Atmospheric Measurement Techniques Discussions

Atmos. Meas. Tech. Discuss., referee comment RC1
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# Needs more data

Anonymous Referee #1

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Referee comment on "Polarization lidar for detecting dust orientation: system design and calibration" by Alexandra Tsekeri et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2021-30-RC1, 2021

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The authors describe the design of a new lidar system designed to measure dust orientation through polarimetry. The sensor concept is built on established theory that strictly backward (single) scattering polarization matrices only have non-zero off diagonal elements if the particles have a preferred orientation. Otherwise, averaging over all orientations causes those off diagonal terms to reduce to zero.

I found the work to be reasonably thorough. Overall, I found the instrument description to be mostly complete. There were a few areas where some information on tolerance could be added. There are several areas where additional information should be provided (detailed below), which should not be difficult to add as minor revisions.

I found the math difficult to follow and generally lacking elegance. There are so many subscripts that I can’t keep track of what everything means. At one point there is an unexplained change from scalar to vector representation (Eq 8 and 9) for several terms. Overall, the presentation of the math is not a strict barrier to publication and this is obviously just the opinion of this reviewer, but some definitions and explanations need to be filled in (details below).

My biggest concern with this work is that it seems incomplete. After a description of the instrument, the data example is lacking. There is hardly any data, and all of that data is shown as time integrated plots. The integration times are very long (10-15 min -- well in excess of variability in atmospheric structure) and separated considerably in time. This needs some explanation. Also the authors should really be showing time resolved plots which tend to be more revealing, allow the reader to see both the vertical and temporal structure (see, for example, the exceptional plots in figure 8 of Kokhanenko 2020, 10.5194/amt-13-1113-2020).

I don't understand why there is so little data. What is the barrier to running this instrument continuously (a very important question for an instrument paper)? The only thing we are shown is a dust layer with no observable orientation, so we have no assurance that the instrument can observe off diagonal elements. The authors could operate the instrument to observe rain, which has very strong orientation signatures (see Hayman 2014 10.1364/OE.22.016976). That would at least provide some coverage of the measurement space. Demonstration would not be fully complete given the intended application, but it may be asking too much to demand the authors to show polarization properties of oriented dust.

To be clear, I think this work needs two things to be publishable:

- Observations of oriented scatterers (not necessarily dust)
- Observations shown as time resolved plots

**Some more general comments:**

Given that this is an instrument paper, I would think operability is part of the design and performance criteria. Is this somehow connected to the very small set of observation examples?

I am somewhat concerned that the authors seem to have decided that oriented dust is a foregone conclusion. The published work on this phenomena appears to be circumstantial (see specific comment about Line 13), so I would recommend the authors adopt a more cautious tone on the subject.

I assume the authors are aware, though they do not explicitly state in the manuscript, that there is no requirement that oriented particles produce non-zero off diagonal elements. Off-diagonal elements (within the constraints of single backscattering) indicate oriented particles, but the absence of off-diagonal terms does not rule out the presence of oriented particles. This is one of the weaknesses of using polarization for this type of measurement.

It is notable that there is no discussion of uncertainty in this work. This seems like a pretty important aspect of the instrument design.

**Specific comments:**

Line 13: "Dust particles have non-spherical irregular shapes and they have been reported to present preferential orientation (Ulanowski et al., 2007)."

It's worth noting that the analysis presented by Ulanowski is circumstantial. Dichroism from starlight was observed and those authors, lacking another explanation, assert that it must be caused by vertically oriented dust. This is not scientifically rigorous proof of oriented dust. The limits of imagination do not constitute scientific proof. (Remember when, lacking any other explanation, a neutrino traveled faster than the speed of light at CERN?).

The correct assertion is that dichroism has been observed in starlight when Saharan dust was present and that has led to the hypothesis that Saharan dust could have a preferential orientation. If the conclusions from Ulanowski 2007 et al are already deemed sufficient and correct, why build a lidar to look at this? Clearly there needs to be more, different observations.

Line 45: The authors note that they are using high power lasers. What is the eye safety classification of the lidar system and does that affect how and when often the instrument can be run?

Line 82: The description of the telescope system does not mention a field stop. What is the angular acceptance of the receiver?

Line 86: "The signals are recorded by two cooled Avalanche PhotoDiodes (APDs) at each detection unit,"

What mode are the APDs operating in? Analog or geiger? How are signals acquired and stored? Are photon counts converted to a histogram, and if so at what time and range resolution? Are analog signals digitized with A/Ds and at what sample rate and what is the analog bandwidth of the digitizer?

Line 124: "Moreover, most of the previous works utilize visible light measurements whereas we use near infrared light measurements at 1064 nm, to better probe the larger dust particles (a more detailed discussion is provided in Tsekeri et al. (2021)"

This statement references work that is neither published nor submitted for publication. Please provide some high level explanation for why IR is better for probing dust.

Line 141: Eq. 1 is in a strange part of the text. The text immediately above is discussing laser polarization, not the scattering matrix. As a reader, I was confused when I saw the equation.

Figure 7: Can you double check the subscripts labeling the components? At this point I feel pretty confused by all the subscripts, but I'm not sure if those in the figure are correct.

Line 162: The transmission term is treated as a scalar (having no polarization effect) in this work, but Ulanowski et al., 2007 specifically measured dichroism in dust extinction. Please state the justification treating the transmission of dust as a scalar.

Line 182: Please explain why the elements of f_{ij} and I, Q, U, V are now being treated as vector quantities.

Line 184 (just below Eq. 8): I think the definition for g_{ij} has the wrong denominator. Shouldn't it be G_{11}?

Line 224: “The optical elements are considered to be perfectly aligned with each other in the detection units after telescopes A and B”

Since there is no such thing as perfectly, this raises the question: What are the angle tolerances on the manufacturing and alignment?

Figure 13: In (c) orientation flag, there appears to be some bias above 1.0 both above and below the dust layer. I would have thought that above the layer, since the orientation is nonlinear, noise could be causing the bias, but below, the noise is quite low. Why is the orientation flag not equal to 1 when there is plenty of signal? Please provide more discussion on this new retrieved quantity and the observations.

I have attached additional comments on the structure of the equations.

Please also note the supplement to this comment:
https://amt.copernicus.org/preprints/amt-2021-30/amt-2021-30-RC1-supplement.pdf