Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2018-397-AC2, 2019

Atmospheric Measurement Techniques
Discussions

Interactive comment on "Evolution of DARDAR-CLOUD ice cloud cloud retrieval: new parameters and impacts on the retrieved microphysical properties" *by* Quitterie Cazenave et al.

Quitterie Cazenave et al.

quitterie.cazenave@latmos.ipsl.fr

Received and published: 2 April 2019

We would like to express our thanks to the reviewer for his/her help in improving the paper. We are grateful for the time spent on this review. In what follows, we respond point-by-point to the comments made.

1. The abstract should be more informative and provide a more precise summary of the findings. At present the statements are too vague. Currently it says IWC can be 'up to 50% with, globally, a reduction'. 50% is a large change. What is the global

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average reduction? Effective radius increases between 5% and 40%, with the largest difference in clouds between -20C and 0C. The new lidar ratio of 35 +/10 sr for cold clouds is quite a reduction on the previous values. Line one of the introduction stresses the importance of ice clouds on the radiation budget, but this aspect does not seem to be directly addressed in the rest of the paper. Do changes in effective radius for the warmer ice clouds lead to changes in the radiation budget? Perhaps not, as such clouds are already optically thick? Do changes in the lidar ration affect the radiative properties of the thin cold ice clouds? If so by approximately by how much? Although only a few days were analyzed, this should be sufficient to make some more definitive statements. The purpose of the abstract is to give the reader a more quantitative summary of the findings and impact of the new results.

Response: Regarding the impact of changes in the effective radius and lidar ratio on the cloud radiative properties, it is not the objective of this paper. This paper aims at giving information on the modifications that were made in the algorithm and how the DARDAR-CLOUD product is impacted. As a result, we only focused on variables available in this product (IWC and effective radius of ice clouds).

Change in manuscript: Abstract: In this paper we present the latest refinements brought to the DARDAR-CLOUD product, which contains ice cloud microphysical properties retrieved from the cloud radar and lidar measurements from the A-Train mission. Based on a large dataset of in-situ ice cloud measurements collected during several campaigns performed between 2000 and 2007 in different regions of the globe, the parameterizations used in the microphysical model of the algorithm – i.e. the normalized particle size distribution, the mass-size relationship, and the parameterization of the a priori of the normalized number concentration as a function of temperature – were assessed and refined to better fit the measurements, keeping the same formalism as proposed in DARDAR basis papers. Additionally, in regions where lidar measurements are available, the lidar ratio retrieved for ice clouds is shown to be well constrained by lidar-radar combination or molecular signal detected below thin semi-transparent cirrus. Using this information, the parameterization of the lidar ratio was also refined, and the new retrieval equals on average 35 sr +/- 10 sr in the temperature range between -60°C and -20°C. The impact of those changes on the retrieved ice cloud properties is presented in terms of IWC and effective radius. Overall, IWC values from the new DARDAR-CLOUD product are in average 20% smaller than the previous version. In parallel, the retrieved effective radii increase between 5% and 40%, depending on temperature and the availability of the instruments, with an average difference of +20%. Modifications of the microphysical model strongly affect the ice water content retrievals with differences that were found to range from -50% to +40%, depending on temperature and the availability of the instruments. Larger IWC values are found with the new version in the cold regions detected by the lidar. On the contrary, in warmer regions, where only the radar measurement is available, a reduction of the retrieved IWC is found. The largest differences are found for the warmest temperatures (between -20°C and 0°C) in regions where the cloud microphysical processes are more complex and where the retrieval is almost exclusively based on radar-only measurements. The new lidar ratio values lead to a reduction of IWC at cold temperatures, the difference between the two versions increasing from 0% at -30°C to 70% below -80°C. Effective radii are not impacted. At cold temperatures, the impact of the new lidar ratio on the retrieved IWC is larger than that of the new microphysical model, hence a reduction of IWC values for the new DARDAR-CLOUD product, for all temperatures.

2. The paper is quite long, but the justification for the four changes in the DARDAR product are not discussed, instead, there is a list of references. Since these changes are of vital importance, a couple of sentences in each case summarising the evidence would be helpful to the reader. For example, on page 6, line 18, four references are quoted to justify reducing the max value of S (the lidar ratio) from 120 sr to 50 sr, and hence changing the coefficient alpha (lnS) by a factor of three from 0.0237 to 0.008 (page 7, line 9). What sort of observations were used? Were they Raman or HSRL lidar – ground-based or airborne? How comprehensive? How confident are we of any implied change in the radiative properties of thin cold ice clouds?

