The paper „Drivers controlling black carbon temporal variability in the Arctic lower troposphere" addresses seasonal differences in the eBC concentration during different atmospheric conditions. During this analysis the authors use compare in-situ measurements with model data to find out the history of advected BC. Substantial conclusions are reached and the outline is clear.

Since only in-situ measurements at Gruvebadet (Boundary layer) are taken, the title is a bit misleading, that only one measurement site is taken into account.

This study presents a detailed data analysis of observations collected at a single site in the Arctic. Nevertheless, the results here reported show that the largest fraction of time variability of eBC concentration at Gruvebadet is controlled by synoptic scale processes, including wet scavenging during transport from emission regions, as well as synoptic-scale meteorological processes that promotes effective transport from lower latitudes, such as diabatic cooling of air masses moving over snow-covered ground, intrusion of warm air from lower latitudes, and specific sea level pressure patterns. Conversely, local meteorology (wind pattern and boundary layer dynamics) have a less significant impact on eBC time variability. For these reasons, we believe that the observations collected at Gruvebadet are representative of the European Arctic lower troposphere, and we modified the title as follows:

"Drivers controlling black carbon temporal variability in the lower troposphere of the European Arctic"

Language:

line 94: one comma too much

Comma was removed

106: Ångström

Thanks for highlighting the typo. We corrected throughout the entire manuscript.

118 "The NAO a a measure..."

The sentence was modified as follows:

"The NAO is a measure…"

208: „per [For?] each grid cell…"

The sentence was reformulated as:

"For each grid cell…"

250: Ångström

Thanks for highlighting the typo. We corrected throughout the entire manuscript.

316: pressure

We corrected it

We corrected the name of the village

The name of the glacier was corrected

Wind speed unit was corrected with "-1" as superscript

We thank the referee for the suggestion, but we hold to the AP Style and CMOS general rule of using lower case for compass directions

 We closed the bracket at the end of the sentence.

Mathematical formulae,...:

line 96: what does «Tr» mean?

Tr stays for transmittance, nevertheless we did not use this abbreviation in any other part of the manuscript and we decided to remove it from this line.

Eq 1: sum over index i is missing

The index i refers to the i-th observation. For clarity the formula was modified as follows:

$$\ln(eBC) = \sum_{j=1}^{p} s_j(x_j) + \sum_{j=p+1}^{q} \beta_j\, x_j + a + \varepsilon$$

line 161: x_(ij)

The formula was modified and the index i was removed, so the actual text that reports $x_j$ is now correct.

Eq 2: What is «R»?

R in formula 2 is the Pearson's correlation coefficient. We agree with the referee that meaning of VIF was not clearly explained. The text after formula (2) was modified to better explain how VIF is calculated and its meaning.

"r is the Pearson's correlation coefficient that defines the correlation of the last added variable against all the other variables already included in the multivariate GAM. As a general rule, VIF

equal to 1 corresponds to no correlation, while VIF between 1 and 5 indicate a weak correlation. In this study, if VIF exceeded 2.5, the variable was not added to the model and the covariate with the second highest deviance explained was tested. A VIF equal to 2.5 was chosen because it corresponds to a coefficient of determination of 0.6, which is the maximum ~~allowed~~ collinearity among covariates that was considered acceptable."

We also noticed that in the text we often used both R (capital letter) and r (lower case) to indicate the Pearson's correlation coefficient. We modified the manuscript to improve consistency and used the lower case indication.

3056, 306,...: What is «R»? What does the value mean?

The text reports the Pearson's correlation coefficient between the monthly averages of eBC derived from Julian day (treated as dependent variable) and the precipitation rate along back trajectories (treated as independent variable).To specify the meaning of r, the text was modified as follows:

Monthly averages of eBC derived from Julian day weakly anticorrelated with the precipitation rate along back trajectories (r = -0.43), whilst the predicted eBC showed no link with BC emission variability (r = -0.11) (Fig. S4), indicating that scavenging efficiency had a stronger impact on eBC seasonality than emission variability. The anticorrelation (negative r value) indicate that an increase in precipitation rate was associated with a decrease in surface eBC concentration, as expected due to wet scavenging.

Tab 1 and 2: p-values printed but not explained in text  -> interpretation needed

p-values indicate the ability of each explanatory variable to describe the time variability of the eBC concentration. At line 285, the manuscript was modified in order to explain the meaning of this parameter:

"Table 1 reports the covariates selected for the cold season GAM, together with the deviance explained by the model after the addition of each variable, and the corresponding p-values. Low p-values indicate high significance of the relationship between ln(eBC) and the explanatory variable."

line 441-442: what is «r»? and what does it mean?

r is the Pearson's correlation coefficient between the model residual time series and the time series of the SLP anomalies over the investigated regions. To clarify the link of this paragraph with the previous one, we merged the two paragraphs and we modified the manuscript.

