We are deeply grateful to the Reviewer for the time spent to carefully read our paper and for his constructive and relevant comments. They helped us to improve our article considerably.
Please find hereafter our point-by-point responses to the comments and suggested corrections.
Comments are in black, our responses in blue and the text modifications in green (in bold when only one part of the sentence was modified).
Note that the indicated line numbers correspond to the line numbers of the "track changes" version.

RC2:

Review of 'Cloud optical properties retrieval and associated uncertainties using multi-angular and multi-spectral measurements of the airborne radiometer OSIRIS'
By Christian Matar et al.

General comments
This paper describes an approach for the retrieval of cloud optical thickness and droplet effective radius from multi-angular and multi-spectral satellite measurements. In addition, estimates of the retrieval errors due to different error sources are presented. The main novelty is an attempt to estimate retrieval errors caused by deviations from vertically homogeneous profile and independent pixel assumptions. The topic is important and suitable for this journal. Overall the retrieval setup appears to be sound and the results are plausible. However, I do have some general concerns and questions that need to be addressed before this paper can be published.
• Only one case is studied, which limits the validity of the results. Retrieval errors, in particular those caused by deviations from homogeneous cloud and independent pixel assumptions, will depend on the scene. While discussing more cases may be outside the scope of the paper, these limitations at least need to be mentioned.

This point was also raised by the first reviewer. To clarify our objectives, we add a paragraph in the end of the introduction section :
"The aim of this paper is not to give an exhaustive view of the possible errors concerning optical thickness and effective radius retrievals but to simply introduce a method to derive the different sources of uncertainties from a specific case of data acquired during an airborne campaign. Uncertainties due to error measurements, to non retrieved parameters but also to the assumed forward model are considered. If generalized to several cloudy scenes, the partitioning of the errors can help to understand if and which non-retrieved parameters or forward model need to be optimized in order to reduce the global uncertainties of the retrieved cloud parameters."

• The paper gives a false impression of the current cloud optical and microphysical property algorithms. Firstly, most of these do consider measurement errors and produce retrieval error estimates (e.g., Platnick et al., 2017), unlike what is written in the abstract. Secondly, for many of these algorithms the total retrieval error has been separated into contributions from individual error sources (e.g., Walther and Heidinger, 2012), unlike what is written on page 10.

We apologize for these major omissions and thank the reviewer for giving us the references. We correct the text accordingly and add the corresponding citations.

In the abstract, we delete : "...and without considering measurement errors and the choice of ancillary data"

In the introduction, we replace line 120 "But most importantly it also lacks the ability to assess the uncertainties on the retrieved properties." by "In addition, until recently, the difficulty was to assess the uncertainties of the retrieved cloud properties. Platnick et al. (2017) succeeded to derive the total uncertainties of COT and Reff and to decompose the contribution of uncertainties from

measurement errors and from several non retrieved parameters, using covariance matrix and Jacobian computations from LUT."
"

In the introduction, line 137, we complete (in bold) the following sentence : "Therefore, it introduces the probability distribution of solutions where the retrieved parameter being the most probable, with an ability to extract **separately** uncertainties on the retrieved parameters **(Whalter et Heidinger, 2012)**."

We correct the false assertion page 10, we replace section 3-3 line 361 "The contribution of each type of error was not separated. To highlight their magnitude and better understand the sources of errors in cloud retrieval algorithms, we separate the contributions of each type of error"
by "Further, Walther and Heidinger (2012) use the optimal estimation framework to separate the contribution of measurement errors and several non retrieved parameters. In our work, a similar framework was used to separate the contribution of each type of uncertainties including also the forward model uncertainties to better quantify and understand the limitation of using simplify forward model in such cloud retrieval algorithm."

In the conclusion section, we add line 777:
"The uncertainties related to the non-retrieved parameters, in addition to the one related to measurement errors, have already been implemented since Collection 5 in MODIS operational algorithm through the computation of covariance matrix where Jacobian are derived from look-up table and was completed for Collection 6 (Platnick et al. 2017)."

• It is not clear why polarization measurements have not been included in the retrieval. It looks like these could, amongst others, further constrain the width of the size distribution, which has instead been fixed prior to the retrievals.

The OSIRIS instrument used for this study is under development in the Laboratoire d'Optique Atmosphérique. At the time of the CALIOSIRIS mission in 2014, the polarized measurements had calibration and straight light issues. The measurements were consequently not usable to do a quantitative retrieval.
We precise this issue, in section 2.2, line 218 : "At the time of the CALIOSIRIS campaign in 2014, the polarized channels presented calibration and stray light issues, which make use of the polarized measurements difficult for quantitative retrievals. In addition, the images from the two sensors were not well co-localized. Consequently, for this work, we use the two channels of the SWIR matrix, one almost non absorbing (1240 nm) and one absorbing (2200 nm) to have information on optical thickness and effective radius respectively."

Even if the polarized radiances were not used for the retrieval, we used an averaged value to determine the effective variance according to the number of the supernumerary bows. Figure 1 represents averaged polarized radiance measurements obtained with OSIRIS and simulated radiances, with an effective variance of 0.02, that has been selected.

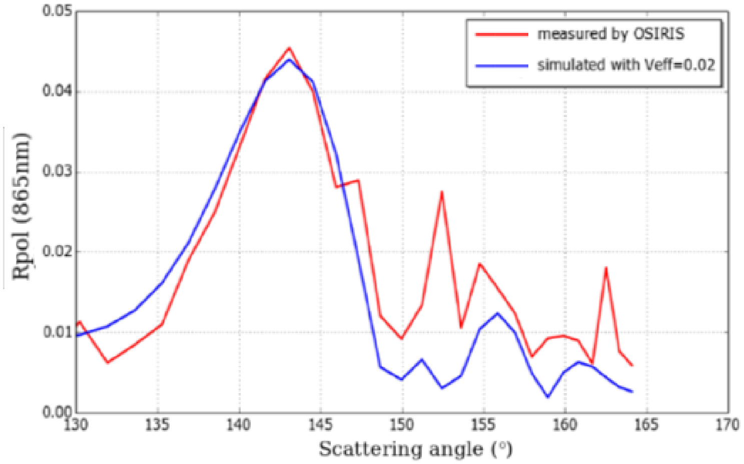

Figure 1 (not included in the paper) : Averaged polarized radiances measured by OSIRIS for a transect in the middle of the central image of CALIOSIRIS scene and simulated polarized radiances with an effective variance of water droplet distribution equal to 0.02 (in blue), as a function of the scattering angles.

We complete the sentence, line 428: "...we fixed a value of 0.02 based on the **number** of supernumerary bows in the polarized radiances **(not shown)**.
and line 430: As the value of V_{eff} was fixed using the polarization measurements of OSIRIS, this uncertainty is weak and is not representative of all clouds"
We add also in the analysis of the non retrieved parameters, line 577 : "We remind that we fixed the value of veff using multi-angular polarized measurements of OSIRIS, which leads to choose a weak uncertainty of veff (15%). However, if no information on veff is available in the measurements, the uncertainty should be higher and thus the errors due to the non-retrieved effective variance. Platnick et al. (2017) obtain 2% and 4% uncertainty for COT and Reff respectively for veff between 0.05 and 0.2."

