The authors would like to thank the reviewer for his/her valuable comments which helped improving the quality of the manuscript. Our point-by-point responses to the reviewer's comments appear in bold below.

Reviewer 1

1. Use of an acronym "ATR-42" in the first sentence of the abstract is not helpful for those who do not know what ATR-42 is. Perhaps "manned research flights" ? Use of the ATR-42 is jargon. I did not know which aircraft it is. Perhaps describe the aircraft in the paper and call it ART-42 thereafter.

"ATR-42" has been replaced by "manned research flights".

2. Line 6: I understand the desire to write a catchy first sentence, but "radiator fins" on traditional "radiators" don't accomplish their purpose through radiation. They actually transfer thermal energy from one substance (a circulating fluid or highly conductive metal) to the air around them through conduction at the interface of the fin and the air that is it immersed within and not so much radiative losses. (Note: most traditional radiator fins are made of shiny metal that have less than ideal emissivity making them poor radiators anyway.) Then, after the air around the fin is warmed, it is transported away either through forced movement or natural convection. The exception are radiator panels on spacecraft that function as the authors are suggesting clouds do, but they are a rare form of embodiment of radiators and actually look like large flat panels and not fins that you find on common devices. So, I understand the author's ambition to convey the importance of clouds in the upper atmosphere, but the current way it is written is not a good analogy and worse could lead an uninformed reader to the wrong idea about how most radiator fins work.

"Subtropical regions have long been considered as the radiator fins of the Earth due to their dry free troposphere and their ability to emit a large amount of heat to space (Pierrehumbert, 1995)."

Has been replaced by

"Subtropical regions play a major role in the radiation balance of the Earth due to their dry free troposphere and their ability to emit a large amount of heat to space (Pierrehumbert, 1995)."

3. The very first sentence of the paper is also interesting because my elementary textbook understanding of the global energy budget is that the low latitudes cannot cool enough via radiation and that surplus energy is transported poleward through large scale circulations. In contrast, the high latitudes experience a deficit in the radiation budget because loss of radiation prevails over incoming radiation. (See Fig. 17 in Ahrens "Meteorology Today")

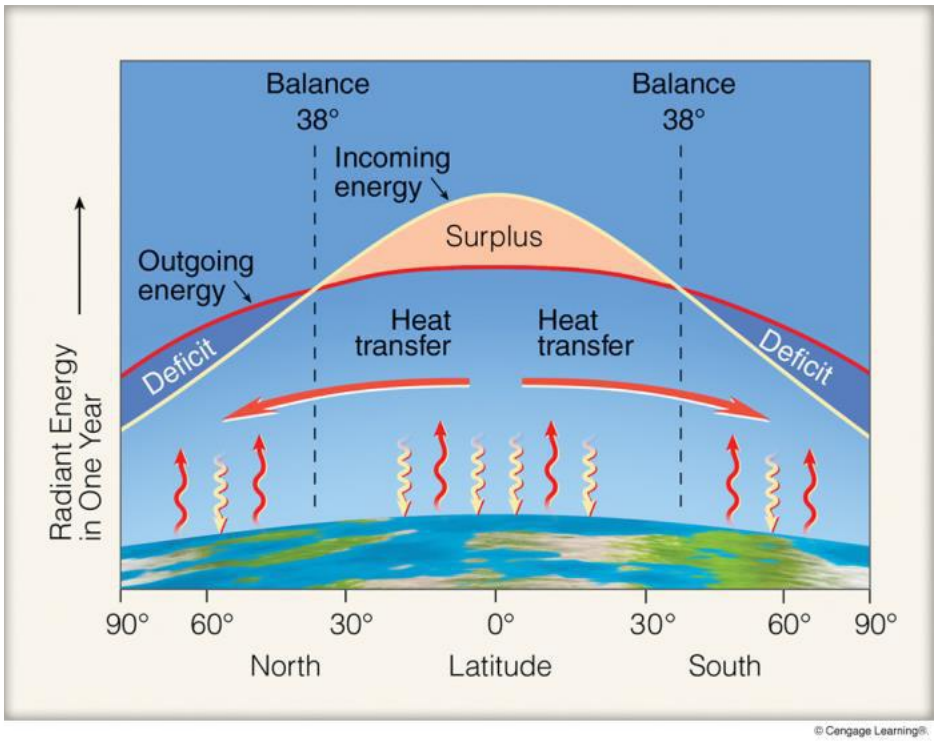
The emission of LW radiation to space is obviously not the only way through which the energy balance of the atmosphere is achieved, but it is a major ingredient of it.

