Reply to F. Xu

The authors would like to thank F Xu for its valuable comments and suggestions that allow to improve the paper.

Please, find below the answers to the comments

1) **The authors may double check Eq.(1) as it is more like a definition for bidirectional reflectance factors (BRF) instead of for "total reflectance"? In addition, to define polarized reflectance, it is better to use sqrt(Q^2+U^2+V^2) instead of "I" in Eq(1) for clarity.**

Right, we modified the definitions and wrote page 7;
From these 3D cloud fields, we simulated the total and polarized bidirectional reflectances function for the viewing zenith angle θ and the viewing azimuthal angle φ. By convenience, in the following, we call them total reflectance R and polarized reflectance Rp:

$$R(\theta,\varphi) = \frac{\pi . I(\theta,\varphi)}{F_0 cos\theta_0}$$

$$R_p(\theta,\varphi) = \frac{\pi}{cos\theta_0}\sqrt{Q^2(\theta,\varphi) + U^2(\theta,\varphi) + V^2(\theta,\varphi)}$$

where $I(\theta,\varphi), Q(\theta,\varphi), U(\theta,\varphi)$ *and* $V(\theta,\varphi)$ are the four Stokes parameters in W.m^{-2}.sr^{-1}, F_0 the solar flux in W.m-2 and θ_0 the solar zenith angle.

Code de champ modifié

Code de champ modifié

2) Does the AOT retrieval closure test use the simulated signals from the whole scattering angular range from 60 to 180 degree ? It can be observed from Figs. 4 and 6 that the 3D impact is more remarkable in the scattering angular ranges from 60 to 80 degrees and from 160 to 180 degrees. What if the authors try doing the aerosol optical thickness (AOT) retrieval using the signals from 80-160 degrees range only (where 1D RT apparently has less plane-parallel bias) and re-evaluating the 3D impact on AOT retrieval ? I assume the aerosol information residing in this reduced angular range may be good enough for AOT retrieval (and may result in reduced error).

3D effects are clearly visible for forward scattering geometries (i.e. scattering angle ranging between 60 and 80°) in case of low solar elevation (see figure 6). The scattering angle range sampled between 60-80° is not necessarily useful for an accurate retrieval of the above cloud AOT. So, reducing the use of forward scattering geometries restricted to scattering angle values larger than 60° will help in reducing retrieval errors in AOT. We will include it in the paper, thanks. However, other large errors due, to 3D effects, are also observed in the primary bow (around 140°) in case of fractional clouds that can be neglected.

We added in the conclusion section :
These results mainly show that 3D effects for fractional clouds are primarily significant at forward scattering geometries in case of low solar elevation (scattering angle < 80° and SZA of 60°) and in the rainbow region (scattering angle of about 140° +/- 5°). The range of scattering angles sampled between 60 and 80° is not necessarily useful for an accurate retrieval of the above cloud AOT. So, reducing the range of scattering angles to scattering angle values larger than 80° will help to reduce the errors associated with the AOT retrievals. The algorithm largely overestimates the AOT when the primary bow is included in the retrieval process and when forward and side scattering viewing geometries are not available. This result suggests that polarized measurements acquired for this configuration should not be used for AAC properties retrievals, at least with a retrieval algorithm based on 1D calculations.

3) For solar incidence angles 20 and 40 degrees, the cloudbow signals (e.g. in the principal plane) should appear in two sides around incidence ray. And their magnitudes should be somehow different. But such a difference is not observed in Figs. 4-6. Is this due to the signals at the same scattering angles are just averaged regardless of the difference in viewing angles ? It may be more clear if the authors plot both of them in those figures.

