# *Interactive comment on* "Cloud heterogeneity effects on cloud and aerosol above cloud properties retrieved from simulated total and polarized reflectances" *by* Céline Cornet et al.

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============== General comments:

The goal of the study is to quantify the impact of subpixel cloud heterogeneity on retrievals of various cloud and aerosol parameters. Four clouds with different heterogeneities are compared: a homogeneous, a flat, a bumpy, and a fractional cloud. The procedure is clear:

- The clouds are simulated using the 3DCLOUD cloud model at a 50x50-m resolution.

- Their reflectances are computed using the 3DMCPOL radiative transfer model.

- These reflectances are averaged to 7x7-km resolution to mimic POLDER observations.

- The POLDER operational algorithm is applied to retrieve cloud and aerosol parameters.

- The retrieval results are compared to the truth.

- Interpretation of intermediate results is provided, mostly by comparison to the homogenous cloud.

This work is very relevant for the interpretation of POLDER and future 3MI data, as well as for the optimization of the retrieval algorithm to minimize retrieval bias, e.g. by weighting angular information. The paper is well written, the work is put into context, and the various intermediate results and interpretation thereof ensure good understanding for the reader.

============== Specific comments:

To draw the right conclusions on the effects of heterogeneity, it is important that the clouds are as similar as possible, except for their heterogeneity. Listed below are comments related to the choice of simulation parameters:

Page 4, line 23-24: Why are the rho's for the fractional cloud not closer to 0.6 for better comparison to the flat and bumpy cloud?

Page 4, line 28: How are the flat and bumpy clouds parameterized? What are the settings for cloud top height, etc?

Page 5, line 6: Why a black surface for polarized reflectances? The surface seems important in particular for the fractional cloud. At certain angles it can be very bright in polarization (sun glint).

Page 5, line 15; Page 18, CTOP: Max(z) / min(z) for cloud top height / bottom of the 3D clouds does not seem like a representative value to me. See Fig. 1: realistic values are

closer to 1.2 (Fig. 1 only shows y=3.5 whereas the realistic value should be computed from all y). Better values should be used, or at least the retrieval results should be compared to more than just max(z).

Page 11, line 3-5: This belongs in Section 2 to put the synthetic clouds into perspective. Apparently, the fractional cloud with stdev(COT)=7 exceeds POLDER's homogeneity limit of 5. The fractional cloud also gives the worst results compared to the flat and bumpy clouds. I think it would be good if the choice for stdev(COT)=7 would be justified in Section 2, and if at least rough numbers are given for how the results compare to a similar fractional cloud with stdev(COT)=5.

============== Detailed comments:

============== Title: "Assessment of A on B" is not correct. Suggestion: "Effects of Cloud Heterogeneity on the Multi-angular Total and Polarized Reflectances from POLDER3/PARASOL, and impact on retrievals of cloud and aerosol above cloud parameters"

============== Abstract: 18: remove "the well-known"

27: remove "well-known"

31-32: "Above the ... can be underestimated ... plane-parallel bias." Specify angles. Be more specific than "can be", because that sounds like "can also not be".

============== Page 2:

13: "implemented or under implementation" Which ones are implemented and which are under implementation?

19: "conducts to" -> "leads to"

27: "AVHRR" spell out first time

27: "solar zenith angle elevation" -> "solar zenith angle"

28: "disseminating through the clouds along the cloud side (or bump), and leads to" -> "received along the cloud side (or bump) and disseminated through the cloud, leading to"

30: "which depends on" -> "which depend on"

============== Page 3:

4: "under and/or overestimated" -> "under- or overestimated"

9: "from nadir (oblique view)" -> "for nadir (oblique) viewing"

10: "made in case of ice" -> "made for ice"

10: "IR" spell out

11: "or or from" -> "or from"

16: "1020nm" -> "1020 nm" Fix this throughout paper.

