We thank Reviewer #1 for his/her analysis and comments on the paper. The responses to major and minor comments are given below. We marked the reviewer's and the author's comments by "RC:" and "AC:", respectively.

General comments

First of all, we want to admit that a simplistic conversion of scattering ratios provided in the first version of the manuscript appeared to be a source of confusion for the reviewers and we apologize for this. Moreover, the reviews helped us to recall that there are two definitions of scattering ratio itself and even though they both are aimed at estimating the contributions of particulate and molecular components to the backscattered radiation, they are not the same. In the present version, we added a section with all necessary definitions and conversion formulae. This section also appears to be helpful in the discussion of the potential discrepancy sources. The collocated dataset has been reprocessed and the new scattering ratios at 532nm have been calculated and analyzed. Despite changes in wavelength conversion methodology, the results and conclusions changed little. But, we noted a certain improvement of the overall agreement between the ALADIN and CALIPSO datasets (e.g. see the numbers representing the normalized cloud detection agreement at different heights).

Major comments

RC: The title does not reflect the content of the paper. In fact, the authors focus only on the cloud detection capability based on scattering ratios.

AC: The present version of the article puts more stress on the scattering ratios profiles. In addition, we updated the title to "Comparison of scattering ratio profiles retrieved from ALADIN/Aeolus and CALIOP/CALIPSO observations and preliminary estimates of cloud fraction profiles"

RC: Furthermore, the whole instruction deals only with clouds and not a single word about scattering ratios is written

AC: We now have a whole new section dedicated to definitions, including those of scattering ratios

RC: The scattering ratio which is the essential part of this manuscript has never been properly defined. According to the reference which is given, I assume that, "the ratio between the total backscatter by particles and molecules and the molecular backscatter" (according to Flamant, 2008) is meant, i.e. the ratio between the total backscatter (represented by particles and molecules) to the molecular backscatter.

AC: We agree that the scattering ratio was not properly defined in the previous version. Please, see the general comments above. Indeed, the quoted definition is what is used in ALADIN product, but a different definition is used in the literature for CALIPSO scattering ratio (as CALIPSO is not a HSRL lidar contrarily to ALADIN). A more sophisticated processing is needed than what was provided in the initial version of the manuscript, to convert the scattering ratio from ALADIN to a scattering ratio similar to CALIOP. We believe that this time both the definitions and the conversion are OK.

RC: The conversion the authors use to account for the different wavelengths of CALIOP and AEOLUS is poor. For example, I have made a sketch using an arbitrary atmospheric molecular backscatter coefficient profile and a height-constant particle backscatter coefficient (equal at both wavelengths) of 7e-6m^-1 sr^-1 in order to obtain a scattering ratio at 532 nm shortly above 5 as given by the authors as detection threshold for clouds

AC: First of all, we'd like to thank the Reviewer #1 for his/her efforts to estimate the SRs and the applicability of thresholds. Second, we were not using the same definition of SR as the reviewer in the previous version of the manuscript. Please, read the Section 3 of the present version of the manuscript, which should clarify SR definition, the wavelength conversion and the cloud detection threshold.

RC: Despite all my own doubts concerning this conversion, the authors themselves state: "We would like to stress here that no linear scaling applied uniformly to SRs at all heights could change the ratio of high cloud detection frequency to low cloud detection frequency of ALADIN." Therefore, I wonder: Why they are doing so?

AC: In the present version of the manuscript, we apply a proper conversion to SR'_532 and we discuss the potential sources of bias associated with the parameters of this conversion. We show that by adjusting the parameters of the conversion one can change the ratio between high- and low-level clouds, but there are physically defined limits for this "tweaking".

RC: The choice of this threshold SR>5 is not clear to me and seems very arbitrary and without justification.

AC: First of all, we draw the Reviewers' attention to the fact that the threshold is applied to "CALIOP-like" SR and not to "ALADIN-like" one (please, see Section 3 for the definitions). Second, the threshold SR>5 is used in CALIPSO-GOCCP product (Chepfer et al., 2008, 2013). It is derived from in depth analyses of the CALIPSO SNR in day time at vertical resolution 480m and horizontal resolution 330m, that has been defined within CFMIP for numerous scientific reasons. SR>5 is the threshold value that avoids false cloud detection in day-time due to low SNR induced by solar photons. Even though we used the nighttime cases for CALIOP, ALADIN's observations are in the twilight zone, so we decided to keep this threshold and to apply it uniformly to both instruments at all latitudes and heights.

RC: What happens if this threshold changes?

AC: The impact of this threshold change is discussed in (Chepfer et al. 2013) for CALIPSO. As for the present manuscript, we discussed the redistribution of the YES_YES, YES_NO and NO_YES cases with respect to threshold value in lines 269-274 of the previous version and we updated this discussion in Section 5.3 of the present version. Briefly, a uniform increase or decrease of the threshold for both SR products will not change the ratio between the ALADIN and CALIOP clouds because both will decrease or increase simultaneously. At the same time, a technical adjustment of the threshold for ALADIN's SR_532 could improve the agreement between the datasets, but there's a tradeoff between the YES_YES and NO_YES cases: by increasing the threshold we reduce the number of unexplained (see the text) NO_YES cases, but we reduce the number of good YES_YES cases. By lowering the threshold, we reduce the number of YES_NO cases, but we increase the number of NO_YES cases, a part of which is already difficult to explain. Nevertheless, the new plot with zonal cloud fractions (Fig. 7) looks promising.

RC: The different vertical resolution for Aeolus and Calipso is not sufficiently discussed

AC: In Section 3.1 and 3.2 of the present version that correspond to Sections 2.1 and 2.2 of the original one, we provide the information about the sampling of the instruments and about the resolution of the products used in collocation. Moreover, we apply the same cloud detection thresholds, on both SR(z)_CALIOP and SR(z)_ALADIN at the same vertical and horizontal resolutions.

RC: Language and phrasing need to be improved. It is hardly understandable and not well explained. Please use simple sentences.

AC: The text has been simplified and proof-read by a professional. We hope that this has improved the readability of the article.

RC: Furthermore, “insider information of Aeolus” need to be explained otherwise it is not understandable for non-Aeolus experts.

AC: We have removed internal variable names from the text and rewritten some explanations related to Aeolus in Section 4.5.

Specific comments in addition to pdf

RC: Some statements are either simply wrong or wrongly phrased, e.g.: “…is characterized by lower sensitivity to high clouds above ~7 km than CALIOP, that we explain by lower SNR for ALADIN at these heights that is due both to physical reasons (smaller backscatter at 355 nm)”. Why should there be a smaller backscatter at 355 nm? This is in absolute contradiction to all my knowledge! The particle backscatter coefficient could be equal in clouds (Angström of 0), but the molecular backscatter coefficient is for sure higher (see plots) and thus the total backscatter is for sure also higher! Could you please comment?

AC: This statement is true and, indeed, the phrasing was misleading. We apologize for that. We meant the contribution of the particles to the total (particulate + molecular) signal. Even though the total backscatter is larger at 355nm, the particulate part can be buried in molecular return because the molecular backscatter is larger at 355nm while the backscatter from cloud particles is about the same. If the signal-to-noise ratio is small, then the cross-talk correction will be noisy and the particulate signal will be retrieved with large uncertainty. To avoid the confusion, in the present version of the manuscript we refer to the formalism defined in the second section and explain what we mean.

RC: Abstract: Just one of many examples: “(b) the cloud detection agreement is better for the lower layers. Above ~7 km, the ALADIN product demonstrates lower sensitivity because of lower backscatter at 355 nm” I do not understand this statement. First of all: What do you mean? The volume backscatter coefficient, the particle backscatter coefficient, the molecular backscatter coefficient? It is not clear! And I also do not know why any of these should be lower at 355 nm compared to 532 nm (and 1064 nm)

AC: We have rewritten the abstract for clarification.

RC: Abstract last sentence: Is not understandable. What values are this? What is a cloud detection agreement value? Abstracts should be self-explaining and understandable.

AC: Thank you for pointing this out. We have added the definition to the abstract. Please, see new Section 3.5 for the details.

RC: Not all references are in alphabetical order

AC: Fixed, thanks.

RC: Some mistakes in the names of the references, please check

AC: Fixed, thanks.

For the rest of the reviewer’s comments in PDF, please, see below.

AC: some of the pages are cluttered with comments, so we could not add an answer beneath or near each of them. Instead, we provided the answers in the same order as they appear in the top of the page. Sometimes, as on this page, one answer covers several questions.

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Open Access EGU

Comparing scattering ratio products retrieved from ALADIN/Aeolus and CALIOP/CALIPSO observations: sensitivity, comparability, and temporal evolution

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Abstract.
The spaceborne active sounders have been contributing invaluable vertically resolved information of atmospheric optical properties since the launch of CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation) in 2006 To ensure the continuity of climate studies and monitoring the global changes, one has to understand the differences between lidars operating at different wavelengths, flying at different orbits, and utilizing different observation geometries, receiving paths, and detectors In this article, we show the results of an intercomparison study of ALADIN (Atmospheric Laser Doppler INstrument) and CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization) lidars using their scattering ratio (SR) products for the period of 28/06/2019–31/12/2019 We suggest an optimal set of collocation criteria (Δdist < 1°; Δtime < 6h), which would give a representative set of collocated profiles and we show that for such a pair of instruments the theoretically achievable cloud detection agreement for the data collocated with aforementioned criteria is 0 77±0 17 The analysis of a collocated database consisting of ~78000 pairs of collocated nighttime SR profiles revealed the following: (a) in the cloud-free area, the agreement is good indicating low frequency of false positive cloud detections by both instruments; (b) the cloud detection agreement is better for the lower layers Above ~7 km, the ALADIN product demonstrates lower sensitivity because of lower backscatter at 355 nm and because of lower signal-to-noise ratio; (c) in 50% of the analyzed cases when ALADIN reported a low cloud not detected by CALIOP, the middle level cloud hindered the observations and perturbed the ALADIN's retrieval indicating the need for quality flag refining for such scenarios; (d) large sensitivity to lower clouds leads to skewing the ALADIN's cloud peaks down by ~0 5±0 4 km, but this effect does not alter the polar stratospheric cloud peak heights; (e) temporal evolution of cloud agreement quality does not reveal any anomaly for the considered period, indicating that hot pixels and laser degradation effects in ALADIN have been mitigated at least down to the uncertainties in the following cloud detection agreement values: 61±16%, 34±18% 24±10%, 26±10%, and 22±12% at 0 75 km, 2 25 km, 6 75 km, 8 75 km, and 10 25 km, respectively

[redacted] mments on amt-[redacted]

Page: 1

Author: Subject: Sticky Note Date: 14 06 2021 09:43:49
Abstract not understandable

Author: Subject: Comment on Text Date: 14 06 2021 09:44:08
poor phrasing

Author: Subject: Comment on Text Date: 14 06 2021 11:26:31
What do these numbers mean? It is not understanable without reading the paper

AC: we have rewritten the abstract and we introduced the normalized cloud detetion agreement, CDAnorm, in the Abstract

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Atmospheric Measurement Techniques
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Discussions

1 Introduction

Clouds play an important role in the energy budget of our planet: optically thick clouds reflect the incoming solar radiation, leading to cooling of the Earth, while thinner clouds act as "greenhouse films", preventing escape of the Earth's long-wave radiation to space. Climate feedback analyses reveal that clouds are a large source of uncertainty for the climate sensitivity of climate models and, therefore, for the predicted climate development scenarios (e.g. Nam et al., 2012; Chepfer et al., 2014; Vaillant de Guélis et al., 2018). Understanding the Earth's radiative energy budget requires knowing the cloud cover, their geographical and altitudinal distribution, temperature, composition, as well as the optical properties of cloud particles and their concentration.

Satellite observations have been providing a continuous survey of clouds over the whole globe. IR sounders have been observing our planet since 1979: from the TOVS (TIROS Operational Vertical Sounder) instruments (Smith et al., 1979) onboard the NOAA polar satellites to the AIRS (Atmospheric InfraRed Sounder) spectrometer (Chahine et al., 2006) onboard Aqua (since 2002) and to the IASI (Infrared Atmospheric Sounder Interferometer) instrument (Chalon et al., 2001; Hilton et al., 2012) onboard MetOp (since 2006), with increasing spectral resolution. Despite an excellent daily coverage and daytime/nighttime observation capability (Menzel et al., 2016; Stubenrauch et al., 2017), the height uncertainty of the cloud products retrieved from the observations performed by these spaceborne instruments is limited by the width of their channels' contribution functions, which is on the order of hundreds of meters, and the vertical profile of the cloud cannot be retrieved with accuracy needed for climate feedback analysis. This drawback is eliminated by active sounders, the very nature of which is based on altitude-resolved detection of backscattered radiation, and the vertical profiles of the cloud parameters are available from the CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization) lidar (Winker et al., 2003) and CloudSat radar (Stephens et al., 2002) since 2006, CATS (Cloud-Aerosol Transport System) lidar on-board ISS provided measurements for over 33 months starting from the beginning of 2015 (McGill et al., 2015). The ALADIN (Atmospheric Laser Doppler INstrument) lidar on-board Aeolus (Krawczyk et al., 1995; Stoffelen et al., 2005; ADM-Aeolus Science report, 2008) has been measuring horizontal winds and aerosols/clouds since September 2018. More lidars are planned – in 2023, the ATLID (ATmosperic LIDar)/EarthCare instrument (Héliere et al., 2012) will be launched and other space-borne lidars are in the development phase. Even though all active instruments share the same measuring principle – a short pulse of laser or radar electromagnetic radiation is sent to the atmosphere and the time-resolved backscatter signal is collected by the telescope and is registered in one or several receiver channels, the wavelength, pulse energy, pulse repetition frequency (PRF), telescope diameter, orbit, detector, and many other parameters are not the same for any given pair of current or future instruments. These differences are responsible for the active instruments' capability of detecting atmospheric aerosols and/or hydrometeors for given atmospheric scenario and observation conditions (day, night, averaging distance). At the same time, there is an obvious need of ensuring the continuity of global spaceborne measurements and obtaining a seamless transition between the satellite missions (Chepher et al., 2018).

