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Review of "Self-lofting of wildfire smoke in the troposphere and stratosphere caused by radiative heating: simulations vs space lidar observations" by Ohneiser et al. (2022)

Anonymous Referee #2

Referee comment on "Self-lofting of wildfire smoke in the troposphere and stratosphere: simulations and space lidar observations" by Kevin Ohneiser et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2022-343-RC2, 2022

The manuscript by Kevin Ohneiser and coauthors addresses the solar-driven lofting of wildfire smoke plumes in the troposphere and stratosphere using ECMWF radiation transfer scheme with different parameterizations and satellite observations using CALIOP and MODIS instruments. The ascent rates of smoke plumes produced by Canadian, Australian and Siberian wildfires derived from CALIOP observations are compared with the calculated ascent rates from radiative transfer simulations. The main goal of the study, as stated in the abstract, is to demonstrate that the radiative heating of intense smoke plumes is capable of lofting them from the free troposphere up to the tropopause and into the stratosphere without the need of PyroCb injections.

After a detailed description of the modeling setup, sensitivity tests and uncertainty discussion, the authors demonstrate in Fig. 11 that a 2.5 km- thick smoke plume with a realistic BC fraction of 2.5% and a very large AOT above 2 should rise from 3 km altitude into the lower stratosphere in two weeks. However, the analysis of CALIOP observations of tropospheric smoke from Siberian wildfires in the following section does not provide any support for the cross-tropopause transport of aerosol plumes rendering the main goal of the study unachieved and casting doubt on the usefulness of the simulation results. More specifically, there are several major issues as follows.

- The description of the satellite instruments, data versioning, measurement uncertainties and the approach to data treatment is totally missing in the manuscript.
- As far as I understood, the authors used CALIOP quicklooks to derive the layer thickness and mean attenuated backscatter, from which the AOT is calculated using an arbitrarily chosen factor of 1.5, which should account for the light attenuation. While the derivation of layer thickness from the quicklooks may be deemed sufficiently accurate (although for compact stratospheric plumes only), it is unclear how the authors derived the layer mean backscatter from the images. Was it done by reading

the colors of each individual pixels and using the color bar to retrieve the values? If so, the uncertainty of such estimates might be unacceptably high and I wonder how such estimates would compare with those by Kablick et al. provided in Fig. 16.

- Constrained by the CALIOP AOT from Kablick et al., the simulated ascent is nowhere near the observed one and the authors opt to constrain the simulation with MODIS total AOT data (ignoring the tropospheric aerosols), which is substantially higher than both the CALIOP-derived AOT and, what is particularly puzzling, much higher than the estimates by Ohneiser et al. (2020), their Fig. 5b, reporting the lidar-derived AOT@532 of 0.1 – 0.3 for the Australian smoke plume in late January 2020 (which would be consistent with Kablick et al. data in Fig. 16). The authors thus seem to deliberately ignore their own observations for the sake of reproducing the observed lofting in the simulation.
- Section 4.4 and Fig. 17. The Siberian tropospheric smoke plumes show rather complex vertical structures, whereas the determination of the aerosol layer vertical boundaries (critically influencing the AOT estimate) appear to be somewhat too arbitrary. Personally, I do not see any significant lofting for the both cases shown in Fig. 17. It rather appears that the smoke was found in the UT from the very beginning, which would point to the PyroCb-driven vertical transport.
- Discussing the Siberian smoke plumes, the authors state that "fractions of this plume must have reached the tropopause and later on the lower stratosphere" without providing any supporting observations, and the only reason I can possibly think of is the absence of such observational evidence. Moreover, the simulations based on an assumption of the persistent Gaussian vertical shape of the layer (which is obviously not the case here) show even weaker lofting than what is inferred from CALIOP quicklooks. I also wonder why the simulation was not extended further in time (using e.g. 15% daily AOT decrease) to provide at least the modeling support for the potential lofting up to the tropopause level.