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Atmospheric Measurement Techniques Discussions

Interactive comment on "Application of infrared remote sensing to constrain in-situ estimates of ice crystal particle size during SPartICus" *by* S. J. Cooper and T. J. Garrett

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I was very interested to read this paper. Understanding when and where small ice crystals dominate the optical properties of ice clouds is very important, but the fact that the primary tool to measure ice size spectra at small sizes (forward-scattering cloud droplet probes) can suffer from shattering of larger particles on the probe inlet has made this very difficult to determine. Remote-sensing techniques seem a logical way forward to resolve this, since they are of course unaffected by shattering.

It may be useful to put these results in context of other remote-sensing approaches which have been taken to this problem. Mitchell et al (2010, J. Atmos. Sci. 67 1106-1125) also used 11 and 12 micron emissivity difference from satellite measurements to try and quantify the presence of small ice crystals.

A second approach which we have taken in the UK is to measure the average fall speeds of the particles within the ice clouds using a Doppler lidar at the Chilbolton Observatory [Westbrook and Illingworth (2009) 'Testing the influence of small crystals on ice size spectra using Doppler lidar observations' (2009) Geophys. Res. Lett. 36 L12810]. The simple idea here is that if small crystals (which, like cloud droplets, fall extremely slowly, a few cm/s) dominate the optical properties of the cloud, the mean lidar Doppler velocity averaged over a long period will be close to zero, whereas if the optical properties are determined by crystals hundreds of microns in diameter the velocity will be significantly faster (tens of cm/s).

Figure 1 shows the mean ice cloud velocity as a function of temperature for 2 years of continuous observations, along with the maximum possible fall speed for a 50 micron ice crystal (the largest particle which an FSSP-100 can sample). It is immediately clear that for clouds warmer than -40C or so, large ice crystals dominate the optics of the clouds, contrary to previous FSSP measurements in such clouds (eg Ivanova et al 2001, Atmos. Res. 59-60 89). However, the mean fall speed does decrease monotonically with decreasing temperature, and I estimate a value of around 0.15m/s at -50C (corresponding to the approximate temperature regime of the clouds in your paper). This suggests that FSSP-sized crystals may become more important (but not dominant) in the coldest clouds, such as the cases you are sampling, as one might expect physically. This conclusion seems to be consistent with your case studies where both FSSP and 2DS spectra were needed to calculate effective radius correctly.

Coming back to your comparison, the in-situ estimates of effective radius are of course linearly sensitive to your choice of mass-area relationship. How confident are you of this choice? The relation in Baker et al was derived for particles hundreds of microns to millimetres in size - have you thought about how well this extrapolates to small sizes?

This is key to establishing the consistency between the in-situ and remotely-sensed effective radii.

A final comment: You mention in your paper that you can find no evidence of shattering effects in the FSSP data. I wonder if it might be helpful to: - quantify what level of shattering would be required for you to be able to conclude that shattering is occurring; - point out the previous literature which HAS found evidence of shattering to put your results in context.

I hope these comments are useful, and my very best wishes to the authors in their work - I think that this may be one of the techniques which will ultimately help to crack this small crystal problem.

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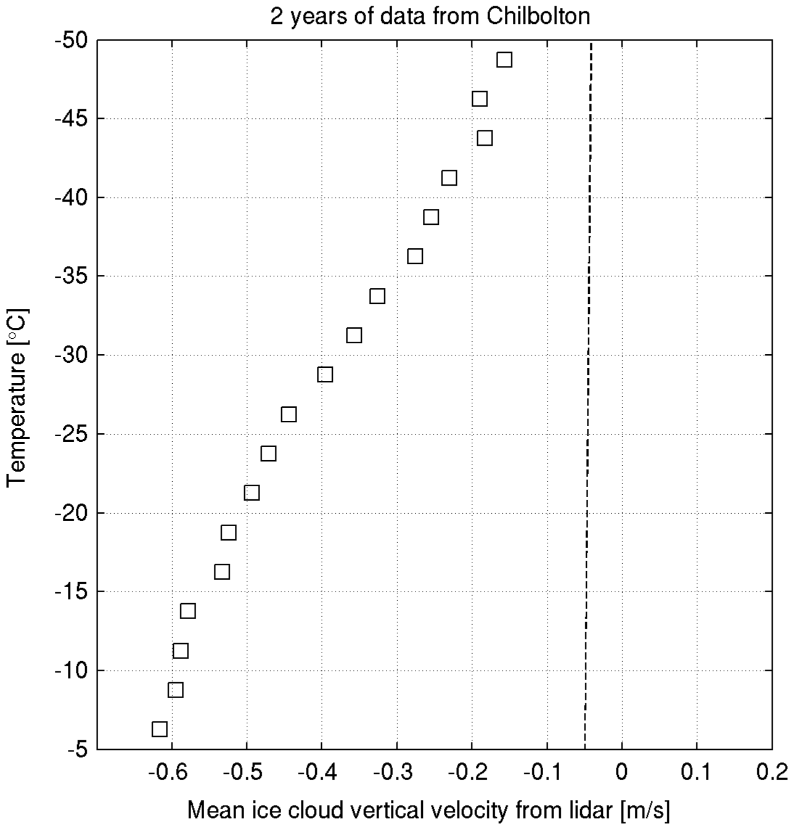

Fig. 1. Mean ice crystal fall speed as a function of temperature, as measured by 1.5 micron Doppler lidar at the Chilbolton Observatory. Dashed line shows maximum fall speed of 50 micron crystal.

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Interactive Comment