So, what is it about the subtropics (roughly 10 – 30 degrees latitudes) that makes them special in terms of their ability to radiate energy? Again, this is in regard to the very first sentence of the paper.

Barbados is located at 13N. In Summer, it can be associated with deep convection from time to time, but most of the time, and certainly during the whole winter season, it is

associated with large-scale subsidence and very dry conditions in the free troposphere (in winter, it is frequent to find relative humidities of 3-5% over the whole free troposphere!). These dry conditions in the free troposphere and the prominence of clouds in the boundary layer (as opposed to deep convective clouds) make the area of Barbados representative of the trade-wind regimes of the tropics. As a matter of fact, the clouds around Barbados have been shown to be representative of the cloudiness of the trade-wind regions of the globe (Medeiros and Nuijens, PNAS, 2016). The Barbados area thus contributes to the strong emission of LW radiation at the top of the atmosphere (the low humidity and rare upper-level cloudiness entail a strong infrared cooling to space) that plays such an important role for the radiation balance of the Earth. Indeed, the moist areas associated with deep convection are too radiatively opaque to get rid of their energy excess through radiation; it is largely done through a redistribution of energy by the Hadley-Walker circulation which induces subsidence in the subtropics and thus allow energy to be emitted to space through infrared radiation (the origin of the 'radiator fins' expression of Pierrehumbert 1995). The effect of subtropical LW emission on the net tropical radiation budget is already taken into account in the figure shown by this Reviewer; if it wasn't, the energy excess in the tropical belt would be much higher, and the large-scale atmospheric and oceanic circulations would need to be much stronger to balance it.

Several factors make the trade-wind regimes 'special' regarding their ability to radiate infrared radiation to space. First these regimes cover a large fractional area of the tropical belt, and thus have a huge statistical weight, making them highly susceptible to influence the tropical radiation budget. Actually, this is the primary reason why trade-wind clouds are so critical for climate sensitivity. Second, as discussed above, they emit much more infrared radiation than the moister deep convective regions. Third, because of the low IR opacity of the free troposphere in these regions, the infrared radiative cooling is very strong at the top of the boundary layer, which has the potential to generate radiatively-driven mesoscale circulations within the boundary layer and can contribute to organize the low-level cloudiness.



4. Line 7: Try to avoid referring to heat as a noun. What is heat? It is ambiguous. Some people regard radiation as heat. Some regard anything having temperature as heat. Yet these are very different forms of energy. More precise language helps avoid confusion. (Read Bohren & Albrecht, Atmospheric Thermodynamics, 1998, pages 24 – 28.)

Here, we are talking about heat in the thermodynamic sense, we are talking about the heat (in J) released by the Earth system through radiation (radiative fluxes correspond to heat fluxes, in W/m2).

5. Line 9: "contribute to cool the Earth further" is awkward wording. Perhaps "contribute to further cooling of the Earth…"

"contribute to cool the Earth further…" has been replaced by "contribute to cool the Earth…"

6. Line 1 on page 2: "lidars have the potential to detect them much better" is a broad-brush statement that may not in fact always be true. The first part of that sentence was about passive sensors and but lidars are active sensors. I think one should not belittle passive sensors because lidars also have limitations where radiometers excel. Just carefully point out what lidars can do that passive sensors cannot. That is fair. But don't be dismissive of all passive sensors in half a sentence.

We are not dismissive of the passive sensors we routinely use for our scientific work. We are well aware of their limitations, such as the advantages and disadvantages of lidars. It remains true that lidars detect clouds better (at least their cloud top for lidars in space, or cloud base for lidars on ground) when the cloud layers are not overlapped or masked by thick clouds. In the latter case, their detection from passive sensors can be also difficult.

In contrast, under certain conditions lidars have the potential to detect them much better (Liou and Schotland, 1971; Spinhirne et al., 1982).