• There are many textual mistakes and inaccuracies, of which only some examples have been included in this review.
We deeply thank the reviewer for his careful reading, the time spent to read the paper and apologize for the different mistakes. We correct it at our best.

Specific comments
Title: The paper only deals with liquid clouds. This must be included in the title.
Done
Abstract, L13: Clouds are really characterized by more properties than these two, e.g. the height of the top and base.
We agree, we add "...and additionally by geometric properties when specific information is available"
Abstract, L16: As mentioned above, measurement errors are considered in most retrieval algorithms.
The sentence was deleted, see above
Abstract, L26: I suggest not to refer to 'traditional' bi-spectral retrievals as 'MODIS-like methods' since these methods are not in any way specific to MODIS.
Done in the abstract and afterwards: "MODIS-like" is replaced by "mono-angular bispectral method"
P1, L36: The statement is still true so why not cite the latest IPCC report here?
Because the paper was written before its release. We update the reference
P2, L40: Measurements of emitted radiation are also important for cloud property retrievals.

We add it

P2, L50: Suggest to cite the more recent Platnick et al. (2017).

Done here and afterwards

P2, L51: The bi-spectral method is applied to many instruments, not 'in particular' to MODIS.

We replace "in particular" by "for example"

P3, L93: What is 'roughening of the radiative field'?

We complete the statement by adding "...by increasing or decreasing radiances compared to the prediction of the plane-parallel homogeneous clouds."

P4, L110/111: LUT-based retrieval algorithms are very well suited to produce retrieval error estimates. Please remove this statement.

We delete it and add "Platnick et al. (2017) succeeded to derive the total uncertainties of COT and Reff and to decompose the contribution of uncertainties from measurement errors and from several non retrieved parameters, using covariance matrix and Jacobian computations from LUT."

P4, L125: 'model': do you mean 'state'?

That's right, we modify it.

P5, Fig. 1: The figure and caption can be improved. Lines cannot be distinguished very well. What are 'optical matrices'? Spectral response functions is probably a more common term. And in what units are these plotted / how have they been scaled? The y-axis only says 'Transmittance'

The caption was completed: "Spectral wavelengths of VIS-NIR (left) and SWIR (right) **spectral response function of OSIRIS** optical **channels** without unit and normalized to unity. The dashed line corresponds to a typical atmospheric transmittance **in %**. The red-colored channels are used in this study (1240 and 2200 nm)."

P5, L163-165: Can you expand a bit on the viewing angles? Here numbers of 19 and 20 angles are mentioned, later it is 13 angles. How many angles were actually used for the retrievals? Can you also comment on how well the pixels for the different viewing angles are aligned? And if they are aligned at ground level, isn't there a spatial mismatch at cloud altitude?

19 or 20 angles corresponds to ground level colocalization.

We explain now in section 2.2, line 223 how the successive images are colocalized and mention that only 13 directions are used because of the cloud altitude : "In order to use the multi-angular capability of OSIRIS, successive images have to be colocalized. After subtracting the average of similar successive images to remove the angular effects, the colocalization is achieved by minimizing the root mean square difference of the radiances between each pair of successive images for different translations along the line and the column in the second image. The reference image is the central one of the sequence. Images with translations beyond its dimensions are ignored. Multi-angular radiances at the cloud level correspond in our case to 9 to 13 directions."

P6, L175: What is 'LIDAR-LNG'? And what is 'the vertical profile' in Fig. 2b? There is a whole series of vertical profiles.

We add a sentence and a reference to introduce the LIDAR-LNG: "The LNG (lidar aerosols nouvelle generation, Bruneau et al. 2015), a high spectral resolution airborne Lidar at 355nm, was also onboard the Falcon-20 aircraft along with OSIRIS during the airborne campaign."

And correct "the vertical profile**s of the backscattered signal"** in the text and in the caption of Figure 2

P6, L179: There are some 'intense white' but also quite dark parts in the reflectance image. Please explain what you mean.

There is not really an intense white signal but looking carefully, we can see the decomposition of the light between the scattering contour lines 140° and 150°. We correct the sentence and write, line 205 :

"The clouds backscatter total solar radiation **more intensely** in the cloudbow regions near 140°. The position of the cloudbow peak depends on the wavelength, resulting in the **decomposition of the light slightly visible between the 140° and 150° scattering angle contours.**"

P6, L182: Where do you see a 'white arc' in Fig. 2d? I only see an arc with rainbow colors.
We modify:
On the polarized image (Figure 2d), we observe a strongest directional signature of the signal, characteristic of scattering by spherical droplets s**howing a cloud bow clearly visible between about 140° and 150°**. ~~The main structure is the peak of polarization around 140° (known as the cloud bow), which forms a white arc in Figure 1d.~~

P6, L185: Could you perhaps indicate in the figure where the reflectance is (or may be) affected by sun glint?
We indicate in the text, line 213 :
"Since the solar zenith angle is 59°, the specular direction corresponds to a scattering angle of 62° in the solar plane (not visible in Figure 2) but the ocean wind enlarges the sun glint area, which enhances the radiances between the 70° and 80° scattering iso-contours."

P7, Fig. 2 and caption: Please use UTC (not local time) throughout to avoid confusion. What is the background in Fig. 2a? Please add explanation of red arrow in Fig. 2a and red rectangle in Fig. 2b in the caption and not (only) in the text. What is the half-visible text on top of that image? What are all the colors in the legend (most of which do not appear in the figure)? What is the blue bar on the left hand side of Fig. 2c? I don't think that 490-670-865 nm is a 'true-color' RGB composite. From which viewing angle are these radiances? The contours are not concentric.
The text at the top of the Fig2-a is only the filename of the image. We delete it. The blue bars on the left hand side of Fig 2C are related to the motion of the airborne between the different filters, which are on a rotating wheel. One OSIRIS image corresponds to several viewing angles represented by the iso-contours of the scattering angles. We add text on it in the legen. In addition, we modify the caption according to the comments (modifications in bold):
"Figure 2: Studied case on 24 October 2014 **at 10:02 UTC** (11:02 local time): (a) **In blue,** airplane trajectories for this day **above a MODIS/AQUA true color image**. **The red arrow corresponds to the studied segment** (b) Quicklook **of the backscattered signal** provided by the LIDAR-LNG around the observed scene. **The red rectangle corresponds to the scene studied** (c) OSIRIS ~~true color~~ RGB composite image, obtained from the total radiances at channels 490, 670, and 865 nm. **The blue bars on the left hand side of the images are due to the motion of the airborne between the capture of the image acquisitions of the different filters**
(d) OSIRIS ~~true color~~ RGB composite **image**, obtained from the polarized radiances at channels 490, 670, and 865 nm. The white ~~concentric~~ **iso-**contours in (c) and (d) represent the scattering iso-angles in a 10° step."

We also add in the text, the range of zenith angle, line 201:
"One OSIRIS image corresponds to several viewing angles. The zenith angle range from about 0° in the center of the image to 55° in the corner of the image."

P8, L205: It is stated that vector y has dimension n_y but in Eq. (8) it has dimension 2*n_y.
The dimension of the measurement vector is well n_y but the dimension in Eq. 8 (now eq. 9) should be n_theta. We correct it.
P8, L218: Please state explicitly how x_a and S_a are defined ('large' is too vague). We add section 3.2, line 309 : "The a priori state vector was set to [10,10µm] and the a priori covariance matrix S_a was to 10^8. The latter was chosen very large in order to favor the measurements in the determination of the state vector (no a priori constraint)."

