Dear Editor,

We thank you and all referees for the constructive feedback. We have revised the manuscript accordingly. Please find below the list of changes that were made in the revised manuscript as well as the point-by-point response to all the referees' comments. We believe the revisions substantially improve clarity, methodological transparency, and robustness.

List of changes in the revised manuscript

Abstract:

- Expanded the MODIS abbreviation at first use.
- Added results for Alaska, now included as one of the source regions of BB aerosol.

Introduction:

- Added a review of altitudes of long-range transported BB aerosol layers observed above Central Europe.

Data and Methods:

- Defined all abbreviations at their first occurrence in the manuscript.
- In the preparatory work for the forward trajectory analysis, limited the maximum starting altitude for estimating the probability of a trajectory from a given region reaching Poland to 5 km AGL, ensuring consistency across all regions.
- Added a workflow diagram summarizing the 7 steps of the methodology.
- Standardized the notation for latitude and longitude.
- Rewrote Step 4 of the methodology to improve clarity and readability.

- Modified the PBL threshold method: instead of using a fixed threshold of 2250 m, now applying the PBL height from the HYSPLIT model at each point along the trajectory.
  Clarified that CAMS GFAS data are provided in metres ASL, while HYSPLIT trajectories were initially run only in metres AGL. In the revised manuscript, specified that trajectories should be initialised in both m ASL and m AGL. Rewrote the CAMS method description to clearly explain how plume-top altitude statistics from CAMS GFAS are implemented.
- Merged the former Steps 6 and 7 into a single Step 6 in the methodology section.

Results:

- After limiting the maximum forward-trajectory starting altitude to 5 km AGL, moved the results for altitudes between 5 km and 10 km (for North American regions) to the Appendix.
- Updated Section 3.5 to account for terrain elevation when discussing plume-top altitude dynamics, since CAMS GFAS data are in m ASL.
- Corrected CAMS GFAS method results to reflect m ASL units (not m AGL); updated figures and tables accordingly.
- Included Alaska as one of the BB aerosol source regions.
- Updated temporal variability results for contributions to BB AOD after correcting CAMS method calculations.

Conclusions:

- Revised the discussion to reflect the updated results.
- Removed the discussion on potential corrections to the previous PBL method with a fixed 2250 m threshold, as this limitation is no longer applicable following the methodological changes.

Response to the referees' comments:

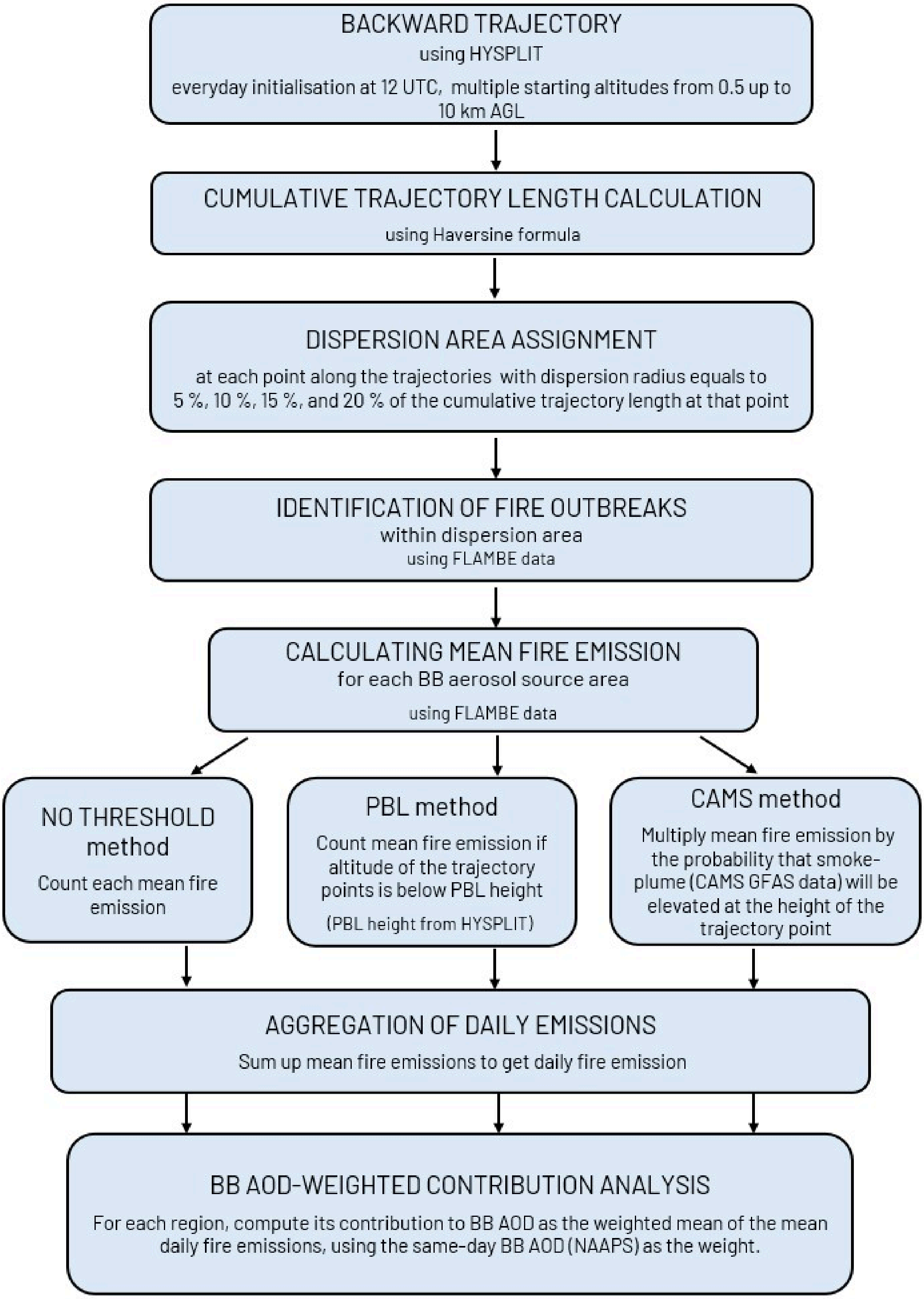
#RC1

RC 1*: "Methods: this section would greatly benefit from a schematic or a workflow diagram summarizing the 7 steps, including which datasets/models are used at each step."*