7. Page 3, Line 25, “shooting”? Like with a gun? Perhaps “projection” is more appropriate for a laser or lidar?

The term "shooting" is often used as for example in J. N. Porter; B. Lienert; Shiv K. Sharma J. Atmos. Oceanic Technol. (2000) “In order to derive the aerosol scattering coefficient […] we have implemented a simple forward stepping algorithm with a modified horizontal shot technique."

8. Page 3, line 24-25: how does one know whether the atmosphere is homogeneous? What constitutes sufficient homogeneity?

This is discussed in section 5.3.2. A reference has been added (Chazette et al., 2007).

9. Lines 32 and 33: use of the word “the” too many times.

The correction has been done:

"The goal of this paper is to present the flight strategy, ~~the~~ measurements, ~~the~~ data processing and ~~the~~ cloud and aerosol products derived from the horizontal lidar measurements made during the EUREC4A campaign."

10. Line 1 on page 4: comma not needed before the word and

The correction has been done:

"Section 2 presents the ALiAS lidar characteristics~~,~~ and Section 3…"

11. Line 8 on page 4: Acronym LSCE was not defined in the body of the paper.

The acronym has been defined:

"LSCE (Laboratoire des Sciences du Climat et de l'Environnement)"

12. Line 11 on page 4: wavelength is not the only issue that makes it eye-safe. The pulse energy, rep rate, and beam diameter also contribute. I suggest stating that eye-safety is a result of all of these parameters. It would be helpful to cite a document that explains in detail the eye-safety calculation.

The sentence has been modified as:

"…emitting at the wavelength of 355 nm. It satisfies eye safety requirements (EN60825-1) at the output window considering the characteristics given in Table 1 (emitted wavelength, pulse energy, repetition rate, beam diameter and pulse duration)."

13. Line 12 on page 4: Is the use of PXI architecture really worth mentioning? Is it related to the performance of the lidar? Why mention it here? For me, what is much more important (and not clear) is the next point:

Yes, this is important to mention because it is a stable technology, specifically suited for airborne experiments. This type of computer is robust to the temperature excursions that can take place in an airplane cabin while flying in the tropics.

14. Page 4 or 5: The paper does not mention the specific detector used. Table 1 lists analogue detection but also indicates a photomultipler (PMT) is used. Aren't PMT digital detection as in photon counting? I suggest being more specific on what detector (please state make and model) and what sampling electronics (make and model) are used. These are critical to understanding the nature of the backscatter data.

The detection is analog as written in Table 1. The detectors are photomultipliers as also indicated in Table 1, they are from the Hamamatsu company, the model is Hamamatsu H10721P-210. They provide an analog signal that is acquired as is by a PXI-5124 fast digitizer working at 200 MHz and 12 bits, without going through a pulse (photon) counter.

This information has been added in the text and in Table 1:

"The acquisition system is based on a PXI-5124 (PCI eXtensions for Instrumentation) fast digitizer working at 200 MHz and 12 bits, without going through a pulse (photon) counter leading to…"

Wavelength	**355 nm**
Pulse repetition rate	**20 Hz**
Pulse duration	**8 ns**
Beam diameter	**25 mm**
Divergence	**<0.2 mrad**
Reception diameter	**150 mm**
Filter bandwidth	**0.2 nm**
Field of view	**3 mrad**
Detector	**Photomultiplier**
Detection mode	**Analogue**
Digitalization	**12 bits**
Native line of sight resolution	**0.75 m**
Dimensions of the optical head	**45 cm (height) 28 cm (width) 18 cm (deep)**
Weight of the optical head	**~15 kg**
Weight of the electronics	**~20 kg**
Power supply	**220 V AC**
Consumption	**<500 W**

15. Line 5 on page 5: How about: "ALiAS was installed in the aft of the ATR-5 42 aircraft in an orientation that enabled a direct near-horizontal line-of-sight." (Use of the word direct indicates that no scanner was required to achieve this. Near is the truth. It is not always perfectly horizontal.) You may include a sentence that there was no effort to steer the beam to maintain horizontal pointing and compensate for aircraft attitude.

