in the supporting text in the supplement (Section S1.2) as follows:

“The Convective Available Potential Energy (CAPE) as well as the maximum unstable CAPE (MUCAPE) during this period were zero, suggesting a lower potential for thunderstorm development. It is likely that much of the energy that lifted the air parcel and produced the pyroCb came from the fire itself rather than the unmodified atmosphere”.

RC: Section 3.1.2: Please show a basic radar image/map at the peak of the pyroCb event for reader orientation.

AC: We have moved the 3D radar image from the supplement to the main article and provided a short interpretation of the pyroCb as shown in the radar image, as follows:

"The period of the pyroCb in Fig. 4 is defined by very high radar returns, with reflectivity values of 48-88 dBZ, representing the most intense parts of the pyroCb. This strong reflectivity is indicative of high quantities of ash, and larger-sized hydrometeors such as ice crystals in the higher elevations"....

RC: Line 233: please briefly describe the significance of the 850-500 lapse rate in the main text.

AC: We have added the following text: “The 850-500 hPa lapse rate gives an indication of the (in)stability of the lower half of the troposphere (1.3-5.5 km above sea level), with lapse rates of >7.5 oC km-1 considered as very unstable lower atmosphere (Peterson et al., 2014)”.

RC: Line 265: “good correlation of 0.5”. . ..what is good?

AC: We have replaced “good correlation” with “moderate correlation”. The sentence now reads: “. . .for the entire month of January 2013, there was a statistically significant moderate correlation (r = 0.5, p <0.05) between these fire weather indices, although FFDI lagged C-Haines by around a day”.

RC: Line 269: “wind change at around 00:00”. . .is this a cold front? Some description is likely needed?

AC: Yes, the wind change was as a result of a pre-frontal trough that passed before 00:00 on 5 January, well after the pyroCb had already established and dissipated. We have also included information on the synoptic weather in the section (3.1.2) preceding this section to provide context.

The sentence now reads: “In the Tasman Peninsula, especially, C-Haines was mostly in the range of 10-12 for both days (peaking at 12-14) but moderated to 4-6 on 5 January after a southwest wind change at around 00:00, as a result of a pre-frontal trough crossing south-eastern Tasmania”.

RC: Section 4: Did you examine additional radar products for this case, such as velocity data? You might be able to get more information on the dynamics of the updraft and even particle characteristics. Radar data are one of the more underutilized tools in pyroCb research.

AC: We greatly appreciate the reviewer’s comments about making further use of the radar data. However, we feel that including all of the work suggested by the reviewer would go well beyond the intended scope of the manuscript, which was to provide a qualitative description of the evolution of the Forcett-Dunalley fire and pyroCb, and their relation to coincident surface weather and lower atmospheric conditions.

Indeed, we feel that it would be more appropriate to pursue the work suggested by the reviewer in a separate and more detailed quantitative analysis, drawing upon the work of Terrasson et al. (2019) and McCarthy et al. (2019). We have amended the

discussion to specifically note this as a natural extension of the qualitative analysis presented in the manuscript.

The section in the discussion now reads: “. . . radars remain a reliable data source that can provide near-real time monitoring of strong pyroconvection, as evidenced by previous pyroCb studies in Australia and globally (Rosenfeld et al., 2007; Fromm et al., 2012; Lareau and Clements, 2016; Dowdy et al., 2017; Peace et al., 2017; Lareau et al., 2018; Terrasson et al., 2019). This study did not analyse radial velocity from the Doppler radar; therefore future research on the Forcett-Dunalley fire and other fires should consider using that information to provide a more quantitative analysis of the thunderstorm, drawing upon previous work in Australia (McCarthy et al., 2019; Terrasson et al., 2019). A feature of our study was linking plume evolution to fire severity mapping - an approach that has received limited attention”.

RC: Lines 335-345: The soundings in the supplement do show the inverted-V structure typical of high-based convection, with some mid-level moisture in the profile at 1500. You can calculate total precipitable water to confirm. I believe that Peterson et al. provide more info on this.

AC: The information on total precipitable water (and other metrics) is now provided in the profiles and in the discussion of the main article. The sentence in the discussion now reads:

“. . . a number of Australian pyroCb events exhibit a distinct lack of midlevel moisture in their associated atmospheric profiles (e.g. the 2003 Canberra fire (Fromm et al., 2006) and the 2013 Wambelong fire (Wagga Wagga sounding for 13 January 2013 on http://weather.uwyo.edu/upperair/sounding.html). However, in this study, the mid- to upper-level moisture was higher during the time preceding pyroCb formation on 4 January (Fig. S2a), with a total precipitable water of 23 mm indicating a moist lower atmosphere (Webb and Fox-Hughes, 2015). Terrasson et al. (2019) report on the effect of a change in moisture between the low- and upper-levels (brought by a cold front) on the development of a pyroCb and enhancement of fire behaviour in the Sir Ivan fire in eastern Australia. Further research is required to properly understand the potential influence of mid-tropospheric moisture in driving pyroCb development in Australia".