Page: 2

Author: Subject: Comment on Text Date: 14.06.2021 09:44:37
"f" missing

AC: fixed, thanks

https://doi.org/10.5194/amt-2021-96
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This works seeks to address this issue using ALADIN/Aeolus spaceborne wind lidar operating at 355 nm and CALIOP/CALIPSO atmospheric lidar operating at 532 nm Even though the main goal of ALADIN is wind detection (Reitebuch et al , 2020; Straume et al , 2020), the calibration of which does not rely on absolute calibration of the detected radiation, its products include atmospheric optical properties and such a comparison serves the inter-calibration purposes In addition, the methods developed in the course of this study, and the interpretation of the results will set the stage for the future validation of the ATLID/EarthCare instrument and other spaceborne lidars

The structure of the article is as follows In Section 2, we describe the datasets used in this study, explain the collocation criteria, and provide an estimate of the best possible theoretically achievable agreement for two instruments in given configuration In Section 3, we strive to provide a multifaceted view of the collocated dataset and discuss the observed differences Section 4 concludes the article

2 Datasets and methods

We start this section with the description of ALADIN/Aeolus optical properties dataset followed by the description of CALIOP/CALIPSO product and its modification aimed at matching the sampling and averaging of Aeolus product In the next steps, we define the procedures and criteria for the comparison of these two products

2.1 AEOLUS

A detailed description of the Aeolus mission and its instrument can be found in (Krawczyk et al , 1995; Stoffelen et al , 2005; ADM-Aeolus Science report, 2008; Flamant et al , 2017) and here we provide only a brief description of the lidar and the details necessary for understanding the key differences between the compared instruments The Aeolus satellite carries a Doppler wind lidar called ALADIN, which operates at 355 nm wavelength and is composed of a transmitter, a Cassegrain telescope, and a receiver capable of separating the molecular (Rayleigh) and particular (Mie) backscattered photons (HSRL, high spectral resolution lidar) The lidar is aimed 35° from nadir and 90° to the satellite track, its orbit is inclined at 96 97° and the instrument overpasses the equator at 6h and 18h of local solar time (LST), see also Table 1 to compare with CALIOP

The laser emitter sends 15 ns long pulses of 355 nm radiation down into the atmosphere 50 times per second The telescope collects the light that is backscattered from air molecules, aerosols and hydrometeors The received backscatter signal in Mie receiver passes through a Fizeau interferometer, which produces a linear fringe whose position on the ACCD (Accumulation Charge Coupled Device) detector of this channel is linked to the wind velocity As for the Rayleigh receiver, it uses a dual-filter Fabry–Pérot interferometer, which throws two images on the ACCD detector of this channel, and the wind speed is defined from the ratio of intensity of these two images (Chanin et al , 1989) Besides the winds, the Aeolus processing algorithms retrieve the optical properties of the observed atmospheric layers (Ansmann et al , 2007; Flamant et al , 2017) The vertical resolution of the instrument is adjustable, but the total number of points in a vertical profile is defined by a number of rows of the detector dedicated to this purpose (24) The observation priorities changed throughout the period of the mission

Page: 3

Author: Subject: Cross-Out Date: 17 05 2021 14:55:03

Author: Subject: Comment on Text Date: 14 06 2021 09:45:08
This statement is very vague

Author: Subject: Sticky Note Date: 17 05 2021 14:56:29
not a single word of scattering ratios so far

Author: Subject: Highlight Date: 17 05 2021 14:59:05

AC: we have rewritten and reorganized the text and we added a whole new section with definitions (Section 3). As for the phrase with "set tte stage", we have rewritten it to "In addition, the methods developed in this study and its conclusions will set the stage for the future comparison of the ATLID/EarthCare observations with other space-borne lidar". We cannot be more specific at this time.

AC: In the updated version of the manuscript, Section 3 is dedicated to the deifinitions and the SR conversion approach

AC: we did not get, why the PRF of 50Hz is marked.

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Preprint. Discussion started: 19 April 2021

(Bley et al , 2021), and for the majority of the period considered in this work (see below), the vertical sampling of both Mie and Rayleigh channels between 2 km and 22 km was equal to 1 km whereas the sampling below 2 km varied from 0 25 to 1 km The native horizontal resolution of 140 m of the instrument is sacrificed to achieve higher signal to noise ratio both onboard by accumulating the detected profiles and on the ground by averaging the downloaded profiles at different steps of the processing chain (Flamant et al , 2017)

The present study has been done using the pilot L2A dataset from Aeolus, Prototype_v3 10, which is available for a limited period of ALADIN's observations, from 28/06/2019 through the 31/12/2019 According to (Flamant et al , 2017), the L2A data is produced from the L1B product of this instrument and it contains height profiles of Mie and Rayleigh co-polarized backscatter and extinction coefficients, scattering ratios, and lidar ratios (Flamant et al , 2008; Lolli et al , 2013) along the lidar line-of-sight For the end user, the profiles are provided both on observation scale (87 km averages) and on smaller scales after applying scene classification, but for the purposes of the present work the scattering ratio on the scale of 87 km is an optimal choice

In Fig 1(a-c), we show the observation geometry and sampling of ALADIN's L2A product as well as three variables retrieved from its observations, namely, the APB (Attenuated Particular Backscatter), the AMB (Attenuated Molecular Backscatter), and the ATB (Attenuated Total Backscatter) The white dashed lines in Fig 1 represent the line of sight of the instrument One has to note, however, that in the real life the ALADIN's line of sight is pointed perpendicular to the flight direction; at the same time, the horizontal variability of the observed scene is nearly the same in latitudinal and longitudinal directions at 100 km distance, so the sketch gives an idea of the comparability of the physical parameters observed by ALADIN (Fig 1a-c) and CALIOP (Fig 1d) The atmospheric scene used in Fig 1 has been calculated for demonstration purposes for two wavelengths, 355 nm (Fig 1a,b,c) and 532 nm (Fig 1d) from the output of the EAMv1 (Energy Exascale Earth System Model (E3SM) atmosphere model version 1) atmospheric model (Rasch et al , 2019) for the conditions of autumn equinox in Northern hemisphere This data has been obtained with the help of the COSP2 (the Cloud Feedback Model Intercomparison Project Observational Simulator Package, v2) package, which is capable of simulating the atmospheric observables for spaceborne instruments (Swales et al , 2018) The CALIOP is built into COSP2 (Chepfer et al , 2008) whereas the ALADIN is not yet a part of this package, so we used the 355 nm calculations by COSP2 (Reverdy et al , 2015) at fine grid corresponding to ALADIN's original laser pulse frequency rate and modified them in accordance with the ALADIN's vertical and horizontal averaging The cloud variability along the satellite's track has been estimated from the gridded EAMv1 data using the parameterization of (Boutle et al , 2014) Figure 1 also serves as an illustration to theoretically achievable cloud detection agreement discussed below

For each profile corresponding to an inclined dashed line in Fig 1, we extracted the corresponding scattering ratio (SR) column of *sca_optical_properties* group of variables where SCA stands for standard correct algorithm (Flamant et al , 2017) An important companion of such a column is a corresponding quality flag column, which we scanned looking for the points characterized either by high Mie signal-to-noise ratio (SNR) or by high Rayleigh SNR, and by a flag that indicates an absence

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Author: Subject: Highlight Date: 14 06 2021 11:05:32
No reference given You need to explain what this means and what is the difference to operational data

Author: Subject: Comment on Text Date: 18 05 2021 09:52:16
the scattering ratio you use is never defined, as it is essential for this work, you should do so

Author: Subject: Comment on Text Date: 17 05 2021 15:05:39
this is not true and heavily depends on the scene

Author: Subject: Comment on Text Date: 17 05 2021 15:07:53
it gives a wrong idea, because scenes are usually by far not so homogenous

Author: Subject: Comment on Text Date: 17 05 2021 15:08:41
for what do you need the autumn equinox in this simulatiuon?

Author: Subject: Comment on Text Date: 17 05 2021 15:09:42
what does this mean?

Author: Subject: Comment on Text Date: 14 06 2021 09:41:29
I don't understand, more explanation needed I do not see any cloud in this figure

Author: Subject: Comment on Text Date: 14 06 2021 11:07:13
nobody who is not familiar with Aeolus L2A data structure will understand this

Furthermore, it is not trace-able/understandable for anyone not within an Aeolus Cal/Val team yet A proper reference should be given or, if not available, a more detailed description of the data set needs to be given here E g , what is the difference to other Aeolus data Why have you used this data set, etc

Author: Subject: Comment on Text Date: 14 06 2021 11:06:50
what does this mean: HIGH SNR? >2, >10, >100?

AC: In the new version, we write "the L2A data is produced from the L1B product of this instrument and it contains height profiles of Mie and Rayleigh co-polarized backscatter and extinction coefficients, scattering ratios (SR), and lidar ratios (Flamant et al., 2017; Lolli et al., 2013) along the lidar line-of-sight". There's no reference per se, this is a test product and we have a corresponding statement in the Disclaimer at the end of the manuscript

AC: Please, see new Section 3

AC: we have updated the description of our numerical experiment

AC: Fig. 1 is now different

AC: There's nothing special about the Autumn equinox itself, this season just happens to be in the middle of the Prototype v3.10 data period.

AC: We got rid of internal Aeolus variable names in the present version of the manuscript

AC: the exact values of SNR used in the Aeolus algorithms are not given in the ATBD, so we just used the binary (yes/no) flags relying on the experience of the processing team.

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of signal attenuation Presumably, these flags are necessary and sufficient for a valid SR profile, which can be then compared with that of CALIOP

2.2 CALIPSO-GOCCP

CALIOP, a two-wavelength polarization-sensitive nadir viewing lidar, provides high-resolution vertical profiles of aerosols and clouds its 705 km orbit is inclined at 98 05° and it overpasses the equator at 1h30 and 13h30 LST, see also Table 1 It uses three receiver channels: one measuring the 1064 nm backscatter intensity and two channels measuring orthogonally polarized components of the 532 nm backscattered signal Cloud and aerosol layers are detected by comparing the measured 532 nm signal return with the return expected from a molecular atmosphere

The CALIPSO-GOCCP (GCM Oriented Cloud Calipso Product) was initially designed to evaluate GCM cloudiness (Chepfer et al , 2010) It is derived from CALIPSO L1/NASA products at LMD/IPSL with the support of NASA/CNES, ICARE, and ClimServ and it contains observational cloud diagnostics including the instantaneous scattering ratio (profiles) at the native horizontal resolution of CALIOP (333 m) and at ~0 5 km vertical resolution This makes it a good reference dataset for ALADIN retrievals because it can be easily recalculated to the latter's horizontal and vertical grids considering the corresponding horizontal averaging Since the CALIOP is not a HSRL, the detailed information on AMB and APB is not available, and one has to compare the SR products Correspondingly, we convert the ALADIN's SR retrieved at 355 nm to SR at 532 nm using the following equation:

$$SR_{532} = SR_{355} \times 3.3 - 2.3 \quad (1)$$

which is derived from (Collis and Russell, 1976) in an assumption that their fitting parameter Λ (see their Section 4 3 1) is equal to 3 The choice of the fitting parameter is not crucial for the purposes of the present work because the conversion described by Eq 1 is linear and it does not change the altitude distribution of the SR On the other hand, using the same physical parameter is highly advisable for the comparisons we are intending to perform Theoretically, one could have validated the parameters of Eq 1 using the collocated data under consideration, but, looking ahead, one can say that the spread of the values is too large to do it with reasonable uncertainty, so we will stay with Eq 1 in the framework of this paper and in Appendix A we justify our choice of conversion coefficients using the collocated data

2.3 Collocation criteria

As for any collocation, there is a trade-off between the quality of collocation and the number of collocated pairs of profiles As we show below, in the case of AEOLUS and CALIPSO, this tradeoff is supplemented with a requirement of a representative geographical coverage, because imposing a strict temporal overlap criterion dramatically changes the latitudinal distribution of the collocated points Since the horizontal averaging and resolution of the Aeolus Prototype_v3 10 product is 87 km, there is no much sense in collocating the data with the accuracy better than this value On the other hand, a fractional standard deviation f_c of cloud water content at 1° (~111 km) distance is about 0 5 for a cloud cover of 1 (Boutle et al , 2014), and there

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Author: Subject: Comment on Text Date: 14 06 2021 11:07:30
I am not sure if these flags are valid in these kind of data These data are all preliminary You should discuss this

Author: Subject: Comment on Text Date: 18 05 2021 09:56:56
This statement is in contradiction to Figure 1, where you clearly see that it is not nadir but only close to nadir

Author: Subject: Comment on Text Date: 18 05 2021 09:56:24
I guess you mean the altitude of the orbit, but this is not written here Please state correctly

Author: Subject: Comment on Text Date: 18 05 2021 10:26:48
GCM never explained

Author: Subject: Comment on Text Date: 14 06 2021 09:54:36
This is not state of the art and not acceptable - see plots in my text

Author: Subject: Comment on Text Date: 14 06 2021 09:55:42
I do not understand this statement And the justification given in the Appendix is not sufficient in my opinion

AC: the Prototype version of the Aeolus data is supposed to be self-consistent. We have a Disclaimer at the end of the manuscript, which states that all the data in this version are preliminary.