P8, L225: Suggest to refer to page 10 where the Jacobian is explained. We refer now to Eq. 10

P9, L250-251: Is this justified? From Fig. 1 it looks like there is considerable absorption, in particular in the 2.2 micron channel, which needs to be accounted for.

We agree with the reviewer that for a proper and operational algorithm, atmospheric corrections should be done. Not accounting for atmospheric absorption in the short-wave infrared bands, lead to a smaller optical thickness and a larger effective radius.

We add, line 322: "As it is not completely true, the retrieved cloud optical thickness will be slightly underestimated and the effective radius slightly overestimated."

P9, L255: What are these 'measurements'?

It was not measurements but the NCEP National Centers for Environmental Prediction) atmospheric reanalysis. We correct :

"…with a fixed ocean wind speed based on ~~measurements~~ NCEP reanalysis of the National Oceanic and Atmospheric Administration (NOAA)"

P9, L258: What is 'independent column approximation'? Is it the same as the 'independent pixel approximation' introduced on page 2? If so, please use consistent terminology.

We correct and use independent pixel approximation, which is the usual term.

P9, L264-268: How do you calculate the Jacobian matrix?

We add, line 340 : "The Jacobian Matrix is computed using finite differences."

P10, L274: The off-diagonal terms are non-zero so it is confusing that they have been written here as zeros. Can you explain?

We assume that the uncertainties for the two terms are independent. Consequently, the off-diagonals matrix terms are null. We add line 353 : "In this formulation, we have assumed that the two terms of the state vector are independent, thus the off-diagonal terms of Sx are assumed to be zero."

P10, L276: Do you mean Eq. (7) instead of Eq. (10)?

Yes, corrected

P10, L287: As mentioned in the general comments, there have been other studies where the types of error were separated.

It is corrected with the insertion of the reference, Walther and Heidinger (2012). See general comments answers

P11, L300: There are other ways of calibration, e.g. vicarious.

We add : "...or can be vicarious calibration (e.g. Hagolle et al. 1999) by using natural or artificial sites on the surface of the Earth"

Hagolle O, Goloub, P, Deschamps, P-Y., Cosnefroy H., Briottet X., Bailleul T., Nicolas J-M, Parol F., Lafrance B., and Herman M., Results of POLDER in-flight calibration, IEEE Transactions on Geoscience and Remote Sensing, vol. 37, no. 3, doi: 10.1109/36.763266.

P11, L301: I would argue that calibration usually addresses systematic (not random) errors in the measurements.

Once the calibration process has been done and the correction coefficient applied, uncertainties remain. We correct the sentence : "The uncertainty of the measurements ~~determined during calibration~~ **remaining after the calibration process** are assumed random, uncorrelated between channels…"

P11, L304: According to Eq. (8) the dimension of the measurement vector is 2 n_y x 2 n_y (?)

Eq. 8 was corrected.

P11, L306: Do you have a motivation for taking a fixed 5% measurement error?

This error was estimated by the engineers working in the development of OSIRIS

P12, L341: This value of v_eff is quite small. Could you add some explanation on how it is determined? Wouldn't it be possible to include its determination in the overall retrieval (by including the polarization measurements in the observation vector)?
As explained in the general comment, the Veff value was chosen using the multi-angular polarized measurements of OSIRIS. They were not well calibrated but allow to see the number of supernumerary bows. As the help of polarized measurements allows to fix Veff value to 0.02, an uncertainty of 15% was added.
We add, line 428 : "..we fixed a value of 0.02 based on the **number** of supernumerary bows in the polarized radiances **(not shown)**."
and in the analysis of the non retrieved parameters, section 4, line 577 : "We remind that we fixed the value of veff using multi-angular polarized measurements of OSIRIS, which leads to choose a weak uncertainty of veff (15%). However, if no information on veff is available in the measurements, the uncertainty should be higher and thus the errors due to the non-retrieved effective variance. Platnick et al. (2017) obtain 2% and 4% uncertainty for COT and Reff respectively for a standard deviation from veff between 0.05 and 0.2."

P12, L336-343: In this case the cloud top height (and thickness) and effective variance can be determined very accurately. However, in 'real life' uncertainties will be much larger (e.g., if you have no lidar available). Wouldn't it therefore be better to work with larger uncertainties so that the resulting error estimates become more representative?
We agree, but as we answer to the first reviewer, our motivation was to present a method that can be applied to 3MI or any other sensors and not to give an overview of the range for each type of error.
The algorithm was implemented according to the information available during the CALIOSIRIS campaign. The LIDAR measurements was one of them. We add several paragraphs in the introduction and conclusion sections to clarify our objectives.
More specifically, concerning the uncertainties of the non-retrieved parameters we add line 418 :
"The values and the uncertainties of the fixed parameters are chosen according to the experiment setup of the campaign."
And we add in the conclusion section :
" Note that, since information provided by Lidar or polarized measurements was used, the uncertainty for the non-retrieved parameters was chosen to be low. For applications to other cases without these available information, errors would be higher. If the method is applied to 3MI for example, the errors related to the cloud top altitude would be higher as the O2-A band leads to cloud top pressure uncertainties between 40 and 80hPa depending on the cloud types (Desmons et al. 2013). A more complex algorithm could also be used with a measurement vector including O2-Aband radiances and multi-angular polarized radiances to have information on and to add the cloud top altitude and the effective variance (Huazhe et al. 2019) in the state vector."

P13, L355-358: In the OE framework errors are assumed to be Gaussian and error estimates reflect 1-sigma of the Gaussian distributions. Can you comment on the Gaussian nature of the forward model related errors? Is it plausible to use the difference between two configurations as 1-sigma of the uncertainty, or would these configurations rather reflect two extremes?
Indeed, the OE method is based on the assumption of Gaussian distribution. If it is not the case and if biases related to the forward model exist, they are included in the Gaussian distribution. This leads off course to an overestimation of the uncertainties.
In the case studied here, the assumption of a Gaussian distribution is not too bad. Indeed, if we look at the Figure 9 of the paper, the difference between 1D and 3D radiances is not so far from a Gaussian distribution. A. This happens because the cloud is flat and the spatial resolution high (about 20m), so the sub-pixel bias can be neglected. However, at a larger resolution, this bias can not be neglected and will increase the uncertainties.