RC: Supplement: Please annotate the time of the pyroCb on the relevant figures.

AC: The timestamps with the pyroCb are now shown in the radar images (Fig. 2 in this supplement below), and the time of the pyroCb is mentioned in the figure captioning (now moved to main article) as follows:

"Areas prone to vorticity-driven lateral spread (VLS, in red) overlaid with a 3D rendering of the vertical cross-section of plumes from the radar reflectivity for specific times during peak fire behaviour. Higher reflectivity values (dBZ >48) in all maps represent the most intense parts of the plume (and the pyroCb which occurred from around 15:24 to 16:30 LT). The asterisk in the 15:24 map represents the likely initiation period of the pyroCb. Dunalley township is represented by a white star. A malfunction in radar for the 15:00 and 15:36 timestamps resulted in plume information to be only available at the lowest elevation angle of the radar scan, and are therefore not shown".

RC: Supplement: Define/explain "BARRA pseudo-soundings"

AC: Pseudo-soundings are atmospheric soundings obtained from the air and dewpoint temperatures produced by the BARRA model. They are not actual weather balloon (radiosonde) observations. We have now clarified in the supplement that the pseudo-soundings are vertical profiles sampled from the reanalysis data.

RC: It would be nice to include a surface and upper level synoptic weather map that coincides with the soundings in Figure S1. This will provide some context on the large-scale meteorology driving this event.

AC: We have now provided the mean surface level pressure charts in the supplement (Fig. 3 below), and information on the synoptic weather on 3-4 January in Section 3.1.2 of the main article, which reads as follows:

On 3 January, a combination of: (1) a high-pressure system to the northeast of Tasmania and (2) a cold front and pre-frontal trough approaching from the west directed a freshening dry and hot northerly airstream over the island, favourable conditions for elevated fire danger (Bureau of Meteorology, 2013). By 08:00 LT on 4 January, the high-pressure system had moved only slowly eastward while the trough had progressed closer to western Tasmania (Fig. S1). This period coincided with moderate north-westerly winds in most locations in the state, except for the southeast (general area surrounding Dunalley) which recorded stronger winds and elevated fire danger. Fire danger steadily increased towards midday (the start of the first fire progression isochrone in Fig. 3c) and by 15:00, the leading edge of the trough was much closer to the west of Tasmania. An increase in pressure gradient brought about gusty conditions and catastrophic fire danger in some locations in southeast Tasmania, causing erratic fire behaviour on the Forcett-Dunalley fire. During that time, the trough crossed western Tasmania. By 17:00, when the pyroCb had likely dissipated (Fig. 3a), the pre-frontal trough was crossing Tasmania and fire danger subsequently reduced due to decreasing temperatures and winds. The trough continued to move eastwards and crossed southeast Tasmania after 23:00, leading to a west to southwest wind change by 00:00 on 5 January. The front passed over the state early morning of 5 January and caused lightning and limited showers across Tasmania. Detailed analysis of the synoptic weather patterns driving this event are provided in Bureau of Meteorology (2013).

RC: Are the times listed local time or UTC?

AC: They are in LT. This information has now been updated in the relevant sections in the supplement and main article.

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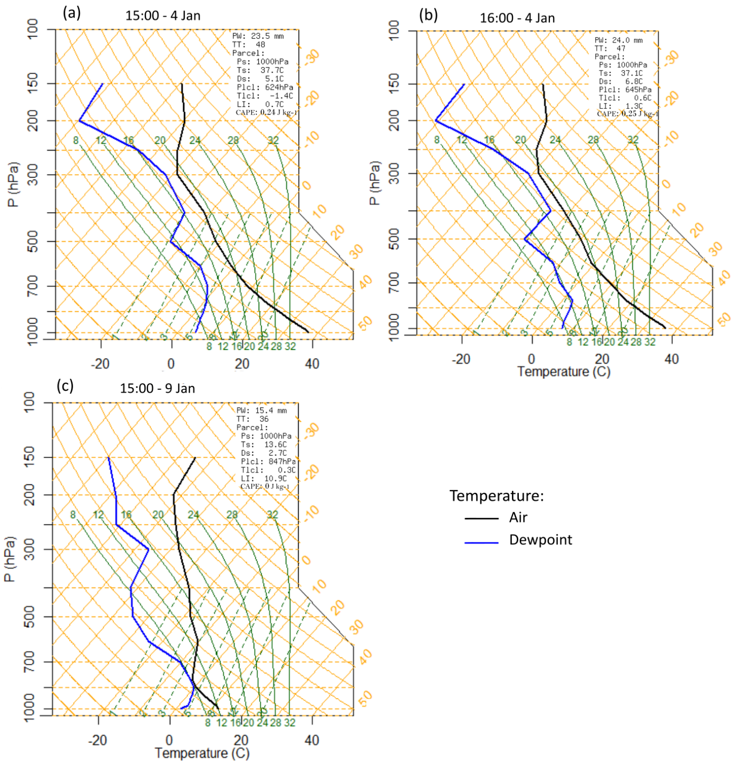

Fig. 1.