AC: The small offset from nadir in CALIOP was introduced to reduce the surface reflection effects. This modification barely changed the optical path lengths, so it still can be called a "nadir-viewing instrument". To be precise, we changed it to "near nadir viewing lidar"

AC: We modified the phrasing about the orbital height, thaks for pointing this out

AC: GCM is now introduced in the explanation of the first abbreviation

AC: We agree that SR recalculation was oversimplified. In the present version of the manuscript, we have a whole new section dedicated to the definitions and recalculation approach.

AC: The validation part and its discussion have been removed

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is a risk of comparing incoherent quantities, so we took Δdist = 1° as a limit for the collocations and created several subsets based on the Δtime, the absolute value of the difference between two collocated measurements In Fig 2, we show three such subsets, and the Table 2 provides the information about the other cases we considered On the one hand, one can see that a strict collocation criterion of Δtime < 1h (Fig 2a) provides the information only about two narrow zones in the Southern and Northern polar regions On the other hand, an excellent geographical coverage shown in Fig 2c comes at the cost of mixing up the cases, which differ by almost one day that is unacceptable from the point of view of temporal variation In addition, this case is characterized by unequal distribution of Δtime throughout the globe Finally, a subset corresponding to Δtime < 6h (Fig 2b) has been chosen for the analysis Over the oceans, the diurnal effects in cloud distribution associated with this difference are small (e g Noel et al , 2018; Chepfer et al , 2019; Feofilov and Stubenrauch, 2019) and the land represents one third of the analyzed cases To avoid the risks associated with the solar contamination, we picked up only the night-time cases, which yield about 7 8E4 pairs of SR profiles In supplementary materials, we provide the complete collocated database, which corresponds to the last line, 4th column of Table 2 (3 7E5 collocations), for further analysis by the interested teams

2.4 Estimating the theoretically achievable agreement between two collocated datasets

To justify the collocation criteria and to estimate the theoretically possible agreement for the clouds detected by two instruments in a given setup and for the selected Δtime and Δdist values, we have performed a numerical experiment using the same calculated data as we used in Fig 1 This time, we picked up the "lidar curtain" at 532 nm calculated at the resolution of CALIOP (333m) and created artificial pairs of "collocated" data with the Δdist distribution modulated by that of a real collocated dataset The "reference", CALIOP profile has been composed using 2000 individual SR profiles covering 67 km region that is somewhat less than the 87 km covered by ALADIN This averaging is supposed to catch the mean atmospheric properties and at the same time it is not supposed to go too far from the ALADIN footprint location The "test" SR profile was created from the SR averages, considering both the ALADIN's off-nadir pointing and its 87 km averaging To imitate the diurnal variation, we modulated the SRs using the 6-hour diurnal cycle amplitudes for land and ocean retrieved from active and passive observations (Noel et al , 2018; Chepfer et al , 2019; Feofilov and Stubenrauch, 2019) and added them to the comparison Besides testing a noise-free simulation, we also checked the effects introduced by instrumental noise for CALIOP Since ALADIN is not yet part of COSP2, we used the estimates from (Ansmann et al , 2007) Overall, we considered about 1E5 pairs of pseudo-collocated data and we present the results of cloud detection in Fig 3 We define the cloud detection agreement as follows: for each altitude bin, the cloud detection agreement is a ratio of a number of cases when both instruments have detected a cloud (SR>5) to a total number of joint observations For a given altitude bin, the cloud amount is a ratio of number of cases with SR>5 to a total number of profiles for a single instrument, and the normalized cloud detection agreement is a ratio of the former to the latter As one can see, the normalized cloud detection quality is mostly defined by a horizontal variability of aerosols/hydrometeors and by differences in viewing geometries of two instruments Observation noise and diurnal variation play the secondary role, and according to our estimates the saturation effects in 355 nm and 532 nm channels associated with opaque clouds (Guzman et al , 2017) do not add more than 2% to the cloud detection mismatch (not shown in

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Author: Subject: Comment on Text Date: 14 06 2021 11:07:47
As Aeolus is flying at a dusk-dawn orbit, how can you select night time cases? Or is this valid for Calipso only? But then you have a bias, right?

Author: Subject: Comment on Text Date: 14 06 2021 09:56:04
I really did not understand what you are doing here Maybe a sketch or flowchart could help

Why do you need to imitate diurnal variation? Please explain!

Author: Subject: Comment on Text Date: 14 06 2021 11:09:06
The choice of this threshold is not clear to me and seems very arbitrary Furthermore, the use of a scattering ratio for cloud detection in questionable to me at all, as the scattering ratio depends on temperature and pressure and thus on height even with uniformly distributed particle load as shown in the attached plots Using one threshold would mean that you detect a cloud at one height while you may not detect a similar cloud at another height Thus, using the scattering ratio for cloud detection is not appropriate in my opinion You could have used the scattering ratio from the satellite data to calculate the real particle backscatter coeff by using the molecular backscatter which you calculate from the meteorological data which is included in the satellite data as well

Author: Subject: Comment on Text Date: 18 05 2021 15:10:14
I do not "see" that At least in Fig 3 it is not obvious To what you are referring to? And can you give more explanation?

Author: Subject: Comment on Text Date: 14 06 2021 10:00:39
Any evidence or proof for such a statement? Again to what are you referring?

Author: Subject: Comment on Text Date: 18 05 2021 15:12:08
is this valid for ALADIN as well?

AC: Indeed, dusk-dawn observations are not equal to night-time observations, but this selection itself does not lead to a bias. We discuss the diurnal cycle effects in the manuscript and according to our estimates performed without local time filtering, the results are nearly the same. The idea here was to get rid of solar photons and to apply the same SR threshold for both intruments.

AC: A flowchart has been added and the text was updated

AC: As for the choice of the SR threshold, please, see the comments in the text version of the review.

AC: If one looks at Fig. 3 (now Fig. 4), one will see that the curves marked "w/o noise" and "w/noise" are virtually the same. The curves with noise correspond to variability caused by diurnal variation and instrumental noise added to the calculations. Therefore, the primary source of deviation from 1 is the observation geometry and the collocation quality.

AC: Saturation effects do not depend on the instrument

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Fig 3 for the sake of clarity) Overall, the theoretically achievable agreement for the collocated data in a given setup can be estimated as 0 77±0 17 for cloud detection

3 Results and discussion

3.1 Zonal averages

To give a general overview of the agreement between two products, we have split the database to latitudinal zones: 90S–60S, 60S–30S, 30S–30N, 30N–60N, 60N–90N (Fig 4) As it was stated above, we rescale the SR_{355} values retrieved from ALADIN observations to SR_{532} using Eq 1 Even though the zonal mean statistics does not imply using collocated data, we do it to avoid any incoherence in sampling different geographic areas By using exactly the same number of profiles collocated within 1°, we ensure the same coverage and sampling by both lidars If the detection efficiency of different cloud types were the same for two instruments, the plots would have been close to each other because the horizontal variability of clouds would cancel out due to averaging over a large number of profiles within the zone and the diurnal variation is small over oceans, which constitute two thirds of the cases used to build Fig 4 (Noel et al , 2018; Chepfer et al , 2019; Feofilov and Stubenrauch, 2019) Analyzing the Fig 4, one can note the following: (1) the SR/altitude histograms of CALIOP (Fig 4a-e) are characterized by two distinct peaks corresponding to low-level and high-level clouds; this feature is coherent with other observations, e g with GEWEX (Global Energy and Water cycle Experiment) cloud assessment (Stubenrauch et al , 2013); (2) the SR/altitude histograms built for SRs retrieved from ALADIN's observations (Fig 4f-j) are characterized by a smoother occurrence frequency plot where the two-peak structure is less pronounced than for CALIOP; (3) even though ALADIN detects some clouds in polar stratosphere (PSCs), its overall sensitivity to high clouds (>7 km) is lower than that of CALIOP; (4) both rows show certain consistency of zone-to-zone change up to ~3km altitude while the behavior above requires a more detailed view We would like to stress here that no linear scaling applied uniformly to SRs at all heights could change the ratio of high cloud detection frequency to low cloud detection frequency of ALADIN The same is true for CALIOP In the next step, we compare the "instantaneous" profiles provided by CALIOP and ALADIN having in mind the peculiarities of cloud detection sensitivity differences observed in Fig 4

3.2 Comparing pseudo-individual profiles at ALADIN's L2A product resolution

To address the high cloud detection sensitivity, we have inspected the 6h nighttime subset of collocated data, looking for the cases, which would satisfy the following criteria: (1) both instruments should have at least one strong SR peak; (2) the vertical position of this peak detected by one instrument should match that of the peak detected by a second instrument within 1 km; (3) the CALIOP SR profile should have a secondary peak at or above 9 km (Fig 5a-j) For the comparison purposes, the panels in Fig 5 represent the individual profiles belonging to the same 5 zones as the panels of Fig 4 For the sake of simplicity, we compare the $SR_{355}(z)$ profiles recalculated to $SR_{532}(z)$, but we also show the source $SR_{355}(z)$ profiles for reference purposes Regarding the conversion using Eq 1, the strong peaks selected this way demonstrate a qualitative agreement between the

Author: Subject: Comment on Text Date: 18 05 2021 15:14:57
which products? SR or cloud product? Unclear

Author: Subject: Comment on Text Date: 18 05 2021 15:15:04
phrasing

Author: Subject: Comment on Text Date: 18 05 2021 15:16:04
phrasing

Author: Subject: Comment on Text Date: 18 05 2021 15:17:14
maybe because your transformation of the SR is incorrect?

Author: Subject: Comment on Text Date: 18 05 2021 15:18:07
If you know that, why have you done so?

Author: Subject: Comment on Text Date: 14 06 2021 09:07:46
What is true for CALIOP?

Author: Subject: Comment on Text Date: 14 06 2021 11:09:47
is the feasible according to the range-bin setting of Aeolus In principle, Aeolus can also have 2 km thick range bins Can you comment on this?

Author: Subject: Comment on Text Date: 14 06 2021 10:08:26
I do not see a reason to use the "sake of simplicity " here A correct conversion is needed

AC: now we specify that we compare SR(532nm,z) and SR'(532nm,z)

AC: we have changed the phrasing

AC: Indeed, the updated transformation of SR gives somewhat better results, but the general conclusions (and the one, which is marked by the Reviewer on this page) remain the same

AC: please, see our answer regarding linear conversion in the text portion of the replies above

AC: That's true, 2km range bins can exist in ALADIN data, but they were not the subject of a case study described here (and we did not see them). As for the averaged plot, they will not spoil the picture, either, because the data is interpolated to a regular grid and then averaged.

AC: We do not use SR355 anymore and we apply an updated (and presumably correct) conversion procedure.

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peak values calculated from SR_{355} and peak retrieved SR_{532} values. In Appendix A, we demonstrate the correlation between individual pairs of CALIOP and ALADIN SR profiles; the conclusion of this exercise is that it justifies using Eq. 1, but the uncertainties of the analysis do not allow to refine the conversion coefficients. As for the potential capability of ALADIN to detect high clouds, the subset Fig. 5a-e represents the cases, for which the instrument was capable of retrieving the peak of the same magnitude and height as the peak detected by CALIOP. Even though these cases exist, they are far less frequent than those shown in Fig. 5f-j. We did not detect and correlation between the collocation criteria (Δdist; Δtime) and the frequency of occurrence of these cases, it's just a statistical observation that both types of cases exist and the former are less frequent than the latter. This observation gives a hint that the instrumental part provides the backscatter information sufficient for some cloud detection up to 20 km, but the detection algorithm suppresses noisy solutions. The PSC detection discussed below (see also Fig. 4f) confirms this assumption because the vertical extent and the composition of these clouds yield a strong signal. Further speculations on this subject are beyond the scope of the present article, but we believe that the high cloud detection agreement might be improved by studying the collocated cases provided in the supplementary materials and by applying different noise filtering techniques in the L0→L1→L2 elements of the ALADIN retrieval chain. Figures 5k-o will be discussed below in the context of low-level cloud observations.

