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Atmospheric Measurement Techniques Discussions

Interactive comment on "An improved algorithm for cloud base detection by ceilometer over the ice sheets" *by* K. Van Tricht et al.

Anonymous Referee #1

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This manuscript presents an algorithm designed to detect optically-thin cloud layers in polar regions. The overarching theme is the inclusion of all detected cloud layers in cloud cover statistics. The manuscript states that major improvements over the standard internal operational cloud detection algorithms provided by the manufacturer have been displayed.

In some senses this is true, however this particular criticism is unfair. Ceilometers are intended for determining the cloud base height of clouds that substantially impair visibility, primarily liquid clouds. Therefore, the algorithms are designed for liquid layer detection. It is not surprising, then, that standard liquid cloud base algorithms do not pick up optically thin layers, as that is not what they are intended for. This is in fact stated several times in the manuscript. In the case of mixed-phase clouds, the standard

algorithms do the right thing, they diagnose the cloud base for the liquid portion of the layer, which happens to be the optically thick layer, usually close to the top. In other words, the first priority is to detect the optically thick layer.

It is true that the standard cloud base algorithms could be improved, as they do not necessarily detect the precise location of the cloud base; however this is also an issue for the definition of cloud base, and the standard algorithms are usually within 50 m of the liquid cloud base.

Some major rewording of many paragraphs is required to reiterate that this manuscript is attempting to detect the base of clouds of a different nature to the those that the instrument is typically used for.

The results and conclusion should focus on the following: detection of optically-thin cloud is very dependent on SNR, and hence range. Any statistics on cloud base height are therefore range-dependent. Calculation of optical depth introduces additional uncertainty (state how much). Cloud cover statistics should then be presented in terms of SNR, height, optical depth thresholds (with uncertainties reported).

General comments ——————-

It is true that optically thin clouds are radiatively important. However, mere detection of all hydrometeors is not sufficient without additional information, such as optical depth thresholds together with instrument sensitivity. For example, using the PT algorithm on powerful lidar systems might return close to 100 % cloud cover at a detection threshold of optical depth > 0.01. See AHSRL data from Eureka, Canada for example.

Cloud cover by itself is not as important as the optical properties of that layer. In Polar night it will be the longwave radiative properties of most importance, while both longwave and shortwave are important in summer. Therefore, stating cloud cover with respect to some optical depth threshold (shortwave or longwave) is of prime importance.

Section 3.1: Should the backscatter threshold not depend on the background light? Especially in summer? Why not use the background value reported by Vaisala? The background light can be derived directly from this voltage value through an appropriate scaling factor. It scales very well with the standard deviation of the attenuated backscatter signal in the noise for the gates at far range (assuming no cirrus is present).

Then, it should be possible to recreate a reasonable proxy for the SNR value for each data point. This is necessary as the SNR varies with range. Note that an SNR value calculated from the ceilometer data in such a manner cannot be guaranteed to show range-squared dependence; this is due to the assumed overlap correction at close ranges. Overlap correction is calculated internally by the manufacturer, but for a generic instrument, not specifically for each instrument. The effect of polar temperatures on the optics is also not fully addressed. However, since full overlap is reached very quickly (certainly within a 100 m or so for both instruments) it is probably safe to assume these effects are negligible for the purposes of this manuscript.

Equation 3.1: What happens if there are large fluctuations in hydrometeor concentration/size within a 10-minute interval? This can be very common in ice (especially ice fall streaks), so would this method incorrectly flag such periods as noise?

Section 3.3: The detection limit should be a function of range since it is dependent on SNR. Figures 5a and 5b merely show something about the detection limit of the ceilometer (although this should really be displayed in terms of range as well), not whether the atmospheric profile is clear or not. The sensitivity analysis appears to imply that, at PE, no more clouds are seen once the detection limit falls below about 100 x 1e-4 km-1 sr-1. Although the instrument at PE is nominally slightly more sensitive due to higher average emitted power, the difference in range resolution (a factor of three) leads to a relative loss in sensitivity of the data at raw resolution. Maybe the true detection limit of this instrument is, on average over all heights, closer to 100 x 1e-4 km-1 sr-1. How would these curves look if plotted for each height?

