

Interactive comment on “Cloud phase identification of low-level Arctic clouds from airborne spectral radiation measurements: test of three approaches” by A. Ehrlich et al.

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This paper presents near-infrared remote sensing of cloud thermodynamic phase for low-level Arctic clouds based on three different indices. The indices rely on 1) slope of the reflectance signal between 1.5 and 1.7 μm ; 2) the ratio of principal component weightings for pure ice and pure water cloud reflectance over the same spectral domain; 3) a parameter incorporating reflectance to albedo that can discriminate angular differences in scattering between water droplets and ice crystals. Results are presented from Arctic Study of Tropospheric Aerosol, Clouds and Radiation (ASTAR) campaign in March and April 2007, comparing the remotes sensing method and in situ

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measurements on board the same airborne platform.

I think this paper is worthy of publication. It presents innovative methods for cloud phase discrimination, making use of spectral albedo and reflectance from above cloud top. The data is of high quality and the analysis methods are sound. Before publication, I would like to see the following comments addressed:

1. The two-wavelength approach, described in Section 4.1, relies entirely on the differences (between liquid water and ice clouds) in the slope of reflected radiance in the near-infrared band between 1550-1700 nm. The utility of this parameter comes directly from the differences in the imaginary part of the refractive index between liquid water and ice. However, by not normalizing by the radiance at a non-absorbing (shorter) wavelength, the authors have not utilized the fact that ice is far more absorbing (about a factor of 4, I think) in this same spectral region. If this can be included in the parameter IS it will become far more effective in discriminating phase. (This was essentially the main point in Pilewski and Twomey, 1987, cited in the manuscript). There will remain an ambiguity due to particle size but I will discuss that later. By the way, the PCA index, described in section 4.2 does normalize by radiance at a non-absorbing wavelength to remove the influence of cloud optical thickness. The same should be done here.

2. The discussion on angular dependent index. IA, is somewhat confusing but perhaps that is more indicative of the shortcomings of the reviewer than the authors. First of all, presumably the analysis was conducted over a limited set of scattering angles (equivalently, solar zenith angles, since the measurements were made at nadir), based on the phase functions shown in Fig. 8? Perhaps I missed it but are the calculated scattering angles the same as the range of measurements (zenith angle between 70 to 85 degrees) or just at a single angle? And on p. 15913, l. 18, how is the scattering angle between 95-110 degrees for nadir viewing with the solar zenith between 70 to 85 degrees? Shouldn't it be 70 to 85 degrees?

However, these are other issues with the use of this parameter that need to be resolved.

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The parameter derived on p. 15914, l. 16, can be simplified as the ratio between the calculated albedo of water cloud to the measured albedo, divided by the calculated reflectance of a water cloud. If all things are known a priori, this should work. But if cloud optical depth is poorly known, it appears that would dominate this parameter. More on this later.

3. Two issues in the section on sensitivity studies should be addressed. The first has to do with the impact on cloud particle size. It was mentioned in the first comment that particle size could lead to ambiguous phase discrimination. However, this was addressed by Pilewskie and Twomey, . J. Atmos. Sci., 44, 3419 (1987), which was a follow up to their first paper to specifically address this ambiguity. Part of the solution was to incorporate measurements beyond $2 \mu\text{m}$, where the absorption of ice and liquid water are closer in magnitude than in the $1.6 \mu\text{m}$ window. This, along with the spectral shape, can completely remove ambiguities due to particle size. The authors state that their measurements extend to $2.1 \mu\text{m}$. Why weren't the measurements at those wavelengths used?

The second issue that I think needs to be addressed is the sensitivity to cloud optical thickness. I understand what the authors did and how they interpreted their results in figures 5, 7, and 11. However, the assumption in all of this analysis is that optical depth is known. A more appropriate test, in my opinion, would be sensitivity to the error in optical depth. As it was pointed out in comment 2, the angular dependent index will have a huge problem if cloud optical depth is poorly known. And that leads to the following question: was optical depth for these analyses always derived from the in situ measurements? If so, there is plenty of opportunity for large errors due to on sampling issues related to the in situ profiling versus the optical derived parameters. The same cloud-top spectral radiation measurements applied to this study can be used to retrieve cloud optical thickness and effective particle size. Have these been compared with the in situ measurements of the same? This I see as perhaps the biggest limitation in determining the sensitivity to optical thickness and perhaps the utility of IA. This may

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even explain to ambiguity in interpreting cloud phase from figure 13.

Minor comments:

1. In the abstracts the three indices were listed but not described. Better to give a short description (slope, p_{ca} , and angular) rather than just listing the symbols.
2. P. 15908, line 12, the formula for R: this is a non-standard definition. It is missing the cosine of the solar zenith angle to make it equivalent to the standard definition of reflectance function (in Chandrasekhar, for example).
3. Equation 1: is it the average slope over this spectral domain computed? How: ratio of mean radiance in the entire band to total wavelength difference, or the mean of the slopes in each wavelength interval in the band (it should be the latter)?
4. The entire document should be proofed for grammar, punctuation, etc. I can send a marked-up if necessary.

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