"The ~~highest anticorrelation~~ lowest Pearson's correlation coefficient (r) between residual time series and SLP anomalies was observed in the region between 55° and 65° north and between 42° and 50° east (r=-0.21), while the ~~higher~~ highest correlation was reported for the region between 30° and 45° north and 10° and 22° west (r =0.19)."

Figures:

Fig 1b, c, 4, 5a, 6, 7, 9a, S3, S5 - S9: not refereed to in text

Reference to figure 1b and c was added to the main text in line 79:

"Figure 1a shows the location of GAL, Ny-Ålesund village, and the CCT, while Fig. 1b and c report the wind rose during the cold and warm season, respectively".

Figure 4 and 5a are already introduced in section 3.3.1, in line 287 and 292, respectively. Reference to Figure 6 is in line 326 and 332, figure 7 in line 352, figure 9a in line 437, figure S3 in line 277, figure S5 in line 312, and figure S9 in line 430 and 433.

Fig: 1a: include Zeppelin Station on map, scale is missing, Maybe you can include a map of entire Svalbard (and maybe even Europe) to clarify the location of the sight?

We replaced figure 1a with the following figure that includes a map showing Svalbard location in the northern hemisphere, as well as a reference scale.
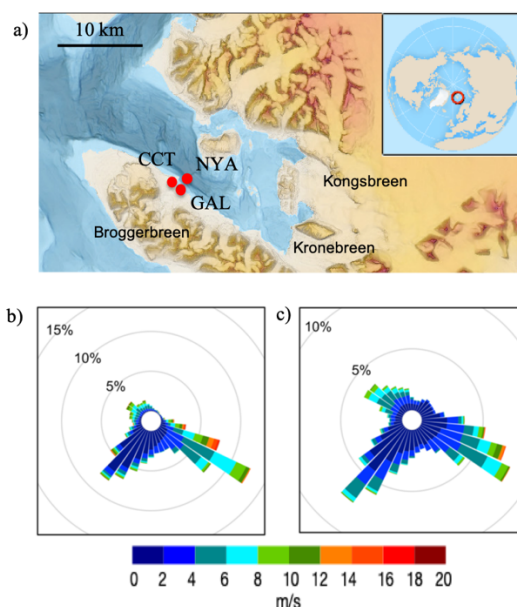


Fig 5b + Fig 6: move to section 3.3.2, where you talk about it.

Figure 6 is correctly located in section 3.3.1. The reviewer likely refer to Table 2, which has now been moved into section 3.3.2. Concerning Figure 5b, we prefer to keep it together with Figure 5a to better highlight the differences between the cold and the warm season. Nevertheless, to avoid misinterpretation of the two panels, we wrote on top of each panel the season it refers to.

Figure 8: How many histograms are plotted? Is it 2 or 3?

Figure 8 reports two histograms. We added colored lines to the bars to make the plot clearer, and modified the figure's caption as follows:

"Histograms reporting the frequency of back-trajectory maximum pressure increase during the last 48 hour before reaching GAL (panel a) and minimum latitude reached during the seven days before reaching the observatory (panel b). Back-trajectory data of colder days are reported in blue, warmer days in red, while purple area corresponds to the overlapping region of the two histograms."

The revised figure is here reported.
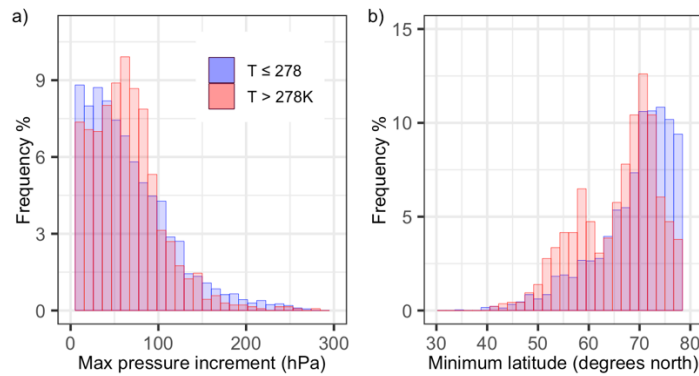
The interpretation of many of the figures is too/very short

We agree with the referee that some of the figures were not appropriately described and explained in the main text. We modified the description of figures 8 to 10 as follows:

Figure 8.
"Higher temperature in the Arctic could be due to diabatic warming, adiabatic warming due to subsidence, or intrusion of air masses form lower latitudes (Papritz et al. 2020. The analysis of meteorological parameters during transport shows that only a limited number of back trajectories arriving at GAL during warmer days (average temperature higher than 278 K) experienced diabatic warming before arriving at the observatory (10%). Furthermore, we investigated adiabatic warming due to subsidence based on the maximum pressure increase experienced by the back trajectories during the last 2 days before reaching GAL (Binder et al., 2017). The frequency distribution of maximum pressure increment in Fig. 8a shows We observed a slightly higher number frequency of back trajectories undergoing a pressure increment between 50 and 100 hPa in warmer days compared to colder days (Figure 8a).. The pressure change indicates the subsidence indicating transport from the lower free troposphere just before reaching the observatory. Finally, to study the intrusion of air masses from lower latitudes lower than 70 degrees, the histograms in Fig. 8b reports the frequency distribution of the minimum latitudes reached by the back trajectories up to 7 days before arriving at GAL, as a function of the average daily temperature. The histogram comparison indicates that it was more likely that air masses originated from regions south of the 70th parallel occurred more often during warmer 62% of the time) than colder days (40% of the time) (Figure 8b). To further validate these results, Fig. S7a…"