20: "solar illumination, lower" -> "solar illumination: lower"

22: "Reflectances simulations" -> "Reflectance simulations"

26: "Accordingly, total but also polarized" -> "Total and polarized"

28: "in section 2" -> "in Section 2" Capitalize Section, Table, Figure throughout paper.

31: "Contrarily to" -> "Contrary to"

34: "reflectances measurements" -> "reflectance measurements"

34: "droplets retrievals" -> "droplet retrievals"

============== Page 4:

1: "have, been" -> "have been"

3: "Consequences ... on" -> "Consequences ... for"

4: "variance cloud" -> "variance, and cloud"

6: "also studied presented" -> "also presented"

7: "synthetic generated" -> "synthetically generated"

13: "optical depth COT" -> "optical thickness COT"

13: "inhomogeneity parameter" -> "heterogeneity parameter" (this word is used later on)

17: "to constrain the intensity of the mean" -> "to constrain the mean"

19: "clouds fields" -> "cloud fields"

21: "heterogeneity parameter . . . of 0.6" -> "heterogeneity parameter across the 140x140 pixels of rho=0.6"

23-24: Why are the rho's for the fractional cloud not closer to 0.6 for better comparison to the flat and bumpy cloud?

26: "which is supposed, in real cloud, to be more important than" Reference? How much more important? Which retrieval parameters are affected?

27: "cloud size" -> "cloud droplet size"

28: How are the flat and bumpy clouds parameterized? What are the settings for cloud top height, etc?

=============== Page 5:

1. "I(theta,phi) are" -> "I(theta,phi) is"

1. steradian "sr" with small "s"

5. "7 m.s-1" "-1" superscript

6. Why a black surface for polarized reflectances? The surface seems important in

particular for the fractional cloud. At certain angles it can be very bright in polarization (sun glint).

8: "Figure 3" -> "Figure 2" I propose to swap Figures 2 and 3, because currently Fig. 3 is mentioned before Fig. 2. Also swap all the references to Figs. 2 and 3.

9: "Polarized reflectances fields" -> "Polarized reflectance fields"

11: "reflectances fields" -> "reflectance fields"

14: "the equivalent homogenous cloud. " -> "three equivalent homogenous clouds, which are subsequently used for retrieval to act as references for the inhomogenous cloud retrievals. The COT of the equivalent homogenous clouds is the mean COT of the heterogenous clouds, and their cloud top and base altitudes correspond to the maximum and minimum altitude of the respective homogenous clouds."

15: Max(z) / min(z) for cloud top height / bottom of the 3D clouds does not seem like a representative value to me. See Fig. 1: realistic values are closer to 1.2 (Fig. 1 only shows y=3.5 whereas the realistic value should be computed from all y). Better values should be used, or at least the retrieval results should be compared to more than just max(z).

17: "e.g. the" -> "namely the"

18: "algorithm retrieves" Does it really retrieve cloud cover, or should it say "algorithm assumes"?

21: "independently of" -> "independent of"

21: "assumption (e.g. 1D" -> "assumption (1D"

22: "the direct simulation" -> "the forward simulation"

23-24: "but not into our" -> "but not in our"

26: remove "well-known". Rather spend one sentence explaining it.

============== Page 6:

4: "differences are important according to the view direction" -> "significant differences between view angles are observed"

10: "pretty well" . . .

11: "the sun making the" -> "the Sun make the" Capitalize Sun consistently.

11: "brighter than in" -> "brighter, in contrast to"

11-12: remove "on the contrary"

13: "seems thus" -> "thus seems"

22-23: "from every view" -> "from all view"

28: "optical thickness lower than" -> "optical thickness, lower than"

33: "cloud fields" -> "cloud field"

============== Page 7:

4: "the one used for the" -> "the retrieved values using the"

7: "the relative is" -> "the relative error is"

8: "quite low" -> "low"

10: delete "(curvature degree)"

10: "in function of" -> "as a function of"

11: "It involves" -> "It implies"

11: "bias is not" -> "bias are not"

12: "2.35 %" -> "2.35%"

