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Interactive comment on "Open fires in Greenland: an unusual event and its impact on the albedo of the Greenland Ice Sheet" *by* Nikolaos Evangeliou et al.

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Anonymous Referee #1

Review of "Open fires in Greenland: an unusual event and its impact on the albedo of the Greenland Ice Sheet" by N. Evangeliou and co-authors.

General comments. N. Evangeliou and co-authors present a paper dealing with the atmospheric emission of black carbon by peat fires in Greenland during an extreme event in August 2017. They estimate the total amount of BC released in the atmosphere and its impact on the atmospheric radiative balance and snow albedo. The

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Discussion paper

authors conclude that none of those impact are really significant. I found the paper lacking a focused scientific objective and finally it will have a limited interest for the scientific community. The methodology is sound but many of the assumptions must be clarify. The validation exercise is too qualitative while the dataset can be used for quantitative assessment. The conclusion that peat fire in Greenland could be of a significant importance for climate is not really supported by the findings of this paper.

–Response: We agree that the methodology and parts of the discussion needed lots of improvement and we have made substantial effort with numerous changes in all parts of the manuscript according to both reviewers' suggestions (please see manuscript with Track Changes). However, we do not agree with this description of our work. The validation is qualitative because no direct measurements of BC concentrations exist from this event occurring in a particularly data-sparse region, and also few satellite data document the event. The only data we found are Lidar data from CALIPSO that confirmed the presence of the plume where our model predicted it. Could the reviewer suggest, in concrete terms, which dataset could be used for quantitative assessment? The reviewer says, "The conclusion that peat fire in Greenland could be of a significant importance for climate is not really supported by the findings of this paper." This is NOT a conclusion, but a logical probability, considering that 25% of Greenland's surface is permafrost that is rich in peat. We now show this more clearly in the updated version of our manuscript. In addition, NASA's satellites show an increasing trend of fires in thawed permafrost over Greenland (see new supplementary figure S1 or attached Fig. 1) and our simulations showed that 30% of the emissions were deposited in the Greenland Ice Sheet (Lines 388-391). We disagree with the comment of the reviewer that this paper will have a limited interest for the scientific community. We present some statistics from the ACP Discussions website. In the Discussions page of the journal (https://www.atmos-chem-phys-discuss.net/discussion_papers.html), at the time that we started writing this response (22-05-2018), there are 30 papers in open discussion (ACPD) that were published the same time as ours (March 2018). If we calculate the average views and downloads we get 302±100 (min: 199 – max: 570), while our paper's visibility is 293. Furthermore, although media coverage does not converge with scientific quality, the present study was selected for a press conference on "Shape of things to come? The 2017 wildfire season" during the EGU 2018 conference (https://client.cntv.at/egu2018/pc5).

Specific comments. Abstract Line 43. Your conclusion doesn't support this fact and it's not scientifically based.

–Response: Line 43 states "If the expected further warming of Greenland produces much larger fires in the future, this could indeed cause substantial albedo changes and thus lead to accelerated melting of the Greenland Ice Sheet." This sentence is NOT a conclusion, but a logical hypothesis (if). We have slightly rephrased the sentence, so it now reads: "If the expected future warming of the Arctic produces more fires in Greenland, this could indeed cause albedo changes and thus contribute to accelerated melting of the Greenland Ice Sheet." Finally, in order to prove that this is not pure speculation but a solid hypothesis, we support it with references (see last paragraph in conclusions).

Introduction. The introduction is missing a comprehensive literature review on Arctic peat ecosystem and fire occurrence to better understand why those particular fires have been studied.

–Response: We have focused our introduction on peatlands and fires in Greenland and think that a more comprehensive literature review on Arctic peat ecosystems in general is out of scope of this paper. After all, this paper studies the impact of fires in Greenland on BC concentration and deposition in Greenland, not on future scenarios of fire occurrence, permafrost melt or such.

Line 83-84. Provide evidence of the significance of this event compared to other events.

–Response: Our statement that ". . . the fires . . . , probably represent the largest fires that have occurred on Greenland in modern times.", is now supported by a new plot of the number of MODIS active fire detections (MODIS MCD14DL) over Greenland (see new supplementary Figure S1 or attached Fig.1).