Response: These changes were initiated after the DARDAR-CLOUD product was compared to other satellite products. To account for the differences that were observed, the lidar ratio a priori, the N0' a priori, the normalized PSD and the M-D relationship have been identified as parameters that could be refined, due to the uncertainty and/or questionable reliability of the current parameterizations.

Regarding the changes in the microphysical model, they are justified by the fact that data from new field campaigns with ice clouds in-situ measurements have been made available, providing more accurate measurements of PSDs and IWC and/or a larger statistic of measured ice cloud properties, compared to the data used for the first version of the algorithm. We decided to refine the parameterizations based on this more recent information.

Regarding the references for the lidar ratio, all four studies consist in measurements of thin/semi-transparent cirrus clouds with a simple elastic lidar, using the difference between the backscatter measured above and below the cloud layer to infer the transmission and then the integrated extinction and lidar ratio. Platt et al. (1987) and Garnier et al. (2015) use additional measurements from an infrared radiometer to account for multiple scattering effects. Average cloud temperatures are between -60°C and -40°C and optical depths below 1. The study presented by Platt et al. (1987) is based on measurement of midlatitude cirrus observed with a groundbased instrument located in Aspendale, Victoria (Australia) during one winter and one summer season, as well as observations of tropical cirrus made in Darwin (Australia). Chen et al. (2002) present one year of ground-based lidar measurements in Taiwan. Yorks et al. (2011) compare measurements obtained during five airborne campaigns in different locations in Central and North America and Hawaii. Finally, Garnier et al. (2015) present a statistic of CALIPSO observations over the year 2008. The lidar wavelength is 694nm for the study performed by Platt et al. (1987) and 532nm for the others. Although these measurements are restricted to situations that can be handled with elastic lidars, the average lidar ratio values are in agreement with those obtained using Raman lidars and presented by Reichardt et al. (2002), Whiteman and Demoz (2004) and Thorsen and Fu (2015). In particular, Thorsen and Fu present a statistic over several years of lidar ratio retrievals using ARM Raman lidars on two locations: Lamont, Oklahoma and Darwin, Australia. This statistic shows lidar ratio values between 5 and 50 steradians, with a maximum of occurrence at 27 sr for Darwin and 22 sr for Lamont.

Finally, about the implied changes in the radiative properties of cold ice clouds, it is again not the objective of this paper.

Change in manuscript (Page 3, line 12): a few issues have been identified. For example, Deng et al. (2013) compared DARDAR-CLOUD with other satellite products and with cloud properties derived from aircraft in-situ measurements obtained with a 2D-S probe, during the SPARTICUS campaign in 2010. Compared to the other CloudSat-CALIPSO product and the aircraft observations, the DARDAR-CLOUD product seemed to overestimate IWC in cloud regions where only lidar measurements were available. Sourdeval et al. (2016) also compared the Ice Water Path (IWP) retrieved with different satellite products over the year 2008 and highlighted the fact that the DARDAR-CLOUD product tends to overestimate IWP, in particular for values below 10 g.m-2.

Change in manuscript (Page 6, line 17-18): This was found to produce values of S that are too large at cold temperatures (up to 120 sr) compared to the climatology. Indeed, several studies on semi-transparent cirrus clouds were performed with elastic lidars in the visible, either from airborne (Yorks et al., 2011), groundbased (Platt, 1987, Chen et al. 2002) or spaceborne (Garnier et al., 2015) instruments. In all cases, retrieved lidar ratios were found around an average value of 25-30 sr and rarely exceeded 50 sr. In addition, more studies were made on cloud optical properties, including measurements performed in the UV by Raman ground-based lidars, showing similar values for the retrieved lidar ratios (Whiteman and Demoz, 2004, Thorsen and Fu, 2015).

Change in manuscript (Page 7, line 21): The idea here is to assess and refine these parameterizations, using a more comprehensive and accurate dataset of ice cloud in-situ measurements.

3. Figure 2 shows the change in the PSD. It would seem that this is crucial to the increase in the IWC, because the longer tail of larger particles with the normalised size above 2.8, will lead to large changes in Z, but smaller changes in IWC, hence a given Z will now correspond to a lower IWC. Is this effect dominant, or is the change in m-d of equal importance? Is the reduction in the concentration of particles with normalised size below 0.2 of any significance? It would help the reader if these aspects were discussed.