15: I found the paragraph about albedo hard to read. If I understand correctly, the train

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of reasoning is: - In order to retrieve cloud albedo, the POLDER retrieval algorithm first retrieves COT from multi-angle reflectances, then does a forward computation from COT to albedo. - A heterogeneous cloud has lower reflectance than a homogenous cloud with the same (mean) cloud optical depth, due to plane-parallel bias. - The POLDER algorithm will thus retrieve a COT that is too low. - From that too-low COT, the POLDER forward computation will produce an albedo that is also too low if the cloud were really a homogeneous cloud, but since it is really a heterogeneous cloud with a lower albedo due to plane-parallel bias, the POLDER-retrieved albedo is actually very close. - To compare this retrieval result to the "truth", the actual albedos are directly calculated from the 3DMCPOL radiances. It would be helpful if this could be explained in a more direct way, e.g. by preparing the reader by summarizing this at the beginning of the paragraph, before going into the details. Other suggestions for textual changes:

- Page 6, line 26: "3D reflectances and from 1D reflectances are not comparable" -> "a heterogeneous cloud are not the same as the ones retrieved from an equivalent homogenous cloud"

- Page 6, line 27: "simulated 3D reflectances are lower than the 1D ones, the retrieved optical thickness is an effective optical thickness, lower than the averaged one (Figure 2)" -> "reflectances off of a heterogenous cloud are lower than the reflectances off of an equivalent homogenous cloud with the same (mean) COT, leading to an effective optical thickness, which is lower than the mean optical thickness."

============== Page 7 (contd):

16: "consequences on" -> "consequences for"

19: "As previously" -> "As explained before"

21: "Figure 3" -> "Figure 2"

22: "saturate" -> "level off"

24: "comparing to" -> "compared to"

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24: "reflectances fiels" -> "reflectance fields"

26: "facing to the sun" -> "facing the Sun"

27-29: If 41%, 52%, and 38% of the pixels are considered "a large part", aren't the remaining 59%, 48%, 62% even larger parts? I don't understand.

31: "shadows area" -> "shadow areas"

32: "reflectances pictures" -> "reflectance images"

=============== Page 8:

3: "we plotted" -> "we plot"

3: "as function of" -> "as a function of"

5: "cloud appear" -> "clouds appear"

6: "cloudbow directions" -> "cloudbow direction"

7: "As for total reflectances" -> "Similar to the total reflectances"

8: "cloud respectively" -> "cloud, respectively"

15: "are consequently" -> "is consequently"

18: "become thus" -> "thus become"

20-21: "thus quite important" -> "thus important"

22: "no present" -> "not present"

26: "surnumerary" -> "supernumerary" Fix this throughout paper.

32: "7.5% error" and "5% error" Errors in what?

=============== Page 9:

1-2: "As previously, we use again" -> "We use again"

3: "differences on" -> "differences in"

3: "quite large" -> "large"

5: "table" -> "Table"

6: "surnumerary" -> "supernumerary"

8: "wavelength are" -> "wavelengths are"

9: "that, the" -> "that the"

10: "more important" What does it mean?

11: "does even not" -> "does not even"

19: "in forward" -> "in the forward"

20: "that cloud" -> "that the cloud"

26: "Figure 6" -> "Figure 5"

28: "impacted but the" -> "impacted by the"

30: "3D clouds effects" -> "3D cloud effects"

33: "Figure 5" -> "Figure 6" I propose to swap Figures 5 and 6, because currently Fig. 6 is mentioned before Fig. 5. Also swap all the references to Figs. 5 and 6.