Method L89-118. This section is very important as it is the starting point for the estimation of the BC amount released by fires. However the methodology used (eg. which sensor, when, spatial resolution, who and how has done the estimation, . . .) is unclear. On Line 241, we can read that the burnt surface area comes from GlobeCover 2009. So finally, what is your point?

–Response: Line 241 has been corrected. We appreciate the reviewer for this constructive comment. As regards to the methodology, we have done a few corrections to explain better what has been done, also giving specifications of the products we used (lines 97-99). In our opinion, detailed explanations on the calculations are not needed, since the method has been already published in the relevant literature and used in many other previous cases. As we explain in the manuscript, the burned area was mapped using severity levels of dNBR index. The methodology of its application is described in details in Lutes et al. (2006) (pp. 201-270), which is attached. There is another paper describing how dNBR was calibrated in field - Escuin et all, 2008 (see reference in the manuscript). Since the index is sensitive to any disturbances, we applied a manually delineated fire perimeter to increase the accuracy of mapping.

You should rewrite this section with a detailed comment of Table 1 and explain how it compares to active fire mapping. Line 118 needs clarification based on quantitative information.

–Response: Line 94 explicitly says that the location of the active fires were downloaded from NASA's website. So, what is shown in Table 1 has been confirmed with NASA's active fires (also shown in supplements' Figure S1 and attached Fig.1). Regarding to the severity levels (Line 118), qualitative information is given in Key and Benson (2006) together with all the details of the methodology used. The same methodology has been used to map the Chernobyl fires (see: Evangeliou et al., 2014; 2015; 2016) The comment to confirm Line 118 based on quantitative information is too generic and we do not really understand what the reviewer wants us to do.

L155 Explain how you get this number and provide a range of possible values

–Response: Line 155 says "In contrast, tropical peatlands can have deep burn depths of 40–50 cm and release an average of 300–450 t C ha-1 (Page et al., 2015; Reddy et al., 2015)." It should be obvious that this range of values was reported by Page et al. (2015) and Reddy et al. (2015). If the reviewer means the average amount of organic fuel available for combustion that we used for the Greenland fires (100 t C ha-1), it has been taken from Smirnov et al. (2015). In this paper, it was assumed that for peat-bog fires, the average amount of fuel available for combustion (including the soil organic matter) is up to 120 t/ha supported from measurements from IPCC (2006).

L180. Provide reference for BC density and size distribution. Peat fires emits large amount of organic carbon. The possible impact of the mixing state of BC and POM on aerosol size distribution, optical properties and residence time should be discuss in this paper.

–Response: We agree that fires also emit large quantities of organic carbon (OC). However, the impact of OC on the albedo of the ice sheet is probably small, although it probably enhances the BC effect, since OC can also be slightly absorbing (e.g., brown carbon). But given the lack of information on the optical properties of the emitted OC, we think an additional analysis of OC would not be very meaningful. With respect to BC density and size distribution, a reference was added in Line 214 of the updated manuscript. We have now also performed a sensitivity study on the impact of different particle size distributions on the deposition of BC over Greenland's Ice Sheet and discuss it in section 3.2. A detailed analysis of residence times of BC has been already presented by Grythe et al. (2017) [reference in the manuscript] and in Evangeliou et al. (2018) [reference under editorial check in ACP Discussions].

L200 and discussion section 3.3 The apportionment between emission from peat fires and other sources remains un- clear for me. The methodology is not same as the one use for assessing impact of peat fire. The figure 4 is not really useful while other figures are in the supplement material.

–Response: Lagrangian models such as the one used in our work (FLEXPARTv10) can run forward in time (like CTMs or climate models) using specific emissions that can be taken from an existing inventory (for example ECLIPSE, see: http://www.iiasa.ac.at/web/home/research/researchPrograms/air/Global_emissions.html). Moreover, Lagrangian models have the advantage that they can also run backward in time, from a specific point or region for which the user wants to calculate concentrations. What is produced then is the footprint emission sensitivity (or footprint), which is simply the residence time of the computational particles (in sec) in each grid-cell of the model. Then, by multiplying this footprint with a given emission inventory (e.g. ECLIPSE) given in kg/m2/s and dividing with the altitude of the lowest vertical level in the model, one obtains surface concentrations again. Notice that forward and backward calculations are equivalent, so the methodology is not different. However, depending on the setup, the computational efficiency can be much higher in backward mode, and that is also the reason we used it to assess the impact of emissions outside Greenland. For FLEXPART that we used in this study, a comparison between forward and backward simulations can be found in Seibert and Frank (2004). We calculate average concentrations of surface BC in four compartments of Greenland based on ECLIPSE emissions. ECLIPSE includes all anthropogenic sources, while we calculate biomass burning emissions using global MODIS-satellite hot spot data (Giglio et al., 2016) and GFAS (references in the manuscript). Everything is well documented in the associated references. Figure 4 has been replaced by Figure S4 as suggested.

