

## ***Interactive comment on “Bulk microphysical properties of semi transparent cirrus from AIRS: a six years global climatology and statistical analysis in synergy with CALIPSO and CloudSat” by A. Guignard et al.***

**Anonymous Referee #2**

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General comments:

The focus of the manuscript is the retrieval of cirrus bulk microphysical properties from AIRS satellite measurements. The methods applied to derive effective diameter, ice water path, prevailing crystal habits as well as coverage of semi transparent cirrus are explained in detail. The vertical structure of the cirrus cloud layers is studied by using collocated GEOPROF data. Global macro and microphysical properties of semi transparent cirrus derived from the retrieval are discussed extensively. As an additional outcome of the study, a parameterization for use in general circulation models is

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presented, which can be used to derive the cirrus effective diameter from the modelled ice water path.

Cirrus clouds are the most frequent cloud type in the upper troposphere. They can have large effects on the Earth's radiation budget and can, therefore, be of large relevance for the climate system. The present knowledge on cirrus microphysical properties and their global and seasonal variation is still very uncertain. Hence, the present manuscript provides very important new results which are of high relevance for atmospheric and climate science. Hence, the paper is well suited as a contribution to ACP.

The methods applied in this study appear to be thoroughly developed, based on large experience gained over more than a decade and documented in a number of previous publications. Each step of adapting the methods to AIRS data is explained in detail. The robustness and uncertainties of the new method are thoroughly assessed in terms of a sensitivity analysis based on varying assumptions on atmospheric parameters in the underlying model calculations. Many new and interesting results on global cirrus properties are described. However, the presentation quality of the manuscript needs to be urgently improved. I recommend publication of the manuscript after the following general and specific comments have been addressed by the authors:

1. Some explanations in the documentation of the retrieval methods are not sufficient to understand the respective operations. These parts of the manuscript have to be improved (see specific comments below).
2. There is an imbalance of results presented in terms of figures and the corresponding discussions in the text. The manuscript presents a large number of figures. Some discussions of the presented results, however, are insufficient and some figures are even not discussed (see specific comments below). On the other hand, some figures are discussed very extensively which makes it hard for the reader to identify the most essential points. The quality of the paper could probably be improved if some of the figures are skipped and only the most essential results are kept. The discussions in the

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text should be rewritten towards a more balanced presentation of the different topics. Key points should be highlighted.

3. The quality of many of the figures needs to be improved. Many figures include too small texts which are hard to read. Explanations of what is presented are missing in some figures. Some key information is provided in the captions only but is missing in the plots themselves, which makes it hard to interpret the results. See specific comments for more details.

4. The paper should be reviewed with regard to grammatical aspects. Many sentences are very long and hard to read.

Specific comments:

Page 24673, line 2: another parenthesis “)” is missing behind “(2004)”.

Page 24673, line 13: Explain which kinds of correlations are meant here.

Page 24673, lines 21-25: Include references for the different instruments.

Page 24673, line 29, “only near the top of the cloud”: To which extent are the inner parts of the clouds considered by these methods?

Page 24674, end of introduction: An additional paragraph should be included (e.g., between first and second paragraph) which should explain what has been done specifically in the present study and what the improvements over the earlier studies are.

Page 24674, lines 3-6: The name CloudSat is mentioned in the title but is not mentioned here. It should be included in the discussion or the title needs to be changed.

Page 24674, line 9: Full stop “.” instead of comma behind “Sect 4”.

Page 24674, line 22: replace “L2” by “level 2”. Replace “water” by “water vapour”, if appropriate.

Section 2.1: Many different data sets are described in paragraphs 2 and 3 of this

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section. It is hard to overview how the data sets are used and how they interact. To understand the retrieval operations, it would be helpful for the reader if a schematic is included, e.g. in terms of a flow chart, which shows the different input data sets, the different steps of operation, and the resulting kind of output data.

Page 24675, line 2: The “proximity recognition” should be explained in more detail.

Page 24675, line 10: It would be helpful if some more details of the X<sup>2</sup> method could be provided here since its application seems to be one of the essential operations in the retrieval.

Page 24678, lines 7-8: Replace “large” (in line 8 and line 9) by “larger”. For readers which are not familiar with cloud radiative transfer issues, it should be explained how emissivity and extinction are related and why the extinction changes while the emissivity stays constant. An appropriate reference should be provided.

Page 24678, line 10: Replace “emissivities” by “emissivity”.

Page 24678, line 20-22: Figure 1 reveals that for a specific emissivity and a certain IWP also a specific effective diameter occurs. How can De vary, with constant emissivity and IWP?

Section 2.2.2: It should be explained in more detail how the De-IWP couple is derived. Is equation 3 used to minimize the deviation of measured and calculated emissivities? If so, it should be explained how the minimization is realized numerically. It should be explained how the minimization handles non-unique solutions for De-IWP (how is the optimal solution with smallest emissivity differences found?) The proximity recognition technique (is this the minimization?) should be explained and an appropriate reference should be included.

Page 24680, lines 14-17: Why do you only keep situations with overcast AMSU golf balls? A reference to section 3.1 could be included here.

Page 24681: With T<sub>s</sub>=300K and a lapse rate of 6.5K/km, a temperature T<sub>cloud</sub> of 235K

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would be obtained instead of 237K.

Page 24682, line 9: Replace 'The first sensitivity study concerns' by 'Additional sensitivity studies concern', since section 3.2 already deals with sensitivity studies.

Section 3.2, paragraph 1: A discussion of the differences between the results obtained for complex and pristine shapes shown in Table 1 is missing.