Section 4.3 The lidar ratios for spherical liquid droplets and ice particles are also wavelength-dependent. For example, the range of theoretical lidar ratios for spherical liquid droplets with diameters between 5-25 microns typical of liquid cloud droplets at 532 nm (lidar wavelength in Yorks et al., 2011 paper) are not quite the same as those for a ceilometer at 905 nm.

Elsewhere in Yorks et al. (2011) the authors actually note mean lidar ratios of 20.41 sr and median lidar ratios of 17.29 sr (not 16 sr as in the conclusion), which are reasonably close to the range of theoretical lidar ratios values (17-20 sr) for spherical liquid droplets between 5-25 microns. The variability in theoretical lidar ratios for spherical liquid droplets between 5-25 microns at 905 nm is actually much smaller. Note that the observed lidar ratios in liquid were quite variable.

The value of the lidar ratio in ice was not found to be constant, in fact it was found to have a wide variation, from about 8 to greater than 50 sr. Other studies show similar wide ranges in lidar ratio. This has important consequences for equation 4. Also note that most of these studies were not performed at the ceilometer wavelength.

If the lidar ratio varies considerably from case to case, then there will be a large uncertainty in the derived optical depth. This uncertainty should be stated since it is optical depth that it is important rather than just the presence of hydrometeors.

Multiple scattering for optically-thin ice clouds can probably be neglected but multiple scattering cannot be neglected for liquid clouds. The assumed lidar ratio for liquid layers will vary with range for ceilometers due to their relatively wide lidar beam divergence and wide telescope field of view. Again, this will lead to uncertainty in the derived optical depth.

Page 9835, lines 15-18: There will be no liquid clouds below -40 C, so isn't this just due to temperature?

Page 9835, lines 7 - Page 9836 line 19: How much of this is due to SNR falling off with range? After accounting for SNR, what is the range dependence for minimum detectable cloud optical depth? I.e. do you expect to detect any optically thin clouds above 1 km?

Technical comments ——————

Abstract:

Page 9820, line 4: Ceilometers are low-power backscatter lidars, not lidar-based.

Page 9820, lines 6-7: As noted in General Comments, standard ceilometer cloud-base algorithms were not expected to derive optically-thin ice clouds.

Page 9820, line 17: Assume you mean 'discriminate' here, rather than 'differentiate'.

Page 9821, line 1: Would be more appropriate to say 'from various hydrometeor' rather than 'about a wide range of hydrometeor' as it is not straightforward to discriminate between different hydrometeors, and a 'wide range' depends on your choice of classification

Introduction

Page 9821, line 14: Precipitation from clouds may be important for surface mass balance.

Page 9822, line 4-7: I.e. liquid clouds

Page 9822, line 1: Arguably, the standard algorithm is reporting the correct CBH, the liquid cloud base, as this is what is important for visibility, and especially for aircraft safety.

Page 9824, line 24: squared transmittance?

Page 9824, line 27: And a generic overlap correction - although this should be instrument-specific.

Page 9825, lines 20-23: This is not strictly true, as the detection limit as defined by SNR

should be range-dependent. What happens if the calibration changes, laser power output declines etc..

Page 9826, lines 15-19: Does this definition include rain (freezing rain/drizzle)?

Page 9827, line 12: Replace 'considerate' with 'considerable'.

Page 9837, line 6: Stating that the 'algorithms fail to report' is unfair, as they are expressly not expected to.

Page 9837, line 14: Identify hydrometeor optical depths of 0.01 at what height?

Page 9837, line 22: How much of this finding is related to range-dependent SNR?

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