3.3 Cloud detection agreement

To illustrate the peculiarities of zonal and altitudinal behavior of cloud detection agreement between two considered instruments, we have split the collocated data into four groups (Fig. 6). For each altitude/latitude grid point, we have estimated the number of cases when both instruments have detected a cloud ($SR_{532}(z)>5$), when neither of instruments has detected a cloud, when only CALIOP has detected a cloud, and when only ALADIN has detected a cloud. For the sake of simplicity, we will call them YES_YES, NO_NO, YES_NO, and NO_YES cases. It is clear that in the ideal experiment the number of mismatched cases (YES_NO and NO_YES) should tend to zero. From the study presented in Section 2.4, we expect that the ratio of (YES_YES+NO_NO)/(YES_YES+NO_NO+YES_NO+NO_YES) should be about 0.77±0.17 if both instruments detect the clouds with the same efficiency. In Fig. 6a we show the ratio of YES_YES cases to the total number of collocated profiles per altitude/latitude bin. This panels resembles a typical cloud amount plot, and this is expected because in the case of an ideal agreement the aforementioned ratio is equivalent to cloud amount definition. Below, we will also discuss the YES_YES statistics normalized to cloud amount, but at this point we also want to study the other cases, which cannot be normalized this way. Even though the distribution in Fig. 6a looks physical, the absolute numbers are somewhat low and this is explained by YES_NO and NO_YES distributions (Fig. 6c and d, respectively). As for NO_NO agreement (Fig. 6b), it is close to 100% in the high-altitude area where there are no clouds. This indicates that the noise-induced false detection rate of both instruments is low, and this is a good sign.

If we consider the mismatch of YES_NO type (Fig. 6c), we will see that the altitudinal/zonal distribution of the mismatch occurrence frequency resembles that of the YES_YES type. A part of mismatch can be explained by theoretically allowed cloud detection disagreement discussed in Section 2.4. However, the occurrence frequency of YES_NO cases above 3 km is

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Author: Subject: Comment on Text Date: 14.06.2021 10:09:39
This is not convincing

Author: Subject: Comment on Text Date: 14.06.2021 10:10:13
how do you account for the different vertical resolution?

Author: Subject: Comment on Text Date: 14.06.2021 10:11:10
This statement is not clear for me

Author: Subject: Comment on Text Date: 14.06.2021 10:14:44
Phrasing needs to be imporved

AC: We do not have Appendix A and the corresponding discussion in the present version of the manuscript.

AC: When the profiles are compared, the resolution of CALIOP is already lowered through averaging.

AC: We've added an explanation after this phrase

AC: This section has beed rewritten

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roughly twice that of YES_YES cases, and this indicates the retrieval sensitivity issue of ALADIN. The NO_YES mismatches (Fig 6d) require specific attention because they are not expected from the methodological point of view: the cloud extinction at 355 nm is larger than at 532 nm and the observation geometry of ALADIN makes the optical paths $1 / cos(SVA) = 1.22$ times longer than those for CALIOP, where SVA stands for satellite viewing angle of 35° The typical individual profiles corresponding to NO_YES mismatches are shown in Fig 5k-o As one can see, despite the unfavorable observation conditions (e q an opaque cloud with peak SR_{532} value of ~22 at 9 km in Fig 5.l), ALADIN reports two valid points beneath the cloud whereas it does not report anything at 9 km height where CALIOP sees a thick cloud These cases do need our special attention On the one hand, many cases of this type are over the ocean, so one can rule out the surface echo mixed with atmospheric backscatter and treated like an atmospheric signal On the other hand, the NO_YES cases are often accompanied by the structures similar to those presented in Fig 5k,l,n which are probably provoked by a presence of a cloud at these heights The perturbations to the extinction and backscatter profile caused by these structures might propagate downwards, thus causing the appearance of the false peaks in the lower layers of ALADIN's data This indicates a need for a quality flag refinement in the lower layers in the presence of a thick cloud above and the improvement of thick cloud detection itself Apparently, the CALIOP cloud retrievals beneath thick clouds do not suffer from these effects

To test whether the aforementioned disagreements are at least partially caused by the cloud definition and SR recalculation to another wavelength and whether the agreement could be improved, we varied the SR threshold for ALADIN, assuming the ±50% uncertainty on the parameters forming the coefficients of Eq 1 However, this exercise yielded no optimum value for SR threshold: its lowering for ALADIN increased the number of YES_YES and reduced the number of YES_NO cases, but at the same time it increased the frequency of NO_YES cases Correspondingly, increasing the threshold reduced the number of NO_YES cases, but it adversely affected the YES_YES agreement Summarizing this comparison, one can conclude that (a) a cloud detected by CALIOP is detected by ALADIN in ~50% of cases for clouds below ~3km and in ~30% of cases for higher clouds; (b) in the cloud-free area, the agreement between the datasets is good that indicates a low frequency of false positive detections by both instruments; (c) one half of the cases when ALADIN detects a cloud missed by CALIOP should be attributed to false positive detection of the low cloud in the presence of a higher opaque cloud, which perturbs the retrieval in the lower layers

3.4 Cloud altitude detection sensitivity

Besides marking the profile elements as "cloudy" and "not cloudy" and comparing the cloud detection statistics as we did in the previous section, it would be interesting to obtain cloud peak detection statistics for pairs of collocated profiles like those shown in Fig 5 This exercise is not aimed at revealing any altitude offset in backscatter signal registration, because this part of experimental setup is robust in both instruments But, as we saw in Fig 4 and Fig 6, the sensitivity of ALADIN to high clouds is lower than to lower clouds and a convolution of sensitivity curve with the backscatter profile can skew the cloud peak position and the average cloud height To illustrate this effect, we have carried out the following analysis For each pair

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Author: Subject: Comment on Text Date: 14 06 2021 10:17:13
What does it mean? It could be also a cause of your rough conversion of the scattering ratio and or the range-bin thickness of Aeolus?

Author: Subject: Comment on Text Date: 14 06 2021 10:18:28
Phrasing! Is this really only one cloud?

Author: Subject: Comment on Text Date: 14 06 2021 10:19:55
Can you explain, how these false peaks could develop? It is not clear to me

AC: as we wrote before, the updated conversion algorithm did not change the magnitude of SRs for high clouds. In any case, the agreement of the updated version is somewhat better, so we changed the phrasing.

AC: this time, we consider all possible reasons for NO_YES cases, including those related to recalculation procedure. Our conclusion is that even if we tweak the conversion parameters, we will explain only half of these cases

AC: We do not know the exact details of the algorithms, so we can only speculate here using the basics of active remote sensing. Since the lidar equation (Eq. 1) is solved layer per layer and the upper layers affect the solution for the lower one,s the "false peaks" we were speaking about, can appear if the solution in the upper layer is perturbed by noise. We have added the explanations and toned down the phrasing of this section.

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of collocated profiles selected for YES_YES plot (Fig 6a), we scanned through ALADIN profile step by step, looking for a local maximum, which we define as a set of the following conditions:

$$SR(i) > SR_{threshold};\ SR(i) > SR(i-1);\ SR(i) > SR(i+1) \quad (2)$$

where $SR_{threshold}$ is the cloud detection threshold at 532 nm, which is equal to 5 For each local peak found, we have searched for a peak or for a maximal value of CALIOP's SR profile in the vicinity of ±3 km from the peak height determined from ALADIN The choice of a "reference" dataset in this case depends on the detection probability, and if one choses CALIOP as a reference, the distance to the nearest ALADIN peak might be spoiled by lower probability of cloud detection by ALADIN and the distribution will be skewed The search limits are arbitrary and they have been chosen from inspecting the collocated profiles taking into account the natural variability of cloud heights at distances of about 100 km, estimated from the analysis of CALIOP data used in this study (~75% of clouds move vertically by less than 1 km, ~8% by 1−2 km, ~5% by 2−3km, ~4% by 3−4km, ~3% by 4−5 km and ~5% by more than 5 km) The differences between the ALADIN's and CALIOP's cloud peak heights have been stored and then averaged in the corresponding latitude/altitude bins (Fig 7) As one can see, the cloud height detection agreement is better than 0 2 km below ~3 km and, surprisingly, for some of high-altitude zones For the tropical zone, this is probably linked with thick Ci clouds which should be reliably detected by both instruments For the Southern polar zone, this figure reveals the PSCs, which are barely visible in Fig 6a, but which can be seen in Fig 4f for ALADIN These clouds form at very low temperatures and are composed of ice particles yielding a reflection, which is reliably detected at both wavelengths if the layer is thick (e g Adriani et al , 2004; Snels et al , 2021) As for the clouds between ~3 km and ~10 km height, the height sensitivity effects skew the effective cloud height detected by ALADIN downwards by 0 5−1 0 km This is coherent with Fig 4, which shows lower frequency of occurrence of high clouds detected by ALADIN At least a part of the cloud peak shifts in the 3−5 km layer should be attributed to the reasons discussed for NO_YES statistics and these differences should reduce when the aforementioned quality flags for cloud-perturbed retrievals are fixed

3.5 Temporal evolution of cloud detection agreement

ALADIN is a relatively young instrument and its calibration/validation activity is still on the way (Baars et al , 2020; Donovan et al , 2020; Kanitz et al , 2020; Reitebuch et al , 2020; Straume et al , 2020) This includes, but is not limited to internal calibration and comparisons with other observations The Aeolus mission faced a number of technical issues, which hindered obtaining the planned specifications These issues are related to several factors: (a) laser power degradation (60 mJ/pulse instead of 80 mJ/pulse) and signal losses in the emission and reception paths (33%) that results in lower signal to noise ratio (SNR) than planned, (b) telescope mirror temperature effects biasing the wind detection and calibration of Mie and Rayleigh channels of ALADIN, (c) constantly increasing number of hot pixels of both ACCD detectors (Weiler et al , 2021) leading to errors both in wind speed and in retrieved optical parameters of the atmosphere (the number of hot pixels increased by a factor of 1 4 during the period considered in this work) The Aeolus teams managed to mitigate some of these adverse effects (e g Baars et al., 2020; Weiler et al , 2021), and it would be interesting to see whether the pilot L2A dataset, Prototype_v3 10 is

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Author: Subject: Comment on Text Date: 14 06 2021 10:22:48
Altitude?

Author: Subject: Highlight Date: 17 05 2021 15:19:17

AC: yes, we meant the altitude, thanks

AC: fixed, thanks

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free of cloud detection quality trends If true, this would indicate a good calibration and consistent processing of Level 0 through Level 1 to Level 2A

In Fig 8 and 9 we show the temporal evolution of cloud detection agreement per height bins The panels of Fig 8 are consistent with those of Fig 6 whereas Fig 9 considers only the evolution of YES_YES statistics, which corresponds to Fig 6a and Fig 8a, normalized by cloud amount Unfortunately, the period available for analysis does not cover the whole year, so the plots can be affected by seasonal variation of cloud distributions Still, the latitudinal and longitudinal coverage of collocated data does not change throughout the year and a mixture of Northern and Southern hemispheres should partially compensate for seasonal anomalies The signatures one should be looking for are experimental artefacts linked with laser power degradation, hot pixels appearance, and bias corrections If these issues are not properly compensated, the "agreement panels" (Fig 8a,b) should demonstrate a decrease in occurrence frequency with time and the occurrence frequency in "disagreement panels" (Fig 8c,d) should increase with time As one can see, this is not the case: visually, all 4 panels of Fig 8 do not show any anomaly, which would go beyond their noise levels (a special region corresponding to a forced bin size reduction in the period of 28/10/2019−10/11/2019 is marked by white dashed lines in Fig 8 and should not be considered at heights below 2250m) To quantify the tendencies and to compare them with noise levels, we have normalized Fig 8a (YES_YES cases) by cloud amount per altitude/time bin This procedure helps to get rid of seasonal variation of clouds The results presented in Fig 9 confirm the previous conclusions regarding the altitude distribution of cloud detection agreement: for the clouds below 3 km it is better than for higher ones (61±16% and 34±18% for 0 75 and 2 25 km, respectively versus 24±10%, 26±10%, and 22±12% for 6 75 km, 8 75 km, and 10 25 km, respectively As for the tendencies, the low-level clouds demonstrate an improvement towards the end of the year whereas the agreement for 6 75 km and 10 25 km becomes slightly worse by the end of the considered period

If we compare the hot pixels distribution for Mie and Rayleigh channel ACCD detectors at the beginning and at the end of the time scale of Fig 8 and 9 (Table 2 of Weiler et al , 2021), we will see 3 and 5 new hot pixels for Mie and Rayleigh matrices, respectively Even though the Rayleigh matrix pixels are not directly linked to cloud detection, their information is used for the ALADIN SR calculations For Mie matrix, the lowermost hot pixel, which appeared during the considered period, corresponds to ~15 km height and this cannot affect the tendencies shown in Fig 9 As for new Rayleigh hot pixels, the lowermost two corresponds to 1 km height, the next two – to 5 km height, and the last one – to 18 km This information does not explain the observed behavior, either Overall, considering relatively large error bars for all five altitudinal sections presented in Fig 9b and the variety of the observed slopes, one cannot make a sound conclusion neither regarding the deterioration (or the improvement) of cloud detection agreement nor regarding the link between hot pixels appearance and change of cloud detection quality A proper conclusion is that one does not detect the tendencies beyond the variability limits of the analyzed parameter and that the hot pixels appearance cannot be tracked from the cloud agreement plot, indicating that compensation for hot pixels effects (Weiler et al , 2021) works properly within the discussed uncertainty limits The same can be said regarding the other known technical issues: the signal losses in the emission and reception paths do not transform into

This page contains no comments

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a clear signature in cloud detection agreement plots Moreover, they should have affected the detection of low and high clouds in the same way that is not observed in Fig 8 and 9