Figure 9.
"To test the impact of potential unaccounted synoptic-scale circulation pattern in the cold period, we calculated the average cold season SLP map from 30 to 90 degrees north, we calculated the SLP anomalies (the difference between each daily map and the cold period average map), and finally we investigated the correlation between the anomaly time series in each cell and the time series of the GAM model residuals (the differences between the measured eBC concentration and the eBC simulated by the cold season model). Figure 9 reports the map of the Pearsons' correlation coefficients and shows that calculated the correlation of the SLP anomalies during the cold season with the residuals GAM model (Fig. 9a). higher residuals were associated with low pressure anomalies over Scandinavia and western Russia and a high pressure anomalies over the Atlantic Ocean, between Spain and the Azores."

Figure 10.
"To investigate GAM model performance, Fig. Figures 10a and b report the scatter plots of modelled versus observed concentration during the two seasons. Most of the points were close

to the 1-to-1 line and the fraction of data with a modelled to observed eBC ratio between 0.5 and 2 (Chang et al. 2004) was equal to 72% and 71% in the cold and the warm period, respectively. GAM models underpredicted eBC ~~concentration~~ during both seasons for concentrations larger than 50 ng m$^{-3}$, likely due to the difficulties the model has to describe the behaviour of an under-represented eBC concentration range. In fact, eBC daily average was larger than 50 ng m$^{-3}$ only during 9% and 1% of the time in the cold and warm season, respectively. Figure 10c shows that overall, the model reproduces well the observed seasonal and interannual variability of the monthly eBC averages ~~(Fig. 10c)~~."

Text:

Julian date is a clear defined date and counts all dates after 1.1.4713 BC. Please use other name for time of your measurement period to avoid miss-understandings.

We would like to thank the referee for pointing out this inconsistency. We decided to use the truncated Julian Date convention introduced by NASA in 1979, which uses as reference time May 24, 1968. We updated the definition of the Jul variable in the "Generalized Additive Model" as follows, and we updated the x-axis range in panels a of figure 4 and 7.

"In addition, we included day of the year (DOY) and Truncated Julian Day (Jul or continuous day count from May 24, 1968) among the investigated variables to take into account all processes that could not be explained by local meteorological variables or circulation indices, such as seasonal and annual variability of emissions and removal processes during transport. DOY ranged between 1 and 366, while Jul varied between 18178 and 19579. In the following section, for simplicity, Truncated Julian Day will be indicate as Julian Day."

line 80f: In which height was the wind measurements performed?

Wind height measurement is now specified in Figure 1 caption:

"Map of the Kongsfjorden area (a) indicating the position of the Gruvebadet Atmospheric Laboratory (GAL), the Climate Change Tower (CCT), and Ny- Ålesund village (NYA); wind rose for the cold (b) (November - April) and warm (c) ( May - October) season derived from the CCT wind measurements performed at 2 m from the ground.
Map from https://toposvalbard.npolar.no,courtesyoftheNorskPolarinstitutt."

Does Fig. 1C already show the selected wind data?

Figure 1c reports all the available data, to clarify that only a limited number of hours were characterized by wind direction from the village.

For some URLs the term «last visited» is missing

The time of more recent visit of the websites had been added, where missing.

l. 219: You write about DOY, but it is not shown in table 1 or fig. 4

DOY is not reported in Table 1 nor Figure 4 because it was not selected during the definition of the GAM multivariate model, according to the criteria described in section 2.6. To avid misunderstanding, lines 290-292 were modified as follows:

"Although DOY was the second variable with the highest deviance explained in the univariate models (16%), it was not ~~added to the GAM in following selection steps~~ selected as explanatory variable during the multivariate model definition (section 2.6), indicating that Julian day already accounted for the seasonal variability that would have been described by the DOY."

Section 3.3 is quite hard to read, because it is not all the time clear, to which figure you refer. When you talk about a new variable, could you please also mention which sub-figure you now analyze?

To improve figure 4 and 6 readability, a reference to the panels is now reported at the beginning of each paragraph describing the behavior of the explanatory variables.

410: See https://doi.org/10.3390/rs14153771 : There is a downward mixing due to a turbulent wind shear zone in Kongsfjorde

We would like to thank the referee for pointing out this publication, that shows how East-southeast wind direction is associated with downward mixing of air masses in the Kongsfjord. We added a reference to this study in line 410.