Natural Hazards and Earth System Sciences Discussions

Nat. Hazards Earth Syst. Sci. Discuss., referee comment RC2
https://doi.org/10.5194/nhess-2021-122-RC2, 2021

Comment on nhess-2021-122

Anonymous Referee #2

Referee comment on "Wildfire–atmosphere interaction index for extreme-fire behaviour" by Tomàs Artés et al., Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2021-122-RC2, 2021

An index designed to identify atmospheric instability that promotes or facilitates extreme fire behaviour (EFBI) is introduced. Indices constructed from surface-based parameters often fail to discriminate between extreme and non-extreme fire behaviour. Decades ago, atmospheric stability was proposed as a missing ingredient in such indices. The EFBI provides a measure of atmospheric stability designed to fill this gap, and be used in conjunction with existing surface-based indices to provide a more comprehensive assessment of fire danger.

Results are presented that suggest using the EFBI in conjunction with a surface-based index (the Canadian Fire Weather Index, FWI) does improve the predictive performance compared to only using the FWI.

Case studies are included that illustrate the EFBI for specific extreme fire-behaviour events, including pyrocumulonimbus (pyroCb) cases.

I have a number of major concerns with this paper:

- It was not sufficiently polished for submission. (It could have benefitted from an internal review before submission.)
- It lacks references to, and comparison with, similar published indices and concepts.
- It lacks explanation of the ideas, theory, or reasoning that underlies the EFBI.
- The EFBI is used and promoted as an index for identifying extreme fire behaviour (defined by fire spread rate), but appears to be designed to identify a small subset of those events – fires that produce deep moist convection.
- The performance of the EFBI is not convincing.

The manuscript will require substantial revision to address these concerns. In anticipation of a major rewrite, I decided not to provide a list of minor points to be addressed.

Major concerns expanded:

- The paper contains incomplete equations with undefined terms (the EFBI equation is difficult to understand and possibly contains a sign error), and insufficient information in figure captions. A number of terms and concepts are used loosely, which make comprehension difficult for the reader. For example, the term "convective fire" is used almost synonymously with extreme fires. Given all fires produce heat and convection, the term "convective fire" needs to be clearly defined. Also, it is not clear if it refers to fires that produce deep convection columns, or specifically fires that produce moist convection (i.e., pyroCu or pyroCb). Discussions often include references to the very broad topic of "wildfire-atmosphere interactions". For clarity the reader needs to know which specific interactions are being referred to.
- There are two main topics that need to be referenced, plus a paper that the authors might wish to consider for comparison: (i) In the manuscript the EFBI is claimed to be similar to the Haines indices (Lines 73-75), but a description of these indices (and the often-used modified Haines index, C-Haines) is lacking. Most readers familiar with the Haines indices will not immediately see the similarities. Indeed, the Haines indices were designed to assess atmospheric dryness and absolute stability, whereas the EFBI assesses conditional instability. The Haines indices were developed because existing stability indices used for thunderstorm forecasting were known to be invalid for extreme fires. Given this historical progression, the EFBI design might appear to readers to be regressing. It follows that a comprehensive justification is required to demonstrate that the EFBI is a better discriminator of extreme fire behaviour than the Haines indices, as is implied in the manuscript. (ii) Recent works that develop indices and techniques for identifying and predicting pyroCb (a specific subset of extreme fire events) should also be acknowledged and compared with the EFBI. The EFBI has much in common with Potter's (2005) FireCAPE concept, Lareau and Clement's (2016) use of the Convective Condensation Level, Tory et al.'s (2018) pyroCAPE concept, the ideas that underpin Tory and Kepert's (2021) Pyrocumulonimbus Firepower Threshold (PFT), and Leach and Gibson's (2021) pyrocumulus prediction model. Section 5 of Tory et al. (2018) discusses and compares some of these concepts and ideas. (iii) The authors might like to compare their FWI/EFBI analysis of extreme fire events, with a paper by Di Virgilio et al. (2019) that performed a similar comparison using the McArthur Forest Fire Danger Index and C-Haines to analyse pyroCb events.
- The EFBI is introduced without sufficient explanation. The paper does not describe the underlying theory behind the index, or why the index takes this specific form, or how it compares with similar indices and concepts.
- The type of convective instability being targeted is not mentioned. The EFBI looks like it is targeting moist convection, but it is used to identify any fire that spreads rapidly. Can the decision to apply a moist-instability index to dry events be justified? In general, hot, dry and windy conditions favour extreme fire behaviour. Large values of the Haines indices correlate well with deep well-mixed layers, which have neutral stability on average. Moist plume growth, on the other hand, requires a much more specific set of conditions and consideration of the atmosphere above the mixed-layer.
- The manuscript doesn't present compelling evidence that the EFBI has significant value as an extreme-fire predictor. The scatter plot in Fig. 8 shows that large EFBI occurs more often with slow spread rates than fast spread rates. 7 shows EFBI is elevated throughout almost the entire fire period, but the extreme fire behaviour was present

only on the first day. Fig. 10 shows poor correlation between EFBI and the burn rates – which is acknowledged by the authors. Fig. 12 confirms southeastern Australia was very unstable during the last few days of 2019 – a result that was also well predicted by the C-Haines and PFT indices.

In summary, the manuscript is rough in presentation, is missing important background information, introduces a concept without sufficient explanation and justification, and the results as presented do not convince me that the EFBI has more to offer than existing indices and extreme-fire prediction methods. I encourage the authors to consider the ideas presented in the referenced papers to see if the EFBI can be adapted to better identify extreme fire conditions, or to develop arguments that demonstrate EFBI superiority over these other indices.

References

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