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Interactive comment on "On the optimal method for evaluating cloud products from passive satellite imagery using CALIPSO-CALIOP data: example investigating the CM SAF CLARA-A1 dataset" *by* K.-G. Karlsson and E. Johansson

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Review of "On the optimal method for evaluating cloud products from passive satellite imagery using CALIPSO-CALIOP data" by Karlsson and Johansson, (amt-2013-3)

This paper uses CALIPSO/CALIOP cloud data to evaluate cloud occurrence and cloud top height in the CM SAF CLARA-A1 dataset, which is based on AVHRR observations. They have identified 99 orbits of the NOAA-18 satellite matched in space and time to the CALIPSO orbit. This provides a matched AVHRR-CALIOP dataset which can be

used to characterize retrievals from not just the NOAA-18 AVHRR but from all AVHRR instruments. The authors take some care in preparing an appropriate version of the CALIOP data for the comparison, develop a number of different statistics for evaluating the PPS cloud data and provide a good discussion and interpretation of the results. The paper provides new and interesting results and merits publication, but would benefit from some revisions.

General comments on description of the CALIOP cloud data products:

The structure of the CALIOP cloud products is rather complicated and not directly suited to the comparison the authors wish to perform in this paper. This is the motivation for their development of an "optimal" method. The CALIOP cloud products are described in sections 2.2and 3.1, but not clearly or in detail, and several key papers describing the retrieval algorithms are not cited. Because of an apparent misunderstanding of the algorithm used to produce the cloud data products, they raise concerns in section 3 which are unwarranted. In its description of the CALIOP dataset the paper repeats some common misconceptions about the nature of the CALIOP data. In the end, I don't think these have a significant impact on the results but it is better to have a clear understanding of the data products being used in any validation study.

To clarify my concerns: The CALIOP retrieval algorithms report clouds detected at 5 different spatial resolutions. The paragraph beginning on line 8, page 1100, and the discussion in section 3.1, describe these as if they are equivalent in some sense. Clouds detected in single shot profiles and in profiles averaged over three shots are reported in the 1/3 km and 1 km cloud layer products, respectively. Clouds detected after averaging to 5 km, 20 km, and 80 km are all reported in the 5-km Layer Product. When the authors discuss using the "5 km dataset" I assume they are using clouds detected at all three resolutions, but this is not clear. The 1-km dataset is independent of the other four and was intended to provide a product with spatial resolution matched to passive sensors having 1 km IFOV. As described in the CALIPSO ATBDs (Vaughan et al. 2005) and several papers (Vaughan et al 2009, Winker et al. 2009 –

see reference list below) the clouds detected at 1/3, 5, 20, and 80 km are complementary and, together, provide the complete description of clouds observed by CALIOP. (Clouds detected at 1 km can be substituted for 1/3 km clouds, somewhat less optimally, as described below.) Clouds detected at higher resolutions are subtracted from Level 1 profiles before averaging, to avoid smearing dense clouds together with more tenuous clouds (and aerosols).

The authors point out that Eqn (1) "is not fulfilled in all cases". This is correct, because Eqn (1) does not follow from the way the products were designed and implies an algorithm different from the one that is used to produce the CALIOP data products. To explain: In trade cumulus regions, for example, where clouds tend to be small and bright, most cloud is detected in 1/3 km, single-shot profiles. These detected clouds are subtracted from the Level 1 profiles before averaging to 5 km and often the 5-km average profiles are found to be cloud-free. Thus, there is no general expectation that CFC_0.3 km < CFC_5km. Similarly, clouds detected at 5 km are subtracted from the Level 1 profiles before averaging to 20 km, and clouds detected at 20 km are subtracted before averaging to 80 km (Vaughan et al. 2005). We may find that CFC_20 km < CFC_80 km, but that depends on the nature of clouds and is not an inherent behavior produced by the algorithm.

Line 23, page 1101, notes that the 1 km dataset sometimes has larger cloud fractions than the 5-km dataset. This is not an inconsistency and does not indicate a problem in the dataset. This has been reported by other researchers because it results from the design of the algorithms. As described above, cloud layers detected at 0.3 km are subtracted from Level 1 profiles before averaging to 5 km. They are not subtracted before averaging to 1 km, however. Therefore, CFC_0.3km is less than or equal to CFC_1km in all cases, because 1 km cloud detection is based on simple averaging of three 1/3 km profiles. In trade cumulus regions, where cloud horizontal extents are often less than 1 km, this leads to an overestimate of cloud fraction in the 1-km product. As described above, if all cloud in a scene is dense and detected at 1/3km, then no

cloud will be reported at 5 km and coarser resolutions.

Finally the author's conjecture, at the beginning of Section 3.1, that "lost clouds" in the 5km dataset are "most likely included" in the 1 km dataset is correct, by the design of the algorithm. These clouds are not "lost", they are detected and reported at 1/3 km and then show up in the 1 km dataset, after averaging. Clouds detected at all 5 resolutions are reported together in the VFM, although only the cloud occurrence and not the optical depths.

In spite of the problems in Section 3, the CALIOP data seem to have been used in a reasonable manner and the results in Section 4 appear to be reasonable and meaningful. Figure 4 indicates the detection threshold of CLARA-A1/PPS cloud mask algorithm is about 0.3, in optical depth, which is similar to the ISCCP threshold (also largely based on AVHRR).

Detailed comments:

1) There is no discussion in the paper on how the method adopted is "optimal." That is, how this method is better than all other methods. In any case, an optimal method is only optimal for certain applications. While the method described here is reasonable and defensible, I would encourage removal of the word "optimal" from the title.