Author's response*:* As suggested, we have prepared a workflow diagram, which will be included in the manuscript. The diagram is depicted below. Please note that the steps 6 and 7 were combined as a one for the clarity of explaining how to calculate the final contribution to BB AOD from each potential region as a source of BB aerosol.

Author's change in the manuscript*:* In Line 148 reference to this workflow is added:

"To estimate the contribution of identified regions to the BB AOD in selected location, such procedure was followed. The workflow summarizing the steps of the methodology is depicted in Figure 1."


BACKWARD TRAJECTORY
using HYSPLIT
everyday initialisation at 12 UTC, multiple starting altitudes from 0.5 up to 10 km AGL
CUMULATIVE TRAJECTORY LENGTH CALCULATION
using Haversine formula
DISPERSION AREA ASSIGNMENT
at each point along the trajectories with dispersion radius equals to 5 %, 10 %, 15 %, and 20 % of the cumulative trajectory length at that point
IDENTIFICATION OF FIRE OUTBREAKS
within dispersion area
using FLAMBE data
CALCULATING MEAN FIRE EMISSION
for each BB aerosol source area
using FLAMBE data
NO THRESHOLD method
Count each mean fire emission
PBL method
Count mean fire emission if altitude of the trajectory points is below PBL height
(PBL height from HYSPLIT)
CAMS method
Multiply mean fire emission by the probability that smoke-plume (CAMS GFAS data) will be elevated at the height of the trajectory point
AGGREGATION OF DAILY EMISSIONS
Sum up mean fire emissions to get daily fire emission
BB AOD-WEIGHTED CONTRIBUTION ANALYSIS
For each region, compute its contribution to BB AOD as the weighted mean of the mean daily fire emissions, using the same-day BB AOD (NAAPS) as the weight.

RC 1: "*I would also recommend that the authors mention before going into the 7 steps that the overall goal of the methodology is to partition the BB AOD according to emissions encountered from different source regions.*"

Author's response: In line 149 it is mentioned that the methodology is implemented to "estimate the contribution of identified regions to the BB AOD in the selected location". Moreover, it is also mentioned in the text in other places e.g: in the line 69: "To assess the contribution of BB regions to BB AOD at a selected location during the BB season, a new framework was developed.", in the line 151: "To estimate the contribution of identified regions to the BB AOD in selected location, such procedure was followed.". Therefore, we believe that adding this information again is not justified.

RC 1.1: "How were the specific regions selected for trajectory analysis (colored shapes in Fig 1a) selected?" "Perhaps a map of the probability of plumes reaching Poland would be useful here. As is, the presented trajectories appear to be somewhat cherrypicked."

Author's response: Points for trajectory analysis were selected based on the mean annual number of fire events reported within each region by the MODIS Active Fire Product (Near Real Time). For clarity in the figure, only pixels with more than 10 fires per year are displayed. Points for forward trajectory analysis were chosen by identifying pixels with the highest number of fire detections. When multiple high-activity pixels were located in close proximity, only one representative point was selected to avoid redundancy. In summary, the selection of points aimed to include areas with elevated fire activity while excluding calculations for points situated very close to one another.

Due to computational constraints, it was not feasible to simulate forward trajectories from every pixel with a high annual number of fires. The analysis period—May to September, 2006–2022—would result in 2,601 trajectories per point, making full coverage impractical. Therefore, only a limited number of representative points were used.

The primary aim of the forward trajectory analysis was to assess whether BB aerosol from a given source region could potentially reach Poland, without explicitly relying on these results in the contribution estimation.

As such, we consider the use of a few well-chosen points sufficient for this type of analysis.

RC 1.2: "*Line 136: please move figure 7 to the first figure discussed, to orient the readers to the source regions of interest.*"

Author's response:: Figure 7 is in such a place because it is a result of analysis of which regions can be the source of BB aerosol flowing over Poland. We don't know which regions will be considered in estimating the contribution to BB AOD in Warsaw before having results presented in Figures 1-6, so we'd rather leave it after the forward trajectory analysis. Figure 7 is placed at this point because it presents the results of an analysis identifying the regions that could be the sources of biomass burning (BB) aerosol transported over Poland. Since the regions contributing to BB aerosol optical depth (AOD) in Warsaw cannot be determined prior to examining the results shown in Figures 1–6, we chose to position Figure 7 following the forward trajectory analysis.

RC 1.3: "Step 1, Line 150: are backward trajectories initialized over Poland/Warsaw?"

Author's response:: While testing the methodology for Warsaw the backward trajectories are initialized in Warsaw. But line 150 is a part of the general description of methodology that is why initialization of backward trajectory shall be done in the location selected for the analysis. In this general description we didn't want to narrow down to Warsaw. specify that we did it for Warsaw.

In the revised manuscript the line 150 it is corrected in such a way that it will be clear that the backward trajectories shall be initialized in the location which is selected for the analysis.

Author's change in the manuscript: We suggest such modification:

"For each day, generate backward trajectories originating at selected location at 12:00 UTC. "

instead of:

“For each day, generate backward trajectories starting at 12:00 UTC.“

RC 1.5: “Step 4: The discussion of fire outbreaks and emissions accounting is very unclear.

