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# ***Interactive comment on “Validation of SCIAMACHY O<sub>2</sub> A band cloud heights using Cloudnet radar/lidar measurements” by P. Wang and P. Stammes***

**Anonymous Referee #1**

Received and published: 9 December 2013

## **General comments**

This paper reports on the comparison between two satellite cloud height retrieval algorithms and ground-based measurements. Satellite input data comprises cloud height data products based on SCIAMACHY measurements and the SACURA and FRESCO algorithms, respectively. Both are compared to ground-based lidar profiles inferred from measurements at Cabauw and Lindenberg. The scope and content of the paper matches those of AMT and the paper is therefore recommended for publication. The paper is well structured and the language may be easily understood by non-native

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speakers like me. The selection of plots is appropriate to illustrate this difficult matter. In my opinion, however, especially the discussion of both the methodology and results requires thorough revision.

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## Specific comments

- 1) In the abstract (p.8604, l.8), the Authors claim that their method to collocate satellite and ground-based measurement achieves “an optimal temporal and spatial match”. In the entire manuscript, it is never discussed, why the selection scheme chosen (ranges plusminus 1h the satellite overpass time) should be optimal. Merging data is never trivial. The parameters for the applied merging scheme appears arbitrary and the influence of their choice is not discussed. From a technical paper like the one presented, I expect an appropriate discussion of the involved parameters. How do the results change when, e.g., the time window for averaging the lidar measurements is modified. Is there a flag indicating how representative a point measurement is for the entire SCIAMACHY pixel? What if the SCIAMACHY pixel just scratches Cabauw/Lindenberg? I am confident that a discussion of this matter would strengthen the paper. The discussion may be added to Section 3.
- 2) The essential results of this study are the deviations of FRESCO/SACURA compared to Cloudnet cloud profiles. The figures for this deviation given in the abstract are  $(0.44 \pm 2.07)$  km (p.8604, l. 13-14) and  $(-0.14 \pm 1.88)$  km (l. 16-17). I do not believe it is serious to give more than one significant decimal in this context. Apparently, the deviations between the satellite measurement and ground-based measurement are not significant at all since they agree much better than 1 sigma. Please
- 3) In the introduction it is stated “It is a challenge to retrieve cloud information from SCIAMACHY because of its large pixel size.” (p. 8605, l. 6-8) There are algorithms taking advantage of the increased spatial resolution of the PMDs, like OCRA and HI-

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CRU for instance. Algorithms using PMDs are not mentioned before p.8610. Please discuss.

4) Please discuss the advantage of using ground-based lidar measurements to “validate” satellite cloud products. I expect satellite measurements (e.g. CALIOP) to be much better suited. These match the SCIAMACHY observation much better in coverage and resolution. Especially for thick clouds, satellite observations will be better suited to detect the upper boundary of the cloud.

5) Cloud heights retrieved from satellite are compared to ground-based lidar observations. I have the following concerns regarding the ground-based measurements applied which should, in my opinion, be discussed in the paper. a) What is the maximum cloud optical thickness the applied lidar can measure? b) How do optically thick clouds influence the comparison between observations from the surface and from space? c) Please discuss whether a limitation of the maximum column optical thickness can result in a systematic bias towards lower clouds (both top and middle heights)? d) Is there a reason why only observations from Cabauw/Lindberg are included in this study? As far as I know, also the other Cloudnet sites feature lidars. e) In this paper, the authors demonstrate a possible yet sophisticated approach to compare satellite and ground-based cloud data. The discussion towards a global perspective is based on satellite observations alone. What about extending this study using ground-based lidar observations also from other regions on the globe. This would strengthen the claim of validating satellite cloud products in this paper.

6) Why is it important that the ground-based measurements cover “the whole SCIAMACHY mission period” (p.8611, l.21)? What is the specific benefit? Now you have the data at hand, it would also be possible to study whether there are trends in the satellite cloud products from 2003 through 2011.

7) Please specify, how “pixels with out snow/ice on the surface”(p.8613, l.10-11) are identified.