We add in section 3.3.3, line 448: "The simplified model used for the retrieval can lead to biased retrieved parameters. In this case, the bias will be included in the Gaussian PDF width, resulting in an overestimation of the uncertainties."
P13, L358: What is the square of a matrix?
We correct and use the transpose matrix
P13, L363: To estimate retrieval errors due to deviations from the assumption of vertical homogeneity, a specific alternative cloud model is outlined in detail. However, it should be realized that this is just one possibility. For example, real profiles have a varying degree of sub-adiabaticity, which is not considered here. What would be the effect on the uncertainty estimates?
We agree and this point was also raised by the first reviewer. We write, line 466:
"Depending on the maturity of the cloud, turbulent and evaporation processes can reduce the size of droplets at the top of the cloud **and collision and coalescence process can increase the size of the droplets in the lower part of the clouds as observed by Doppler Radar (Kollias et al., 2011). The profile used in this study aims to represent the case of droplet size reduction at the top of the cloud but other and more sophisticated and representative profiles can be used (e.g. Saito et al., 2019) "**

P14, Fig. 3: The cloud is placed between 5 and 6 km. Where do these numbers come from? They are not the same as on page 12. Please include the settings (top and bottom height, cloud optical thickness, maximum effective radius, …) for this particular figure in the caption.
The cloud is between 5 and 6 km. We correct the value page 12.
We add the cloud properties in the caption of the Figure 3 :
The cloud is between 5 and 6km. The maximum extinction coefficient and effective radius are 6.6 km-1 and 12 µm respectively and the altitude zmax is 5.85km

P15, L396-398: Is it correct to determine the maximum effective radius such that the average effective radius of the heterogeneous and homogeneous profiles are the same? Shouldn't R_eff be weighted with extinction? Or, alternatively, a requirement to arrive at the same liquid water path for both profiles seems better justified.
Several solutions can be used, and we chose $Reff_{max}$ in order to have the mean Reff of the heterogeneous vertical profile equal to the Reff of the homogeneous cloud. We add in the text that other options can be possible, we add line 490. "Several options are possible for these values."

P15, L407: Only the IPA seems to be addressed here. What about the PPH assumption?
To clarify it, we correct line 496, by replacing "IPA" by "PPH" line and add a sentence to describe the PPH effects (next comment) and another one to explain the choice of studying only the IPA errors, line 509: "At the high spatial resolution of OSIRIS (less than 50 m at the cloud level), it was shown from airborne data that the dominating effect is related to the IPA error (Zinner et Mayer, 2006). In the following, we consider thus only this error and assume that the pixel is homogeneous at the measurement scale."

P15, L409-411: It seems to be stated that the PPH assumption includes the IPA, whereas in earlier parts of the manuscript they were introduced as different things (which I think they are).
The Plane Parallel Homogeneous (PPH) cloud assumption includes the PPH bias due to subpixel variability of the cloud and the IPA errors due to transport of horizontal photons not accounted for with the PPH assumption. To clarify if we add, line 508 "This PPH assumption includes errors known as the PPH bias due to the subpixel variations of the cloud and errors related to the photon horizontal transport between columns (IPA error)"

P16, Fig. 4: Does the scene contain clear-sky pixels? If so, how are they reflected in the COT and Reff maps? Are there any failed retrievals? If so, how are they reflected in the maps?
The studied case is a stratocumulus, with thin optical thickness but no clear sky pixel.

We add line 541 “Some values of COT are very small but no clear sky pixel is present.”

P16, caption Fig. 4: Is the date a typo or is this really a different case from the one introduced in Fig. 2?

It was a mistake and was corrected

P16, L436: A figure with COT and Reff uncertainties as functions of COT and Reff would be very instructive to illustrate this.

We add COT and Reff uncertainties as functions of COT and Reff values in Figure 5 (panels c et d) and add comments in section 4, line 541 :

“These uncertainties are plotted according to their respective values in panels (c) and (d). RSD COT (mes) increases with the magnitude of the retrieved COT, as RSD Reff (mes) with Reff for values until 15 µm. The uncertainties due to measurement errors are low, especially for optical thickness (less than 5%).”

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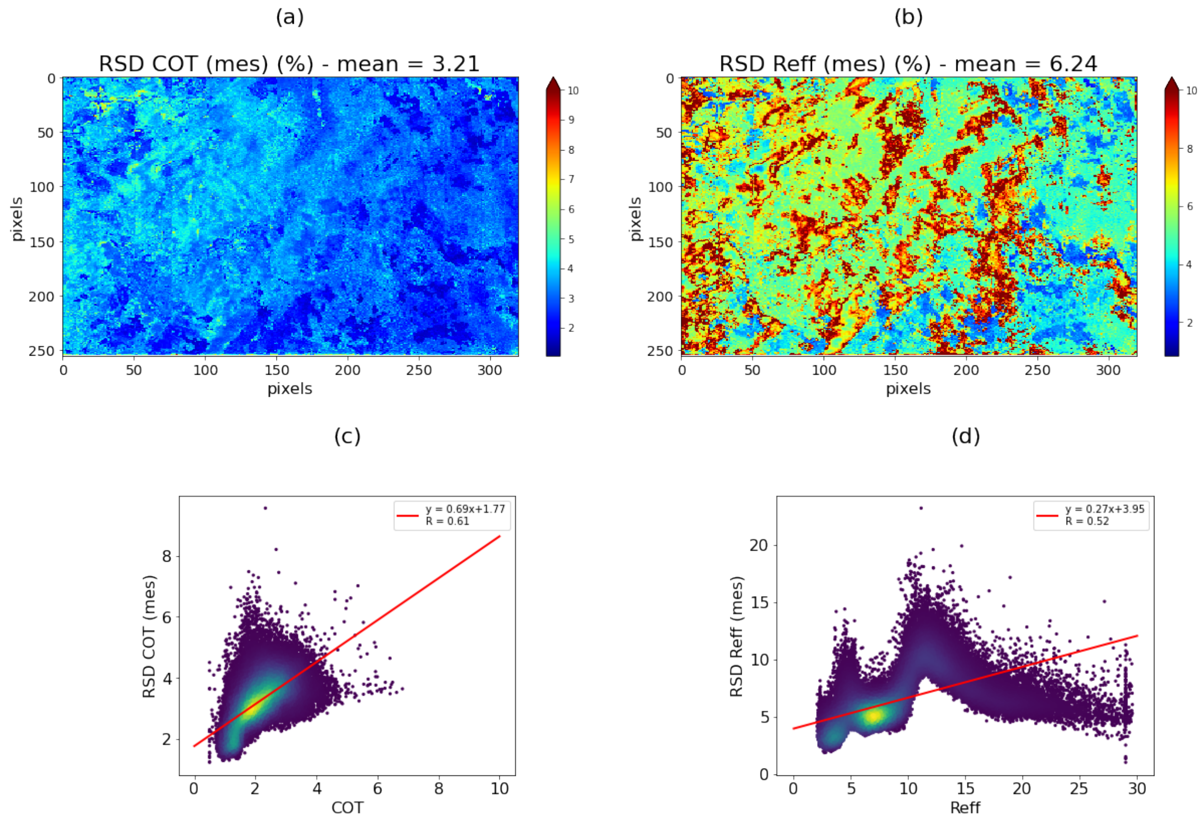

Figure 5 (revised version): Uncertainties (RSD (%)) of COT (a) and R_{eff} (b) originating from the measurement errors for the case study of CALIOSIRIS. **COT uncertainties in function of COT (c) . Reff uncertainties in function of Reff (d).**

P16, L435: The uncertainties in COT appear to be very low. Is a retrieval error of 0.5% realistic? For thin clouds COT depends approximately linearly on the reflectance. How can a reflectance measurement uncertainty of 5% result in an order of magnitude lower uncertainty in COT? Is this thanks to the combined information from different viewing angles. But, if that’s the case, isn’t the assumption of uncorrelated errors between the measurements from these different angles much too optimistic?

