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Atmospheric Measurement Techniques Discussions

Interactive comment on "Ground-based remote sensing of thin clouds in the Arctic" *by* T. J. Garrett and C. Zhao

Anonymous Referee #4

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This article describes a methodology to retrieve microphysical and macrophysical properties of single layer clouds in the Arctic using ground based measurements of downwelling thermal radiation. The method is very interesting, especially the idea of using the information derived from the stratospheric ozone emission transmitted through clouds in order to assess the cloud optical properties. My opinion is that this paper is a useful contribution to ground based remote sensing technique. However, the paper requires a substantial number of minor revisions before being published.

General Comments :

The methodology described in this paper is based on several independent measurements which can limit the applicability of the method to other arctic datasets. This

should be clearly mentioned in the abstract / conclusion. Additionally, independent measurements should also be used to validate/estimate the retrieval especially for the ice retrievals (in the case study only a LWP comparison is presented). Section 2 could also be modified in order to clarify the different steps used in the retrieval methodology. The authors seem to make the assumption that ice crystals are spherical which impacts the retrieval of ice crystal effective radius. I think this needs to be justified and compared to "conventional" ice crystal habits used in infrared remote sensing (hexagonal columns or plates. . .). Finally, mixed phase clouds in Arctic play a dominant role in the surface radiation balance. The authors should clarify the way their retrieval algorithm treats these types of clouds (phase determination, microphysical and optical properties).

Specific Comments :

Abstract :

- P8654 ; Line 4 : specify the wavelengths or wavenumbers values of the three "micro-windows".

- Line 13 : Please mention that the LWP intercomparison was perform during one single case study.

Introduction :

P8655 ; Lines 12-17 : Could be rephrased/shortened to clarify the text.

Section 2.1:

This section is crucial for understanding the physics behind the micro-window selection. Unfortunately it is not always clear mainly because figure 3 and 9 are swapped. Additionally, Lorentz-Mie theory is used regardless of the cloud phase. This should be justified considering the wavelength domain used; are the authors assuming that the ice crystal shapes are spherical?

P8658 ; Lines 8-9: I don't agree with the authors when they state that the choice of their split window technique gives broad sensitivity to "a wide range of values of Re". It looks sensitive to small ice crystals with size smaller than 25 μm (Figures 4 and 9). Ice crystals are expected to be larger than that. Could you comment on that?

Figure 4: please check for typos in the figure caption : "emssivity" "labeld"

P8658 ; Lines 13 to 20 and Figure 5 : I have trouble to clearly understand this paragraph mainly because figure 5 is hard to read. Could you clarify your figure and its description?

Section 2.2

The authors point out the difference between "radiatively" mixed phase cloud and "microphysically" mixed phase cloud. This is an important point but I'm not sure they make that kind of differences in their retrievals (their method is sensitive to radiatively mixed phase clouds). Moreover, it is not clear if the clouds labelled "uncertain" are "mixed phase" cloud. The authors need to clarify this as it makes the phase determination algorithm quite confusing.

Section 2.3 :

Don't you think this section could be modified and part of it moved in an appendix as the contribution of the precipitation water vapour to the total cloud emission does not seem that significant given the measurements uncertainties presented in section 3? Additionally, I don't understand how equation 3 is evaluated (how do you estimate the number concentration for instance). Do you have an idea of the errors made considering crystals as spheres rather than non spherical particles (using r instead of a projected surface of ice crystals).

Section 2.4 :

In this section, it is not clear why it is necessary to make an interpolation to obtain the cloud brightness temperature within the P and R branches (needs more scientific

arguments) could you clarify? Figure 8 : the authors should separated the two top panels

P8662 ; Lines 4-6 : the sentence is incomplete :" Finally, to calculate cloud transmittance t. . ..."

Section 2.5 :

P8663 ; Lines 7-9 : The mixed phase cloud identification is not clear, please state explicitly when does your retrieval algorithm identifies a mixed phase cloud. I'm surprised that a simple average of the effective radius is used to determine the effective radius of the mixed phase clouds. I may be making a mistake but the sum should be weighted by concentration (microphysically) or extinction coefficient (radiatively).

P8663 ; Lines 19-20: . What instrument did you use to assess the droplet size distribution? Is there any contamination of small ice crystals in your measurements ?

P8664 ; Lines 5-9 : Please clarify this, I don't get your point here.

Section 3 :

I have the feeling that this section could be more appropriate if it was positioned before section 2. This might contribute to a better understanding of the retrieval algorithm.

Section 3.1 :

P8665 ; Line 9 : What is the impact of precipitation on the uncertainty of the Ceilometer measurement ?

P8665 ; Lines 13-17 : MMCR profiles of radar reflectivity are used to exclude cases with multiple cloud layers. The problem is that most of the clouds in arctic have multiple layers (for example with liquid layers at the top and ice crystals near the cloud base). Doesn't this limit the significance of the study?

Section 4 :

Figure 10 : please clarify the caption of this figure. It is difficult to understand without looking for additional information in the text

P8668 ; Lines 1-2 : it is said that clouds are assumed to be vertically homogeneous. Did you make any simulations with vertically inhomogeneous clouds? It would be nice to say something about that as most of the arctic clouds are clearly not homogeneous.

P8668 ; Line 4 : Section 4 should be Section 3.

Equation 12 : Could you justify why the covariance between the quantities is assumed to be zero (Temperature and water vapour. . .).

P8668 ; Line 28 : I'm surprised that the uncertainty of the ice crystal concentration is only 38% (better than in situ probes and liquid phase), could you comment on that please ?

Section 5.1 :

p8669 Line 18 : The authors state that there is a fairly high correlation between measured and retrieved LWP. In my opinion 0.46 cannot be considered as "fairly high correlation". Could you moderate this statement, please?

Figure 11 and 12 : please specify the meaning of the different contours. Additionally, I'm surprised that the effective radius of ice clouds is so low. I would expect typical values higher than 35-40 μm, especially at the cloud base. Could you specify that your infrared measurements are not sensitive to large particles? In your conclusions it is said that the retrieval technique is limited to particle smaller than 50μm.

Section 5.2 :

P8670; lines 6-10 : In section 2.3, the impact of water vapour and precipitation on the cloud retrievals is considered in details. In section 5.2, it is said that the contribution of water vapour is negligible. Therefore, I don't understand the purpose of section 2.3. Could you consider moving part of section 2.3 in an appendix?

Section 5.3 :

I would suggest that the case study includes some independent measurements in order to validate your technique.

Figure 15 : Could you use colours to separate liquid, ice and uncertain in your phase retrieval? In the conclusions it is said that the limit of effective radius retrievals is 50μm. You find a median effective radius of 48μm for the ice phase. Is this a real 48 μm or can it be regarded as the maximum size that you can retrieve using your technique?

Section 5.4 :

Could you give a statistics on the relative fraction of graybody clouds compared to blackbody clouds.

Figure 16: I'm surprised by the fairly high concentration of ice crystals (reaching more than 1000 particles /liter). Could you compare this to previously published data (aircraft or ground based measurements over Barrow). I'm wondering if this high concentration retrieval is not a compensation of the limited effective size range authorized by your technique.

Interactive comment on Atmos. Meas. Tech. Discuss., 5, 8653, 2012.