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Atmospheric Measurement Techniques Discussions

Interactive comment on "Retrieval of aerosol microphysical and optical properties above liquid clouds from POLDER/PARASOL polarization measurements" *by* F. Waquet et al.

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Reviewer 1

Main comments (1) The main problem with the paper is its lack of a clear structure. The current structure of the paper is: Algorithm description in Sect. 2.2, Results in Sect. 2.3; Algorithm description in Sect. 3.2, Results in Sect. 4; Algorithm description in Sect. 5.1, Results in Sect. 5.3. This chaotic structure of the paper – constantly jumping between different algorithms and retrieval results - prohibits the readability and good understanding of the paper. Are the cases selected for the three results

sections the same? It seems now that the paper is a composite of three other papers. Please reorganize the paper and give it a clear structure, so that there is one section on algorithm(s), including the relationship between those algorithms, and one section on results.

We reorganized the structure of the paper. We now have the following structure : 1-Introduction 2-Background and methods 3-Observations 4-Results 5-Discussion 6-Conclusion.

Are the cases selected for the three results sections the same?

Yes, we investigated the same cases studies with two different algorithms. Note that we reduced the number of case studies treated in the new version of the paper (as explained below).

. . .including the relationship between those algorithms

We were not clear in the first version of the paper with the description of the different algorithms and the description of their links. The "OEM algorithm" or "hyper-pixel method" described in the first version of the paper is now referred as the "research algorithm" for better clarity. This algorithm is dedicated to case studies analysis and it is used to perform a sensitivity study analysis. A less sophisticated algorithm is proposed for a global treatment of the POLDER data that is called the "operational algorithm".

We added a paragraph in the new version of the paper that clearly indicates the roles of both algorithms (operational algorithm and research algorithm) and their links : (see section 2.2 in the new version of the paper)

"First, a Âń research algorithm Âż, that uses all the available polarization measurements provided by the POLDER instrument, was developed in order to parameterize a non spherical aerosol particles model and to evaluate the potential of the POLDER polarization measurements for the simultaneous retrieval of the aerosol and cloud microphysical properties. Indeed, the cloud droplets distribution effective radius primarily controls the magnitude of the cloud bow for a single layer cloud (Bréon et Goloub, 1998). A cloud particles model and an aerosol model must be therefore determined to analyze the POLDER data acquired for AAC scenes. We used also this research algorithm to perform a sensitivity study analysis, which is presented in section 5. A second algorithm was developed for reducing time computations. It is referred hereafter as the "operational algorithm" and uses a specific strategy to incorporate the observations acquired in the cloud bow as well as auxiliary MODIS and POLDER cloud products to retrieve the AOT and the Ångström exponent above clouds at global scale. Note that the two algorithms are connected since the research algorithm is first used to define the mineral dust particles model that is used in the operational algorithm in a second step. The next section is dedicated to the description of both algorithms, including the description of the particles models and radiative transfer codes, used to accurately compute the polarized radiances. We present also a study concerning the 3D radiative cloud effects that may impact polarization reflectance magnitude in the cloud bow."

(2) The paper is quite long, and should be reduced. The above reorganisation will probably lead to a reduced length. Please also reduce the amount of figures. Figure 6 seems too detailed and is unnecessary. There are also (too) many different topics in the paper. The aspect of 3-D radiative transfer modelling is a side-step, and seems not essential for the aim of the paper.

Some parts of the paper were reduced :

The section 4. "Sensitivity study and discussion" was reduced

"Section 4.3 General comments on the refractive index retrieval" was removed.

"Section 5.2 Effects of various approximations" was removed too.

We added a table that sum-up the cloud products used in the paper and reduced the section "observations".

The figure 4 is removed since figure 8 shows the same kind of observations. The

figure 13 and 14 are removed too. The results obtained at a large spatial scale will be presented in a future paper.

We reported the description of the truncature procedure in annex.

Figure 6 seems too detailed and is unnecessary.

Figure 6 show an example of the aggregated POLDER data. We recall that the technique of aggregation is very useful since it allows obtaining a fine angular sampling of the polarized radiance, which helps to simultaneously retrieve the aerosol and cloud properties with the research algorithm. We want to keep this figure for the following reasons : (1) the procedure used to aggregate the POLDER data is rather complex (this is not a simple average of the data) and was not previously well described, (2) figure 6 makes possible for other scientists to reproduce and check our results, (3) we also plan to use this aggregation technique for future works and for other types of scenes (e.g. ocean scenes with sun glint).

The aspect of 3-D radiative transfer modelling is a side-step, and seems not essential for the aim of the paper.

