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Atmospheric Measurement Techniques Discussions

Interactive comment on "Combined retrieval of Arctic liquid water cloud and surface snow properties using airborne spectral solar remote sensing" *by* André Ehrlich et al.

Anonymous Referee #2

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This paper introduces a tri-spectral method for the retrieval of liquid cloud optical thickness and droplet effective radius, simultaneously with the effective grain size of an underlying snow surface. This method is original and represents a significant contribution to passive Arctic remote sensing. It carries the potential to be implemented for existing imagers (MODIS, VIIRS) which, for some reason, is not emphasized in the current version.

The paper starts by establishing that cloud retrievals are sensitive to the grain size of the underlying snow, especially for small cloud optical thickness. Such clouds are ubiquitous in the Arctic, making this study highly relevant. Grain size retrievals based on MODIS observations exist, and yet the operational cloud retrieval algorithm employs

a climatology for snow-covered regions in the Arctic that does not vary with season and location.

Once the sensitivity of the three key retrieval parameters (cloud optical thickness, cloud droplet radius, snow grain size) have been mapped to spectral radiances that they are most dependent on, a simple lookup table approach is developed in this manuscript. It largely assumes a quasi-orthogonal retrieval grid in the three dimensions of the retrieval and measurement parameter space (see criticism of this aspect below). Finally, a few cases from airborne measurements are used to demonstrate the algorithm.

As noted above, the approach seems highly significant scientifically, and this alone should warrant publication in a major journal such as AMT.

However, there are two main flaws: 1) The language, structure and grammar diminish the potential impact of the manuscript because it becomes hard to read as a result. In sections 4 and 5, it was obvious that it had not been fully proof-read, and it seemed premature to afford it a full review at this point in time. It is beyond the scope of a science review to highlight such issues, but a few examples are listed below. It is in the interest of the authors to revise the language. In some sections (4 and 5 in particular), it could be shortened without losing its content.

2) In general, the science seems sound. However, it is surprising that the retrieval characterization is done without invoking principles of general inverse theory. This is especially important because the retrieval grid is not orthogonal for the most part. This means that there is no 1:1 mapping from observations to retrieval parameters, as the authors clearly acknowledge. But why, then, is the error characterization and propagation done in a fairly "brute force" way as visualized in Figure 7? In the framework of optimal estimation, one could have arrived at a statistically defensible retrieval characterization on the basis of the a-posteriori co-variance while fully taking into account measurement and model uncertainties. That said, a less rigorous error analysis such as done here is acceptable for initial and exploratory studies, as long as it is categorized

as such.

It is hard to tell whether the two above concerns can be alleviated through minor or major revisions; probably the former for the language, and the latter for the scientific approach. If the study were more clearly categorized as exploratory in nature in the revised version (to be followed by a more rigorous paper with a more formal approach routed in inverse theory), the whole manuscript could probably be published with minor changes and a professional copy-editing service.

Other comments:

* It should be mentioned somewhere in the manuscript that this study is strictly valid only for snow-covered surfaces with sufficient geometric (and therefore optical) thickness of the snow. The reference to Malinka (2016) is a bit mis-leading because it sounds as though white ice could be still be represented as snow. This is in stark contrast to multiple publications by, e.g., Perovich for such cases. They show a distinct spectral dependence in the visible wavelength range, and albedos well below 1. Furthermore, "white" ice is not explained. What other ice types are there that might be relevant for cloud remote sensing? A wider literature overview may be helpful.

* p5, L5-11. The reflectance at 1600 nm and 2100 both depend on optical thickness and effective radius; it is simply wrong to decouple them. Figure 2 clearly shows the non-orthogonality of such a lookup table.

* Figure 3a/b are nice visuals of the main direction of this paper; perhaps this could be emphasized more.

* p8: The "standard deviation" and the "PCA" method are insufficiently explain. What is the data set that these methods operate on? Also, the PCA components don't necessarily have to map to a physical parameter as the manuscript seems to suggest.

* p10, L10: Using 860 nm as a reference wavelength for the first ratio is probably a bad idea unless the paper specifically limits itself to snow (rather than including ice). This is

because (as stated above, and described by Perovich) ice has a distinct spectral shape and albedo magnitude at wavelengths below 1000 nm.

* p10, Table 1: This table is reminiscent of a covariance matrix. Why were these relationships not exploited in the framework of optimal estimation? What is the inverse theory foundation of this work?

Grammar/English:

Only a few examples are listed here. In some cases, a spell check could have identified these. In many cases, I did not include line numbers to make it clear that these are not isolated instances but represent a larger problem.

* Inadequate use of emphasis "do cause much lower errors"; "do significantly influence", "field did affect", "did show an oscillation"; "where cloud optical thickness did increase"

* use of "eminent" (p1,L21)

* rep of "retrieve" in short succession in abstract

* consistent punctuation errors (e.g. "analysis showed, that..."; "Both, snow and clouds considerably..."; "...is only possible, if..."

* "Different to land surfaces" ... "In constrast to land surfaces?"

* Therefor [spell checker would pick this up)

* affect = verb; effect = noun (e.g., p3,l2)

* dependence on (not to)

* Section 2.2 (in general); for example: "pretend not to know" [reword]; "range up to"; "Contrarily" [by contrast?];"back through top of" [?]; "procedure ends up with..."

* weight = noun; weigh = verb

* exemplary cloud (this means "outstanding; superb"; surely not the intention)

* p8l15: In case –> When?

* p8l21: "measures" –> "metrics"

* p8L32: "longer wavelength larger" [?]

* spectral pattern[s] result

* "in laboratory"

* "cross almost perpendicular"

* "to week" (too weak?)

* "the measurements itself"

* "Two different extracts from the observations"

* "this constrain might not..." Is it "constraint"?

* "causes...surface to reduces the albedo" [?]

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