Page 24683, line 9: A parenthesis is missing behind '1999'. It should be explained what is meant with 'these two cloud properties' (probably IWP and De).

Page 24683, line 10: 'Stable solutions' should be explained.

Page 24683, line 13: The difference between emissivity and effective emissivity is not explained in the manuscript. The two terms are mixed up several times.

Page 24683, line 18: Replace 'the retrieval is not sensitive' by 'the sensitivity of the retrieval is low' or similar, since there actually is a small sensitivity.

Page 24683, line 23: Replace 'observe' by 'recognize', or similar. 'Observe' in this context would imply observations of the atmosphere.

Page 24683, line 25: Replace 'as well as' by 'This is similar for'.

Page 24684, line 6: Replace 'the same' by 'similar' and start new sentence: 'The behaviour ...'

Page 24684, line 13: 'Wrong atmospheric profile' of which quantity?

Section 4.2, discussion of Fig.6: Why is the sum of the different fractions smaller than one? Because the shape was not determined for all clouds? Should be explained.

Page 24685, line 2: Replace 'columns-like' by 'column-like'.

Page 24685, line 3: Replace 'only' by 'preferably'.

Page 24685, line 19: Replace 'in general' by 'generally'.

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Page 24686, lines 1-2: Skip 'are not Gaussian and'.

Page 24686, line 23: Replace 'observed in' by 'revealed by'.

Page 24687, line 15: Replace 'fraction' by 'fraction of'.

Page 24687, line 17: Begin new paragraph after next sentence (start paragraph with 'Figure 12 ...').

Page 24687, line 17: Replace 'averages' by 'corresponding averages'.

Section 5.1, end of last paragraph: Include discussion on the De distributions.

Page 24688, lines 12-15, 'The vertical extent of the uppermost ST-HICs ...': Where is this shown? The figure does not distinguish between multilayer and single layer clouds. As a way out, '(not shown)' could be included in the text.

Section 5.2.2, headline: Replace 'with' by 'on'.

Page 24690, line 1: Replace 'distributions' by 'frequency distributions'.

Page 24690, lines 2-4, 'We also include results ...': I miss these results in the figure.

Page 24691, line 12: Replace '20' by 'about 20'.

Page 24692, line 2: Replace 'in tropics and' by 'in the tropics and the'.

Page 24692, line 12: 'De varies only 10 to 20  $\mu\text{m}$  ...'. I do not understand this since the variation of De revealed by Figure 16 is larger.

Page 24692, line 14: Replace 'more important' by 'better suited to parameterize De', if appropriate.

Page 24692, lines 17-18: 'because IWP and temperature present a weak dependence ...'. This explanation is not clear to me and should be discussed in more detail.

Page 24693: Include references (examples) for 'Some GCMs use a parameterization ...'.

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Page 24693, last sentence of paragraph 5.4: Replace 'between De and IWP' by 'of De by IWP'.

Page 24694, line 5: 4A-OP was not yet explained. Only 4A was mentioned in section 2.2.1.

Page 24695, line 8: Replace 'on' by 'of'.

Page 24695, line 14: 'The large extent . . .'. It is not clear what is meant here.

Page 24695, line 26: Replace 'between De and IWP' by 'of De driven by IWP'.

Table 4: The caption should explain which quantities are shown in the table and the symbols and abbreviations used should be explained. The values for Delta z presented in the table are not consistent with figure 13.

Figure 1: Replace 'De (um)' by 'De ( $\mu\text{m}$ )'

Figure 2: The line types used for columns are different in the figure and the legend. The black squares are hardly visible. The channels could also be shown by marking the wavelengths by vertical lines through the plots.

Figure 3: The difference between emissivity and effective emissivity should be explained.

Figure 4: Explain more details directly in the figure. The figures should be more or less interpretable without reading the caption. Otherwise the figure is hard to interpret. Caption: The 'left side' and 'right side' plots are mentioned but the figure has three columns. The latitude bands have to be explained. Replace 'peiod 2007-2008' by 'period 2007-2008'.

Figure 5: Explain vertical lines in the caption.

Figure 7: Replace 'distributions' by 'frequency distributions'. Include 'ocean' and 'land' directly in the figure (at top of plots).

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Figures 9 , 10, and 13: Enlarge numbers of the scales.

Figure 10: With regard to the crystal shapes it is not clear what is shown in the figure. Are these the most frequent shapes? It is not clear why in a specific region only one specific shape should occur.

Figure 11, caption: The figure doesn't show a correlation (in a mathematical sense). Replace by 'Dependence'. Write 'Fraction of aggregate-like . . . dependent on . . .'.

Figure 12: Replace 'distributions' by 'Frequency distributions'.

Figure 13: The plots are too small. I cannot read the numbers and texts. The plot does not show correlations. Write 'Dependence of . . . on . . .'. Explain symbols directly in the plots.

Figure 15: The plots are too small. Replace 'distributions' by 'frequency distributions'. Replace 'optical thickness' by 'emissivity', if appropriate (since results are shown for different emissivities).

Figure 16: The symbols in the plots are much too small to be interpreted. They are much smaller than the corresponding symbols in the legend. The text is also too small. The figure doesn't show a correlation (in a mathematical sense). Replace by 'dependence'. Explain latitude bands in detail (which latitudes separate the bands).

Figure 17: Enlarge texts. Caption: The figure doesn't show a correlation (in a mathematical sense). Replace with 'dependence'. Replace 'global' by 'global annual'. The figure only shows the in-situ data (fit) from McFarquhar et al. (2003). Could the other in-situ data mentioned in section 5.4 also be shown here?

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 24671, 2011.

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