Author’s response: To make the description of Step 4 more approachable and understandable, we propose rewriting the text as follows. Please note that our methodology has slightly changed after suggestions from another referee. Now, there is no rigid PBL height threshold, but the PBL height is changing along the trajectory. Such PBL height is now given by the HYSPLIT model.

Author’s change in the manuscript*:*
“4. Identification of fire outbreaks:
Within the defined dispersion areas at each trajectory point, check for fire outbreaks that occurred on the same day with the outbreak hour, not later than the hour of the trajectory point. If any fire outbreaks are found, assign them to one of the regions which during preparatory work were found to be a possible BB aerosol source. For each such source of BB aerosol and each dispersion area, apply three different methods to account for the fire emissions:

- No Threshold method:

For each fire pixel within the dispersion area, calculate the fire emission as the product of the fire flux and the fire area. Then, compute the mean fire emission by dividing the sum of all fire emissions by the number of fire pixels.

- PBL method:

Check whether the trajectory altitude is below the PBL height. If so, calculate the mean fire emission as described in the No Threshold method.

- CAMS method:

Calculate the mean fire emission as described in the No Threshold method. Then, multiply it by the probability that the fire plume is elevated to the altitude of the trajectory point or higher. This probability is obtained by fitting a cumulative distribution function (CDF) to the CAMS GFAS top of the plume altitude data for the considered BB source region. A separate CDF is fitted for each BB source region. The plume-top altitude h is modeled using a log-normal distribution, for which the probability density function (PDF) is given by

$$f(h;\mu,\sigma)=\frac{1}{h\sigma\sqrt{2\pi}}\exp\Big(-\frac{(\ln h-\mu)^2}{2\sigma^2}\Big) \tag{4}$$

where h represents the plume-top altitude expressed in m ASL, while μ and σ are the mean and standard deviation of the natural logarithm of *h*, ln *h*, respectively. The CDF, representing the probability that the plume altitude does not exceed *h*, is defined as:

$$\mathrm{CDF}(h)=P(X\leq h)=\int_0^h f(x;\mu,\sigma)\,dx. \tag{5}$$

Accordingly, the probability that the fire plume extends beyond altitude h is:

$$P(X>h)=1-\mathrm{CDF}(h) \tag{6}$$

This log-normal fit yields a Pearson correlation coefficient r of 1 with the observational data, indicating an excellent fit."

RC 1.5: What does "source region" mean in line 177?

Author's response: Source region meant the region which was identified during preparatory work as a possible source of BB aerosol. This is rephrased in the revised manuscript in the following way:

Author’s change in the manuscript*:*
“If any fire outbreaks are found, assign them to one of the regions which during preparatory work were found to be a possible BB aerosol source. ”

instead of:

“If any fire outbreaks are found, assign them to each potential source region.”

RC 1.5: “Won’t the No Threshold and PBL method count the same emissions multiple times? Please clarify this.”

Author’s response: Yes, this may happen — each method can potentially count the same emission multiple times. However, we aimed to mitigate this by assigning a single mean emission value to each dispersion area, rather than assigning the whole sum of all emissions within it. We believe that counting the same emission more than once can reflect the dynamics of the trajectory: if a trajectory remains longer over a region with intense fire activity, the likelihood and amount of smoke being transported to Poland increases compared to a case where the trajectory passes over fire-affected areas only briefly and is counted once.

RC 1.6: “*Step 5: it might make sense to refer to “each method” as “each emissions method” or something similar.*”

Author’s response: Changed as suggested.

Author’s change in the manuscript: “each method” changed to “each emissions method”.

RC 1.7: “*Step 6: What does “specific region” mean in line 202?*”

Author’s response: There is no “specific region” in line 202. Did RC1 mean “specific location”? If yes - we meant the location selected for the analysis in the methodology.

Author’s change in the manuscript: We suggest rewriting this in the revised manuscript as:

“BB AOD given at 12:00 UTC for that day at the analysis location.”

instead of:

“BB AOD value in specific location for the selected day for 12UTC.”

RC 1.8: *“Step 7: make it clear that the contribution is a percentage.”*

Author’s response: We suggest combining step 6 and step 7 to make these two steps more clear in the following way. Here it is also highlighted that we express this contribution as a percentage.

Author’s change in the manuscript:

“Step 6: BB AOD-weighted contribution analysis:
For each study day, and for every emission method, source region, and dispersion radius, multiply the mean fire emission by the NAAPS-mode BB AOD given at 12:00 UTC for that day at the analysis location. Then sum these BB AOD-weighted emissions over the entire study period and express each regional total as a percentage of the all-region sum for the given method and dispersion radius. The resulting percentages quantify how much each source region contributes to the overall BB AOD.”

RC 1.8: “*What does “BB AOD across mean*”?”

Author’s response: Thank you for catching that. That was a typo, and the correct phrase is “BB AOD in the analysed location”. Corrected in the revised manuscript.

Author’s change in the manuscript:

“BB AOD in the analysed location”

instead of

“*BB AOD across mean*”

RC 2:”*Alaska: Why was Alaska not included as a potential region impacting Warsaw BB AOD? The authors note that lofted plumes have a 1% chance of reaching Warsaw, which seems at odds with their threshold of excluding plumes which have a <0.5% chance of reaching Warsaw.*”

Author’s response: Alaska will be included as a potential source of BB aerosol in the revised manuscript. We conducted additional calculations to present the results for this region as well.

It turned out that during the BB season, the mean Alaska contribution equals 2.6 % ± 2.1 %. The contribution was minimal in May (0.2 % ± 0.2 %) and reached its maximum in July (6.1 % ± 0.4 %). The No threshold method overestimated the Alaska contribution by up to 3.7% in July, while the PBL method underestimated the contribution, showing for each month the contribution below 1.5%. More thorough description of results will be included in the revised manuscript.