Two reasons explain this low value : the quasi-linearity and the steep slope of the radiance as a function of COT and Reff and the multiangular measurements. Indeed, this is one main advantage

of the optimal estimation method, which allows the use of several measurements per cloudy pixel to obtain the best estimation of an unique COT value. For the same pixel, each additional information reduces the uncertainty on the retrieved parameters in the presence of the same 5% random noise in the measurement.
We mention, line 557 "...the steep slope…" of the radiances in function of COT.
The advantage of using multiangular measurements is mentioned several times in the paper. For example, line 699:
"The multi-angular approach leads indeed to more information available for each cloudy pixel and each additional information reduces the uncertainty on the retrieved parameters in the presence of the same 5% random noise in the measurements."

Concerning the correlation between the measurements from different views, we agree that it could exist but they are currently not characterized. We add a mention of these possible correlations in the conclusion section, line 735: "Since they are not characterized, the correlations between the measurements issued from different viewing angles are not considered in our retrieval, but they could increase these values."

P17, 459-460: Could this estimate be too optimistic? In case of broken clouds, sun glint can have a relatively much higher impact on the measured reflectance, which would not be captured here.
As we wrote above, the cloudy scene studied is completely overcast but, of course in case of broken clouds the errors due to the ocean wind speed uncertainties will be higher, even if the multiangular measurements can mitigate the effects of these errors.
We add, line 588 : "In case of broken clouds, the errors resulting from the ocean wind speed uncertainty would be larger."

P18, L474: For COT it seems to be rather something like 8 %.
Right, we separate the two : "... to 8% and 20% respectively."

P19, L481-484: This is a firm statement, for which no evidence is provided.
We change the verb to be more cautious and add also the fact that the cloud is flat, which mitigates illumination and shadowing effects: "**However, in this work, we are dealing with flat cloud tops that induce weaker 3D effects than bumpy cloud tops (Varnai et Davies, 1999). In addition,** with multi-angular measurements, the same cloudy pixel is viewed under different viewing angles, which **may** tend to mitigate the influence of illumination and shadowing effects."

P19, L485-486: There are no sub-pixel measurements, and sub-pixel cloud variability is not represented in this work. Again, this is a statement without proof. A PPH error estimate should be added to the retrieval setup, so the PPH effect can be quantified.
That is right. As mentioned above, we assume that the PPH bias is negligible and do not include sub-pixel spatial variability in the simulations and then we are not able to estimate it.
We delete line 616-618 and add line 606 : "We remind here that, given the high spatial resolution of OSIRIS measurements, we consider the PPH bias as negligible and do not account for the sub-pixel variability of cloud properties in the 3D radiative transfer simulation."

P20, Fig. 8: How is radiance defined here? Is it the sun-normalized radiance or true reflectance?
It is reflectance. We modify the caption
From which of the 13 viewing angles are these measurements taken?
It corresponds to the central image of the sequence used for multiangular retrievals but one OSIRIS image corresponds to several viewing angles. It is now indidated section 2.2
Fig. 9: Nice figure, illustrating the different response of thin and thicker cloud portions to 1D versus 3D radiative transfer.
Thank you

P21, L508-509: Is the nearest-nadir view used for the mono-angular retrievals?
The mono-angular retrieval is done according to the geometry of the central images of the series used for the multiangular retrieval. Zenithal angles range from 0° to 55° and azimuthal angle from 0 to 360 (See figure below).

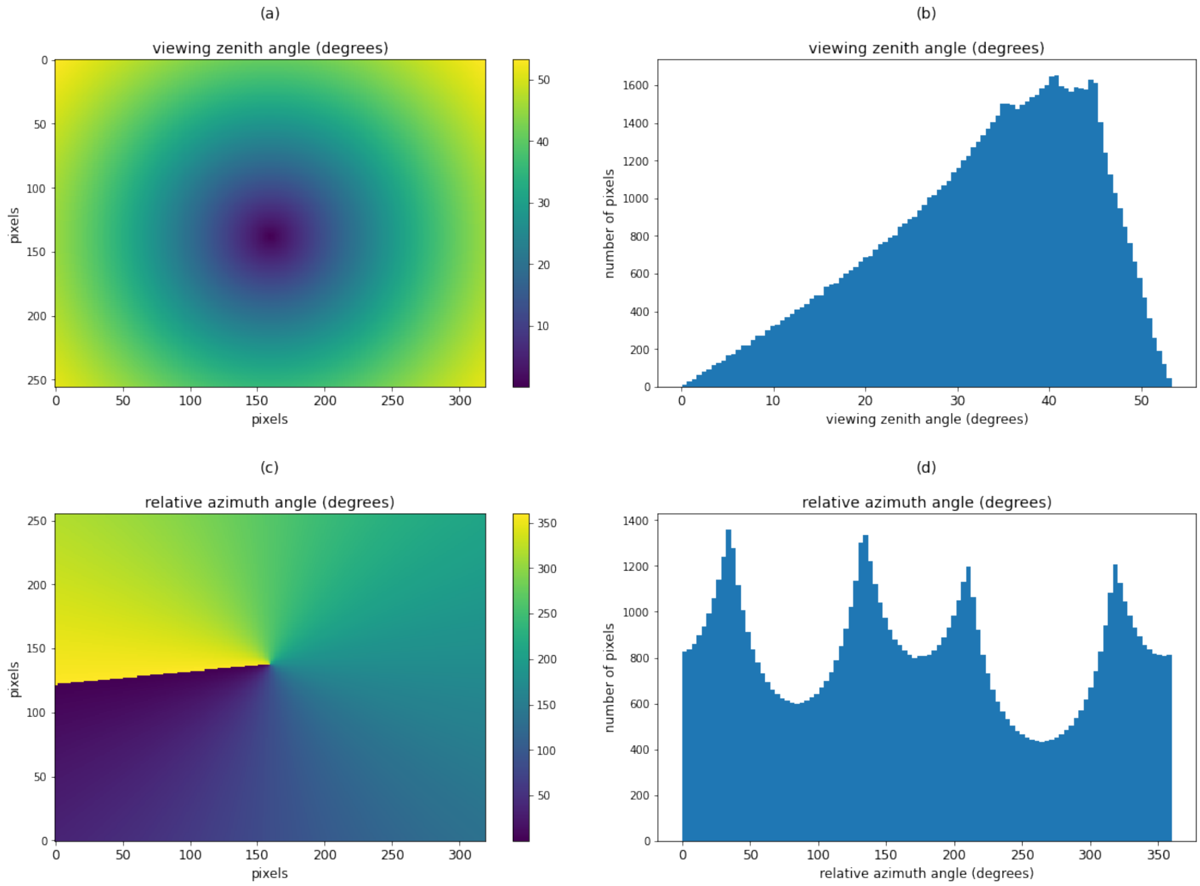

Figure 2 (not included on the paper) : Zenith (a) and azimuthal angle (b) of the central OSIRIS image. Histograms of the zenith (c) and azimuth angle (d).

The zenith angle range is now mentioned in line 201 : "One OSIRIS image corresponds to several viewing angles. The zenith angle ranges from about 0° in the center of the image to 55° in the corner of the image."