2) There are quite a few references to a CALIOP "5 km FOV." The CALIOP FOV is 100 m. Averages over 15 laser shots are usually referred to as "5-km averages" or "5-km segments".

3) The citation for Stubenrauch, et al. (2012) can be updated. The final report (WCRP Report No. 23/2012) is available at:

http://www.gewex.org/gdap/gdap_assessment_wgs.html

I'm not sure what document is referenced on the NASA NTRS server. When I attempted to locate it, access to the NASA NTRS data server was blocked.

4) A slight comment on page 1098, lines 11-12, which imply CALIOP data products contain only geometric cloud top height: They also contain cloud top temperature. The justification for only looking at the CALIOP cloud height product is that cloud height is directly measured, whereas temperature is derived from a meteorological analysis product and the observed cloud height.

5) Page 1099, line 24: the lidar signal becomes fully attenuated after penetrating an optical depth of 3 to 5, not 6-10. Larger optical depths are sometimes reported in the data products, but these are highly uncertain and should be ignored.

6) Page 1099, line 27: a better URL for the CALIPSO data archive would be: http://eosweb.larc.nasa.gov/PRODOCS/calipso/table_calipso.html

7) I'm afraid my communication quoted on lines 1-2 of page 1102 will be misunderstood, as it is taken out of context. My statement that the CALIOP dataset is not "ideally suited for this task" was not that cloud information was lacking, but that the information was split between the 5-km and 1/3-km (or 1-km) Cloud Layer products and so required the combination of multiple products. When constructing a Level 3 monthly gridded cloud product we used the 1/3-km and 5-km Cloud Layer Products (Chepfer et al. 2013), avoiding the 1-km product which can overestimate low cloud cover.

8) On page 1102, lines 11-15, the results of Chan and Comiso (2011) are referenced. Unfortunately, some misconceptions in that paper are repeated. Chan and Comiso report on MODIS and CALIOP observations at high latitudes. They show several scenes which CALIOP retrieves as "clear" but MODIS retrieves as cloudy: marine stratus with cloud top heights of 1.5 km or more. CALIOP Level 1 data shows these 'clouds' are fog layers confined to within about 300 m of the surface. MODIS retrieves a reasonable optical depth, but places the layers much too high above the surface. Because the fog layer extends to the surface it cannot be distinguished from the ocean surface by the CALIOP Version 3 algorithm, and is classified as part of the surface return. The limitation of the CALIOP retrieval has nothing to do with the optical depth of the layers

(as stated by Chan and Comiso) but that they are immediately adjacent to the ocean surface. Technically, this is not a problem of missed detection, but a problem of being unable discriminate the fog layer from the ocean surface.

9) Page 1103, line 10: I don't understand why a 5-km segment is set to 'clear' if one or two of the 1-km segments within the 5-km is cloudy. The 5-km segment is obviously partly-cloudy if at least one and less than 5 of the 1-km observations is cloudy. Why draw a threshold at 50%? Will the AVHRR threshold test be unable to detect cloud if the 4-km AVHRR pixel is less than half-filled? In any case, the CALIOP swath can only characterize the cloud cover of partly cloudy AVHRR pixels in a statistical sense.

10) Page 1104: I'm not sure what the concern is in lines 8-16. It is not clear the authors are aware that, at altitudes below 4 km, clouds detected on single shots are subtracted from 1/3 km profiles before being averaged to 5 km. At low altitudes, the cloud layers reported at 5 km tend to be either the bases of dense overcast clouds or the averages of thin, broken cloud which is missed by 1/3 km detection. Because 1/3 km cloud detection is already more sensitive than passive cloud detection, we tend to ignore low-altitude 5-km cloud layers when computing cloud cover. At altitudes above 4 km, the cloud fraction within 5 km layers could be tested by comparison with 1/3 km or 1 km cloud detections. The final paragraph is correct, however, that results based on both 1 and 5 km products will be better than if 1 km or 5 km products are used alone.

Additional references:

Chepfer, H., G. Cesana, D. Winker, B. Getzewich, M. Vaughan, and Z. Liu, 2012: "Comparison of two different cloud climatologies derived from CALIOP attenuated backscattered measurements (Level 1): the CALIPSO-ST and the CALIPSO-GOCCP" , J. Atmos. Oceanic Technol., doi:10.1175/JTECH-D-12-00057.1, in press

Vaughan, M., K. Powell, R. Kuehn, S. Young, D. Winker, C. Hostetler, W. Hunt, Z. Liu, M. McGill, and B. Getzewich, 2009: "Fully Automated Detection of Cloud and Aerosol Layers in the CALIPSO Lidar Measurements", J. Atmos. Oceanic Technol., 26, 2034–

2050, doi: 10.1175/2009JTECHA1228.1

Vaughan, M., D. M. Winker, and K. Powell, 2005: CALIOP Algorithm Theoretical Basis Document Part 2: Feature Detection and Layer Properties Algorithms. PC-SCI-202.02. available at http://www-calipso.larc.nasa.gov/resources/project_documentation.php

Winker, D. M., M. A. Vaughan, A. H. Omar, Y. Hu, K. A. Powell, Z. Liu, W. H. Hunt, and S. A. Young, 2009: "Overview of the CALIPSO Mission and CALIOP Data Processing Algorithms", J. Atmos. Oceanic Technol., 26, 2310–2323, doi:10.1175/2009JTECHA1281.1.

Interactive comment on Atmos. Meas. Tech. Discuss., 6, 1093, 2013.