Author’s change in the manuscript: In sec 3.5, 3.6 and 3.7 and in sec 4 Alaska is included as a potential source of BB aerosol.

RC 3: “*Figures: throughout the manuscript there are figures with monthly or regional subplot maps. My recommendation is to add subplot titles identifying the plotted month or region.*”

Author’s change in the manuscript: Subplots titles are added.

RC 3: “*I would also recommend moving tables 1 and 2 to the supplement and presenting this information in Figure 11 instead.*”

Author’s response: We appreciate the suggestion; however, we would rather keep Tables 1 and 2 in the main manuscript, as the numerical values they provide are frequently referenced and discussed in the results section—for example, when analysing how changes in the dispersion radius affect regional contributions, or when comparing absolute differences between methods. In our view, it is not feasible to present all this detailed information clearly in a single figure without compromising readability. Figure 11 already presents the maximum amount of aggregated information in a visual form, while the tables complement it by offering precise numerical values necessary for in-depth interpretation.

#RC2

RC: "*An important (rather old) reference on modelling of long-range transport of wildfire aerosol with trajectory models is Forster et al. (2001) which should be mentioned in the introduction or in connection with the results presented for the contribution of Canadian aerosol.*"

Author's response: We thank the reviewer for this suggestion. The reference to Forster et al. (2001) will be added in the revised manuscript, in the introduction part.

Author's change in the manuscript: We suggest mentioning this reference in Line 46:

"While several studies have reported incidents of BB aerosol influx over Europe, comprehensive analyses of these phenomena, particularly over Central Europe, are still scarce. Nevertheless, smoke layers over Central Europe have been documented in earlier work. A pronounced aerosol layer at 3–6 km over Germany in August 1998 was attributed to Canadian wildfires (Forster et al., 2001). "

RC: "*Note that in the paper the altitude of the BB aerosol layer was between 3 and 6 km over Germany, i.e. partially above the maximum altitude in Figures 1-3.*"

Author's response: Figures 1–3 present the probability that an air parcel, initialised at a given starting altitude and location, will reach Poland—not the altitude at which it arrives over Poland. Therefore, the figures do not indicate the vertical distribution of aerosol over Poland, but rather the likelihood of long-range transport from different altitudes.

RC: "*It is confusing that in the paper 3 different time periods are used.*"

Author's response: We agree this can be confusing, but each month-restricted period serves a specific purpose. BB AOD was first shown for March–October to acknowledge the seasonal cycle, including elevated April values in Europe that are mainly linked to agricultural burning (not wildfires). Our contribution analysis is limited to May–September to focus on the wildfire-related BB season and to avoid mixing in the agricultural signal from April. Finally, the FLAMBE emission record had to include April because 10-day backward trajectories initialised on 1 May extend back into ~20 April; without April emissions, early-season transport would be truncated.

Author's change in the manuscript: Also in the revised manuscript, all time periods are unified to time period 2006–2022, except for the use of MODIS Active Fire Product data in the fire frequency analysis, which will retain the extended period of 2001–2022. We believe that this longer time span provides a broader climatological perspective on fire activity in the potential BB source regions.

SPECIFIC COMMENTS

RC: "*Line 38 and/or later: Please provide information on typical plume altitudes.*"

Author's response: We agree and have added a short overview of typical biomass-burning plume altitudes in the Introduction (in Line 46):

Author's change in the manuscript: "While several studies have reported incidents of BB aerosol influx over Europe, comprehensive analyses of these phenomena, particularly over Central Europe, are still scarce. Nevertheless, smoke layers over Central Europe have been documented in earlier work. A pronounced aerosol layer at 3–6 km over Germany in August 1998 was attributed to Canadian wildfires (Forster et al., 2001). Potential smoke layers over Warsaw spanning a range of source regions were examined by (Janicka et al., 2023), who found that layers that could originate from North America occurred between about 2 and 8.5 km, whereas layers attributed to Eastern Europe were most frequently detected between 2 and 4 km, with some reaching as high as 7 km. In addition, (Ortiz-Amezcua et al., 2017) reported smoke layers of 1–2 km thickness located at roughly 5 km above sea level (ASL) over Granada and Leipzig, and around 2.5 km ASL over Warsaw, linked to long-range transport from North America."

RC: “Line 60 and 210: Months inconsistent to peaks in Fig. 9 (expand!).”

Author’s response: In lines 284-288 it is explained: “Interestingly, BB AOD values are higher in March and April compared to May and June. This pattern can be attributed to early spring BB practices, such as agricultural waste burning and land management fires, which are prevalent during the planting season, particularly in Eastern Europe and Russia (Stohl et al., 2007; McCarty et al., 2012; Hall et al., 2021)”.

In our analysis we focus on BB associated with wildfires, not agricultural practices. That is why our contribution analysis is limited to May–September to focus on the wildfire-related BB season and to avoid mixing in the agricultural signal from April..

RC: “*Line 97: A reference for FLAMBE is missing or is this included in the reference in line 102 or one of the other references in the NAAPS-section? Please clarify or refer at least to the next section where the same references appear again.*“

Author’s response: The missing reference is the one given in line 102. It was added in line 97.

Author’s change in the manuscript: “FLAMBE program (Reid et al., 2009), initiated in 1999, is a collaboration between the U.S. Navy, NASA, NOAA, and the academic community. It integrates fire detection algorithms like NOAA/NESDIS’s Wild-Fire Automated Biomass Burning Algorithm (WF_ABBA) and NASA’s MODIS fire products to monitor BB emissions, incorporating these data into the NAAPS model to study smoke particle emissions and their atmospheric transport on regional to continental scales (Reid et al., 2009).”

