Reviewer ID# 2
Manuscript No.: egusphere-2024-3124
Authors: Olga B. Popovicheva et al.
The title of manuscript: **Multi-year black carbon observations and modeling close to the largest gas flaring and wildfire regions (Western Siberian Aretic)**

General comments:

The Arctic has warmed three times more quickly than the planet as a whole, making it the most sensitive region to climate change. To understand the impacts of BC emissions on the Arctic from source regions, particularly from the Siberian Arctic, the authors present three and a half years measurements of equivalent BC (eBC) concentrations from 2019 to 2022. These measurements are complemented by elemental carbon (EC) data obtained using therma-optical method, conducted at the recently established station "Island Bely" (IBS). The station is located along the main pathway through which the highest levels of anthropogenic pollution from industrial regions, as well as emissions from Siberian wildfires, enter the Arctic.

Furthermore, the authors evaluate seasonal variations in intensive optical properties and their dependence on wavelength, as indicated by Absorption Angstrom Exponent (AAE). They also estimate the site-specific absorption coefficient (*SAC*), which serves as the basis for calculating eBC values.

By coupling the FLEXPART Lagrangian particle dispersion model with the latest black carbon (BC) emission inventories for anthropogenic and biomass burning sources, the study investigates the detailed aerosol aging spectrum, source region attribution, and source sector apportionment for the entire period as well as during pollution episodes. This approach effectively integrates observations with model simulations and emission inventories.

However, it is noted that this work appears very similar to a study published in 2022 by the same group (Popovicheva et al., 2022), conducted at the same location with similar observations and using the same model. The conclusions are largely the same, apart from the inclusion of two additional years of observations.

I would recommend publishing the manuscript in *Atmospheric Chemistry and Physics* (ACP) after the authors address the following aspects:

- Reduce or condense repetitive content that overlaps with the previous paper published in 2022.
- Emphasize aspects that are being discussed for the first time in this study, such as "BrC and its relationship with the corresponding AAE" and "eBC (derived from SAC) and its comparison with eBCAET".
- It is noted that the eBC values are approximately half of the eBC_{AET} values (Table 1). Could the authors have a further discussion regarding the difference?
- There appears to be a significant discrepancy between the results in Table S3 and Figure 10 b). For example, in July 2020, Figure 10 b) shows that biomass burning (BB) accounts for about 80%, whereas Table S3 indicates only a 7% contribution of BrC during the same period. Conversely, in February 2020, Figure 10 b) shows less than 10% BB, while Table S3 also reports a 7% BrC contribution. Could the authors clarify why these differences occur?

Specific comments:

L27-L28: Is the "92%" an average value of cold seasons over the entire study period?

It appears that the 92% mentioned in abstract is not consistent with the 83% stated in the conclusion.

L87-L88: Are the Biomass Burning (BB) results in Figure 10 a) and b) from ground level or from the altitudes (600-800 hPa)? Do the BB results in Figure 10 support the previously work by Qi and Wang, 2019?

L150: Should this be Fig. S1, instead of Fig.1d ?

L159: What are the two inlets with a much higher flow rate (~ 38LPM) than 5LPM?

L170: Please specify eBC_{AET} as "equivalent black carbon concentration by aethalometer", when mentioning it for the first time.

L182: Please spell out for "NIR-VIS"

L240: What is the highest level of the 137 vertical levels?

How do you couple with the BB burning injection height in the emission inventory?

L276-L277: Please be consistent with the wavelength mentioned (880nm or 800 nm?). Only 880nm is shown on Fig. 2.

L277: The expression is confusing, i.e., "the mean ± sigma (median) values".

It is suggested to use "the mean ± sigma and the median, respectively".

L285: Please ensure consistency between the text and Table 2.

L295-L297: The sentence is not well expressed. Please consider re-phrasing it.

L308 & L1083: Please ensure consistency in the wavelength between the text on page 11 and Figure 3(a). The caption for Figure 3(a) should indicate 590 nm. Additionally, please add (a) and (b) to Figure 3.

L378: Is it the cold season, or the warm season over the entire period?

L385-L388: The numbers in the text differ slightly from those in Table S2. Please ensure consistency between the text and the table.

L427: No box-whisker plots are shown in Figure S3, which presents the emissions of BC from CAMS-GFAS. This should be Figure S4.

L431: It is suggested to add "in percentage" (shown in Table S3) after the "contribution".

L439: Can the authors explain why eBC_{AET} is higher than eBC by a factor of two?

L498: Should it be Figure 9?

L520-L521: It is interesting to see a lack of consistency between Figure 10b and Table S3. It appears that a high BB contribution does not result in a relatively high percentage of BrC.

L546: It should be ~ 50%, instead of 60%.

L547: It is suggested to use 72,400 km^2.

L560: what is the unit of "150,000"?

L574: In general, the 'Conclusion' section is too long and should be more concise.

L596: "BrC light absorption coefficient in the UV spectrum showed similar trends as BC, although it exceeded BC by 2.4 times during both cold and warm periods." What is the basis of this statement?

L607: Please confirm the numbers. They should be consistent with these in Table S2, where the numbers are 106 ± 67 ng m^{-3}.

L669: Please use “MAC”, instead of “*MAC*” to ensure consistency when writing the initials. Otherwise, it would be confused with the Mass Absorption Coefficient (*MAC*).