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Interactive comment on "Tracing devastating fires in Portugal to a snow archive in the Swiss Alps: a case study" *by* Dimitri Osmont et al.

Anonymous Referee #1

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Osmont et al.

This manuscript describes a very interesting study attempting to make quantitative connection between emissions of BC, charcoal, and ionic species by fires burning in Portugal from 17 to 24 June 2017 and their deposition to snow near Jungfraujoch (JFJ) in the Bernese Alps. The case for charcoal is compelling, while the findings for BC and ionic tracers of smoke are not so clear.

A combination of remote sensing and in-situ atmospheric sampling, plus back trajectory and chemical transport modeling do show that smoke from the subject fires was transported to JFJ and was observed in the atmosphere above the snowpit site from 22 through 24 June. Atmospheric concentrations of BC dropped sharply on 25 June, coincident with significant snowfall at JFJ, and remained low until the end of June. Detailed

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stratigraphy and sampling for chemical analysis in a 1 m deep snow pit showed that layers representing 3 different snow events (on 25-26, 28, and 29 June) were present in the top 40 cm of the pit. Concentrations of BC were modestly enhanced and the abundance of charcoal fragments hugely increased in the layer from the first snowfall (25-26 June), but none of the ions often suggested to be smoke tracers (formate, ammonium, potassium, acetate, nitrate) were elevated. It should be noted that BC and the ions were measured in the same samples that were nominally 5 cm depth resolution while charcoal fragments were quantified in samples collected at 10 cm resolution; the BC signal in the pit appeared in 3 samples between ∼22 and 38 cm depth while enhanced charcoal was in a single sample covering the 30 to 40 cm depth range. It is unfortunate that the different records are not all at the same depth resolution, but the fact that the sample with peak charcoal contained some fraction of "older" snow than the deepest of the samples with elevated BC becomes important when the model results are considered. It is not possible to say from the information provided in the manuscript whether the snow between 38 and 40 cm just fell early in the event on 25 June, or included snow that had fallen days earlier, but the model suggests that much of the charcoal deposition occurred during 23-24 June compared to peak deposition of BC on the 27th and 28th.

The model also suggests that the BC peak is not due to smoke, rather it just reflects efficient scavenging of regional pollution by snow falling mainly on 27 and 28 June. The pit stratigraphy suggests that most of the BC is in snow that fell on 25-26 June, but there is some ambiguity in depth to age conversions. The authors suggest that coarse spatial resolution of the model prevents it from accurately capturing the fire emitted BC on top of a large regional background. That may be partially true as suggested by the fact that it did not actually snow at JFJ on the 27th and only a small amount of rain was observed at the nearest weather station. However I find the performance of the model to be surprisingly good, and urge the authors to consider the possibility that while the charcoal is doubtless dominated by smoke from Portugal, the BC may be essentially just a mix of European pollution. I will first outline evidence that the model is closely reproducing the observed deposition of both BC and charcoal, and then suggest some ways the authors might be able to convince me, and other readers, that the BC is actually dominated by deposition from the smoke plume.

In section 3.6 the authors suggest that the CTM underestimates charcoal deposition by about a factor of 20 and that of BC by two orders of magnitude. It is not entirely clear how the fluxes were estimated from the observations in the snow pit since there is some ambiguity regarding the proper timescale, but here is a straightforward approach that suggests much better agreement.

The charcoal sample # 2 contains 20,000 fragments/L of snow or 20 fragments/g. The density of 0.54 g snow/cmˆ3 times the depth of the sample indicates that the 30-40 cm layer contains 5.4 g snow/cmˆ2, when multiplied by 20 fragments/g this indicates that 108 fragments/cmˆ2 were deposited (total for the event, not per second, day or year). From Fig 5 I estimate that the model deposited this on 23, 24, and 25 June at rates of 2200, 1500, and 600 fragments/cmˆ2 y, respectively. Using simple average of 14,333 fragments/cmˆ2 y x 1/365 d/year x 3 days gives modeled deposition of 118 fragments/cmˆ2 which is almost too close to 108 to be possible, given concerns about the model and especially the emissions of charcoal by the fire (scaled to BC estimates from a completely different model).

Similar calculation for BC starts with estimate of 7.5 ng/g (average of the 6 samples #s 4-6, all replicated, in Fig 2) x 0.54 g/cmˆ3 x 15 cm (depth of the 3 samples combined) yielding total burden of 61 ng BC/cmˆ2 in this layer. For the model estimate an eyeball average of the calculated flux over 26-28 June is 6 ng/mˆ2 sec x 3 d x 86,400 sec/d x 1/10,000 cmˆ2/mˆ2 = 155 ng BC/cmˆ2. Not as close as the agreement between observed and modeled charcoal deposition but a factor of 2.5 is nowhere near 100-fold difference.