RC: “*Both sections might be merged for clarity.*”

Author’s response: We acknowledge the suggestion to merge the FLAMBE and NAAPS sections for clarity. However, in our opinion, keeping them separate helps distinguish between the different roles these tools play in our methodology. NAAPS is used primarily as a source of aerosol-related output (AOD and BB AOD), while FLAMBE is used independently to extract information on fire size and fire emissions. Although FLAMBE feeds emission data into the NAAPS model, in our analysis, both tools are applied separately and serve distinct purposes. We believe that maintaining this distinction improves the clarity of our methodological description.

RC: "Line 139: Is it possible to perform simulations in Europe also for higher altitudes for consistency with the next sections and Fig. 10?"

Author's response: We propose a modification in response to this comment. In the main part of the manuscript, we will limit the maximum starting altitude for estimating the probability that a trajectory from a given region reaches Poland to 5 km AGL, ensuring consistency across all regions. Higher altitudes (up to 10 km AGL) were originally included for North American regions due to their specific transatlantic atmospheric circulation patterns. In particular, for Alaska, this approach yielded interesting results. However, after considering the reviewer's suggestion, we will move the results for altitudes up to 10 km AGL to the appendix and focus on altitudes up to 5 km AGL in the main figures.

We believe this change is justified, as the probability of smoke being lofted above 5 km AGL is very low, and omitting these higher layers in the core analysis will not affect the overall conclusions. Therefore, we will agree the altitude range used for North American regions (Figures 4c, 5c, 6c) with that used for European regions (Figures 1c, 2c, 3e,f), while keeping the results for higher altitudes as supplementary material for completeness.

Author's change in the manuscript: Limiting the maximum starting altitude for estimating the probability that a trajectory from a given region reaches Poland to 5 km AGL, ensuring consistency across all regions and moving the results for altitudes up to 10 km AGL to the appendix.

RC: “*Eqn. 1 to 3: Please use consistent symbols for latitude and longitude. It is rather confusing to use Φ for latitude in one equation and for longitude in the others.*”

Author’s change in the manuscript: We revised symbols for latitude and longitude. We decided to use θ for latitude and ϕ for longitude.

RC: “*Lines 190ff: Relation of CDF to f(x,..) and x to h? An additional equation would be useful. Include also 'r' (line 333 too late) and be consistent with later text (line 333ff) concerning inclusion of 'ln' in mean and standard deviation. The text should be rearranged here, caption of Fig. 10 appears to be OK.*”

Author’s response: In the revised manuscript, the CDF will be expressed as a function of plume-top altitude *h* in m ASL. Whole CAMS method section (Lines 190ff) will be changed. We will also clarify that, within the CAMS method, HYSPLIT trajectories must be initialised also with altitude output in m ASL so that *h* in the CDF corresponds directly to the trajectory altitude. Referring to the remarks about lines 333ff we can suggest modification of lines 331-333:

Author’s change in the manuscript:

- “**CAMS method:**

Calculate the mean fire emission as described in the No Threshold method. Then, multiply it by the probability that the fire plume is elevated to the altitude of the trajectory point or higher. This probability is obtained by fitting a cumulative distribution function (CDF) to the CAMS GFAS top of the plume altitude data for the considered BB source region. A separate CDF is fitted for each BB source region. The plume-top altitude h is modeled using a log-normal distribution, for which the probability density function (PDF) is given by

$$f(h;\mu,\sigma)=\frac{1}{h\sigma\sqrt{2\pi}}\exp\Big(-\frac{(\ln h-\mu)^2}{2\sigma^2}\Big) \tag{4}$$

where h represents the plume-top altitude expressed in m ASL, while μ and σ are the mean and standard deviation of the natural logarithm of *h*, ln *h*, respectively. The CDF, representing the probability that the plume altitude does not exceed *h*, is defined as:

$$\mathrm{CDF}(h) = P(X \leq h) = \int_0^h f(x; \mu, \sigma)\, dx. \tag{5}$$

Accordingly, the probability that the fire plume extends beyond altitude h is:

$$P(X > h) = 1 - \mathrm{CDF}(h) \tag{6}$$

This log-normal fit yields a Pearson correlation coefficient r of 1 with the observational data, indicating an excellent fit."

"**1. Backward trajectory simulation:**

For each day, generate backward trajectories originating at selected location at 12:00 UTC. Extend each trajectory 240 hours (10 days) backward in time. Initialize each trajectory at multiple altitudes, starting from 500 m up to 4000 m in increments of 500 m AGL, and additionally at 5000, 6000, 7000, 8000, 9000, and 10000 m AGL. For every starting height, run HYSPLIT twice: once with the height specified in metres ASL (m ASL) and once in metres above ground level (m AGL), with the latter run computed together with PBL height output (expressed in m AGL). After computation, merge each ASL–AGL pair so that the resulting trajectory record contains both m ASL and m AGL height fields."

"Using the data of the altitude of the top plume provided by CAMS GFAS during the years 2006-2022 for the months of May–September, density histograms of this parameter were plotted density histograms of this parameter were plotted, alongside the fitted log-normal PDF f (x; μ, σ), described by the parameters μ and σ, which are the mean and standard deviation of ln x, respectively (see Figures 11a–11f). For each fit, the Pearson correlation coefficient r was calculated. "

RC: "*Figures 1 to 6: Are the shown data only for May to September? If yes include in captions.*"

Author's response: Yes, these data cover only months May-September only. This will be clarified in the figure captions and also in the text of the manuscript in sec 3.1.

Author's change in the manuscript: Figure caption (e.g. for USA) is corrected to:

"Figure 4. Spatial analysis of fire events and trajectory analysis in the USA. Panel (a) displays the average number of fires during BB season (in months May-September) in the USA over the period 2001-2022, with fire frequency represented on a logarithmic color scale. Panel (b) shows the specific locations selected for trajectory analysis within this region. Panel (c) presents the percentage of trajectories reaching Poland during BB season from each location defined in (b) as a function of starting altitude. Each symbol corresponds to a specific source point, as indicated in the legend."