We want to keep the aspect of 3-D radiative transfer modeling in our paper for the following reasons : (1) this is not possible to accurately model the cloud bow in polarization with plan parallel transfer radiative code : this is a fundamental and completely new result, (2) the study leaded by Knobelspiesse et al., (2009) (that also studied aerosol above clouds scenes with polarization measurements) mentions that 3-D transfer radiative effects are potentially important for the retrieval of the AAC properties but does not investigate this effect. So, it seems important to evaluate the amplitude of this effect and to evaluate for the first time its impact on the retrieved aerosol properties. We found that the plan parallel transfer radiative code overestimates the cloud magnitude by 4-8%, which leads the operational algorithm to slightly overestimates the retrieved AOT (maximal error of 6%). It can appears as a small effect but we think it's worth to show it since this information was missing in previous related works (Knobelspiesse et al., 2009, Waquet et al., 2009a). It also slightly perturbs the retrieval of the aerosol microphysical properties, as shown by the analysis of synthetic retrievals asked by the reviewer 2 (see below).

(8) Sect. 3.1: what is the aim of this algorithm? Was the previous algorithm not good enough?

The first algorithm described in Waquet et al. (2009a) was not able to accurately retrieve the AOT in case of AAC scenes with mineral dust particles. In order to have a more general algorithm which allow to study both anthropogenic and natural aerosols, we developed a new algorithm that works for the two types of particles.

We added a section "motivations" (section 2, paragraph 2.1 in the new version of the paper) that explains in details why the development of a new algorithm for the treatment of Aerosol Above Clouds scenes with POLDER was required :

Waquet et al., (2009a) developed a method that allows retrieving the Aerosol Optical Thickness (AOT) above clouds using polarized measurements. A global processing of one year of POLDER data was performed. The analysis of the results pointed out that the method was not able to accurately retrieve the Aerosol Optical Thickness (AOT) when mineral dust particles were present above clouds. Indeed, the AOTs were underestimated (by a factor 2 or 3) compared to the retrieval performed over the nearby clear-sky ocean pixels using the standard POLDER aerosol algorithm (Herman et al., 2005). The reason was that the method developed by Waquet et al., (2009a) was restricted to the use of observations acquired for scattering angles around 90-120° where polarization measurements are highly sensitive to scattering by fine mode aerosols and only weakly sensitive to cloud microphysics. Since non-spherical particles, such as mineral dust particles, do not much polarize light in the selected scattering angle range, it led the algorithm to systematically underestimate the AOT by ignoring the contribution of the coarse mode. The lack of sensitivity of this method to mineral dust particles is the main motivation for the development of a new retrieval method able to retrieve the

properties of any type of particles lofted above liquid water clouds. To a lesser extent, this shortcoming was also due to the use of an approximate modeling of the polarized reflectance.

(11) Sect. 4, p. 6107: Which of the five OE options, or inversion schemes, listed in Tables 2 and 3, is the best one? Did you test these options using simulations where you knew the aerosol properties? Please conclude clearly with option is being preferred.

In table 2, we showed that we were able to model the POLDER data with various combinations of aerosol parameters with and without absorption properties and we concluded that our method was not able to accurately retrieve the aerosol absorption optical thickness. We did not use synthetic data to test the different options in the previous version of the paper. It is now done as suggested by the second reviewer (see the responses to reviewer 2). The results obtained with synthetic data confirmed the results obtained with real measurements : the aerosol absorption properties cannot be accurately retrieved when the particle size distribution includes coarse mode particles. Since, we cannot retrieve all the aerosol microphysical parameters, it seems reasonable to consider some assumptions on the particles microphysics, for instance on the coarse mode particles to obtain better accuracy for the retrieved parameters. This is the option 5 in table 2 that is our "best retrieval option" for treating the AAC scenes with biomass burning aerosols.

We added a sentence in the version of the paper that clearly mentions that option 5 is the retrieval option that is preferred for treating the biomass burning AAC scenes encountered in this paper (see section 5.2.1 in the new version of the paper) :

"We describe hereafter the retrieval option that is finally preferred to simultaneously retrieve the aerosol and cloud properties for biomass burning AAC scenes."

For mineral dust particles, we are primarily interested in defining a model that is suitable to reproduce the POLDER data acquired for mineral dust AAC scenes at a global scale. The model defined with option 5* (see table 5 for case (4), in the new version of the paper) appears to be a good choice for a global treatment since the proposed model fit well the POLDER data and also because the retrieved microphysical are representative of the mean properties of mineral dust particles given in aerosol climatologies."

We also added the following sentences in the paper : (see section 5.2.2, in the new version of the paper).

"For mineral dust AAC scenes, we modified solution 5 to include two additional parameters in the retrieval scheme in order to be able to reproduce the POLDER data. Solution 5* is thus similar to solution 5 but includes the retrieval of the coarse mode AOT and the retrieval of the fraction of spherical particles (SF)."

