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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Variability of cirrus cloud properties using a Polly^{XT} Raman Lidar over high and tropical latitudes" *by* Kalliopi Artemis Voudouri et al.

Anonymous Referee #2

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In the study discussed below, the authors around Kalliopi Artemis Voudouri present a cirrus cloud statistics for several sites where a multi-wavelength Raman lidar system of type Polly-XT was deployed.

The lidar data was analyzed with a newly developed cirrus retrieval algorithm. Cloud boundary detection was based on wavelet transformation of a kind of normalized background-corrected raw signals. For the identified cirrus layers cloud optical properties for 355-nm and 532-nm wavelength were derived and a multiple-scattering correction was applied.

The derived statistics of geometrical and optical cirrus cloud properties are diverse.

Clear conclusions could not be drawn.

I see a certain strengths in the manuscript, given the following facts:

- Presentation of a newly developed cirrus cloud identification algorithm

- Retrieval of Raman-based cirrus optical properties for 355 AND 532 nm

- Demonstration of the potential of a network of similar Raman lidar systems for application of one single retrieval scheme

Nevertheless, flaws in the description of the data analysis technique and in the discussion of the statistics dominate my impression while I was reading (several times) through the manuscript. I felt uncomfortable reading through the results section without knowing exactly how the statistics were derived. "Cases" are presented, but how is one case defined? To how many cloud profiles was the wavelet transform applied to get the boundaries? Are the presented optical properties based on Raman or Klett? These are important questions. Without knowledge about these, the value of the study is very limited.

I thus recommend a major revision of the manuscript, including a second review phase in order to put the study on a more solid footing.

Major comments:

1 – Ch.3; Retrieval Scheme/Fig. 1:

- The presentation of a retrieval scheme should always be done in such a way that others are able to reproduce it. The scheme given in Ch. 3 does not allow for that, because important information is missing:

o Was there range-averaging applied? If yes, under which conditions (see e.g. Fig. 1 b vs. 1 c)

o What happened to 1-hour intervals not filled entirely by cirrus clouds?

o How were irregularities in the cirrus cloud structure within the 1-hour averaging period treated?

o “the signal is normalized with a maximum value below 1.5km”. What does this mean? Was the signal normalized using the maximum value found between the ground and 1.5 km height (or range)?

o In Eq. (1): What is z? altitude or range? Is this z the same z as the one in Eq. 3? I fear that range and height are mixed-up somewhat. Introduce separate variables for height and range where applicable/needed. Also: Is altitude above ground or above sea level (asl)? Was this considered in the statistics (given that the station elevation varies from 190 to 1745 m asl)?

o Eq. 2: What is Csig? Raw signal? Counts? What is Cbg? What is the difference between C and P (Eq. 1 vs. Eq. 2)?

o Case study/Fig. 2: The case study spans over about 4 hours, but the standard averaging period to derive the wavelet and particle depolarization ratio was 1 hour, wasn't it? I propose to show a case study that uses the actual time- and range-resolution used in the cirrus retrieval scheme.

o According the Figure 1, zero and background levels as well as normalization were applied to the range-corrected signal. Is this true? Shouldn't at least the background and zero values be subtracted from the raw signal?

o The selected base temperature of <-20°C (see Fig. 1) gives risk to the inclusion of layers of supercooled liquid water into the statistics, as ice formation occurs predominantly via the liquid phase at T>-27°C (Westbrook et al., 2011). Was there any threshold put on the temperature at cloud top? I'd believe a good value for this could be -38 °C or so in order to assure that at least at cloud top no liquid water was present any more.

o In Fig. 1: Again, what is altitude? Above sea level?

o In Fig. 1: Particle linear depolarization ratio is used as criteria for cirrus classification. But this parameter requires the detection of particle backscatter coefficient first. Shouldn't Fig. 1 thus contain an additional column (between CWT and cirrus criteria) that describes the calculation of the optical properties and multiple-scattering correction?

o In Fig. 2: Why do the cloud boundaries differ between (b) and (c)? Was there vertical smoothing applied to (c)?

2- Cirrus optical properties:

- During daytime, Klett-Fernald was applied, and during nighttime Raman was applied? Which values went into the statistics of lidar ratio, optical depth and particle depolarization ratio? Both? Only nighttime?

- How were reference height and values determined/set?

- In the results section, there should be a discussion of Klett-vs-Raman-based results.

3- Ch 4.02 Multiple Scattering correction:

- The lidar observations provide Ptot, but P1 is required. Eq. 4 thus contains 2 unknowns: P1, and F(z). How could the authors solve this equation?

4 – Ch. 5.01 Cirrus cloud cover detection:

- How is a case defined? What does it mean if there were 28 cases observed over Kuopio in April (P7, L175)?

- Table 2: What is N? Are these the number of hourly samples?

5 – Ch. 5.05:

- The title can be modified to ‘cirrus classification at Kuopio’ because the section only deals with this site.

6 – Ch. 5.06, Line 321:

- Could the decrease of particle LDR with increasing temperature be explained by the sporadic presence of supercooled liquid water?

7 - Conclusions:

- What conclusion can be drawn on the conversion of cirrus optical properties from 532 nm to 355 nm, considering that such conversion factors might be required to make future 355-nm/532-nm spaceborne lidar observations comperable? Can the authors make suggestions on which aspects future studies should look in more detail?

- In addition to the points addressed above, I recommend a thorough peer-review of spelling and grammar by the co-authors in beforehand to the submission of the revised manuscript.

- Minor comments will be addressed in the revised version.

References:

Westbrook, C. D., and Illingworth, A. J. (2011), Evidence that ice forms primarily in supercooled liquid clouds at temperatures > -27°C, Geophys. Res. Lett., 38, L14808, doi:10.1029/2011GL048021.

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