"The average number of fires in BB season (in months May-September) for the years 2001–2022 retrieved from MODIS Fire Active Product data is presented in Figures 1a, 2a, 3a-b for Europe and Russia, and in Figures 4a–6a for North America, including the United States, Alaska, and Canada."

RC: "*Figure 9: I suppose BB AOD and total AOD are meant in caption.*"

Author's response: Yes, in this context, AOD refers to total AOD. In the revised version of the manuscript, the figure caption will be updated to explicitly state that total AOD is shown.

Author's change in the manuscript: Figure 9 caption is corrected to:

"Figure 9. Monthly values of BB AOD, total AOD, and their ratio for Poland and Warsaw averaged over the period 2006-2022. Panel (a) displays the mean BB AOD values for each month, comparing Poland and Warsaw. Panel (b) shows the monthly mean total AOD values for both Poland and Warsaw. Panel (c) presents the ratio of BB AOD to total AOD, expressed as a percentage, for each month, comparing values between Poland and Warsaw. "

RC: "*Line 337ff: Isn't there also the effect of fires on mountains or other elevated regions?*"

Author's response: Yes, terrain elevation does influence the plume-top altitude distributions. In the revised manuscript, we updated the discussion of the fitted PDFs for the identified BB aerosol source regions to reflect this aspect. We thank the reviewer for this helpful remark. We suggest such modifications for Lines 337–351:

Author's change in the manuscript: "The fitted PDF parameter μ, representing the mean of the natural logarithm of the plume-top altitude in a log-normal distribution, can reveal differences in plume-elevation dynamics. From a physical standpoint, the quantity $\overline{\mu} = e^{\mu}$ is more informative, as it corresponds directly to the mean plume-top altitude. However, because CAMS GFAS altitudes are reported in m ASL, local terrain elevation must also be taken into account. Among the European regions, Southern Europe exhibits the lowest mean plume-top altitude, $\overline{\mu}$ = 1110 m ASL (μ = 7.01), followed by the Iberian Peninsula, $\overline{\mu}$ = 1150 m ASL (μ = 7.05). Eastern Europe shows a higher value of $\overline{\mu}$ = 1460 m ASL (μ = 7.29). In North America, plume tops are generally higher: Canada $\overline{\mu}$ = 2100 m ASL (μ = 7.65); the USA $\overline{\mu}$ = 1840 m ASL (μ = 7.52); and Alaska $\overline{\mu}$ = 2040 m ASL (μ = 7.62).

Since CAMS GFAS data are reported in m ASL, and the variability of terrain elevation significantly affects the interpretation of plume rise above ground level, it is not possible to clearly predict how the different methods will estimate contributions. Based on the forward trajectory analysis for Alaska, the No Threshold method is likely to overestimate the contribution from that region. Aside from this case, there is no clear basis to determine how the results of the various methods will differ for certain BB aerosol source regions. Among the methods considered, the CAMS-based approach is expected to provide the most reliable estimates of regional contributions to BB AOD, as it statistically accounts for differences in fire plume rise dynamics across the identified BB aerosol source regions."

RC: "Line 381: Cite Table 1 and 2."

Author's response: Citation added.

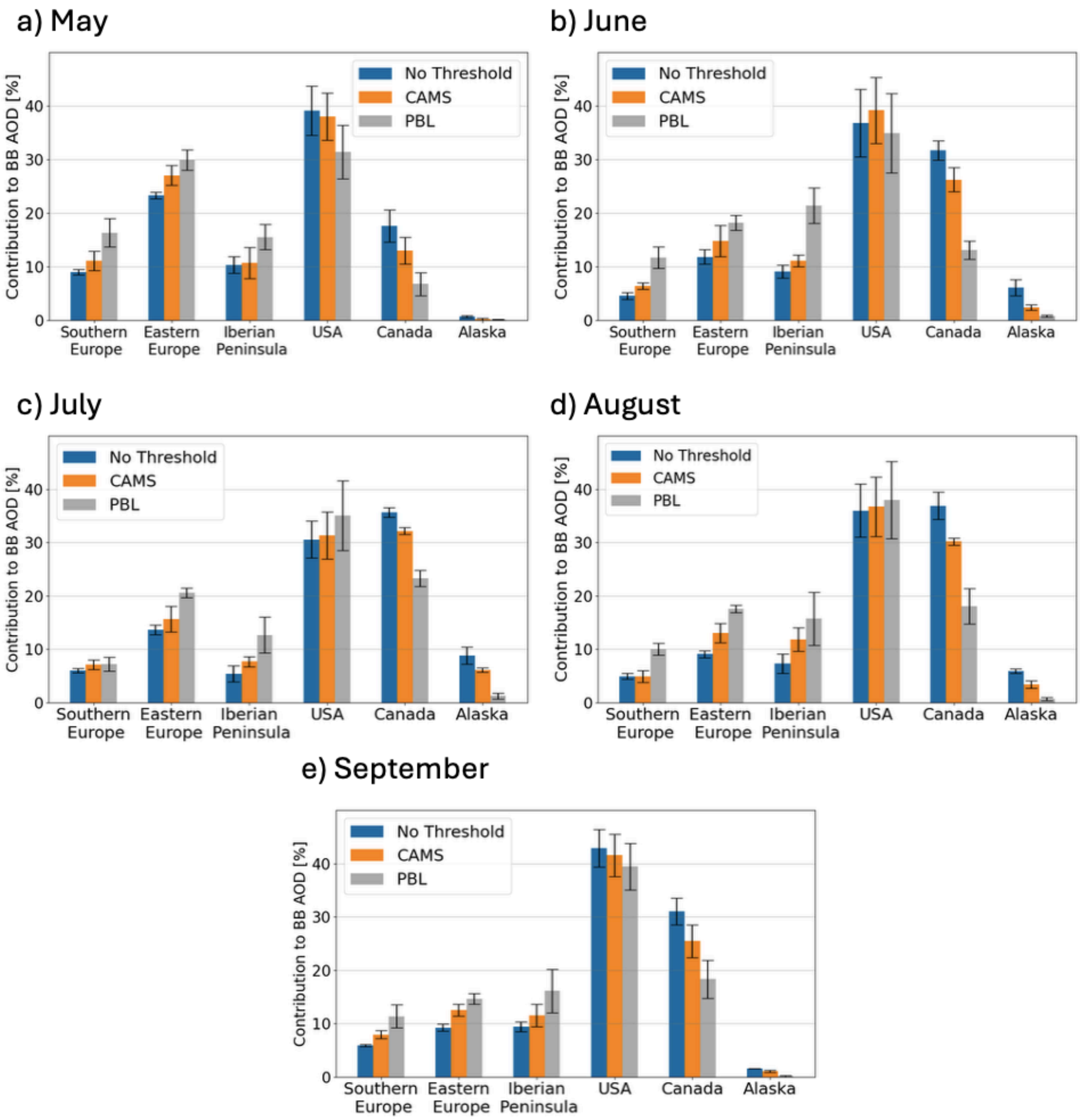
Author's change in the manuscript:

