

The diurnal cycle and temperature dependence of crystal shapes in ice clouds from satellite lidar polarized measurements, proposed to publication in ACP by V. Noel, H. Chepfer, C. Barthe and J. Yorks

Reply to comment from reviewer 2

Original comments from Reviewer 2 are shown in blue, our replies are shown in black.

This paper uses the methodology of Sato and Okamoto (2023) that was applied to CALIPSO lidar (CALIOP) measurements to estimate the relative abundance of various ice particle shapes in clouds but now applies this methodology to the CATS (Cloud Aerosol Transport System) satellite lidar dataset for this same purpose. As a “sanity check”, consistency between the results from this new study and that of Sato and Okamoto (2023) was verified. Then the diurnal variation of ice particle shape was investigated for the first time, with quite interesting results. This paper is of high caliber and worthy of publication in ACP after minor revision by addressing the comments listed below. The paper is well organized and well written.

We thank the reviewer for taking the time to give feedback on our work.

Specific Comments

1. Section 2.2: As shown by Eq. 1 in Sato and Okamoto (2023), the lidar backscatter β is an integral product of the particle size distribution (PSD) and the particle’s mean backscattering cross-section (C_{bk}) where C_{bk} depends on particle size. Thus, β appears to be a measure of the PSD second moment, while the ice particle number concentration N_i denotes the 0th moment of the PSD. Is it safe to relate the fraction of a particle shape in this paper to the relative N_i of that particle shape in the clouds? That is, there may be a tendency for readers to interpret these results as a relative measure of N_i for each ice particle shape. Since the lidar depolarization ratio δ that is used to discriminate cloud particle shape is the ratio of two β values (for horizontal and vertical polarization), PSD effects should cancel, leaving just the depolarization effect. The statistics in this paper would thus be reporting the frequency of occurrence of δ corresponding to various cloud particle shape categories as defined in Sato and Okamoto (2023), where δ identifies the dominant shape sampled. While in essence this is implied in Sect. 2.2 (and is evident in Sato and Okamoto), more of this information could be presented so that the reader can more clearly understand what the statistics in this paper actually mean.

The reviewer notes that when the lidar probes ice particles with different particle shapes, the importance in the measured backscatter signal will depend on the number of particles in each shape and on their size distributions. In other words, particle number concentrations being equal, larger particles will generate a larger backscatter coefficient. Meanwhile, since the depolarization ratio is a ratio of backscatters, in its retrieval the effect of particle size cancels out. This means the retrieved particle shape in a sampled volume is representative of the shape of the most numerous particles in that volume, with no regard to their size. We thank the reviewer for bringing up this valid concern that was not explicitly addressed in the original submission. We have added comments regarding this within Sect. 2.2 and at the beginning of Sect. 3.

2. The paper would be more interesting if it included images for the different ice particle shapes being evaluated. Voronoi ice particles are especially important since many readers may not be familiar with them, and several images may be justified due to their varied, complex shapes.

This is a very good suggestion, and we agree that the paper would be more intuitive to understand if it included images of particle shapes, especially for unfamiliar shapes like Voronoi or Droxtals. However, there is to our knowledge very little imagery documenting these particle shapes. We are not aware of in-situ studies providing imagery appropriate to document the visual aspect of e.g. Voronoi or Droxtal particles, alongside the lidar measurements of depolarization ratio required to categorize their shapes. Building such a dataset would provide important validation to the results shown here, in Sato and Okamoto (2023), and in other related works. Following this comment, Voronoi particles are described in more detail in Sect. 2.2, and the conclusion now mentions the need for gathering in-situ imagery able to document the visual aspect of Voronoi and Droxtal particles to provide a more direct interpretation of the Sato and Okamoto classification.

3. Lines 251-252: Please cite Ken Sassen's work from the 1990's here. Ken was the first to relate lidar depolarization ratios to cloud particle shape as per my understanding, and he has many published papers on this topic.

We thank the reviewer for reminding us about the pioneering work done by K. Sassen. In the revised article the conclusion now includes two appropriate references authored by K. Sassen (1977 and 2001).

Technical Comments:

1. Line 69: This line contains "1.1.1 Subsection (as Heading 3)" and should be deleted.

We thank the reviewer for noticing this error, which has been corrected.

2. Line 92: ATB => TAB?

We thank the reviewer for noticing this error, which has been corrected.

3. Line 107: -80°S => -80°C ?

We thank the reviewer for noticing this error, which has been corrected.