4. Conclusions

The active sounders are advantageous for atmospheric and climate studies because they provide atmospheric parameters at altitude resolved scale with high accuracy For continuity of climate studies and monitoring the global changes it is essential to understand the differences between spaceborne lidars operating at different wavelengths, flying at different orbits, and utilizing different observation geometries, receiving paths, and detectors In this article, we addressed an intercomparison of ALADIN and CALIOP lidars using their scattering ratio products (CALIPSO-GOCCP and Aeolus L2A, Prototype_v3 10) for the period of 28/06/2019−31/12/2019

Using the COSP2 lidar simulator coupled with output from the EAMv1 model and a horizontal cloud variability parameterization, we estimated a theoretically achievable agreement in cloud detection of 0 77±0 17 for these two instruments with their orbits, averaging, and observation geometry

On the one hand, the spatial collocation criterion of 1° chosen in this work is based on averaging distance of Aeolus L2A Prototype_v3 10 data On the other hand, the temporal collocation criterion of Δtime < 6h is a tradeoff between the geographical coverage of the collocated profiles, their number, and uniformity of Δtime distribution throughout the globe With the named criteria, we managed to find ~7 8E4 collocated nighttime profiles, which underwent a series of analysis summarized here For the simplicity of the comparison with CALIOP, we converted SR_{355} of ALADIN to SR_{532} and we discuss the sensitivity of the results to the conversion parameters

Overall, the SR product of ALADIN is characterized by lower sensitivity to high clouds above ~7 km than CALIOP, that we explain by lower SNR for ALADIN at these heights that is due both to physical reasons (smaller backscatter at 355 nm) and technical reasons (hot pixels, lower emission and lower transmissivity of receive path than planned) Large sensitivity to lower clouds leads to prioritizing the lower cloud solutions to higher ones in the case of a continuous cloud or a double layer This skews the ALADIN's cloud peak height in pairs of ALADIN/CALIOP profiles by ~0 5±0 4 km downwards Interestingly, the agreement of PSC peak heights does not suffer from these effects We explain this by large vertical extent and composition of PSCs, which make them a better target for ALADIN than the tropospheric clouds In the cloud-free area, the agreement between two instruments is good indicating low rate of noise-induced false detection for both instruments Last, but not least, the temporal evolution of cloud agreement does not reveal any statistically significant change during the considered period This indicates that hot pixels and laser energy and receiving path degradation effects in ALADIN have been mitigated at least down to the uncertainties of the following cloud detection agreement values: 61±16%, 34±18%, 24±10%, 26±10%, and 22±12% estimated at 0 75 km, 2 25 km, 6 75 km, 8 75 km, and 10 25 km, respectively We believe that the provided collocated dataset will facilitate the further analysis and improvement of ALADIN L2A data

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Author: Subject: Comment on Text Date: 14 06 2021 10:28:59
why should there be a smaller backscatter at 355? This is in absolute contradiction to all my knowledge? Particle backscatter coefficient could be equal (Angström 0), Molecular backscatter coefficient is for sure higher and thus total backscatter is fore sure also higher!

Author: Subject: Comment on Text Date: 14 06 2021 10:30:01
phrasing poor

AC: please, see our comment in the text section. What was meant was the "information content" of particulate backscatter with its noise with respect to molecular one, not the signal itself. Please, apologize for the confusion.

AC: we have rewritten this section

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Appendix A

The analysis of the collocated data may enable the researcher not only to validate one dataset against another one, but also to validate a physical concept or to retrieve an important model parameter (e g Holl et al , 2010; Feofilov and Petelina, 2010; Feofilov et al , 2012; Virtanen et al , 2018) In this section, we report the results of a validation attempt aimed at the retrieval of the scaling coefficients used in Eq 1 and through them the model assumptions To do this, we searched the collocated database for the events which would satisfy the following criteria: (a) the ALADIN SR profile should contain at least one valid point with the corresponding quality flags (see Section 2 2) and with SR higher than halved $SR_{threshold}$; (b) the profiles should fit the selection criteria used for cloud altitude detection sensitivity (Section 3 4); (c) the CALIOP peak should contain more than one point to avoid sampling problems For these profiles, we picked up not only the major peak values, but also the secondary peak values if the vertical agreement of the profiles was good like in Fig 5a,c,d,e The corresponding pairs of SR_{CALIOP} and $SR_{ALADIN355}$ values have been binned using the 0 2 × 0 07 SR bins, which reflect the differences between SR_{532} and SR_{355} The corresponding frequency occurrence distribution for this dataset is shown in Fig A1 Even though the SR pairs exist for opaque domain, the spread increases and the values beyond $SR_{532} = 10$ are neither informative nor suitable for the maximal probability search algorithm (see Dawkins et al , 2018) used for the analysis Like in Fig 11 of (Dawkins et al , 2018), the red dots in Fig A1 represent the centers of Gaussian fit to perpendicular transects White dashed line shows a linear fit to the dataset represented by these red dots, and the corresponding conversion if given by the following equation:

$$SR_{532} = SR_{355} \times (3.8 \pm 1.0) - (3.3 \pm 1.4) \qquad (A1)$$

Even though the coefficients in Eq A1 differ from those of Eq 1, the black dashed line in Fig A1 representing Eq 1 does not significantly deviate from the white dashed line representing Eq A1 and both lines fit the maximum probability plot within its uncertainty limits We conclude that the collocated dataset proves the basic equations used to derive Eq 1 though its uncertainties do not allow to retrieve the corresponding fitting parameter Λ of (Collis and Russell, 1976) from such a comparison

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Data availability

The collocated dataset used in this work can be downloaded from ResearchGate repository using the following link https://doi org/10 13140/RG 2 2 11237 12009 (Feofilov et al , 2021)

Author contribution

HC, VN, MC, and AF: conceptualization, investigation, methodology, and validation; RG, CG, and AF: data curation and formal analysis; AF: writing original draft; AF and HC: review and editing

Competing interests

The authors declare that they have no conflict of interest

Disclaimer

The presented work includes preliminary data (not fully calibrated/validated and not yet publicly released) of the Aeolus mission that is part of the European Space Agency (ESA) Earth Explorer Program This includes aerosol and cloud products, which have not yet been publicly released Aerosol and cloud products will become publicly available by spring 2021 The processor development, improvement and product reprocessing preparation are performed by the Aeolus DISC (Data, Innovation and Science Cluster), which involves DLR, DoRIT, ECMWF, KNMI, CNRS, S&T, ABB and Serco, in close cooperation with the Aeolus PDGS (Payload Data Ground Segment)

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AC: This is true, but this is the only source of information available. A comment from a Technical Editor is needed for such a case.

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Instrument	Orbit inclination [deg]	Equator crossing LT [h]	Off-nadir angle [deg]	PRF [Hz]	Native resolution [m]	L2 resolution resolution [m]
ALADIN	96 97	6:00 / 18:00	35	50 0	140 (H) x 1000 (V)	87000 (H) x 1000 (V)
CALIOP	98 00	01:30 / 13:30	3	20 1	333 (H) x 60 (V)	333 (H) x 500(V)

Table 1: Comparison of orbital parameters, viewing geometries, and resolutions of ALADIN and CALIOP instruments

Δtime [h]	Daytime ×1E3	Night-time ×1E3	Total ×1E3	Remarks
< 1	4 3	3 7	8	Narrow polar zone
< 3	13 1	11 2	24 3	Broader polar zone
< 6	91	78	169	All zones covered
< 12	135	116	251	Unequal distribution of Δtime
< 24	176	146	322	Unequal distribution of Δtime

Table 2: Number of collocated cases for Δdist < 1° and different Δtime values

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250-2000

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125-2000

AC: Fixed, thanks

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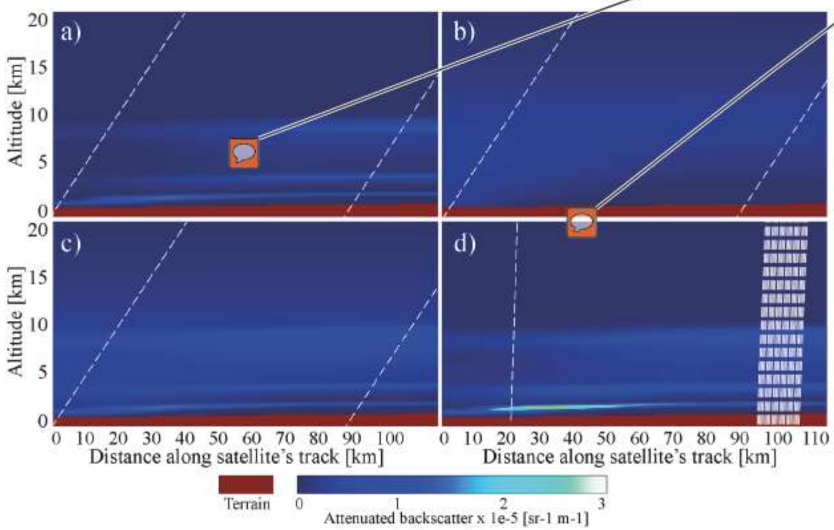

Figure 1: Observation geometry, averaging, and retrieved parameters for (a-c) ALADIN/Aeolus at its L2A resolution of 87 km and (d) CALIOP/CALIPSO at its native resolution: (a) Attenuated particular backscatter (APB) at 355 nm; (b) Attenuated molecular backscatter (AMB) at 355 nm; (c) Attenuated total backscatter (ATB) at 355 nm; (d) Attenuated total backscatter (ATB) at 532 nm. The scene has been calculated for demonstration purposes using COSP2 simulations with the EAMV1 model data as an input. White dashed lines stand in (a-c) for ALADIN's observation paths for centers of averaged profiles and in (d) for CALIOP averaged observation path corresponding to averaged ALADIN on the left and for individual CALIOP profiles on the right (with its 3° off-nadir viewing angle). ALADIN observes the atmosphere at 35° to the nadir and perpendicular to the flight direction. This inclination is schematically shown as an inclined line lying in lidar curtain plane whereas the real projection to the same plane should be a vertical line.

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only valid for a cloud free scene IF at all

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hard to understand A clearer description is needed in the caption what the dashed lines mean It is also not clearly evident while reading the text Furthermore, I recommend to use different colours for the dashed line and then clearly describe which dashed line represents what

AC: Fig. 1 has been replaced with a 3D orbital view. The explanation of the numerical experiment refers more to a flowchart in Fig. 3

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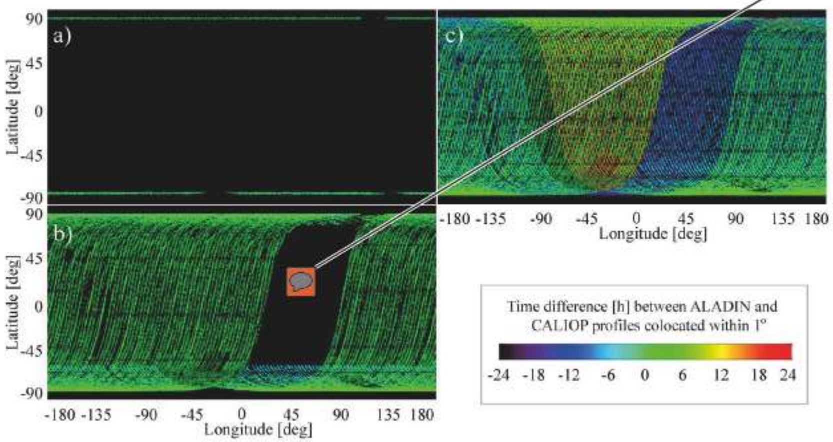

Figure 2: Geographical distribution of collocated points for (a) Δtime < 1 h; (b) Δtime < 6 h; (c) Δtime < 24 h for Δdist < 1°.

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why there is a gap?

AC: this is a good question - due to large overhead at the collocation, we did not read the previous or next day. As a result, the collocation algorithm did not find anything for the data measured, for example, 4h earlier at a given longitude. In the present version, this figure has been replaced with 2D histograms in the latitudinal bins, but the gap remains in the collocated dataset.

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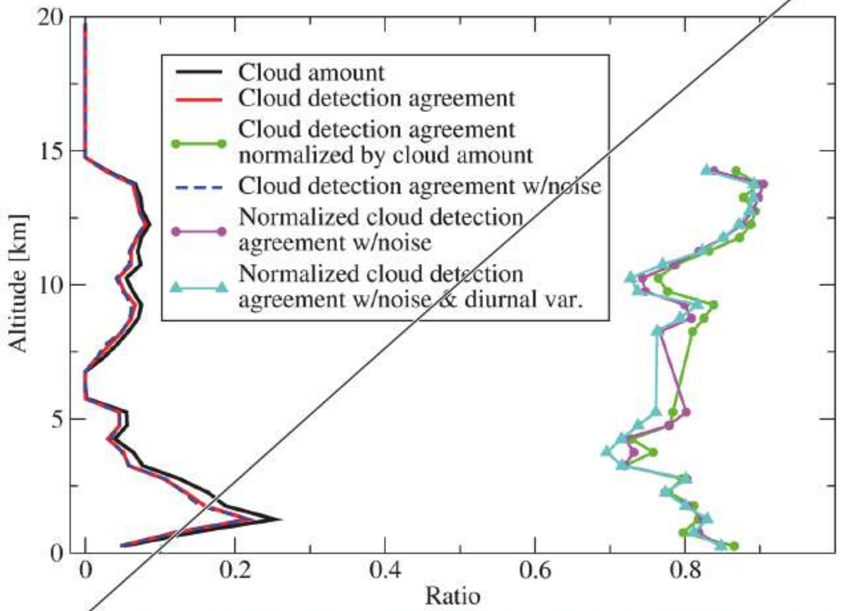

Figure 3: Estimating theoretical cloud detection agreement using pseudo-collocated scattering ratio (SR) data calculated using COSP2 lidar simulator coupled with the output of the EAMv1 atmospheric model. For each altitude bin, the agreement is defined as a ratio of number of cases when both CALIOP and ALADIN have detected a cloud to a total number of simulations for a given bin. The cloud amount corresponds to a ratio of number of cases when a reference CALIOP SR value without noise was above the detection threshold to a total number of simulations for a given bin. The normalized cloud detection agreement represents a ratio of the former to the latter.

