Response to Referee #2

Thank you for carefully reading the manuscript and providing useful suggestions to improve the paper. The replies to the referee comments are given below. The referee comments are in blue with our responses in black. The sentences in the manuscript are *italic*, with the modifications in the revised manuscript in red.

This is a very interesting study that attempts to investigate an aerosol transport event from different perspectives – perhaps, from almost all possible angles: ground, space, and models.

My main concern is that, in general, the authors should have addressed the possible uncertainties in detail, such as temporal/spatial collocation mismatches, lidar ratio assumptions, and assumptions in the trajectory model. Perhaps it would be helpful to have dedicated sections discussing these uncertainties. I don't mean to suggest that the authors are unaware of these uncertainties. In fact, the later part of the manuscript mentions that future lidar missions/studies would be important. However, that message could be strengthened by a dedicated section on uncertainties.

Thank you for the comments, we have added discussions about the uncertainties in the revised version in section 2.4.1:

> *The conversion factor at 532 nm of 0.16 ± 0.01 $\times 10^{-6}$ m for the fresh and medium-fresh smoke (i.e. less than 2 days), or 0.13 ± 0.01 $\times 10^{-6}$ m for aged smoke, and a particle density of 1.3 g cm^{-3}, were used for the biomass burning particles (Ansmann et al. 2021). Following Ansmann et al. (2021), we assume uncertainties of 10 % and 20 % in the conversion factor and smoke mass density. Using ground-based multi-wavelength lidar measurements, the lidar ratio at 532 nm and the backscatter-related Ångström exponent between 532 and 1064 nm were derived as 71 ± 5 sr and 2.2 ± 0.3, respectively, for the smoke plumes during the same wildfire event as in this study (Shang et al. 2021). For the backscatter coefficient retrievals we used relative uncertainties of 10 %, 15 %, and 25 % for ground-based lidar, ceilometer, and spaceborne lidar, respectively. These values were taken from Shang et al. (2021) and Ansmann et al. (2021). The Ångström value of 2.2 was applied to convert the ceilometer measured backscatter coefficients at 1064 nm to 532 nm (Eq. 2), resulting a relative uncertainty of 24 % on the converted backscatter coefficients. This study employed a lidar ratio at 532 nm of 70 sr, which was the value used for the aerosol subtype of "elevated smoke" in CALIOP version 4 (Kim et al. 2018). The lidar ratios at 532 nm for ground-based lidars are measured with a typical relative uncertainty of about 20 %, which can also be assumed for the 532 nm CALIOP lidar ratio for elevated smoke (the uncertainty is 70 ±16 sr in CALIPSO V4 lidar data). More details of the uncertainties in the CALIPSO products can be found in Young et al. (2013, 2018). Applying the law of error propagation to Eq.1 with the above-mentioned uncertainties, we expected an overall uncertainty in the mass concentration estimates of 32 % for ground-based lidar, and 40 % for ceilometer and CALIOP.*

We have also changed the figure 2 in the revised version, by adding some error bars on sub-figs (c) (e) (f).

The assumption in the trajectory model was that the air parcels, aerosols included, were moved only by the winds (all 3 components). The trajectory model is described in Section 2.3.3. We acknowledge the uncertainties due to trajectory model, wind data and spatial/temporal collocation. However, as we started new trajectories from the fire locations frequently and from multiple altitudes, and as the trajectory and smoke observations match reasonably well also after a relatively long transport we think our trajectories and collocation strategy is working well enough for this study. We have added the following sentence to the manuscript (section 2.4.2):

> *The uncertainties due to trajectory computations, wind data, and temporal and spatial collocation causes uncertainty to the estimates of the dominant air mass pathway. However, we estimate these uncertainties to be small and not to significantly affect the results of our study.*

Additionally, I do not quite understand how you derived these trajectory frequencies. I suggest refining Section 2.4.2.

We have modified the text for the clarity:

6480 trajectories were generated considering originated from ~~the same~~ a single day (0 to 24 h), from all initial heights (0 to 7.5 km), and from both wildfire sub-regions (~~18 intial spots~~ 9 initial spots in each, Fig. 1). ~~The trajectory frequencies were used here to determine the dominant air mass pathway.~~ The dominant air mass pathway was determined by the trajectory frequencies, which were calculated via the bivariate bin counts in two steps: The latitude and longitude trajectory frequencies were calculated based on 1° x 1° pixels, whereas the altitude and time trajectory frequencies were calculated based on 500 m x 1 h pixels. The pixels with ~~a probability~~ an occurrence frequency above the median value were selected, referring to the most possible air mass transportation. Only the trajectories included in the predefined pixels were kept (less than 10 % of the total trajectories). These screened trajectories were then used to define 4-dimensional hypercubes, with a doubled resolution as previously used for the frequency pixels, considering the model uncertainties. Each hypercube has eight values of four variables (i.e. the edge values of latitude, longitude, altitude and time). Next, the CALIOP-derived smoke layers (after the quality control, see Sect. 2.2.1) were automatically selected using these 4-D hypercubes to ensure that they are on the dominant air mass pathway.

While I am not an expert in writing, I feel that this manuscript may not be easily readable. Considering that it's a good study with nice ideas on combining different perspectives, I wish the writing also matched that high standard.

Thank you for the comment. We have revised the manuscript and made modifications to the text to improve the clarity of the manuscript.

Corrections:

Line 49: "…vastness of the boreal region; it cannot be covered with advanced ground-based…" (added a ';', removed the second 'based')

Thank you for the suggestions, we have corrected the text:

Due to the vastness of the boreal region, it cannot be covered with advanced ground-based ~~based~~ observations or flight campaigns.

Line 79: works -> studies

We have corrected the word.