P21, Fig. 10: I am shocked by the enormous differences between the mono- and multi-angular retrievals. Ok, for the cloud bow geometries it is well known that mono-angular retrievals do not work. However, for other geometries the mono-angular retrieval should give a reasonable solution, in particular for a reasonably 'well-behaved' cloud field as studied here. This asks for further clarification. Can you also include a scatter-density plot comparing COT and Reff from the two retrievals on a pixel basis?
The differences were enlarged because the color scales were not the same. We modify it in Figure 4 and 10 to have the same color scales in the revised version of Figure 4 and Figure 10. The retrieval looks more consistent except in the cloud bow region and in some cloud parts that may be particularly heterogeneous. The comparisons of the two figures clearly show, as it is already mentioned in the text, higher values of optical thickness and effective radius in case of mono angular retrievals. Figure 3 presents the scatter plots of the retrieved parameters using multi-angular and mono-angular and confirms this behavior. The correlation between the two optical thickness is good with higher value obtained with mono-angular retrieval. For effective radius, the values are more dispersed but we can still see a relationship between the two effective radii. In the paper, we choose to add in Figure 10 (panels e and f) represented below, the spatial difference between the two retrievals.

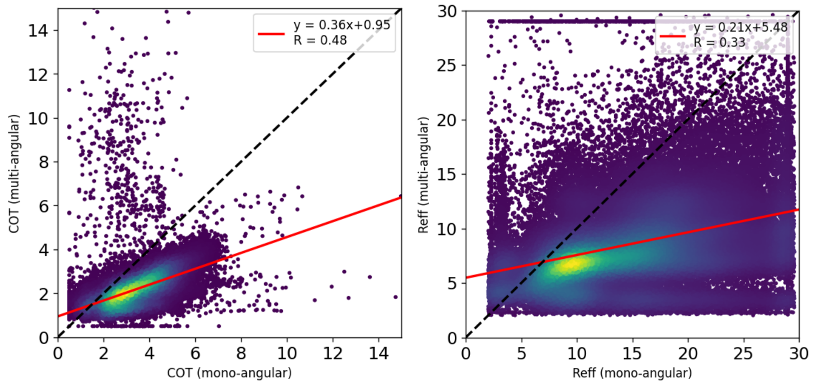

Figure 3 (not included in the paper) : Scatter plots of the COT (left) and effective radius (right) multi-angular and mono-angular retrieval

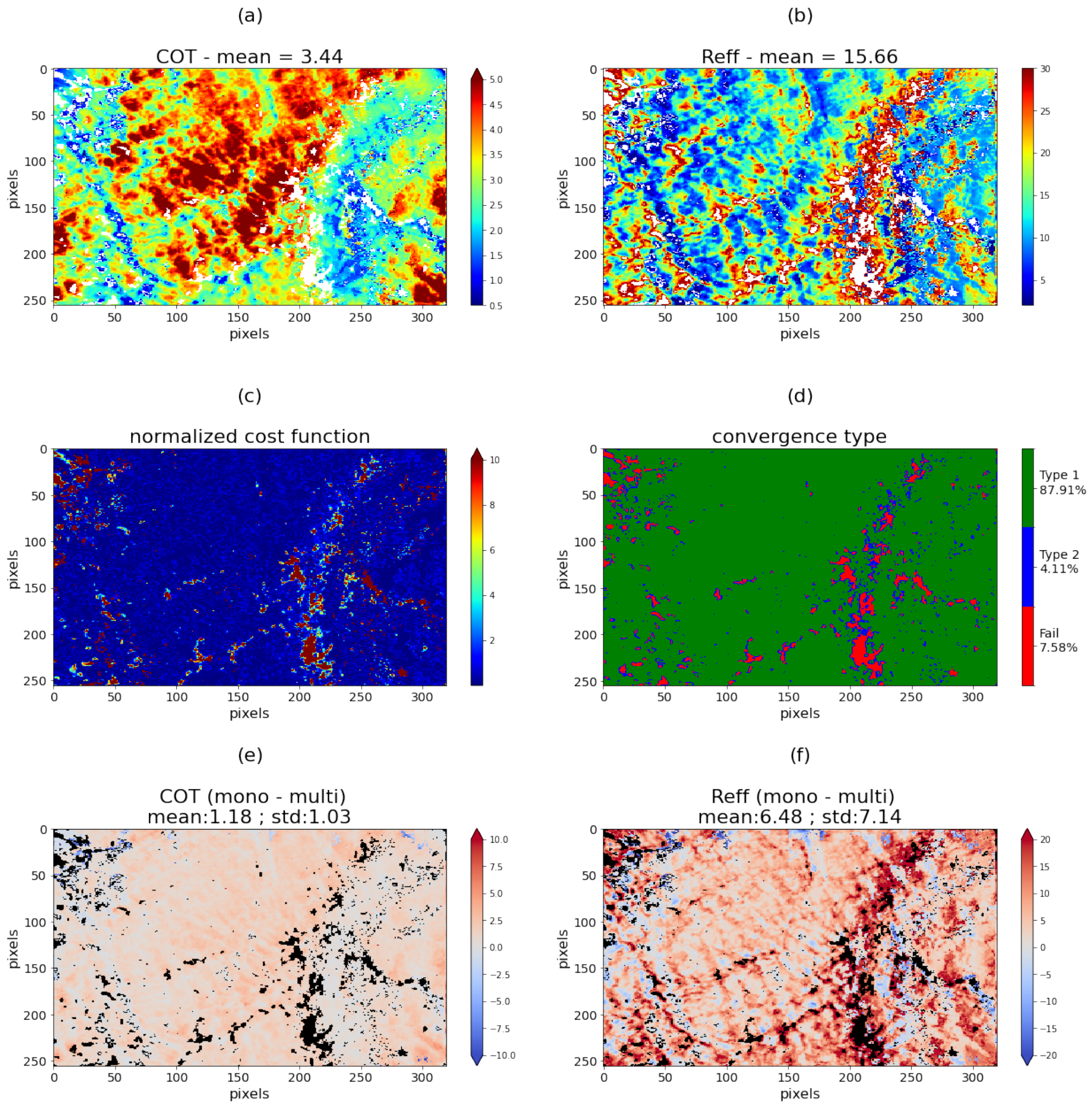

Figure 10 (revised version): COT (a) and R_{eff} (b) retrieved using mono-angular bispectral method for the CALIOSIRIS liquid cloud case study on 30 June 2014 at 11:02 (local time). **Pixels associated to failed retrievals are represented by white pixels. (c) Normalized cost function. Convergence type (Eq. 6 for Type 1 and Eq. 7 for Type 2) and failed retrieval (d). Differences between mono-angular and multi-angular retrieval for retrieved optical thickness (e) and for retrieved effective radius (f).**

Concerning the comparisons of the two retrievals, we add comments in section 5, line 651-655: **The results are presented in Figure 10.** The retrieved COT over the whole field varies between 1 and 12 with a mean value equals to 3.44 **Comparing to multi-angular measurements (mean COT of 2.13), the retrieved COT values tend to be higher**. The range of retrieved Reff has a mean value of 15.65 µm, **compared to 8.76 µm for multi-angular retrieval. Mono-angular retrieval** is particularly affected by the high value of Reff retrieved around the scattering angles 130-140° where the sensitivity of 2200 nm radiances to the water droplet size is known to be small."