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Not really understandable, please rephrase

AC: we have updated the figure caption

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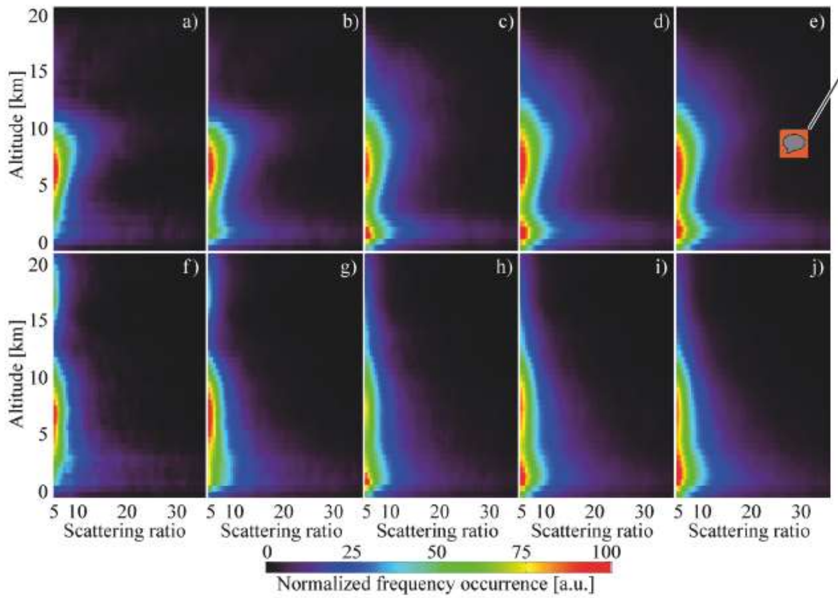

Figure 4: Zonal mean comparison for the Δtime < 6h, Δdist < 1° collocated nighttime data subset (see Table 2): (a)-(e) CALIOP averages; (f)-(j) ALADIN averages, converted to SR at 532 nm for comparison purposes; (a,f) 90S-60S; (b,g) 60S-30S; (c,h) 30S-30N; (d,i) 30N-60N; (e,j) 60N-90N.

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you may consider using white backgrounds

AC: we tried white background, but it didn't improve the image. Instead, we zoomed in and moved the left-hand-side limit to SR=3 to show more of small SR values. We believe, this made the figure more informative.

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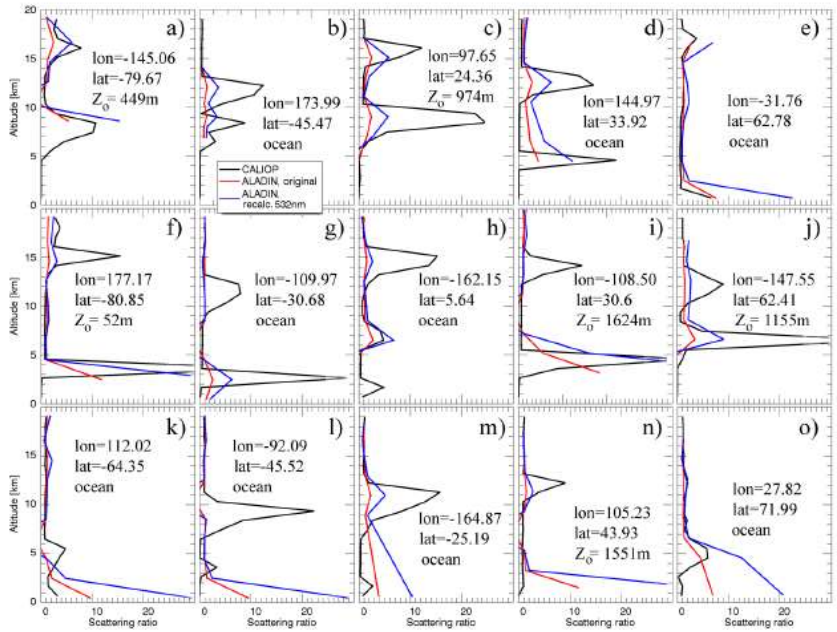

Figure 5: Pseudo-instantaneous comparisons of collocated ALADIN L2A SR profiles and CALIOP SR profiles averaged over 67 km along the track: (a, f, k) 90S-60S; (b, g, l) 60S-30S; (c, h, m) 30S-30N; (d, i , n) 30N-60N; (e, j, o) 60N-90N; (a-e) cases confirming ALADIN's capability to detect high-level clouds; (f-j) cases showing the cases when ALADIN misses a high cloud detected by CALIOP; (k-n) cases explaining the presumably false detection of a low level cloud by ALADIN; (o) a case with a real low cloud detected by both instruments with an extra point near the surface reported by ALADIN.

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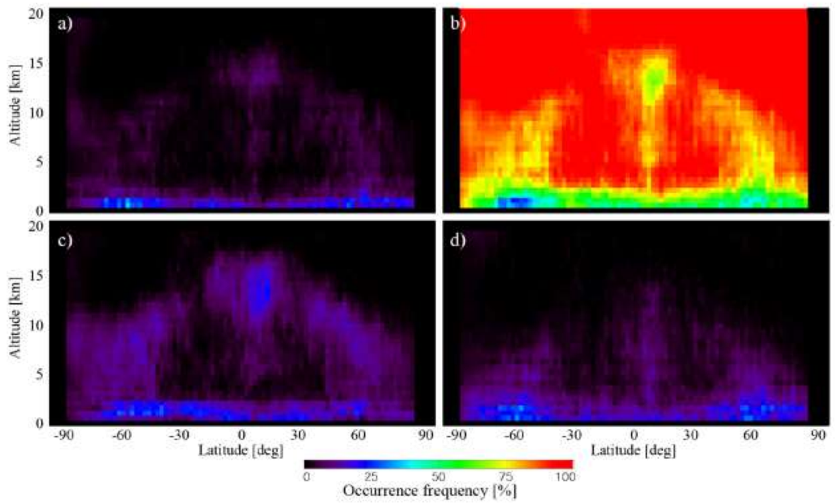

Figure 6: Cloud detection agreement: a) both CALIOP and ALADIN have detected a cloud (YES/YES cases); b) neither CALIOP nor ALADIN has detected a cloud (NO/NO cases); c) CALIOP has detected a cloud whereas ALADIN has not detected a cloud YES/NO cases); d) CALIOP does not detect a cloud whereas ALADIN has detected a cloud (NO/YES cases).

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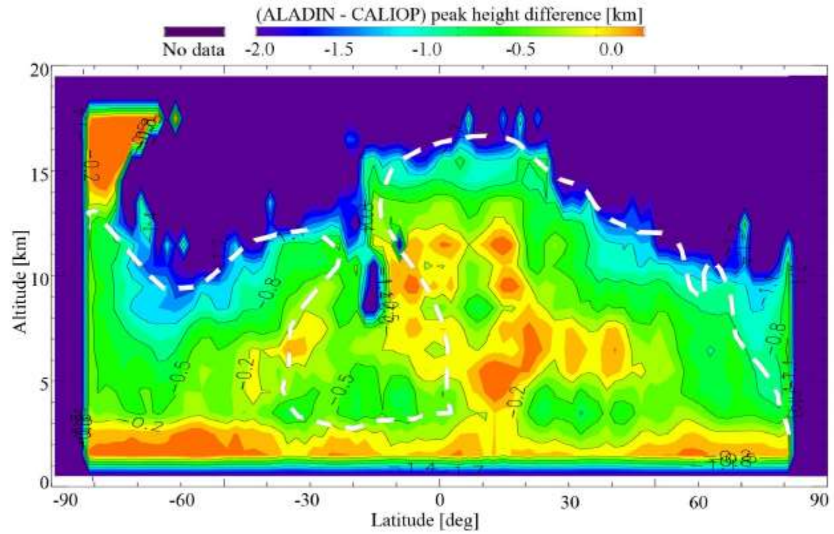

Figure 7: Cloud altitude detection sensitivity represented as a height difference between the CALIOP local peak height and corresponding ALADIN's cloud peak height or maximal SR height found in the ±3 km vicinity of CALIPSO peak. The subset corresponding to YES_YES selection (Fig. 6a) was used. White dashed isoline corresponds to colored area in Fig. 6a (occurrence frequency of about 5% and higher).

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Atmospheric Measurement Techniques Discussions
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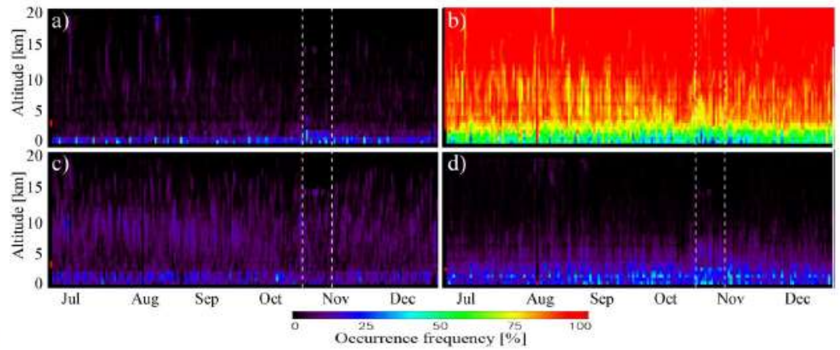

Figure 8: Temporal evolution of cloud detection agreement for the period of 28/06/2019-31/12/2019. The legend is consistent with that of Fig. 6: a) YES/YES; b) NO/NO; c) YES/NO; d) NO/YES. White vertical dashed lines correspond to the period of Air Motion Vector (AMV) campaign (28/10/2019–10/11/2019), which is characterized by smaller bin sizes and, therefore, larger SNRs for Mie and Rayleigh channels up to the height of 2250m.

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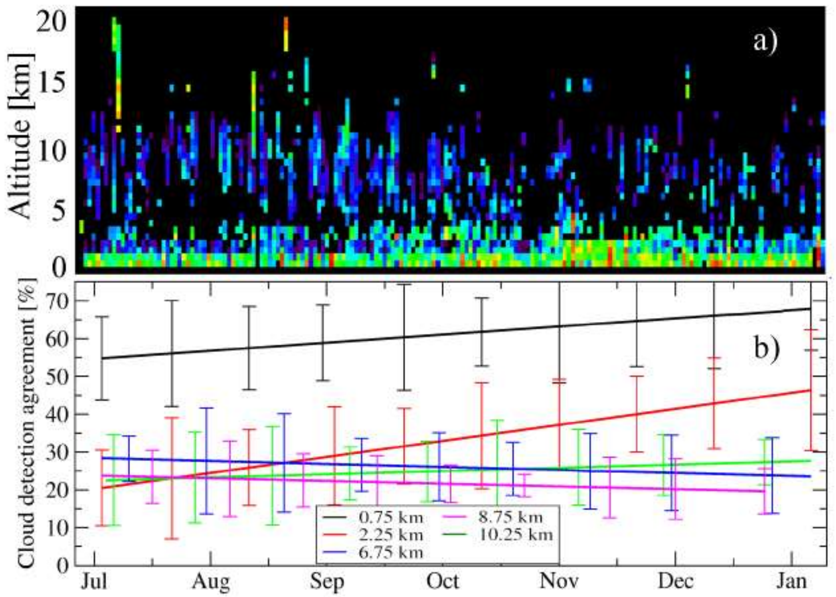

Figure 9: Temporal evolution of normalized cloud detection agreement for the period of 28/06/2019-31/12/2019: a) YES_YES statistics of Fig. 8a normalized by cloud amount; b) the same information presented for 5 heights as linear fits in 2D with error bars. The color scheme for panel (a) is consistent with that of Fig. 8.

