Dear Mike,

We thank you for your very careful reading and fruitful suggestions.

Please find below are our responses highlighted in BLUE.

In our revised manuscript, text that was significantly changed or new text parts that were added are given in BOLD.

Ansmann et al. (2022) (hereafter A22) focus equally on Antarctic and Arctic ozone depletion and its proffered connection to stratospheric wildfire smoke. This comment offers questions/concerns with both aspects.

Regarding the Antarctic aspect of A22, the only smoke-particle information presented is from Punta Arenas. At 53°S, this location is generally on the extratropical side of the Antarctic polar vortex. Smoke observations at such a position with respect to the polar vortex interior provide no information on aerosol conditions inside the vortex edge, an effective mixing barrier according to volumes of previous research. To make a plausible link between Punta Arenas stratospheric smoke and PSCs, the authors may need to demonstrate evidence of smoke inside the vortex, especially in the days leading up to PSC formation (typically late May). Any observation at Punta Arenas that is outside the vortex edge has no direct bearing on PSCs and PSC-related ozone depletion. It would be very interesting and important to see Punta Arenas lidar profiles segregated by their location with respect to the vortex edge. If inside-vortex aerosol enhancements consistent with the pyroCb smoke signature can be demonstrated, in air too warm for PSC support, that would immeasurably advance A22's argument.

Thank you for this comment. In Sect 5.2, we explain that we assume that the Punta Arenas time series represent well the aerosol conditions over the entire southern part of the Southern Hemisphere. We support our assumption by satellite observations presented by Rieger et al. (2021) and Yook et al. (2022). Furthermore, simulations of the spread of smoke and volcanic aerosols in the Southern Hemisphere and Northern Hemisphere corroborate the fast transport towards the polar regions within a few months (Haywood et al. 2010, Kloss et al., 2021, Zhu et al., 2018).

Regarding the potential differences between the aerosol conditions outside (Punta Arenas) and inside the vortex we can only speculate. Nobody knows! Is there an accumulation of particles (because an exchange with the air outside the vortex is not possible) or an enhanced decrease (by stronger downward transport within the vortex)? However, we use our Arctic (MOSAiC) observations to characterize the potential impact of the polar vortex on aerosol properties (accumulation of aerosol with time during the vortex lifetime, Ohneiser et al., 2021). We state that in Sect. 5.4.

Regarding the Arctic aspect of A22, they build on conclusions drawn by Ohneiser et al. (2021) (O21), namely that smoke polluted the Arctic stratosphere in 2019 and 2020. O21 hypothesized that smoke arrived in the stratosphere by a non-pyroCb pathway; Siberian smoke was diabatically lofted from the lower troposphere across the tropopause and continued its diabatic ascent thereafter. O21's confident determination of smoke altitude extent, based on the Polly lidar-ratio calculation, was capped at 12-13 km. A22 loosen that constrain in section 4.3.1: "Before we can deepen this discussion, we need to clarify that wildfire smoke was the dominating aerosol component throughout the entire stratospheric aerosol layer up to 18 or even 20 km height. Ohneiser et al. (2021) left the question open whether smoke or sulfate aerosol originating from the Raikoke volcanic eruption (Kloss et al., 2021) was prevailing at heights >13 km. Because of too noisy Polly lidar signals, wildfire smoke could unambiguously be identified up to 13 km height only." A22's presentation of Figures 8 an 9 appears to be an argument toward a reinterpretation of O21's smoke-altitude cap. The argument is based largely on an admittedly noisy HSRL AOD profile and a set of generated AOD curves spanning a selection of lidar ratios. Figure 9b reveals that a lidar-ratio selection of 60 would give a solution with significant HSRL-data overlap throughout the displayed z range. Prata et al., (2017) demonstrated a 532 nm lidar-ratio central tendency between 59-66 sr in an analysis of two distinct stratospheric volcanic sulfate plumes (Kasatochi and Sarychev Peak). Considering the lidar-ratio error bars in Figure 9a, Prata et al. (2017), and Mattis et al. (2010), it appears that sulfates could explain the HSRL AOD profile in Figure 9b as convincingly as smoke. Given the undisputed evidence that Raikoke sulfates were a hemispheric, high northern latitude presence in 2019 and 2020 (Kloss et al., (2021); Gorkavyi et al. (2021); Cameron et al. (2021)), shouldn't equal weight be given to their establishment in the Arctic during MOSAiC?

Following your comment, to better emphasize the Raikoke aspect, we introduce a new subsection (Sec. 6.2). In this new section, we present another approach to estimate the Raikoke fraction. This approach is based on satellite observations (personal communication, Linlu Mei, Bremen University). Linlu Mei presented aerosol optical thickness (AOT) retrievals (for 60-90N) during a MOSAiC workshop (in April 2022), and showed that the 550nm AOT was close to 0.3 over the High Arctic in August 2019, around 0.15 in September 2019, 0.1 in October, and 0.06-0.07 in the beginning November 2019. These estimations are in a good agreement with our MOSAiC Polarstern observations since the beginning of October 2019.

These satellite observations together with our observations (discussed in the Ohneiser-2021 paper, lidar observations at Ny Alesund, Polarstern observations later on) point to a high UTLS AOT of 0.15-0.2 in the High Arctic in August 2019. This is described in Sect.6.2

We again discuss in Sect.6.2, as in previous publications, that according to the emitted SO2 mass of 1.5-2 Tg, the Raikoke volcanic eruption produced, to our best knowledge, 550nm AOTs of 0.025-0.03 (on a hemispheric scale). This is a contribution of 10-20% to the observed AOT of 0.15-0.2. These values are in good agreement with the more advanced approach presented by Ohneiser et al., 2021 (10-15%) (based on multiwavelength Raman polarization lidar observations).

Now to Prata et al (2017) and the CALIOP data analysis. Two things should be mentioned here. Prata et al were forced to apply the forward mode of the Klett method. This data analysis method is quite uncertain. Furthermore, they had to assume pure Rayleigh backscatter below an isolated sulfate layer. To our opinion, there are always sulfate particles below a volcanic sulfate layer. If there is sulfate backscatter below the volcanic layer, the assumption of pure Rayleigh backscattering above and below a volcanic layer leads to an overestimation of the layer-mean lidar ratios. In the case of long signal averaging (curtain profiles, much improved signal-to-noise ratio), the lidar ratio was close to 50sr (in the Prata paper) as expected for aged volcanic sulfate aerosol and would have been probably close to 40sr when keeping smoke below the layer into account.

There is no doubt for us that lidar ratios of 65-75 sr at 532nm, and 40-50sr at 355nm, clearly indicate smoke and not volcanic aerosol. These results were comprehensively explained and discussed in our previous pulications (Haarig et al., 2018, Ohneiser et al., 2020, 2021, 2022).