"This particles model is the mineral dust particles model implemented in the operational algorithm. It was used to retrieve the AOT above clouds shown in figures 10-a and 10-b. This is justified since this model allows to reproduce well the POLDER data (see figure 1-b) and also because the retrieved optical and microphysical properties (i.e. Angström exponent, complex refractive index and shape) are realistic for mineral dust particles according to Dubovik et al., (2002)."

Specific comments:

(3) Abstract, p. 6084 : why are here only dust particles mentioned and not smoke particles over clouds? Biomass burning aerosols are missing from the abstract while they are included in the main text.

We added the following sentence in the abstract :

"We also use the polarized measurements acquired in the cloud bow to improve the retrieval of both the biomass burning aerosols properties and the cloud microphysical properties."

(4) The introduction is quite complete and well written, but a few recent papers on the topic of aerosols over clouds are missing. In De Graaf et al. (JGR, 2012) the radiative effect of aerosols over clouds is determined directly from satellite spectrometry mea-

surements. The height detection of absorbing aerosol plumes over clouds is discussed in the paper by Wang et al. in ACP (2012).

Thanks, we added these two references in the introduction and in the list of references :

"Regional studies of the AAC radiative forcing were achieved (Chand et al., 2009, Peters et al., 2011, De Graaf et al., 2012)."

"A method that allows to detect the height of absorbing aerosol layers present above clouds was also recently developed using absorbing aerosol index data and oxygen A Band measurements provided by the Global Ozone Monitoring Experiment (GOME-2) instrument (Wang et al., 2012)."

(5) When using the words: clouds, aerosols, droplets, or particles (etc.) as an adjective, please use the singular. For example, aerosols transport events > aerosol transport events (title sect. 2.3); this occurs often in the paper.

Thanks, we corrected it.

(6) p. 6093, l. 18: the symbol phi is already in use as the symbol of azimuth; please use another symbol for the phase.

Ok, we use now "phase_index" instead of "ÏŢ_CLD".

(7) Quotes should not be used if the term between quotes has been introduced already. For example, on p. 6095, l. 3, the quotes (2x) can be removed, because these retrieval methods were explained on p. 6093. This holds throughout the paper.

Thanks, we corrected it.

(9) Sect. 3.3: which elements are in the state vector of this OE method?

For the cloud droplets, we retrieve 5 elements (the effective radius, the effective variance and the real part of the refractive index in the three bands).

For the aerosols, we wanted to retrieve 8 elements : 3 elements for each mode (rg and σ : a mean value and a standard deviation used to describe the lognormal function and N : the column number density of particles) + 2 additional elements for the complex refractive index (mr and mi). This is in fact not possible to accurately retrieve the 8 aerosol parameters according to our sensitivity study analysis. For the biomass burning aerosols : we then only retrieve rg, σ and N for the fine mode and mi. For the mineral dust particles, we retrieve rg, σ and N for the fine mode and also N for the coarse mode as well as the fraction of spherical particles (FS).

We added a sentence in the manuscript to indicate the parameters included in the vector X.

The aerosol parameters included in the vector X are : Nf, rg,f, σf and mi. The cloud parameters included in the vector X are : reff,cld, veff,cld and mr,cld(λ).

(10) p. 6100, l. 17ff: the mean of a quantity should be indicated by an overline or brackets like <x>, not by an underline. This holds throughout the paper.

Ok, we used overlines.

(12) Sect. 5.1: is this description about an OE algorithm? What is the state vector?

No, this is the description of a LUT algorithm.

(13) p. 6121, l. 8: viewing directions and number of channels are interchanged.

Thanks, we corrected it

(14) Table 1: some symbols have a minus before the subscript; please remove the minus-signs; to separate two subscripts use a comma. This also holds for symbols in the main text.

Thanks, we used a comma when two subscripts are used.

(15) Table 3: what does 1* etc. mean ?

It indicates a retrieval option. The 1*, 2*, 3* and 4* retrieval options are not used anymore in the new version of the paper.

(16) The figures are not clear: (a) Much larger fonts are needed for the axis labels, legends, etc.. (b) In the captions, first the subplot letter (a, b, : : :) should be given and then the text (now it is the other way round).

We changed the captions.

(17) Figures 1, 2 and 3: please indicate in the legend of the profile figures which data are from CALIOP.

This is a minor improvement. We will consider it for the final version of the paper.

(18) Fig. 4: give a legend for the three subplots: pristine, BBA, DDA.

We removed this figure in the new version of the paper.

(19) Fig. 8: which cases or events are these?

We added a sentence in the caption to clearify this point.

(20) Fig. 9: Is this a single pixel or a hyper pixel algorithm?

This is the operational algorithm that works for single pixels.

(21) Please improve the lay-out of Figure 12, and give lat/lon grid. Give a subdivision in the color bars of Figures 12 and 13.

These figures were removed.

Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/5/C3911/2013/amtd-5-C3911-2013-supplement.pdf

Interactive comment on Atmos. Meas. Tech. Discuss., 5, 6083, 2012.