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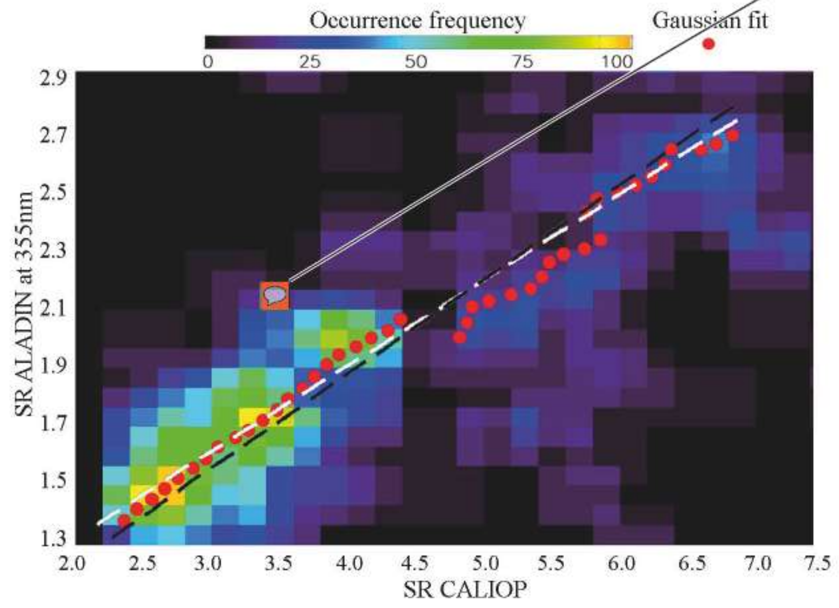

Figure A1: Correlation between individual pairs of CALIOP and ALADIN scattering ratio profiles, for all altitudes. The colors of the bins represent the occurrence frequencies for 0.2 × 0.07 SR bins, as a function of both CALIOP's SR_{532} and ALADIN's SR_{355}. For each point along the diagonal, a Gaussian was fitted to the data points lying along a perpendicular transect and the central point of the Gaussian is plotted as a red filled circle. The white dashed line represents a linear fit to these points. For comparison, black dashed line shows the fit given by Eq. 1.

Page: 29

Author: Subject: Sticky Note Date: 14 06 2021 11:11:55
Didn't you apply SR>5? So why are SR below 5 are shown?

AC: this Figure does not exist in the new version. As for the question, we wanted to check the conversion itself, regardless of the SR threshold used later.

We thank Reviewer #2 for his/her analysis and comments on the paper. The responses to major and minor comments are given below. We marked the reviewer's and the author's comments by "RC:" and "AC:", respectively.

Major comments

RC: These findings are quite valuable to understand how to interpret both data sets and also valuable to construct longer time records than those obtained by lidar on a single satellite. There is a lack of clarifications in the current form of manuscript.

AC: We thank the Reviewer for pointing out the importance of the work for merging the different space-borne datasets into one long-term record. As for the clarifications, we have added the definition of the Scattering Ratio, the formalism to convert the scattering ratio from 532 to 355nm, and the definition of the different variables (Sect. 3). We have also updated the figures and the corresponding text, and we have addressed all the comments of all the reviewers.

RC: Theoretical justification of using the simple SR conversion factor method between 355nm and 532nm in Equation (1) is not sufficient.

AC: We agree with this statement. We have added a section with all necessary definitions and conversion formulae. This section also appears to be helpful in the discussion of the potential sources of discrepancy between CALIPSO and ALADIN. The collocated dataset has been reprocessed and the conversion has been re-calculated and analyzed

RC: When model outputs are used, there is no need to rely on the conversion factor and the SR for 355nm and 532nm/1064nm can be estimated independently.

AC: This is true, but we do not used this conversion factor for the model+simulator part. We have re-written the simulation section, and we added a flowchart to clarify the steps of this simulation experiment.

RC: The choice in Equation (1) seems to be essential to the theoretical derived value (0.81) for cloud detection agreement between CALIOP and ALADIN. That is, the treatment of model output as well as cloud detection algorithm affect the estimation of the value of 0.81.

AC: Please, see the answer to the previous question. The theoretically estimate of the best achievable normalized cloud detection agreement (= value of 0.81, refined in this version) does not use Eq. 1. As we show in Fig. 4 of the new version of the manuscript, the value is mostly determined by difference in observation geometry and orbital parameters leading to non-ideal collocation.

RC: There are no descriptions about the output parameters for EAMv1 model used in this article.

AC: The outputs of the EAMv1 model are the usual standard inputs for COSP/lidar (e. g. Chepfer et al. 2008; Tang et al. 2019). But, we added several modifications to a standard model+COSP/lidar simulation for this study. Those are presented in the flowchart (Fig. 3) and described in Section 4: (a) subscale horizontal cloud variability; (b) instrumental noises for ALADIN and CALIOP; (c) diurnal variation of cloud fraction.

RC: The actual signals in the CALIOP and ALADIN contain the aerosols as well as clouds and molecules. Aerosol signals at 355nm might be larger than those at 532nm and it is naturally expected that the discrimination between clouds and aerosols is more challenging at ALADIN compared with CALIOP.

AC: First, we did not try to build the cloud detection scheme based on ALADIN-defined SR (see Eq. 2 in new version). As for the CALIOP-like defined SRs (new Fig. 5), the SRs from CALIOP are equal or larger than those estimated from ALADIN, so the cloud-aerosol discrimination problem mentioned in the question is not revealed.

RC: It is not clear how to incorporate the wavelength dependence of aerosols into the equation (1). It is not clear whether aerosols are contained in the EAMv1 model or not. There is no description about how multiple scattering effects for CALIOP and ALADIN are treated in the simulations in section 2.

AC: Again, the simulation experiment does not use Eq. 1. We apologize for a lack of clarity in the previous version of the manuscript regarding the simulations and we hope the new Sect. 4 is helpful. However, the question about multiple scattering is relevant and it is included into the present version of the manuscript in its new theoretical part (Sect. 2) as well as in the discussion of possible reasons for the discrepancy of low-level clouds.

RC: It seems to be possible to apply practically the same cloud detection algorithms used in the ALADIN L2A as well as CALIOP GOCCP products in the theoretical analyses in section 2. If one will do so, it would give a different cloud detection agreement of 0.77. The above-mentioned information is important to interpret the results in section 3 and conclusions.

AC: Since we did not convert the SRs for the simulation study (but only for the actual observations), we actually apply the same detection algorithms to the ALADIN an CALIPSO theoretical analyses. We agree that it was not well described in the previous of the manuscript, we hope the new Sect. 4 and the flowchart help.

RC: There are also lack of clarifications in the treatment of CALIOP clouds for the comparisons. It seems there is no sub-grid scale treatment for 87km-ALADIN L2A products so that 0 or 1 cloud fraction for each 87km-grid.

AC: First, the sub-grid treatment of ALADIN is a part of a Prototype v_3.10 algorithm from ESA, which is not available for the end user. The current end-user ALADIN dataset contains the backscatter and extinction profiles at 355nm that are standard for an HSRLidar (but not for non-HSRL like CALIOP). There's no 0 or 1 in this ALADIN dataset nor does it define the cloud fraction itself. Therefore, we performed a conversion from ALADIN's backscatter and extinction at 355 to SR'_532 and apply the uniformly defined cloud detection threshold on this SR'_532 profile (see Section 2 in the updated version of the manuscript). Second, we used high-resolution CALIOP data on 333m grid, averaged its AMB(z) and ATB(z) profiles at the same vertical and horizontal resolution as ALADIN and calculated SR_532(z). These procedures ensure that the two averaged profiles (SR'_532 derived from ALADIN and SR_532 derived from CALIOP) are comparable.

RC: On the other hands, CALIOP product has finer resolution (333m or 1km). It is not clear how to treat cloud fraction for CALIOP after 67km averaging for the comparisons compared with ALADIN in sections 2 and 3.

AC: We do not use the existing cloud fraction from CALIOP. As mentioned above, we averaged ATB and AMB(=ATBmol) over similar resolution as ALADIN and only then do compute SR and apply the cloud detection threshold. We are well aware of the fact that this might lead to an overestimation of cloud fraction in the boundary layer, but we perform this procedure to ensure the comparability of two datasets.

RC: Brief description of Aeolus L2A cloud product is also instructive.

AC: Such a product doesn't exist (yet), we defined the cloudy or non-cloudy bins by applying the cloud detection threshold to SR_532(z) values.

RC: The SR for CALIOP was originally estimated to create CALIPOSO GOCCP products where Equation (1) is not needed. It is not convincing why equation (1) is used to simulate SR at 532nm.

AC: In the present version of the manuscript, we do not use Eq. 1 anymore. Instead, we use a more precise recalculation approach presented in Section 3. But, the idea of converting ALADIN's 355 data to 532nm was to compare apples to apples and apply the same cloud detection threshold to the 'same' SR profile at the same spatial resolution.

RC: After reading the manuscript several times, any reasonable explanation was not found why the upper clouds are smaller for ALADIN compared with CALIOP, though CALIOP did not detect most of PSCs where ALADIN detected (in shown in the Figure 4a and f).

AC: Actually, we discussed PSC detection in lines 230-231, 301-303, and 374-376 of the previous version of the manuscript, but in the rest of the manuscript there was a confusing explanation regarding the particulate backscatter and we apologize for this. As we wrote in response to the Reviewer #1's question, we meant the detection of the particles. Even though the total backscatter is larger at 355nm, the particulate part can be buried in molecular return. If the signal-to-noise ratio is small, then the cross-talk correction (used in High Spectral Resolution lidar) will be noisy and the particulate signal will be retrieved with large uncertainty. We do not know the details of the L2 algorithm computing SR, extinction and backscatter used in ALADIN products, but a common sense tells us that if the signal is noisy then there's a high chance that the algorithm will reject it. Summarizing, our explanation of smaller ALADIN's sensitivity to high clouds is linked with a combination of weaker-than-planned SNR and smaller particulate backscatter compared to molecular one.

RC: The authors attributed the lower sensitivity of high clouds for ALADIN to smaller backscatter at 355nm without conducting further analysis.

AC: Please, see the previous answer for the corrected explanation. The text of the manuscript has been also updated to avoid misunderstanding.

RC: More discussion of the discrepancies in the cloud detections are requested. It is also noted that it is well established that CALIOP has a good capability to detect PSCs so that Figure 4a is strange.

AC: Please, check the new version of Fig. 4 (now Fig. 5) where we show the SRs starting from SR=3. In Fig. 5, one can also see the PSCs detected by CALIOP with SR>5. Note that this threshold is not optimized for PSC that can be optically thin. And, last, but not least, Fig. 8a does contain the PSCs, but their frequency of occurrence is low.

RC: There are several CALIOP based global cloud products, including NASA Langley's VFM products, GOCCP, DARDAR and KU cloud products and large differences were reported in (Cesana et al., 2016) JGR among GOCCP, NASA standard and KU products, indicating the different cloud detection methods caused the differences. There are several ways to bridge gaps between CALIOP and AEOLUS. Some comments are needed in this regard.

AC: The works mentioned by the reviewer are all using the same source that is L1 collected by CALIPSO. For comparing ALADIN and CALIPSO, the main challenges are because of the difference of nature of their L1 data: (1) ALADIN measures APB and AMB (and not ATB) because it is an HSRL, while CALIPSO measures ATB (and not APB and AMB) because it is a non-HSRL (See Eqs. in Sect. 3), (2) the wavelengths are different (355 nm vs 532nm), (3) the orbits and overpass times are different (see Sect. 2). We tried to state these points more clearly in the new version of the manuscript.

Specific comments

RC: p.6 line 182-184, need clarification for the methods and typical values of noises for Aeolus and CALIOP in the target data sets.

AC: We have updated the methodological part (see new Section 3). As for the noise values, we estimated them from the upper part of the vertical profiles, which are cloud-free and contain only molecular return, which is supposed to be smooth. We added this information to the manuscript (Section 4.1)

RC: p.25 Figure 6, zonal mean cloud frequency for CALIOP and ALADIN would be preferable prior to Figures 6a-d.

AC: Thank you for this suggestion. We added the requested figure and the corresponding text. It is interesting to note that visually the cloud distributions for the compared instruments are much more alike than the SR distributions. But, cloud detection threshold for higher clouds is reached less frequently for ALADIN than for CALIOP.

We thank Reviewer #3 for his/her analysis and comments on the paper. The responses to major and minor comments are given below. We marked the reviewer's and the author's comments by "RC:" and "AC:", respectively.

Major comments

RC: The authors should state clearly in the title that this study is dedicated to cloud products only.

AC: The present version of the article puts more stress on the absolute values of scattering ratios themselves. In addition, we updated the title to "Comparison of scattering ratio profiles retrieved from ALADIN/Aeolus and CALIOP/CALIPSO observations and preliminary estimates of cloud fraction profiles"

RC: The study should include a quantification to some extent, and discussion, on the percentage of the clouds not detected from the 2 lidars with the methodology used. Additionally, a discussion is needed on the effect of these cloud-miss-detections on the results of the intercomparison per altitude (low, mid, high-level clouds).

AC: If we understand this question correctly, it is related to the evaluation of clouds in the GCMs, and this question has been already addressed in (Chepher et al., 2008). For the current work, we are looking for similarities/differences in scattering ratio and cloud fraction profiles between the two lidar missions. If some clouds are filtered out in our approach, they are filtered out in the same way for both lidars.

RC: Although the title clearly states that this is a comparison of the scattering ratio products retrieved from the 2 systems, in the discussion throughout the paper the authors comments are attributed to the 2 systems only. It should be more clear that different approaches for cloud detection products from the 2 missions could lead to different results. See also specific comment below.

AC: We agree with the statement that different approaches for cloud detection products from the 2 missions could lead to different results. But, the idea of the paper was not to reconcile cloud product by "tweaking" the cloud detection algorithm, but to compare the fundamental differences. Therefore, here we used the same cloud detection for the two system. We agree that after having fully understood and quantify the differences due to the 2 systems (like we try to do here), the future work will include the algorithm adaptation to retrieve the same clouds and to build a long-term cloud record. We added the corresponding text in the conclusion as an interesting and exciting outlook.

