Review of manuscript acp-2021-117

Anonymous Referee #1

Referee comment on "The unexpected smoke layer in the High Arctic winter stratosphere during MOSAiC 2019–2020 " by Kevin Ohneiser et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-117-RC1, 2021

The manuscript reports lidar observations of a persistent smoke aerosol layer in the upper troposphere lower stratosphere (UTLS) in the 7 – 18 km altitude range during Arctic Winter 2019 – 2020, which was characterized by a very strong and long lasting stratospheric polar vortex. The lidar was implemented on the Polarstern icebreaker during the MOSAiC experiment that was dedicated to the observation of atmospheric compounds at very high latitude in the Arctic. The manuscript provides interesting and detailed insights of range resolved aerosols observation in the high Arctic latitude region that is generally subsampled. Observations are of high quality and convincingly described. The manuscript is well written with generally adequate reference to recent work on the subject. However, there are a number of issues and recommendation that need to be considered before publication in ACP.

Major comments

- In the introduction, the authors mention that the burning season in 2019 was largest on record, they also employ superlatives like "tremendous environmental disaster" without a quantification of how the wildfires compare to previous years.
- Little information is provided in the article on the Polarstern trajectory with respect to the stratospheric polar vortex. A figure showing potential vorticity and temperature evolution along the cruise is lacking. Such a figure would be very useful for interpretation of the measurements and especially for section 4 that addresses PSC, smoke aerosols and ozone depletion.
- The fact that the observed aerosol layer originates from the Siberian wildfires is not demonstrated in the manuscript. As mentioned in the paper, several other sources of aerosols can be identified during that winter: volcanic aerosols from the Raikoke eruption, aerosols from pyroCb injection linked to fires in Northern America and PSC. The distinction between smoke and volcanic aerosols is made primarily from the spectral difference of the lidar ratio without consideration of meteorological processes that could further document the origin of the observed aerosol layer. Only one

ensemble of trajectories is displayed for one day in the campaign in the manuscript. Such considerations on the evolution of meteorological evolution during the Arctic winter is needed especially in order to better differentiate smoke aerosol from PSCs.

- The methodology used for the analysis and retrieval of aerosols parameters is not described in sufficient quantitative details. The description relies mainly on references, some of which e.g. Ansmann et al., 2020 is still under review. For instance, section 2 does not summarize the method used for deriving main aerosols parameters such as the backscatter coefficient or the lidar ratio and their respective error. A table could summarize main characteristics of these retrieved parameters in terms of error and vertical resolution. A summary of the POLIPHON method used to derive the aerosol mass concentration is also needed. The GMAO method is used to retrieve the tropopause height but no explanation is given on why such method is better than the classical WMO one. Since tropopause height is generally more difficult to determine at high latitude than at lower ones, such explanation is needed. Also, a description of the method used to derive the bottom and top of the aerosol layer is lacking.
- The hypothesis of mixing between several particle types is not fully explored. For instance, there is no clear explanation of the quantification of less than 20% for the fraction of volcanic aerosol observed in Fall 2019 (page 7). In Figure 9, PSC are only identified over the smoke aerosol layer. Is there a possibility that PSC are also formed within the aerosol layer? Without knowledge of temperature history, it is difficult to conclude.
- What is the objective of section 3.3 (comparison with foregoing Aerosol studies)? This section cites a number of other studies analysing aerosol vertical distribution in the Arctic but not clear conclusion is driven from this section.
- In the same way, the discussion of the interplay between PSC, smoke aerosol and ozone depletion is very vague and relies only on general considerations. The link between PSC formation and persistence, and ozone depletion is quite well known. There is no demonstration that the smoke aerosol layer played a role in the ozone depletion. Qualitative arguments are based only on coincidences in the height range of the aerosol layer and strong ozone depletion. Both section 3.3 and section need to be better focused and reduced in size.

Specific comments

P2 L16 – 19: What parameters were considered from FIRMS and CAMS databases?

P2 L34 – 35: Provide details on the mentioned simulations.

P3 L7 – 9: How do we know that the aerosol was trapped in the strong polar vortex?

P5 L8 – 9: How were identified the PSC: by visual inspection? There is no explanation.

P6 L14: How are the bottom and top of the aerosol layer determined?

P6 L18 – 20: The HYSPLIT trajectories do not demonstrate that the smoke aerosol layer could have been trapped within the polar vortex. Figure 5 is not very clear: provide explanation for the colours of trajectories.

P6 L23 – 24: How are determined error bars in Figure 6? Are they shown as one or 2 sigma?

P8 L28 – 31: How are the refractive index and SSA shown in Table 1 determined?

P9 L22: Figure 10 is not well explained. Significance of the layers mentioned in the legend is not clear.

P9 L23 – 24: If the aerosol layer was trapped in the strong polar vortex, how could it be influenced by smoke aerosol from lower latitudes? What about subsidence within the vortex? The situation of the lidar measurements with respect to the polar vortex is not clear and needs better description.