To me, this suggests that the scenario suggested by the model is plausible even if not precisely correct in detail. Passage of smoke over JFJ caused dry deposition of charcoal sometime (hours or maybe a few days) before it started snowing on 25 June. Very little BC or ionic smoke tracers were removed by this process. Then a change in transport just before or coincident with the snow fall event brought air with regional pollution but very little or no smoke from Portugal to JFJ. Wet deposition via the snow created an anthropogenic BC enhancement that lacks any formate, ammonium, potassium, etc.

Using a regional CTM with grid size in the 4-10 km range rather than the global version selected initially might help to clarify whether the BC is linked to the fires rather than being mostly regional pollution. A simpler/cheaper, but also complementary, approach would be to run forward trajectories from the fire, possibly over the entire 17-24 June lifetime but at least beginning early enough to capture the first time smoke reaches JFJ on 22 June and continuing until the fire is out. In the scenario laid out in the manuscript these trajectories would have to show strong connection between the fire and JFJ lasting well into 25 June, while the alternative outlined above predicts that the smoke clears out over JFJ before it starts snowing.

As noted right at the beginning, this is an interesting story, and the firm results for charcoal make it important to get before the community. I think that the argument linking the BC in the snow to the fires needs to be made much more convincingly, or ruled out just as strongly. Neither option would impact the charcoal connection, while insisting that the BC is fire derived based on weak evidence lessens the power of the manuscript.

Following are a list of specific comments and editorial suggestions, keyed to line number.

27 As noted above, the correspondence between eBc measured through 24 June and rBc measured in snow that fell 25-26 June may be more tenuous than asserted.

28-29 Calculated scavenging ratios may be oversold since there is no assurance that BC at cloud height 25 and 26 June was same as inferred from measured eBc on the ground 24 June.

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33-34 “This study unambiguously links charcoal in the snow with the highly intensive fires in Portugal. . .” At least one reader is not convinced that rBC in the snow is from these fires, and would liked to have seen some of the ionic tracers supporting that inference yet none do.

35 Is the BC emission estimate not basically straight from FINN, rather than ECHAM?

39 what do you mean by “landscape” fires, as something distinct from biomass fires

50 consider citing some of the pioneering studies of fire tracers in polar ice cores, for example; Legrand et al., 1992 (GRL); Whitlow et al., 1994 (Tellus; Legrand and De Angelis, 1996 (JGR)

92-94 Sentence pointing out that ice cores from near JFJ have been studied is not needed unless you later make some connection to the cited papers.

97 located on the eponymous pass between—→ located between

135-138 Might want to state the dates for which backtrajectories were calculated. And as noted above, consider running forward trajectories from the fire as well.

139-149 If you cannot, or decide not to, run a regional model, I think you should provide more justification for choosing to run this particular version of ECHAM, especially since you kind of denigrate its performance later in the manuscript 151-157 Curious why you chose to only use MODIS products. It is becoming increasingly clear that important details are missed due to coarse spatial resolution, and the fixed single overpass time. Are there not relevant products from the Sentinel satellites? Geostationary platforms (mainly supporting meteorology forecasting) can provide insight throughout the day, especially later in the afternoon when many fires are strongest.

184 I would not say that peak rBC of 9.8 ng/g is “remarkable”. It is only about 2 x higher than the secondary peak at 60-70 cm depth. The Thomas et al., 2017 paper cited elsewhere found the average peak in 22 north Greenland pits to be 15 ng/g, with max of 43 ng/g with longer transport distances back to the source fires.

193-194 I would mention the secondary rBC peak in samples 12/13 that overlaps the bump up in charcoal sample 5, especially since you point out the increased size later to suggest more local source.

197 Regarding the "narrower" charcoal peak, I think it may mostly be in the 2 cm interval 28-30 cm below rBC sample 6, but that is just a hypothesis.

270-280 As noted above, consider forward trajectories from the fires, specifically looking to see if smoke was likely over JFJ when it started snowing 25 June. And seriously consider whether ECHAM is possibly correct that the BC in the snow is not from the fires.

Section 3.5 See earlier question about exclusive reliance on MODIS, and the on-line comment from Paolo Fernandes.

Section 3.6 Consider the "deposited" BC and charcoal calculations presented in introductory comments. If you decide to stick with flux estimates provide more details about assumptions used to get values so much higher than the model.

Last paragraph of this section, seems that the model thought there was no smoke at all over JFJ, pointing to a transport shift (or error) rather than problems with emissions. I made a case that the model came within factor of 2.5 of the total amount of BC in the snow from 25-26 June, even though it wants to deposit most of it on the 27th and 28th . Might be worth comparing the timing and amount of precipitation in the model to observations.

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