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8) On “More statistics of the comparison between SCIAMACHY cloud heights and Cloudnet cloud heights for multi-layer clouds is given in the Appendix in Tables A5-A8.” p.(8619, l.17-19) Please specify, what the reader can expect from the tables in the Appendix. Otherwise he/she will be quite lost at this point. I suggest to either discuss the tables in an Appendix, provide a cross-reference in the captions of Figs. 7 and 11 to the respective data, or put both a description and the tables into a Supplement.

9) Conclusions (p.8620, l. 7): Please specify the similarities to and deviations between the presented study/data and Lelli et al., 2011. What do we learn from this study using SCIAMACHY data?

10) Conclusions (p.8620, l. 10-12): a) How “accurate” are the FRESCO cloud middle heights? b) Is the ESA L2 cloud top height “on average reliable” or does it merely have “a large scatter”? Please be more specific.

11) Conclusions (p.8620, l. 13-14): How “limited” is the number of ground-based radar/lidar measurement sites world-wide? There are certainly more.

12) Conclusions (p.8620, l.21-22): What are “other satellite cloud height products“? Please specify.

13) Conclusions (p.8620, l. 24): What does “accurate” in “FRESCO cloud height is accurate for low clouds“ mean? Within 1 sigma?

14) Comparing the last columns of Tables A1 and A2 reveals that the pixel selection for FRESCO and ESA L2 cloud products are different. Why?

15) The captions of Figs. 4, 5, and 8 state whether the plotted correlations are significant or not. What does that mean? I suggest to calculate p-values and define, below which value significant correlation may be assumed for this kind of data. Furthermore, I suggest to put this information as well as a discussion in the main text body.

16) Are Figures 7 and 11 really histograms as stated in the captions? In general, a histogram shows the number, occurrence, or frequency per unit interval or bin. Figures

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7 and 11, however, merely illustrate statistics within each bin. I therefore suggest to use candlestick type plots instead in order to avoid confusion with histograms typically associated with bar graphs. This would also highlight that the mean FRESCO cloud height is systematically lower than the ESA L2 cloud top height (except 7-8 km bin in Fig. 7) when binned according to the respective Cloudnet cloud middle/top height.

17) In fact, Figures 3a and 3b are histograms.

18) More on Figures 7 and 11: Do you really need the mean values for the Cloudnet data? The binning of the FRESCO/SACURA values is according to the Cloudnet data rendering the grey bars (and especially the corresponding errorbars) rather meaningless. I suggest to remove them from the plots for the sake of clarity.

19) Could one “validate” ground-based measurements of the cloud parameters with the help of satellites?

## Technical corrections

p.8604, l. 2: The reference for “For the first time” is not clear (two products, SCIAMACHY, investigated period). Please rephrase or, even better, drop this claim.

p.8605, l.2: “yr” -> “years”

p.8605, l.14: Please give a more balanced selection of references to tropospheric trace gas measurements influenced by clouds.

p.8605, l.23: “accurately determined with” -> “accurately determined from space with”

p.8606, l.9: drop “as being”

p.8608, l. 4-5: “the latest SCIAMACHY ESA L1 product (version 7.04) is used” Please specify when it has been released.

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p. 8610, l. 16: Please add the number of Cloudnet measurement sites.

p.8612, l. 1: The term “pixels” is confusing with respect to satellite pixels. There are two kinds of pixels in the manuscript. Please specify.

p.8620, l. 24: insert “,” between “that” and “as”

p.8626, Table 2: I suggest to divide the second `\hline` between “Effective cloud fraction” and “Cloud (top) height (km)” (three columns each) for the sake of clarity.

Figures 7 and 11: The x-axis of the plot are unclear. Does the first bin (denoted “1”) contain the measurements between 0 and 1km? Please denote the range of each bin or put the axis ticks between the bars to indicate bin limits.

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Interactive comment on *Atmos. Meas. Tech. Discuss.*, 6, 8603, 2013.

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