Specific comments

RC: Page 1, line 22: "the ALADIN product demonstrates lower sensitivity because of lower backscatter at 355 nm": This statement is not clear. The backscatter at 355 nm is not expected to be lower than at 532nm. Please explain and revise accordingly.

AC: This is an important comment made by all three reviewers. Indeed, there was a confusing explanation regarding the particulate backscatter and we apologize for this. As we wrote in response to the Reviewer #1's question, we meant the contribution of the particles to the total (particulate + molecular) signal. Even though the total backscatter is larger at 355nm, the particulate part can be buried in molecular return because the molecular backscatter is larger at 355nm while the backscatter from cloud particles is about the same. If the signal-to-noise ratio is small, then the cross-talk correction will be noisy and the particulate signal will be retrieved with large uncertainty.

RC: Page 2, line 43: “Despite an excellent daily coverage and daytime/nighttime observation capability (Menzel et al., 2016; Stubenrauch et al., 2017), the height uncertainty of the cloud products retrieved from the observations performed by these spaceborne instruments is limited by the width of their channels’ contribution functions, which is on the order of hundreds of meters, and the vertical profile of the cloud cannot be retrieved with accuracy needed for climate feedback analysis.” The sentence is confusing. Consider revising to make it easier to follow. Possible suggestion: “…is limited by the width of their channels’ contribution functions (which is on the order of hundreds of meters), and their uncapability to retrieve the vertical profile of the cloud with accuracy needed for climate feedback analysis.

AC: Thank you for this suggestion, we have simplified the text of this paragraph.

RC: Page 2, line 47: “This drawback is eliminated by active sounders, the very nature of which is based on altitude-resolved detection of backscattered radiation, and the vertical profiles of the cloud parameters are available from the CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization) lidar (Winker et al., 2003)and CloudSat radar (Stephens et al., 2002) since 2006, CATS (Cloud-Aerosol Transport System) lidar on-board ISS provided measurements for over 33 months starting from the beginning of 2015(McGill et al., 2015).”: Too big sentence, difficult to read. Consider revising.

AC: We have simplified it, thanks.

RC: Page 4, line 106: “In Fig.1(a-c), we show the observation geometry and sampling of ALADIN’s L2A product as well as three variables retrieved from its observations..”: consider revising as: “…as three simulated variables that can be retrieved from its observations..”.

AC: Since other Reviewers found this plot difficult to understand, we have replaced it with a 3D view of the orbits and observation geometries. Correspondingly, the description of Fig. 1 has changed.

RC: Page 4, line 106: “In Fig.1(a-c), we show the observation geometry and sampling of ALADIN’s L2A product as well as three variables retrieved from its observations..”: consider revising as: “…as three simulated variables that can be retrieved from its observations..”.

AC: Thank you for the suggestion, but in the new version of the manuscript we have a different Fig. 1 with a somewhat different discussion.

RC: Page 4, line 120: “The cloud variability along the satellite’s track has been estimated from the gridded EAMv1 data using the parameterization of (Boutle et al., 2014). Figure1 also serves as an illustration to theoretically achievable cloud detection agreement discussed below.”: Although the cloud variability is estimated, in the plot the scene is cloud free. As the paper mainly investigates clouds, it would be interesting to have a cloudy demonstration also in addition to Figure 1.

AC: Fig. 1 does not exist in its previous form anymore, but in any case, the scene was not cloud free. The horizontal structures with large ATB values corresponded to the clouds.

RC: Page 4, line 123: “…scattering ratio (SR)..”: Please write how the scattering ratio is calculated.

AC: This is a good point. In the new version of the manuscript, we have a whole new section (Sect. 3) dedicated to the definitions and formalism.

RC: Page 4, line 124: “An important companion of such a column is a corresponding quality flag column,…… which can be then compared with that of CALIOP.”: The description is vague, please write more clearly what filtering you used in the data.

AC: We have updated the text to "The important companions of these profiles are quality flag columns. For our analysis, we kept only the layers, which are marked either by a high Mie SNR flag or by high Rayleigh SNR flag, and by a flag indicating an absence of signal attenuation."

RC: Page 5, line 141: "Since the CALIOP is not a HSRL, the detailed information on AMB and APB is not available, and one has to compare the SR products.": One could also use the temperature and pressure profiles from NWP (provided with Aeolus & CALIPSO) to produce the particulate backscatter coefficient, and convert/compare these parameters. So this part should be revised to highlight the choice of this study and not state it as the only option.

AC: Thank you for this suggestion, that's exactly how it's done in the new version of the manuscript. There's a small correction, though – the molecular backscatter coefficient is recalculated using P/T profiles, and not the particulate one.

RC: Page 5, line 145-150: "The choice of the fitting parameter is not crucial for the purposes of the present work … collocated data.": I strongly advise the authors to follow the comment of the first reviewer regarding the wavelength conversions. Alternatively, if they decide to keep the analysis as is, then please provide a detailed discussion on the uncertainties induced from this simplified conversion.

AC: For the new version we have updated the wavelength conversions and we discuss the uncertainties associated with it.

RC: Page 6, line 167: "To avoid the risks associated with the solar contamination, we picked up only the night-time cases": As Aeolus is in dusk-dawn, still variability is expected in the PBL with the CALIPSO nighttime observations above land. Can you comment on that in the manuscript?

AC: This is a valid point and, indeed, the diurnal cycle can spoil the comparison. Our answer is in our Fig. 3 (now Fig. 4), which estimates the diurnal effects along with the geometric and sampling differences. In addition, we rebuilt our new Fig. 5 (SR-height histograms) and Fig. 7 (cloud fraction profile per latitude) for the daily data without temporal difference filtering (these versions are not shown in the manuscript). In this approach, the diurnal effects are compensated because both local times are used for both instruments. Still, the SR-height histograms (Fig. 5) and cloud fraction profiles (Fig. 7) plots look about the same for this enhanced dataset as they do for a subset used in the manuscript, so one can conclude that the diurnal effects cannot explain the observed behavior.

RC: Page 6, line 172: "…we have performed a numerical experiment using the same calculated data as we used in Fig.1": Shouldn't they be stated as "simulations"?

AC: This is correct, but now we have a different Fig. 1 and a new section dedicated to the simulations, so this phrase does not exist anymore.

RC: Page 6, line 173 – 180: "This time… the passive observations": It is very hard to follow the approach. A scheme/flowchart would be useful

AC: We added a flowchart and we simplified the text, thanks for the suggestion.

RC: Page 6, line 182: "Overall, we considered about 1E5 pairs of pseudo-collocated data and we present the results of cloud detection in Fig.3": Please include also the region and season(s) used to produce these pseudo-collocated data, which represent the outputs of Fig. 3.

AC: We have updated the text of the paragraph and added a flowchart (Fig. 3). Briefly, we used 15 simulated orbits of one day in autumn equinox that cover both hemispheres and give, therefore, a representative snapshot of various atmospheric scenarios.

RC: Page 6, line 184: “or each altitude bin, the cloud detection agreement is a ratio of a number of cases when both instruments have detected a cloud (SR>5) ….”: Please elaborate this choice of cloud cut off (e.g. literature) and comment on the uncertainties on the cloud detection induced from this choice for different altitudes. Could you include in results (Figure 3) and discuss, the percentage of the clouds missed to be detected, from the 2 sensors in your simulation, with the presented methodology?

AC: As for the choice of cutoff, we’d like first to refer to our answers to Reviewer #1’s questions and to the two definitions of SR existing in the community. Indeed, a threshold applied to the SR defined as in Eq. 2 of present version of the manuscript should be altitude-dependent. But, as it is shown in (Chepfer et al., 2008, 2013) a fixed threshold can be applied to a SR defined as in Eq. 3 of the manuscript to estimate the difference between the two lidars. Future work will include a more advanced cloud detection algorithm to build a long-term cloud record. But this will be a whole new study.

RC: Page 7, section 3.1. It should be stated clearly in the section that the discussion refers to the SR retrieved products used in this study from the 2 sensors. As for example, a study with the cloud statistics from the Atlid L2A and CALIPSO L2 backscatter coefficient product products may provide different results.

AC: This is true, we hope that the new title clarifies that point.

RC: Page 8, line 224: “In Appendix A, we demonstrate the correlation between individual pairs of CALIOP and ALADIN SR profiles; the conclusion of this exercise is that it justifies using Eq.1, but the uncertainties of the analysis do not allow to refine the conversion coefficients”. This statement is very strong. One could refine the conversion coefficients, independently of the uncertainties of the analysis. I support that the authors should formulate this statement to correctly reflect the choices and limitations.

AC: In the new version of the manuscript, we do not use Eq. 1 and we do not want to retrieve or validate its parameters anymore, so we do not seek to rebuild this plot.

RC: Page 8, line 229: “This observation gives a hint that the instrumental part provides the backscatter information sufficient for some cloud detection up to 20km, but the detection algorithm suppresses noisy solutions.” This sentence is not clear. Please improve the phrasing.

AC: We added some explanations after this sentence.

RC: Page 8, line 246: “Below, we will also discuss the YES_YES statistics normalized to cloud amount, but at this point we also want to study the other cases, which cannot be normalized this way” Consider to improve the phrasing.

AC: We have rewritten this section.

RC: Page 9, line 283: “This exercise is not aimed at revealing any altitude offset in backscatter signal registration, because this part of experimental setup is robust in both instruments”. Consider improving the phrasing.

AC: We have changed it to “We note that we are not looking for an altitude offset here. The altitude detection of both instruments is beyond question. Instead, we would like to check …”

RC: Page 9, line 10: “For each local peak found, we have searched for a peak or for a maximal value of CALIOP’s SR profile in the vicinity of ±3km from the peak height determined from ALADIN”. Consider including the information that only the 82% of the clouds are used for this comparison (according to the statistics presented in line 296-297.

AC: We added the proposed information in the following form: “By imposing the ±3 km search criteria, we filter out about 12% of the cases linked to natural variability, but at the same time we lower the rate of picking up the peak from a different cloud layer.”

RC: Page 9, line 304: “As for the clouds between ~3km and ~10km height, the height sensitivity effects skew the effective cloud height detected by ALADIN downwards by 0.5−1.0km”, It is not clear which are the high sensitivity effects between 3 to 10 km. Maybe the authors could summarize them in a sentence again here. Also, please comment to what extent could the actual 100-km-cloud-variability at these altitudes be responsible for the deviation in the altitudes seen by Aladin and Caliop in these altitudes. It is not clear if the authors point out on the Aeolus capability to detect the top of the cloud, on the SR methodology capability for the same, or on the effect of the natural variability between the 2 instruments on their products.

AC: We have updated the figure due to an improved recalculation of SR. The text has been updated, correspondingly. As for the possibility of 100km variability to be responsible for the observed shift, it is unlikely. The very nature of this variability is random and we do not expect it to have a bias. Moreover, the figure does not change that much if we loosen the collocation criteria, thus adding even more random variability.

RC: Figure 1: “…ALADIN’s observation paths for centers of averaged profiles …”: How they are averaged? In Aladin L2A resolution?

AC: We have a new version of Fig. 1 and the caption is now different, too.

RC: Figure 1: “ This inclination is schematically shown as an inclined line lying in lidar curtain plane whereas the real projection to the same plane should be a vertical line”: This part is hard to understand. Same comment for the part inside the manuscript.

AC: This figure has been replaced with a 3D view and the text has been modified correspondingly.

RC: Figure 2: Can the authors comment on the absence of collocated points between 0-60° lon at Δtime < 6hrs?

AC: This is a good point. The problem is purely technical: in this part, the data at 6 h difference come from another day and our collocation used the same day files. The collocation procedure is already heavy enough on resources, so we opted out of reading the other day’s files. Technically, this is possible, but practically we would get only ~10% more of the collocated cases in the geographic area, which is not crucial for the comparison.

RC: Figure 7: No data is difficult to be distinguished from the -2km color, both have dark purple. Consider changing the no data color.

AC: We have changed the no data color.

RC: Figure 9: Consider adding the colorbar here also in the upper panel. Additionally, consider stating what the error bars account for.

AC: We have merged old Fig. 8 and Fig. 9 to a new Fig. 10. Correspondingly, all color panels share now the same color bar. As for the error bars, they correspond to r.m.s. of 1-week chunks of analyzed altitude subsets.

RC: Figure A1: The red points are not scaled in the same frequency ranges as the occurrence frequencies. Wouldn’t that be better?

AC: This figure was removed from the new version of the manuscript.

Technical corrections

RC: Page 4, line 101: “According to Flamant et al. (2017).”

AC: Fixed.

RC: Page 6, line 182: “Ansmann et al. (2007)”

AC: We do not quote this work in this context anymore. Please, see the next-to-last answer to the Reviewer #1 comments.

RC: Page 7, line 195: “…between the two products..”

AC: This sentence has been rewritten

RC: Page 7, line 200: “..for the thw instruments”

AC: Fixed

RC: Page 7, line 203: “Analyzing the Fig. 4”

AC: Fixed

RC: Page 8, line 242: consider rephrasing to “from the sensitivity study..”

AC: This part has been rewritten

RC: Page 8, line 237: consider rephrasing to “..behavior of the SR cloud detection product agreement”

AC: We have updated the phrasing here.

RC: Figure 3: “...to the total number of simulations ..”

AC: The whole caption of Fig. 3 (now Fig. 4) is different in the new version

RC: Figure 7: “...+-3km vertical vicinity…

AC: Fixed, thanks.