"Changing the dispersion radius significantly affects the contributions from different regions to BB AOD in Warsaw (Tables 1, 2)."

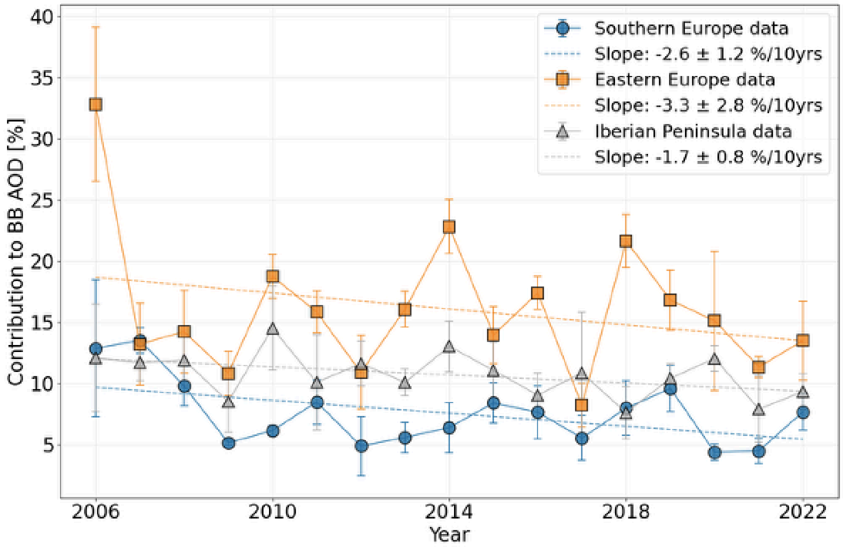
RC: "Fig. 11 and 12: Include Alaska."

Author's response: Included in the analysis.

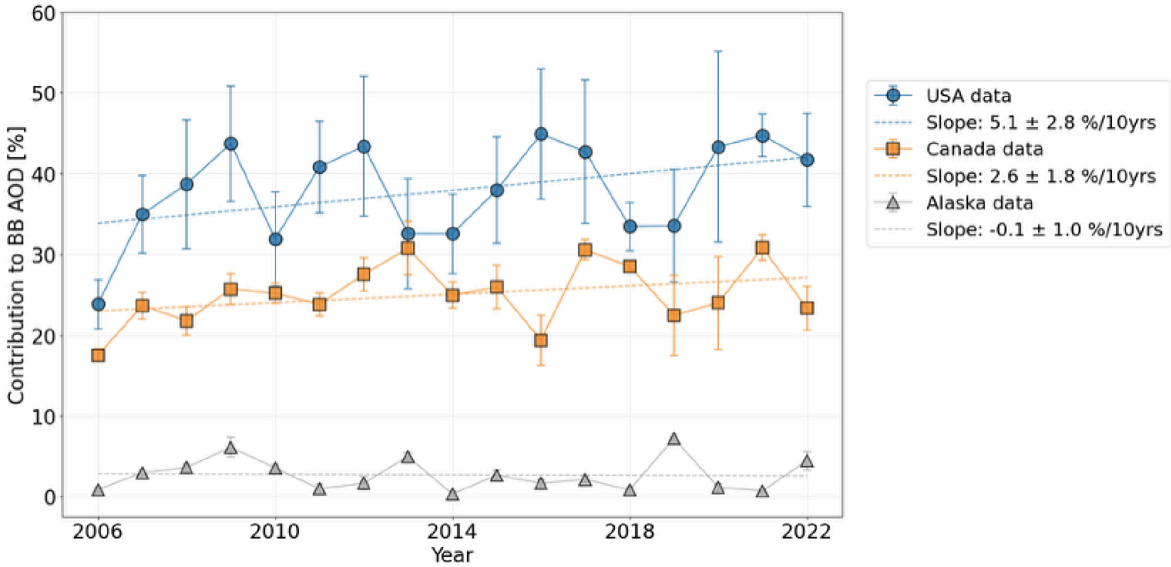
Author's change in the manuscript: After adding Alaska Figures 11 and 12 look like that:


a) May
b) June
c) July
d) August
e) September
No Threshold
CAMS
PBL
Contribution to BB AOD [%]
0
10
20
30
40
Southern Europe
Eastern Europe
Iberian Peninsula
USA
Canada
Alaska

a) Iberian Peninsula, Southern Europe and Eastern Europe



b) Canada, USA and Alaska



RC: “*Eastern Europe with or without European part of Russia?*”

Author’s response: Eastern Europe comprises the European part of Russia (it is discussed in lines 266-271 and depicted on Fig. 7a.)

