

The manuscript titled “Drivers controlling black carbon temporal variability in the Arctic lower troposphere” by Gilardoni et al. investigates the seasonality and meteorological influences on black carbon (BC) concentration in the Svalbard region through a combination of modeling and observational measurements. It is found that wet scavenging plays a large role in modulating seasonal variability and that circulation, from a boundary layer to synoptic scale, impacts the shorter-term BC variability. The paper has significant potential to increase understanding on Arctic BC concentration and its controlling factors.

Overall, the manuscript is well-written, with the knowledge gap and scientific objective of the manuscript clearly laid out. The paper flows well and is organized in a way that distinctly addresses each objective. However, there are several areas throughout the paper that are unclear or lack necessary supporting information. These issues should be addressed to improve the clarity and strengthen the claims of the manuscript. Following minor revisions, I recommend publication.

### **General Comments**

The manuscript is strongly based on the idea that there are two periods (cold and warm seasons) with different responses in each period. The data were separated into these two chosen periods, November-April and May-October, before any analysis or underlying trends were observed. What is the basis for the selection of the month range for each period? There is little discussion in the manuscript that gives support and explanation for the reason why the data were separated in this way. Is this cold season of November-April and warm season of May-October similarly used to subset data in this region in previous publications? If so, please include references and brief discussion in the introduction or methods. If not, was this based on analysis of measurements? For example, if it is based on average temperature (or some other variable) and there are clear differences between the two periods, then it would be useful to include a discussion (perhaps in the methods or supplement) on how and why these two periods are distinguished. I understand that the goal is to investigate seasonal variability, but why was it chosen to separate the data into two periods rather than say four? The manuscript would benefit from further clarification and support on this subject.

### **Specific Comments**

Line 37: This paragraph appears to be contradictory and the key point is unclear. The first sentence states that overestimation of BC scavenging may cause BC model underestimation. The following two sentences agree with this first statement. However, the last statement suggests the opposite by stating that models tended to underestimate rather than overestimate BC scavenging. Is this sentence supposed to say that models underestimate *BC* in agreement with the first sentence or underestimate *BC scavenging* which opposes the first sentence? If this last sentence is supposed to contradict the previous sentences, then it should be placed in another paragraph with further discussion on the opposing point. Alternatively, with more emphasis that there are contrasting results in the literature they can be placed in the same paragraph. Please clarify on the key point of this paragraph.

Line 236: The second paragraph of Section 3.2 on the BC MAC reported in literature and the determination of the value used in this paper does not seem vital to this section or the main manuscript. By moving this discussion to the supplement, it would aid in flow and readability of the manuscript and better highlight only the necessary key points of the results. Additionally, there are several literature values listed throughout this paragraph which makes it hard remember each in order to place the  $10.2 \text{ m}^2\text{g}^{-1}$  in context of the literature. It could be beneficial to summarize all values in a figure. This way, it would be easier to visualize where the  $10.2 \text{ m}^2\text{g}^{-1}$  used in this manuscript falls in comparison to previous literature.

Line 272: “the largest difference was observed in July 2020, when eBC concentration was...”. It is unclear whether “eBC concentration” here is referring to the mean or median value. I assume it is the mean value, but it would be useful to specify.

Table 2: Do none of the variables in the table have statistical significance greater than 99%? In the caption it is stated that this is marked with two asterisks (\*\*), but (\*\*) never appears in the table. Please remove this description if it is unused, and/or verify that none of the variables mistakenly have one (\*) or three (\*\*\*) asterisks instead of two (\*\*).

Line 380: It is hard to tell from Figure S7 that colder temperatures corresponded to airmasses that spend more time over the Arctic Ocean and Greenland coasts. There is hardly noticeable difference between Figure S7b and S7d. I suggest reproducing this figure by plotting a contour map of the difference of Figures S7b and S7d. This would clearly show the locations of greatest difference and perhaps more strongly support this claim. Otherwise, I suggest removing this statement.

Line 395: This paragraph is lacking support for the reason why eBC increases with increasing radiation. Is the statement “Low-level clouds are usually associated with rain and drizzle, with the later [sic] one not well captured by cumulative daily precipitation measurements” based on previous literature or based on measurements analyzed in this study? Please include supporting references for this statement and/or add further discussion of the analysis that led to this statement.

Figure S6: It is hard to visualize how the winds are changing (which is a relevant point discussed in the manuscript) with a different axis range in each plot. Please use the same fixed axis range for all plots to be able to compare and contrast the plots with each other more easily.

Figure S8: Are the vertical lines extending to the 25<sup>th</sup> and 75<sup>th</sup> percentiles or standard deviation? Is the thick line the median or mean? Please clarify in the caption/description.

Several small grammatical issues are listed below, please address them for clarity and ease of reading:

- Line 38: Add “the” so that it reads “optimizing the in-cloud and...”
- Line 52: The word “challenging” appears in the wrong place in the sentence. It should read “Both these factors make the quantification of biomass burning impact on the Arctic lower troposphere challenging” or “Both these factors make it challenging to quantify the biomass burning impact on the Arctic lower troposphere”.
- Line 119: Replace “to” with “with”.
- Line 296: Change “increased” to “increase” (or remove “of”).
- Line 298: “investigates” should be “investigate”.
- Line 316: “pressire” should be “pressure”.
- Line 325: This sentence is unclear. It seems it should read as “air masses reaching Svalbard spent most of the time over the ocean”, or “air masses reached Svalbard after spending most of the time over the ocean”.
- Line 339: Missing “Å”. Should be “Ny- Ålesund”.
- Line 357: This sentence should be either plural or singular (not both). It should read as either “indicates a larger interannual difference” or “indicates larger interannual differences”.
- Line 374: Change “increased” to “increase”.
- Line 396: Add “than” so that it reads “to more than 100...”.
- Line 400: Change “later” to “latter”.