Response: Due to normalization, particles with the normalized size above 2.8 does not only mean large particles but also large particles with respect to the mean size of the distribution (D_m). Those particles correspond to the tail of the distribution. Unless the un-normalized particle size distribution is very broad, these particles have very little contribution to the overall size distribution. As presented by Delanoë et al (2014), the majority of the data is concentrated in the area where D_eq/D_m=1. As a result, the change in M(D) is expected to be of more importance. The same reasoning also applies for normalized sizes below 0.2.

Change in manuscript (Page 8, line 12): However, as presented by Delanoë et al (2014), the majority of the data is concentrated in the area where D_eq/D_m=1. The change in M(D) is therefore expected to be of more importance than the modification of the normalized particle size distribution.

4. The figures are of very poor quality and are scarcely legible.

Response: This has been modified, examples are presented in Fig. 1 and 2.

5. Finally, there are quite a few typos.

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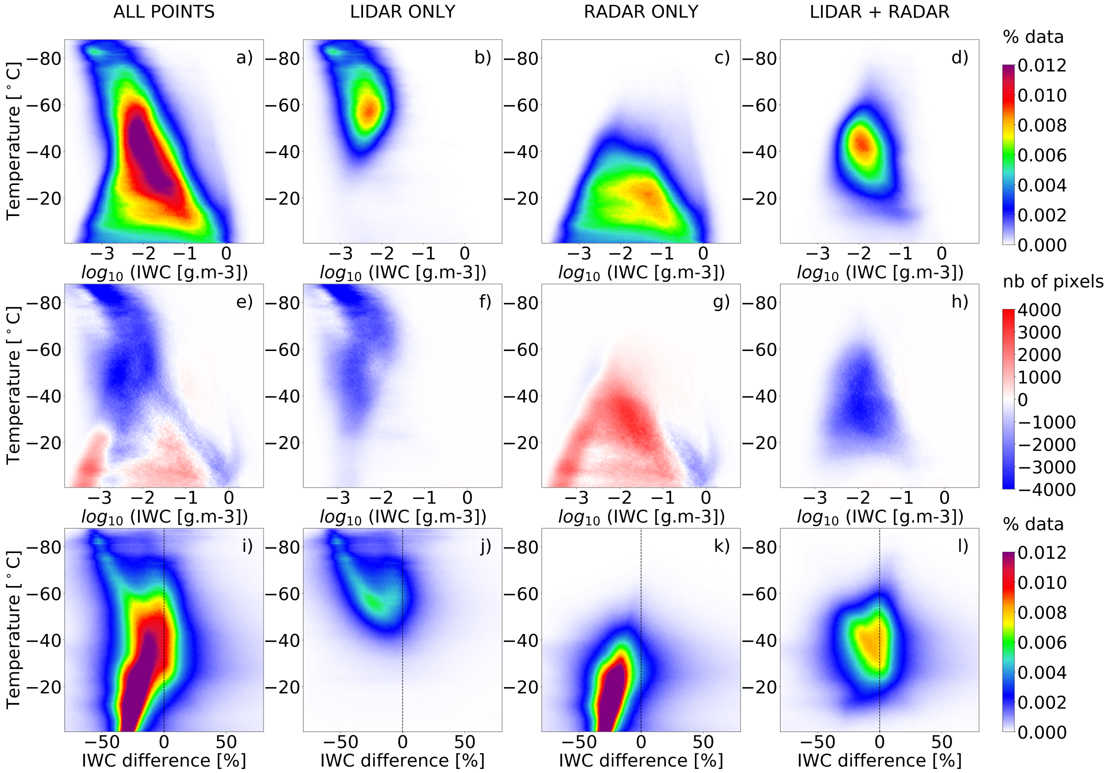

Fig. 1.

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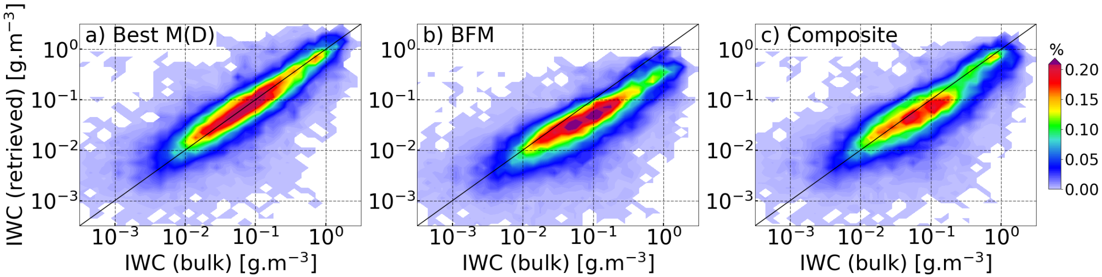

Fig. 2.

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