In Figures 4-6, (now Figures 5 to 7), we plotted only the figures for the case SZA=60° which allows to display all the scattering angular range (between 60 and 180°). Figure RC4-1 shows polarized reflectances for three solar incidence angles (left) and absolute difference between 1D and 3D polarized reflectances (right). For a same range of scattering angles, the effects of cloud heterogeneity are very similar for all the solar incidence angles, so we chose to plot only the graphs for SZA=60°. Note for SZA=20° and 40°, the two branches appear representing the two sides of the scattering angles around 180°.

We added it in the manuscript at the end of section 4-1:
Figures5 illustrate results obtained for simulations for SZA=60° with a scattering angular range between 60 and 180°. Note that for SZA = 20° and SZA = 40°, the plots are similar with a reduced scattering angular range that is between 100° and 180° for SZA=20° and between 80° and 180° for SZA=40°. Consequently, for SZA = 20 ° and SZA=40 ° the attenuation due to the plane-parallel bias is the main impact of the measurements.

And removed the sentence “3D cloud radiative effects are thus important, particularly in the forward direction, but it is important to note that such 3D effects are weaker for smaller SZA and almost not present for SZA=20°.” that speak about shadowing effects but may be confusing.

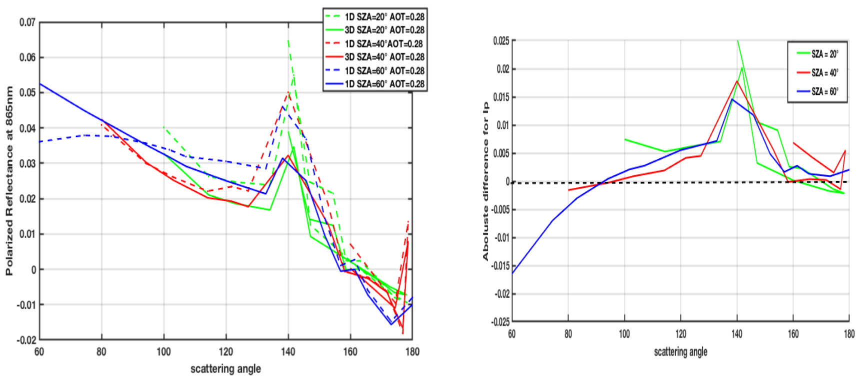

Figure RC4-1: (left) Polarized reflectances at 865nm as a function of scattering angle for three solar zenith angles. Dashed lines are for homogeneous cloud and solid for heterogenous cloud. The case presented is the one with a biomass burning aerosol layer above. (Right) Absolute differences between 3D and 1D polarized reflectances.

4) It may be necessary to describe a little more on the criterion for setting 50 m as the small scale (pixel scale). Is this set up due to the sufficiency in ensuring a) representativeness of cloud microphysical property variation and/or b) accuracy of cloud signals in a certain scale ?

The choice of pixel scale dimension is not a simple question. It depends on the studied scale, here it is a POLDER pixel that is 7 km x 7 km. We assumed that the description of sub-pixel variability at 50m is sufficient to simulate correctly POLDER observation. In addition, interaction between cloud and radiation can be estimated using the mean free path of the photon. For an homogeneous cloud, it is computed as the inverse of the extinction coefficient σ: $MFP = \frac{1}{\sigma} = \frac{H}{COT}$ where H is the geometrical thickness and COT the cloud optical thickness of the cloud. In the paper the mean COT is 10 and H≈700m, consequently the $MFP \approx 70m$ so above the 50m resolution and it is even larger in heterogeneous media (Davis and Marshak, 2004). Availability of computer memory and time computation were also considered for this choice .

We add:

We assumed that the description of the cloud fields at 50m is sufficient to simulate correctly the POLDER observation at 7 km x 7 km. Moreover, the interaction between cloud and radiation can be characterized by the mean free path (MFP) of the photon that is of the order of 70 m ($MFP = \frac{1}{\sigma} = \frac{H}{COT}$) for the equivalent homogeneous cloud and larger for heterogeneous cloud (Davis and Marshak, 2004). Availability of computer memory and time computations were also considered.