P22, L530-531: Apparently both retrievals fail to converge in some cases. But there do not seem to be missing values in Figs. 4 and 10. How can that be explained? What output does the algorithm give
in case of no convergence? Are these cases included in the statistics? Are statistics based on a common set of mono- and multi-angular successful retrievals?
The convergence tests used are presented in Eq. 6 and Eq. 7. There is a convergence failure when neither the inequality of Eq. 6 nor that of Eq. 7 is reached after 15 iterations.
We add this information in section 2
Line 288: "The iterative process stops when the simulation fits the measurement (**Eq. (5)), named convergence of Type 1** or when the iteration converges **(Eq. (7)) named convergence of Type 2**. **The left side of Eq. (6) represents the normalized** cost function without taking into account the a priori negligible contribution. **When the cost function is smallern_y than or the normalized cost function (J/n_y) less or equal to one,** the iterations stop."

And line 298: "When neither the inequality of Eq. 6 nor the inequality of Eq. 7 is reached after 15 iterations, the retrieval is considered as failed."

We add the normalized cost function as panel (c) in the revised version of Figure 4 and 10 and the convergence type and the failed convergence in panel (d) . In the initial version of the paper, the failed convergence were represented by dark blue color. In the revised version, we replace the dark blue color by white color to more clearly show the retrieval fails.

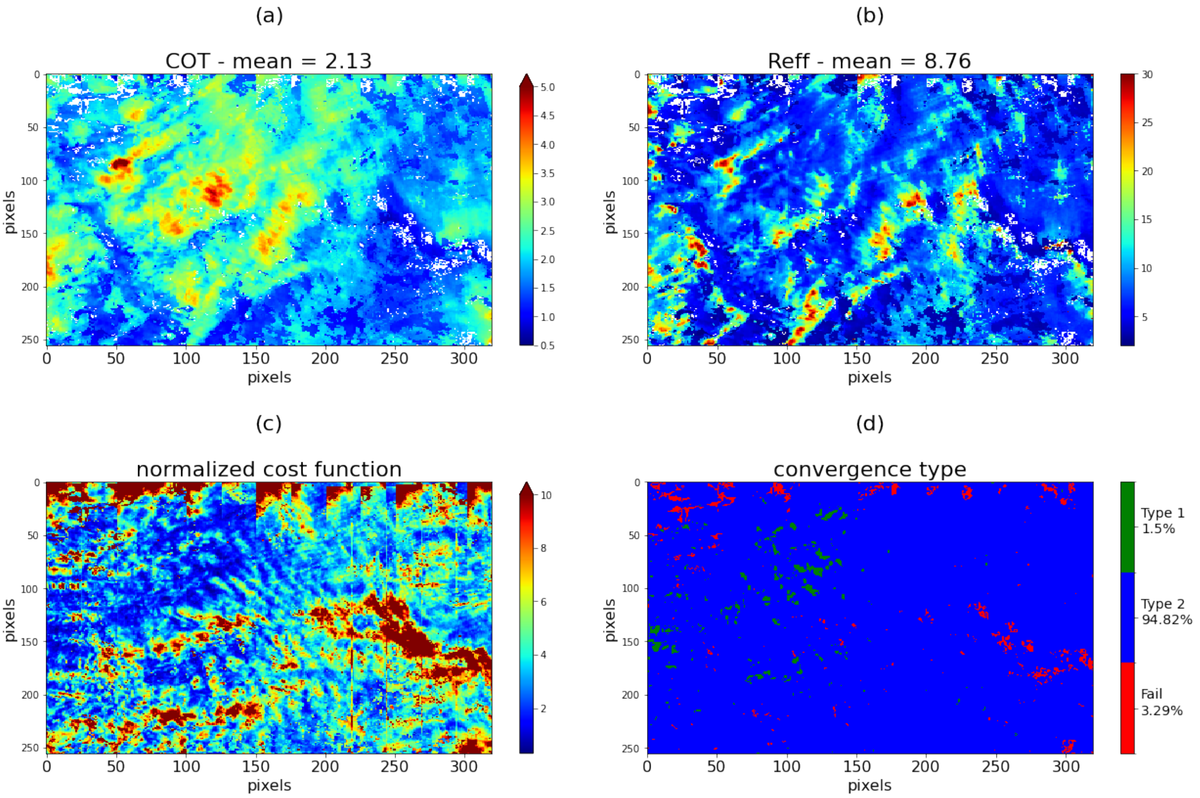

Figure 4 (revised version) : COT (a) and R_{eff} (b) retrieved **using multi-angular bispectral method** from a liquid cloud case observed during the CALIOSIRIS airborne campaign on 24 october 2014 at 11:02 (local time). **Pixels associated to failed retrievals are represented by white pixels. (c) Normalized cost function. (d) Convergence type (Eq. 6 for Type 1 and Eq. 7 for Type 2) and failed retrieval.**

As comment, we add line 542:

"Figure 4c presents the normalized cost function, which is less or equal to one when the retrieval successfully converges according to Eq. 6 (convergence of Type 1). In case of multi-angular measurements, the normalized cost function is often above one meaning that the simulated radiances do not fit the measurements while considering the measurements error covariance only. This comes from the attempt to fit the measured radiances from all the available viewing directions with a too simple forward model far from reality. The retrieval stops thus mainly according to Eq. 7 (convergence of Type 2) indicating that the state vector remains almost constant between two successive iterations. When neither Eq. 6 or Eq. 7 are achieved the retrieval fails. For the whole scene, failed retrievals account for 3.3% of the pixels. The failure may be associated with pairs of radiances outside the LUT that can occur for several reasons well documented in Cho et al. (2015)."

Concerning Figure 10, we add 655: "This area corresponds also to a more important number of failed retrieval" and line 677 "**A normalized cost function value (Figure 10c) less or equal to one** is not necessarily an indication of an accurate retrieval…"

P22, L531-532: Is the multi-angle retrieval expected to retrieve smaller Reff? Can you explain that? And why would smaller Reff lead to lower COT?

In case of mono-angular retrievals, high values of effective radius are retrieved, in particular in the cloudbow and in the glint regions. These effects are mitigated by multiangular retrieval. In case of muliangular retrievals, the effective radius tends thus to be smaller and more homogeneous over the scenes. A reduction of the effective radius leads to an increase of the backward scattering and, which results for the same visible radiance value, in a lower optical thickness.

We add, line 672 "A smallest effective radius leads to increase the backward scattering and so the reflected radiance, which results in a lower retrieved optical thickness"

P22, L533-534: This is not true. The measurement pair can be outside the 2D LUT spacelb (and I guess
this is what happens in the reported 5.9% cases of failed convergence).

We agree. We modify the sentence and add the possibility of having a radiance pair outside the LUT and the reference to the well-documented paper by Cho et al. (2015) regarding this issue.

We add in the description of Figure 4, line 548:

"For the whole scene, failed retrievals account for 3.3% of the pixels. The failure may be associated with pairs of radiances outside the LUT that can occur for several reasons well documented in Cho et al. (2015)."

We delete the false assertion "it is always possible to find a cloud model " and write line 677:

"Excepted in case of failed retrievals that occur for values outside the LUT ranges, the relatio between radiances and COT-Reff being monotonical, …"

P24, Fig. 12: The decrease in retrieval error from mono- to multi-angular retrievals is spectacular, especially with respect to the vertical homogeneity and IPA assumptions. Can you explain in some more detail how that is achieved? Still, differences between the two retrievals (Fig. 10 vs. Fig 4) appear (much) larger than accommodated by the respective error estimates. Can you comment on That?