=============== Page 10:

3: "vary with" -> "varies with"

5: "Figure 5" -> "Figure 6"

7: "biomass-burning layer" -> "biomass-burning aerosol layer"

10: "in function" -> "as a function"

11: "Figure 6" -> "Figure 5"

12: "heterogeneities effects" -> "heterogeneity effects"

13: "section" -> "Section"

17: "plane parallel" -> "plane-parallel"

25: "between 60" -> "between scattering angles of 60"

26: "which is comparable to" -> "which resembles"

28: "ones at 60 deg" -> "ones at 60 deg (see Fig. 2)"

28-29: "3D effects . . . because of the plane-parallel bias" So far 3D effects was used to refer to brightening / shadowing and not for plane-parallel bias. I would not use 3D effects in this sentence, because this is really about plane-parallel bias.

29: "corresponds to" -> "resembles"

31: "at the two" -> "at two"

31-32: "corresponds in the retrieval to the best-selected model" What does this mean? In the next 2 sentences it looks like the Angstrom exponent is directly calculated instead of taken from a best-selected model.

32: "close for" -> "similar for"

33: "Angstrom" Add dots on "o". Fix this throughout paper.

============== Page 11:

1: "consists in" -> "consist in"

2: "angstrom" -> "Angstrom" incl. dots

5: "is 7 so above" -> "is 7, which is above the homogeneity limit for POLDER."

3-5: This belongs in Section 2 to put the synthetic clouds into perspective. Apparently, the fractional cloud with stdev(COT)=7 exceeds POLDER's homogeneity limit of 5. The

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fractional cloud also gives the worst results compared to the flat and bumpy clouds. I think it would be good if the choice for stdev(COT)=7 would be justified in Section 2, and if at least rough numbers are given for how the results compare to a similar fractional cloud with stdev(COT)=5.

8: "retrieve values" -> "retrieved values"

8: "of optical" -> "of cloud optical"

9: "effective radius" -> "droplet effective radius"

10: "POLDER radiometer" -> "POLDER radiometer and polarimeter"

18: "yields to" -> "yields"

20: "to the shadowing" -> "to shadowing"

20: "maximal ? bias" ?!?

25: "lead to" -> "leads to"

26: "reduced the" -> "reduce the"

27: "are not too much affected" -> "ard hardly affected"

28: "surnumerary" -> "supernumerary"

32: "retrieve non-negligible" -> "retrieves non-negligible"

32: "value when" -> "values when"

32: "only a limited range of scattering angles is available" -> "only larger scattering angles are available" Important difference!

============== Page 12:

3: remove "" around "shadowing effects"

4: "and since the information of the" -> "and the"

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10: "also obviously" -> "also"

14: "platform than the" -> "platform as the"

============== Page 17:

40 deg is missing in top row

============== Page 18:

1: "Fraction-al" -> "Fractional"

CTOP: Max(z) for the cloud top height of the 3D clouds does not seem like a representative value to me. See Fig. 1: realistic values are closer to 1.2 (I can only see y=3.5 but the realistic value should be computed from all y). Same for min(x) for bottom. Better values should be used, or at least the retrieval results should be compared to more than just max(z).

Caption: "Effective radius" -> "Cloud droplet effective radius"

============== Page 19:

"Angstrom" add dots

============== Page 21:

"Figure 2" -> "Figure 3"

6: "(1D) COT" -> "(1D) COT."

Plot symbols all look alike. (Symbol missing in "1D sza20".)

Hard to distinguish different shades of blue

============== Page 22:

"Figure 3" -> "Figure 2"

Minus sign in titles (e.g. Rtot - Cloudbow) is confusing.

C13

5: "the forward scattering" -> "the cloudbow scattering"

I don't understand the exact meaning of the yellow color. And what does the black/grey mean?

============== Page 23:

Hard to distinguish two shades of blue.

4: "Polarized reflectances" -> "Polarized reflectance"

4: delete "(SZA=60 deg)

4: "in function of the scattering" -> "as a function of scattering"

6: "solar incidence" -> "solar zenith angle"

============== Page 24:

"Figure 5" -> "Figure 6"

============== Page 25:

"Figure 6" -> "Figure 5"

"reflectances in function" -> "reflectance as a function"

"solar incidence" -> "solar zenith angle"

Hard to distinguish shades of blue and red.