RC: “*Fig. 12, caption: Do the error bars represent the 4 dispersion radii?*”

Author's response: Yes, the averaging was done not only over months in BB season, but also over 4 dispersion radii as it is written in the caption of Fig 12: "Contributions were determined using the CAMS method and averaged over months May-September and averaged over four dispersion radii (5 % , 10 % , 15 % , and 20 % of the trajectory length)."

TECHNICAL CORRECTIONS

RC: "*Line 4: Spell out MODIS.*"

Author's change in the manuscript: Corrected.

RC: "*Line 56: Improve wording.*"

Author's change in the manuscript: Instead of

"Given the diverse vegetation types in different source regions and the aging processes that BB aerosol undergoes during transport, it is important to determine their origins."

it is changed to:

"given the diverse vegetation types across source regions and the aging processes that BB aerosol undergoes during transport, identifying its origins is essential."

RC: "*Line 136: Poland only in Fig. 1b or 7.*"

Author's response: There should be Fig. 7 - this will be corrected.

Author's change in the manuscript: "Subsequently, the probability of air parcels arriving over Poland from these fire locations was calculated as the percentage of simulated forward trajectories from each source point that reached Poland, defined within coordinates [49.0 °N, 55.0 °N] × [14.0 °E, 24.2 °E] (see Figure 7a)."

RC: "*Line 191: Typo*", "*Line 195: Include equation number.*", "*Lines 232ff: Cite figures.*", "*Line 267: Should be Fig. 3.*", "*Line 372: Wrong citation style (use \citep).*", "*Figures 10 and A1: Typo in legends and labels (10 times each!)", "Figure 13c: Typo in legend.", "Lines 558, 559, 566: Acronyms with first name?", "Line 588: Use correct abbreviation or full name for journal.*"

Author's change in the manuscript: Corrected.

RC: "Line 217: Southwestern and Fig. 2? Meant or misleading?"

Author's response: On the Iberian Peninsula the number of fires is lower (maximum of 70 fires per pixel) than in Southern and Southeastern (around 150-200) so the Southwestern was not mentioned in this line on purpose.

RC: "Line 430: Supplement or Appendix? "

Author's response: "Supplementary analysis" wording will be changed to "additional analysis." The numeration of the Appendix figure has changed because there was one more figure included in the Appendix.

Author's change in the manuscript: "In the additional analysis (Figure A3), annual BB AOD contributions in Warsaw were examined for aggregated European regions (Southern Europe, Eastern Europe, Iberian Peninsula; Figure A3a) and Northern American regions (Canada, USA and Alaska; Figure A3b)"

#RC3

RC 1: "Acronyms should be defined at the first place in the manuscript."

Author's change in the manuscript: Corrected.

RC 2 : "*Section 2.2. It is unclear to me how you used the back trajectory. Did you identify the wildfire events then use the back trajectory simulation to understand the wildfire plume transport?.*"

Author's response: The initialisation of backward trajectory is done every day at 12 UTC (line 150) regardless of the value of BB AOD. Even if there is no wildfire event (BB AOD is low) our methodology uses BB AOD as a weight (line 206) in mean contribution estimation, so if the BB AOD is close to 0, the result obtained for a certain day won't alter the final result.

RC 2: "*Moreover, would you think just using the average back trajectory to select time and days will overlook some wildfire events.*"

Author's response: We may not be fully understanding the reviewer's concern, so to clarify: no single "average" back-trajectory is used. Instead, for every day in the study period we initialise 14 backward trajectories at 12 UTC at different starting altitudes (see lines 150–152). This daily, multi-altitude sampling is intended to minimise the risk of overlooking wildfire influence.

Because NAAPS is fed with FLAMBE fire emissions which uses a two-day maximum correction (previous day + current day) that sustains the fire signal over ~48 h (Lynch et al., 2016; Reid et al., 2009), launching back trajectories once per day (12 UTC) is sufficient for our purposes. Any fire detected in FLAMBE will remain represented in the NAAPS fields over the 24-hour interval between launches, so significant events influencing BB AOD are unlikely to be missed. Our study targets long-term, climatological regional contributions; the daily, multi-altitude (14-level) trajectory strategy therefore provides adequate coverage while remaining computationally tractable.

RC 3: “could you justify why you chose 2250 m as your threshold and how a fixed PBL height will affect your results?“

Author’s response: The PBL analysis will be modified such that, instead of using a fixed threshold, the PBL height obtained from HYSPLIT at each point along the air parcel trajectory will be applied. In this approach, emissions will be included only when the air parcel remains below the PBL height at a given location; otherwise, they will be excluded.

The analysis shows that, for European regions, the results averaged over the four dispersion radii obtained with a fixed 2250 m threshold almost replicate the results averaged over the four dispersion radii obtained with the updated PBL method. Differences in mean values between the two approaches are below 2.5%. For individual dispersion radii, the deviations are larger but still below 5%.

The largest differences are observed for contributions from North American regions: the mean (over the four dispersion radii) Canadian contribution decreases by up to ~9%, whereas the USA contribution increases by a similar amount. Deviations for individual radii are of the same order of magnitude as the four-radius mean. The mean Alaska contribution in the PBL method is marginal (maximum 1.2% in July, below 1% in the other months).

Author’s change in the manuscript: Modification of PBL method in such a manner that instead of using a fixed threshold, the PBL height obtained from HYSPLIT at each point along the air parcel trajectory will be applied. Changing the results to one obtained for a modified approach in the PBL method.