Right, the differences in the assessment of the uncertainties due to the forward model are large. The reason that explains the difference between mono-angular and multi-angular measurements lies in the higher number of measurements used with the multi-angular retrieval. The state vector retrieved with multi-angular measurements is less sensitive to the cloud model. We already discussed the advantages of multiangular retrieval in section 5 for example line 687 to 690 :

" On the other hand, multi-angular retrieval increases the constraint on the forward model make much more challenging to find a solution allowing to fit the measurements. The retrieved state is then consistent at the best with all the measurements associated with different viewing angles."

Concerning mean differences between mono and multi-angular retrieval, they are 1.18 and 6.48μm for optical thickness and effective radius respectively (news panels c and d in Figure 10) for mean values of 3.44 and 15.66μm. Even if not directly comparable, these values are in agreement with mean RSD values for COT and Reff, in Figure 12, which are 16 and 28% for optical thickness and 54% and 45% for effective radius. As added in the conclusion section (line 726-732), only numerical experiments, with known optical thickness and effective radius would allow to check if errors of the retrieved parameters are included in the uncertainties assessed by the method presented in the paper.

P24, Fig. 12: The mean Reff retrieval error due to measurement errors is 12.55 in Fig. 11 but 12 in this figure, which is not consistent.

Right. This is a rounding error. We correct in the figure and indicates 13%

P25, L596: In Fig. 12 the mean COT error is 4%, not 5%.

Right this is 5% for the vertical profile error

P25, L605-607: Please remove since this was not shown (or alternatively include in the retrieval error
estimates).

We delete this sentence as we agree that we did not bring out the illumination and shadowing effects.

Technical corrections

P1, L22: Acronyms (POLDER in this case) must be written out.

Done
P1, L16/L17: '… without considering … the choice of ancillary data': What does it mean that the choice of ancillary data is not considered?
The sentence was deleted
P1, L31: 'uncertainties on': should be 'of'. Occurs frequently throughout. Please correct.
Thank you. It was corrected for the whole text
P2, L53: The second sentence does not follow from the first, so the word 'Therefore' is misplaced.
Deleted
P3, L76: increase -> increasing
Done
P3, L80: 'radiations' is not really a word.
Replaced by radiative energy
P3, L90: by its -> in
Done
P3, L96: vertical -> vertically
Done
P4, 113: Usually, the acronym is put between brackets after the full name instead of the other way Round.
Done
P4, L124: Bayesian (with capital)
Done
P9, L242: Add lambda_a and lambda_b after wavelengths.
Done
P9, 239: Italic case is not needed here (similar occurrences throughout).
Modified
P9, 240: Variables in italic (R in R_eff should be italic). (similar occurrences throughout).
Done
P9, L243: (8) is duplicated.
Corrected
P9, L250: 'All the' -> 'the two'?
Done
P10, L271: 'implantation': do you mean 'implementation', 'inclusion', ..?
Inclusion
P10, L271: adjust -> adjusts
Done
P10, L306: 'measurement errors that cover the measurement errors'?
Keep just "based on 5% of measurement errors"
P11, L13: Italics appearing here and there are not needed and confusing.
Modified
P12, L327: Should (17) and (18) be reversed?
It is (19) and (20)
P12, L328: Should this be K_b_i instead of K_i?
Done
P12, L340: for -> to
Done
P14, Fig. 3: Minus sign in the x-axis label is confusing.
We change "-" by ";"
P15, L395: exctinction -> extinction
Done
P15, L417: minimized -> underestimated (?)
Done

First paragraph on page 16: here I give a more complete inventory of textual mistakes as guidance for the rest of the manuscript.
P16, L422: Both bispectral and bi-spectral occur in the manuscript.
Bispectral is chosen
P16, L423: weak -> weakly
Done
P16, L423: .. channel partially absorbed by ..: how can a channel be absorbed?
We modified :"…and a radiance partially absorbed by the water droplets in the channel centered at 2200 nm,..."
P16, L424: on -> to
Done
P16, L424: Remove 'up to' (?) I guess all viewing angles are available. By the way, does this mean that n_y = 13?
Some images in the sequence have to be removed because they were degraded. It leads to a decrease of the number of angles for the left side of the central image. In addition, the plane moves slightly above the cloud, which decreases the number of view directions in the edges. Consequently, 9 to 13 directions can be used for the retrieval depending of the part of the central images (see figure below)

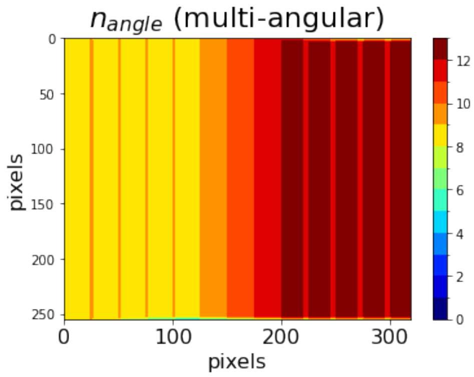

Figure : Number of viewing angles used for the multiangular retrieval

P16, L425-426: 'This error is straightforward': how can an error be straightforward?
Straightforward was deleted
P16, L429: ertically -> vertically
Done
P17, L443: As noted before, do not write variables like COT, and mathematical operations like RSD,
in italics.
Done
P17, L457: 'enlarge the directions': what does that mean?
We modified "... and the bright surface, named glitter, is enlarged by waves formed by the wind."
P19, caption Fig. 7: 'model' missing after 'forward'?
Done
P19, L478: What are 'these differences'?
We detailed : "At high spatial resolution, these differences are mainly caused by the so-called smoothing effects that can increase or decrease the radiance according to the optical thickness gradient between the considered pixel and its neighbors."
P21, L503: assumption -> assumption
Done
P21, Fig. 10: For comparability with Fig. 4 it would be good to use the same color scales. Can you also add the mean values? Also, add some whitespace between the maps and the color bars.

As detailed above, the figure 10 was modified.
P22, caption Fig. 11: Add ‘angle’ after ‘scattering’.
Done
P22, Fig. 11: Is this figure for the mono-angular retrieval?
yes , we now specify it in the legend
P23, L542: spatially -> spatial
Done
P23, L557: ‘to the’ is duplicated.
Corrected
P23, L557: what is a ‘homogeneous assumption’?
We specified: “... the **cloud** homogeneous assumption **used** in the forward model”.
P24, L571: ‘retrieve’ is duplicated.
corrected
P24, L583: horizontal -> horizontally, vertical -> vertically
Done
P25, L587: for -> to
Done
P25, L590: what is ‘miss-knowledge’?
replaced by unknown value
References: Journal names are missing in all references.

References

Platnick, S., Meyer, K. G., D., K. M., Wind, G., Amarasinghe, N., Marchant, B., Arnold, G. T., Zhang, Z.,
Hubanks, P. A., Holz, R. E., Yang, P., Ridgway, W. L., and Riedi, J., 2017: The MODIS Cloud Optical and
Microphysical Products: Collection 6 Updates and Examples From Terra and Aqua, IEEE T. Geosci. Remote, 55, 502–525, doi: 10.1109/TGRS.2016.2610522.

Walther, A. and Heidinger, A. K., Implementation of the daytime cloud optical and microphysical properties algorithm (DCOMP) in PATMOS-x, J. Appl. Meteorol. Climatol., 51, 1371-1390, doi:10.1175/JAMC-D-11-0108.1.