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Comment on acp-2022-610

Anonymous Referee #2

Referee comment on "In Situ Microphysics Observations of Intense Pyroconvection from a Large Wildfire" by David E. Kingsmill et al., Atmos. Chem. Phys. Discuss.,
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Overview

This study evaluated airborne in situ and remote sensing and ground-based remote sensing measurements of wildfire-induced pyroconvection. The authors analyzed the shape and size of particles with diameters ranging from 10 μm to 6 mm. They make a distinction between a penetration that appears to be primarily composed of ash (pyrometeors) and penetrations composed of a mixture of pyrometeors and hydrometeors. This manuscript does an exceptional job of relating their unique and novel results to past literature and placing it in the context of auxiliary measurements. The manuscript is also exceptionally well-written, concise, and the figures are of very high quality. I recommend this manuscript be accepted for publication upon addressing a few minor comments listed below.

Minor Comments:

- Fig. 1b: What is the dBZe threshold used to define echo top?

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Echo tops in this figure use a threshold of 18 dBZe, which is the threshold employed for the NWS echo-top product. Labeling for this figure has been modified to indicate this threshold and a reference (Lakshmanan et al. 2013, Weather and Forecasting) has been added to the text.

Fig. 1: panel labels (a-d) should be bigger

The minimum font size on almost all figures has been increased.

- Lines 292-294: I do think it is interesting that the distribution shapes of N^{\wedge} and A^{\wedge} are different, but can you really say anything about comparing the order-of-magnitude

ranges when the units are not the same? I'm not sure that yields any relevant information.

The order-of-magnitude comparison between N^{\wedge} and A^{\wedge} has been removed from the narrative. The three sentences in question have been reduced to two sentences as follows: "Most notably the size distribution of \hat{A} is bimodal in nature. A secondary peak is evident in the 2D-SV and CIP data over the 150-400 μm diameter range."

- I understand to some degree the interpretation of TWC vs. LWC in terms of collection efficiency from the Nevzorov probes. However, lines 473-475 are a bit confusing. I don't understand why an overestimate of cloud droplet effective radius by the PVM-100 probe leads to a smaller collection efficiency. Is this a reasoning that's due to the different techniques of PVM-100 vs. the Nevzorov probes or are you using the PVM-100 as a supplement to your conclusion? This reasoning in general could stand to be restructured as it is also hard to understand the paragraph that starts on line 480 regarding IWC without a little more context.

The last two paragraphs of section 3.2 have been significantly revised to increase clarity. Below is the revised text:

"While particles less than 50 μm in diameter during penetrations 2-6 are likely cloud droplets, the nature of larger particles is unclear since ice particles, pyrometeors and a combination of the two are plausible explanations. Pyrometeors in the form of ash particles could be lofted upward to the tops of the pyroCus, especially in penetrations 2-3 where updrafts larger than 1 m s^{-1} are observed (Fig. 14a-b). Likewise, ice particles are possible since air temperatures at flight level are well below freezing (Fig. 14f-j). Also, conditions of ice supersaturation are evident in four of the five penetrations (Fig. 14f-i). Finally, the distributions of A_r and F_r in Figs. 10b-f and 11b-f, respectively, are consistent with values expected for ice particles. If these larger particles are composed of ice, they should produce a signal in the Nevzorov-TWC (NEV_{TWC}) data whereas ash particles should not be detectable by the Nevzorov probe. However, this analysis is complicated by the presence of small cloud droplets. Cloud droplets also produce a signal in the NEV_{TWC} data, but the magnitude of that signal depends not only on the water content, but also on the size of the droplets themselves. For the same liquid water contents, the signal in NEV_{TWC} will increase by $\sim 50\%$ as droplet effective radii increase from ~ 5 to ~ 15 μm , while over the same range of radii, the signal in NEV_{LWC} only increases by $\sim 2\%$ (Fig. 4 and Equation 13 of Korolev et al., 1998). Thus, clouds composed of liquid, even when devoid of ice, will have different signals in NEV_{TWC} and NEV_{LWC} depending on droplet size regardless of liquid water content.

Values of NEV_{TWC} , NEV_{LWC} and the ratio of these signals ($NEV_r = NEV_{TWC}/NEV_{LWC}$) are presented for penetrations 2 through 6 in Fig. 16. Following the discussion in the previous paragraph and the definition of NEV_r , an increase in NEV_r may result from either (or both) an increase in droplet effective radius and/or an increase in IWC. In penetration 3, NEV_r is 0.36 (Fig. 16b). Assuming the cloud is devoid of ice, this value corresponds to a droplet effective radius of ~ 2.5 μm . If, on the other hand, ice was present, then the radius would be even smaller. This radius is about half of that measured by the PVM-100 probe across all penetrations (Fig. 14 k-o) suggesting that the PVM may be overestimating the droplet effective radius by a factor of 2. NEV_r varies from 0.36 to 0.69 across all five penetrations. If cloud droplet effective radii are assumed to be the same across these penetrations, then the variations in NEV_r might be explained by the presence of ice particles. To further investigate the possible presence of ice, an independent measure of IWC is needed. Size distributions of OAP number concentration at 1 Hz are integrated over diameter with a mass-diameter relationship for ice-crystal aggregates from Brown and Francis (1995) to derive IWC (OAP_{IWC}). The derivation is restricted to particles having diameters greater than or equal to 50 μm to eliminate the contribution of cloud droplets.

Results of this analysis show that the smallest OAP_{IWC} occurs during penetration 3, which coincides with the smallest NEV_r (Fig. 16b). The largest and next largest OAP_{IWC} are observed in penetrations 4 and 6, respectively where NEV_r is largest (Fig. 16c,e). These trends suggest that ice particles larger than 50 μm diameter are present in the data produced by the Nevzorov probe and OAP's. However, this analysis does not eliminate the possibility that pyrometeors are also in the sample volume. Indeed, many of the measurements from penetration 3 show more similarity to those for the smoke/ash plume in penetration 1 than those for the pyroCu in penetrations 2 and 4-6. This suggests that the particles sampled during penetration 3 might be composed of a greater proportion of pyrometeors than the particles sampled during the other pyroCu penetrations.”

Line-specific comments:

- Line 128: Maybe mention what the native sampling resolution is

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This sentence has been modified as follows: “This study uses versions of these parameters temporally degraded to 1 Hz from raw data sampled at 100-1000 Hz.”

Lines 165-167: Where did this 18 dBZe threshold come from?

The 18 dBZe threshold is specified by the NWS in its radar echo top product. A relevant reference has been added for context (Lakshmanan et al. 2013, Weather and Forecasting)

- Line 212: “...and a large as...” should be “...and as large as...”

Corrected

- Lines 279-280: This sentence is worded awkwardly because there is no overlap between the 2D-P and the other instruments. I would reformat the sentence to immediately imply a lack of overlap.

This sentence has been modified as follows: “In contrast, there is essentially no overlap of mean \hat{N} from the 2D-P with mean \hat{N} from the 2D-SV and CIP.”