

Interactive comment on “Scale dependence of cirrus heterogeneity effects. Part I: MODIS thermal infrared channels” by Thomas Fauchez et al.

Anonymous Referee #2

Received and published: 19 March 2017

The authors present the impact of the horizontal heterogeneity of cirrus clouds on TOA brightness temperatures for 4 TIR MODIS channels. The study is based on a “realistic” cirrus case simulated using the 3DCLOUD model, MODIS Collection 6 ice crystal properties, and the 3DMCPOL radiative transfer code. This study discusses the impact of the plane parallel homogeneous bias (PPHB) and of the horizontal radiative transport (HRT) in various conditions of optical depth, optical depth inhomogeneity, and viewing angles. The paper also discusses the optimum horizontal resolution that minimizes the horizontal heterogeneity effects on TOA brightness temperature.

General comments:

The simulations and the results are solid. The simulated cirrus case is well adapted to illustrate the PPHB and the HRT. However, the impact of this choice on the conclusions

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of the paper should be discussed. It would be important to know to what extent these results could be generalized. The main characteristics of the simulated cloud should be given in the abstract (lines 7-9).

The reasoning and the story are sometimes difficult to follow. Introductory and linking sentences would be sometimes helpful for the clarity of the manuscript.

My recommendation is to publish this manuscript after clarification on the several points listed above and hereafter.

1) Title:

The title could specify that this paper discusses cirrus heterogeneity effects on TOA brightness temperatures. “cirrus heterogeneity effects” is too vague, in my opinion.

2) Goal of the paper:

Page 3, lines 17 to 21: Please explain the choice of these 4 TIR channels. In which MODIS algorithm(s) are they used and what are the retrieved geophysical parameters? “. . . the impact of horizontal heterogeneity. . .” Please specify impact on which quantity (TOA BT, optical depth, CED, other?).

3) Realistic cirrus case:

The rationale for the choice of the “realistic” cirrus case should be clearly presented. Table 1 should be presented and discussed in more detail. I agree that assuming a “constant” CED of 20 μm (page 6, lines 9-12) is “realistic”, but it is not typical nor statistically representative. The fact that TIR techniques are often limited to CED between 5 and 50 μm (page 6, line 10) clearly does not mean that all CED are so small (as shown in Table 1). Please clarify the rationale.

The impact of this choice on the conclusions of the paper should be discussed. In particular, how does it impact the highlighted difference between the 8.52 μm channel and the three other channels?

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Page1, line 7: “A unique but realistic cirrus case is simulated...”: Why is the cirrus case “unique”? Do you mean that only one case is simulated?

4)Averaging and aggregation:

Please define “averaging” and “aggregation”, and use consistent terms throughout the paper. Below are some examples (there are more in the text):

Page 7: line 17: “...averaged to the scale being considered...”. Please detail the averaging process. Which parameter?

Page 7, line 26: “..aggregation..” Please explain what “aggregation” means.

Page 7, line 30 : “..the averaged BT..” Are you averaging BT? I am surprised because the observations are radiances (same comment page 10, line 8).

Page 10, line 7: “, while 1-D BTs are directly computed at the xkm scale after aggregating the 50 m optical thickness” My understanding is that 1-D BT are computed using an averaged optical depth. Is is what you mean?

5)Other comments (mostly for clarification):

Page 3, lines 24-25: “we describe the heterogeneity and 3-D effects” For more clarity, it is suggested to specify PPHB and IPAE (or horizontal radiative transport).

Page 5, line 9: Figure 1, caption: what is ‘Cirrus 1’?

Page 5, line 29: “For the cirrus used in this study...” Is it cirrus 1 listed in Table 1? Please clarify. Introduce Table 1 earlier. The references listed in Table 1 should be presented and discussed in the text.

Page 5, line 34: ‘...vertical variability of the geometrical and optical thickness..’ Please clarify. I don’t understand the notion of vertical variability of such quantities.

Page 6, line 3: for more clarity, title of Sect. 2.2 could be “ice crystal optical properties”.

Page 6, line 4: “cirrus optical property parametrization”: not entirely clear to me...what

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about “bulk scattering properties? Is there really a parametrization?

Page 6, lines 5-6: “Note that TIR...between 5 and 50 μm ”. Why this sentence here?

Page 6, lines 7- 9: “...Holz et al. (2015) better consistency between ...the IR-split-window technique...and (VNIR/SWIR/MWIR) techniques, as well as with lidar retrievals...”. This sentence is very confusing and I do not think that it is entirely correct. You are talking about the consistency between techniques and retrievals. Are you talking about retrieval of optical depth, or CED, or both? “Split-window technique” suggests CED. “Lidar retrievals” suggests “optical depth”. Holz et al. (2015) discuss only optical depths, but not CED. Please clarify.

Page 6, line 32: “... as will be explained...” Specify in which section.