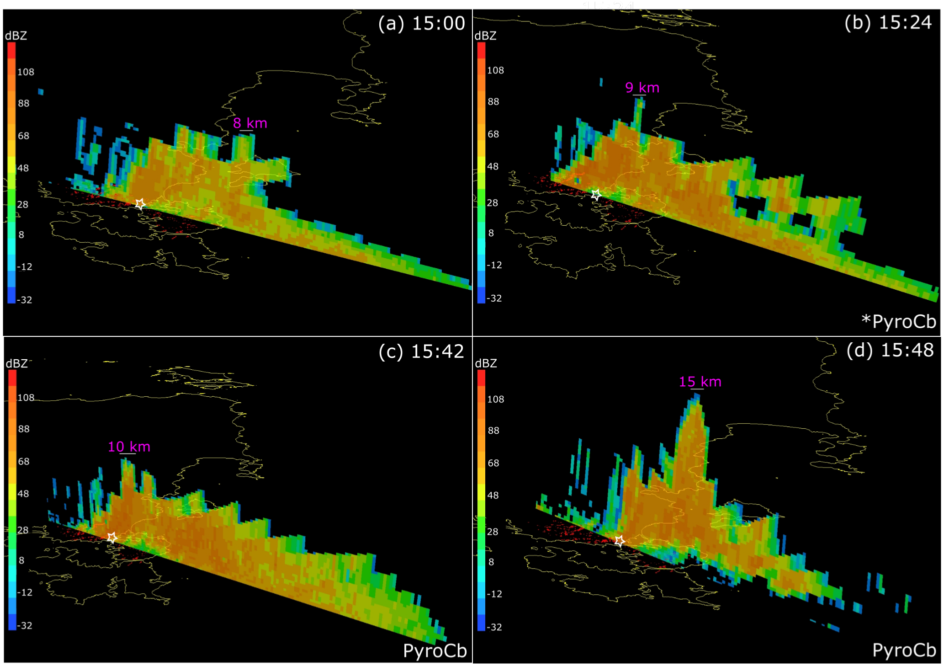
(a) 15:00
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Fig. 2.

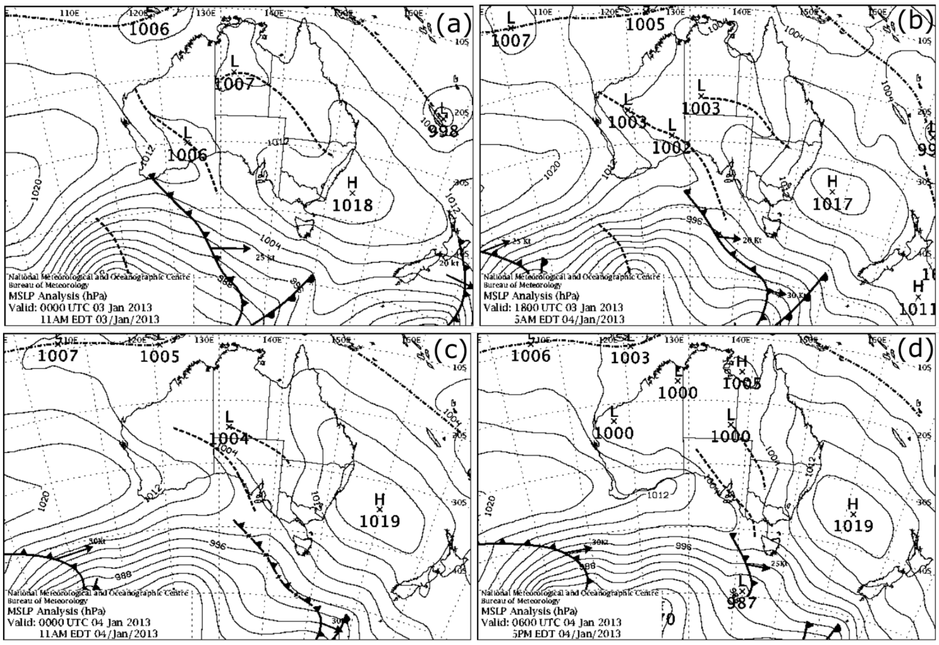
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Fig. 3.