Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2019-14-RC1, 2019

Atmospheric Measurement Techniques Discussions

Open Access

Interactive comment on "Evaluation of differential absorption radars in the 183 GHz band for profiling water vapour in ice clouds" *by* A. Battaglia and P. Kollias

Richard Roy (Referee)

richard.j.roy@jpl.nasa.gov

Received and published: 12 March 2019

The manuscript builds on previous theoretical and experimental studies of differential absorption radar near the 183 GHz water vapor absorption line, with a central focus on the retrieval of water vapor density inside of ice clouds. Specifically, it extends the multi-frequency line-fitting retrieval method from Roy et al. 2018 to include a linear term in the measured differential absorption coefficient in order to account for frequency-dependent scattering from hydrometeors. This retrieval is implemented in the context of spaceborne and ground-based instrument simulators that utilize CloudSat microphysical products in conjunction with ECMWF reanalysis fields (as done in Millan et

Printer-friendly version

Discussion paper

al. 2016). The ice crystal scattering calculations employ a more sophisticated method (the self-similar Rayleigh-Gans approximation) than that used in previous DAR simulation studies (Mie), and thus provide a more realistic picture of what a DAR would measure in the presence of ice clouds. Furthermore, this study explores radar transmit frequencies on the high-frequency side of the water line peak, while previous studies have focused on the low-frequency side. The results are presented and discussed in a thorough manner, and the manuscript is generally well organized and written. In terms of scientific impact, measurements from such a proposed spaceborne DAR instrument would provide important observations for ice cloud studies.

I have a few comments/questions that I would like the authors to address.

1. As a general comment for G-band radars, it is important to acknowledge the international frequency allocation restrictions that prohibit transmission within certain frequency ranges. Since this has impacted similar technologies in recent years, it seems reasonable to address this issue in the introduction to the paper.

2. Page 4, Line 1: The discussion of relative humidity measurement precision only addresses the role of absolute humidity measurement uncertainty. However, the temperature uncertainty is likely to dominate the error in RH. For instance, assuming the absolute humidity (i.e. water vapor density) is known perfectly, an error of 1 K in the temperature would lead to an error of 8% in RH at 260 K. This is much larger than the 3% level that is used as a metric for good accuracy in the paper. How would coincident temperature measurements be performed for precise RH studies? Since a principal goal of the paper is to show the utility of DAR for retrieving RH (and not simply water vapor density) for ice microphysics studies, this point needs to be addressed.

3. Page 5, Line 9: The authors use the phrase "mean square fitting procedure" a couple times in the text. Do they mean to say "least squares fitting procedure"?

Printer-friendly version

Discussion paper

4. Page 5, Line 11: What sets the necessary frequency span to be 10 GHz if one wants to allow for the linear term with coefficient B? Shouldn't this depend on where the window of frequencies is positioned relative to the line center?

5. Page 7, Line 1: The issue of sacrificing duty-cycle for an increased number of frequencies in DAR is very important. It is unclear what the authors mean when saying that sensitivity can be held constant while increasing the number of frequencies by "increasing the duty cycle of the radar." Presumably, one wouldn't want to sacrifice the current range resolution of roughly 500 m, which means the pulse width cannot be lengthened from 3.3 μs. Additionally, since the pulse time-of-flight through 10 km of atmosphere takes roughly 70 μs (2-way), how can the PRF be increased much from 6 kHz?

   Furthermore, the implementation of frequency diversity is technologically non-trivial for the large number (up to 7) and range (≈ 15 GHz) of frequencies proposed in this work. Since the large frequency range is critical for the 3-parameter fitting routine, and since a reduction in the sensitivity per channel by a factor of $\sqrt{7}$ would certainly affect the DAR measurement precision, a comment on the technical feasibility of such a system is needed.

6. Page 9, Line 15: The statement that water vapor can be retrieved to better than 15% accuracy in regions of the atmosphere where the water vapor density varies by more than one order of magnitude can be misleading. An important property of the DAR measurement method is that the measurement parameters (specifically the transmit frequency locations and number of pulses per frequency) and the local pressure and temperature determine the maximum achievable absolute precision in water vapor density for a given spatial resolution (i.e. value of Δr). This has the consequence that for a given measuring system, lower values of absolute humidity will be measured with lower relative precision. The important relationship between absolute humidity value and relative precision of the DAR measurement should be discussed.

As a related point, while the line-fitting retrieval routine implemented in this work gives an estimate of the measurement precision, this information is not discussed. The authors do go into great detail about the measurement biases (i.e. accuracy) in the form of relative error plots, but do not present results on the measurement precision. It would be useful to include a corresponding plot of measurement precision in Fig. 6 along with the relative error plot. Do the statistical errors from the line-fitting procedure agree well with the scatter of measured values relative to "truth." Such a discussion would elucidate the difference between systematic biases and random error in the measurement.

7. Page 12, Line 19: It is confusing to read that results worsen for high reflectivities, where one usually expects the SNR to be large. Maybe what is meant here is that regions of high reflectivity are also associated with high absorption (or are lower in the atmosphere where frequencies near the line center have already been strongly attenuated)? It would be helpful to clarify this point.

8. Page 12, Line 20: Recommend changing "...signal significantly above the SNR" to "...signal significantly above the noise floor".

   Same line: Recommend changing "...reduced value of the tones further away..." to "reduced absorption for tones further away..."

9. Page 12, Line 31: To say that for fixed duty-cycle there is improvement in going from two to four frequencies is misleading. In the 2-frequency case, one cannot perform the 3-parameter fit, and therefore the frequency-dependent hydrometeor scattering effects enter directly as a bias in the retrieved humidity. Thus, these two situations are fundamentally different.

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2019-14, 2019.