L204 and section 4.2 The methodology and the discussion section on RF computation must be improved and clearly states how you deal with both surface albedo and atmospheric effect of BC on the radiative balance. Figure 7 is confusing as it deals with both BOA, TOA, time series and geographical distribution as the same time.

–Response: We have re-written and re-structured the whole chapter, both in the Methodology and analysis of the Results (see manuscript with Truck Changes). Our perception is not to present in detail methods that have been documented in previous publications. For RF calculations we used the uvspec model from the libRadtran radiative transfer software package (http://www.libradtran.org/doku.php) (see references in the manuscript: Emde et al., 2016; Mayer and Kylling, 2005). Snow albedo was calculated with the SNICAR model (http://snow.engin.umich.edu/info.html) in a two-layer configuration (see references in the manuscript: Flanner et al., 2007, 2009). These are open source codes that have been used by many groups worldwide. Figure 7 has been improved as suggested.

L218 and section 4.1 along with Figures 5 and 6. The validation exercise is really too qualitative and based on visual inspection of satellite data that are not really used scientifically. AERONET data can provide detailed information on aerosol optical properties and radiative forcing. CALIOP data products give aerosol extinction profiles which can be used in the RF computations.

–Response: The reason the validation exercise is so qualitative is that we have no clear observations of the Greenland fire plume. The AERONET data show impacts of the forest fires burning outside Greenland. Only at one site, the AERONET data show an AOD increase that is partly (but not exclusively) due to the Greenland fires.

L466 Your last bullet point is rather speculative and not supported by the findings of the paper.

–Response: This is true and we have now corrected it. The last bullet is NOT ALL OF IT a conclusion, but rather a comment and therefore, we now show it as a comment (not bulleted) below the bullet. We further support what we say in the sentence with references.

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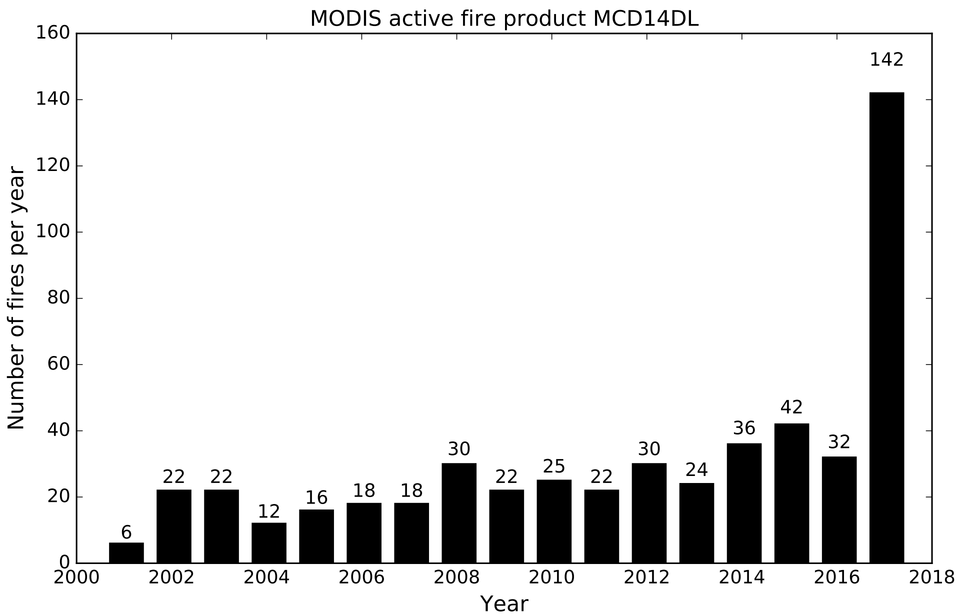

Fig. 1. Annual number of active fires over Greenland during the last 17 years as seen from NASA's MODIS satellite (product MSC14DL).