Page 7, line 21: Figure 5 According to the caption, this is now optical depth at 0.86 μm not introduced earlier. Please explain.

Page 7, line 33: “decreasing” resolution can be misunderstood. The notion of coarse or fine resolution would avoid any confusion.

Page 8, lines 8-13: The authors are discussing Fig. 5, and I am surprised to find these 6 lines with results from another paper. Why not discuss BT 3-D – BT 1D from Fig. 5?

HRT section: please re-organize the text for more clarity. - Lines 1-2 page 9 (HRT effect only when BT from 3-D and 1-D at the same resolution of 50 m) should be at the beginning of this sub-section, because important for a good understanding of the discussion. - Figure 6: it is suggested to add arrows to point to the areas of specific interest discussed in the text. A second panel showing BT differences between 3-D and 1-D could be helpful. - page 8, line 29: can you give an example of cloud optical property retrievals that use a combination of the 8.52 μm and 13.36 μm channels? - Figure 6, caption: I don’t see the BTs computed at 11.01 and 12.03 μm . Lines 5-6, page 9 (“as seen in Fig. 6...”) could be useful earlier in text the when Fig. 6 is described. - page 9, line 8: “..negative ΔBT values dominate because fewer FLIPs

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come from thick and cold areas, decreasing the BT of these pixels..". Why "fewer"?
- Page 9, lines 12-25 and Figure 7: for more clarity, it is suggested to superimpose averaged ΔBT (FLIP) vs optical depth. These simulations are using $CED=20 \mu m$. Would the difference between the $8.52 \mu m$ channel and the 3 other channels be as important for a larger CED, for instance $100 \mu m$? I think that it should be discussed. -
Page 9, line 25: In my opinion, this sentence is a little weird.

Page 12, line 1; " We can also see in Fig. 8 (b)" Are you actually discussing both Fig. 8a and 8b? Please clarify.

Page 12, lines 7-8: "... When the effects on BTs are roughly the same for all channels, the MAD... impact on retrieved products may be mitigated (not show here) " Please develop. Are your referring for instance to larger CED? If yes, I think that it should be shown.

Page 12, line 14 to page 13, line 24: - The total number of pixels found in the 4 optical thickness categories is 52131. I was expecting $40000+10000+1600+400+100+40+16+1= 52157$, which is close. Please explain the difference between these 2 numbers. - The total number of pixels found in the 4 optical thickness heterogeneity parameters categories is 12129. I was expecting $10000+1600+400+100+40+16+1= 12157$, which is close. Please explain. How is the heterogeneity parameter computed? Is the definition given page 13 line 4 the same as page 5, line 16? I am not sure because the reference is different. Please clarify.

Page 14, lines 11-13: I don't fully understand. Looking at Fig.12, I would say that the saturation in BT appears at about 8 at 30 degrees and at about 9 at 0 degrees. Please clarify and perhaps illustrate the "saturation" in Fig.12.

Page 14, line 22: "...We can also see this in Fig. 13 (f) where.." Please describe Fig.13 first. Fig. 13 and Fig. 12 could actually be shown and discussed before Fig. 11.

6) Technical comments:

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Page 1, line 18: in Earth's climate and radiative budget

Page 2, line 1: "cirrus clouds reflect part of the incident solar radiation into space due, but this albedo effect is generally negligible..." It looks like something is missing

Page 2, lines 5 and 6: "by taking accurate observations of their optical properties" Please rephrase.

Page 2, line 8: "from microwave to visible ranges" Please specify, for instance spectral ranges.

Page 2, line 35: Top Of Atmosphere (TOA): not consistent with page 1, line 2.

Page 3, line 6: (under $20 \mu m$). Please specify. Do you mean CED under $20 \mu m$?

Page 3, lines 17-18: this sentence should be rephrased.

Page 3, lines 22-24: the long sentence is confusing. As it is, I read that the ice crystal model used in MOD06 is simulated by the 3DCLOUD model.

Page 7, line 23: "we see that 3-D and 1-D BTs, decrease " delete comma

Page 8, line 2: "...Fauchez et al. (2012, 2014) have shown..."

Page 9, line 4: "highly asymmetric regarding" I don't understand.

Page 9, line 7: " for very largest values.." : for the largest values? Please quantify.

Page 9, line 19: " the emission temperature between large optical thicknesses". I don't understand.

Page 11, line 23: "...rapidelly " rapidly

Page 11, line 24: "...through this is more clearly visible at 500 ". even though?

Page 11, line 32: " the single scattering albedo is about 0.3 larger than the value ". Please rephrase.

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Page 12, line 32: “. . .we decided pixels. . .” Please rephrase

Page 13, line 13: “ in on the figures “ Please correct

Page 14, line 2:” and may be generalize to cirrus with similar patterns.” Please correct
generalized

Interactive comment on Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2017-51, 2017.