Agreed, we have modified the sentence as:

"ALiAS was installed in the aft of the ATR-42 aircraft in an orientation that enabled a direct near-horizontal line-of-sight."

16. Line 19. Could "right" be replaced with something more specific like "starboard"?

" …back of the ATR-42 aircraft, on the right side."

has been replaced by:

"…back of the ATR-42 aircraft, on the starboard side."

17. Line 23 page 6: what does prototypical mean here? Was it the actual flight or the flight plan? The first of two per day? Maybe prototypical is not the right word choice.

"prototypical flight plan" has been replaced by "flight strategy".

18. Line 23 on page 6 to line 3 on page 7. This is one huge sentence that does not read well. I recommend breaking it up.

"It was built along 5 major phases (see Table 2), each of which was designed to address a particular lidar-related science needs, and requirements of the lidar and other remote sensing and in situ instruments composing the ATR-42 payload (radar, aerosol and cloud microphysics, water vapour stable isotopes using cavity ring-down spectrometry, turbulence), while contributing to the multi-aircraft and statistical sampling strategy implemented during the field campaign:"

has been modified as:

" The flight strategy is given in Figure 3 for the flight on 26 January 2020. It was built along 5 major phases (see Table 2), which contributed to the multi-aircraft and statistical sampling strategy implemented during the field campaign. Note that during straight-line flights, the typical speed of the aircraft was ~100 ms-1. Each phase was designed to address particular scientific requirements of the lidar and other remote sensing and in situ instruments composing the ATR-42 payload (radar, aerosol and cloud microphysics, water vapour stable isotopes using cavity ring-down spectrometry, turbulence):"

19. Line 25 on page 6: what is a "lidar-related science needs" ? This is a vague phrase and leaves the reader wondering. I think the word "needs" should be singular (need) and not plural.

Agreed. Resolved with previous response.

20. Line 7 on page 7: I suggest "Such an aircraft sounding was aimed at…"

" Such aircraft sounding aimed at…" has been replaced by "Such an aircraft sounding was aimed at…".

21. Line 8 on page 7: Please clarify whether "retrieving aerosol extinction coefficient and volume depolarization ratio profiles" was done using in situ sensors or the lidar. I think this requires a much more explanation and references.

It is done with the lidar. Information and references are given in section 5.3.2. The sentence has been revised as

"Such aircraft sounding aimed at retrieving aerosol extinction coefficient and volume depolarization ratio profiles from the lidar measurements (see subsection 5.3.2) and…"

22. Line 10 and 11 on page 7: If it is worth noting then why not tell the poor reader the dates and times? Why tease them? Maybe a footnote or a reference to where they can find these cases?

Reference was made to subsection 5.3.2 where this is presented.

23. Line 25 on page 7: “Lower troposphere” is pretty general and not helpful. Can you be more specific? In or out of the boundary layer? At the top of the convective boundary layer? Were you flying through the entrainment zone (EZ)? Above the EZ? Perhaps in the capping inversion?

" …performed in the lower troposphere, at CBH,…" has been replaced by "performed at CBH…"

24. By the way, flying in the entrainment zone is typically pretty bumpy ride and the atmosphere is not very horizontally homogeneous (a horizontal lidar beam penetrates inversion air and BL air in plumes). This is challenges two requirements for this project: (1) minimal rolling to maintain horizontal probing and (2) horizontal homogeneity. So, if the flights were indeed near the top of the BL (just above cloud base) near the EZ, can you please comment on whether these issues challenged the measurement goal?

In fact, the measurement goals have not been affected. The ride turned out to be rather smooth, which we could experience directly by flying on board with the lidar. The variations in the attitude of the aircraft did not induce a deviation in the horizontal of the lidar line of sight of more than 1±0.5° (measured at all times by an inclinometer along a straight route). In addition, there is a quality indicator given in 5.3.1.c.

We have added in Section 3 the sentence:

"Its orientation was measured at all time by an inclinometer."

We have added the mean value and the standard deviation of the angle of the lidar line of sight with the horizontal in subsection 5.3.1.a:

" …(the mean value is 1° and the standard deviation is 0.5°)."

25. Lines 8 – 9 on page 8: breaking the sentence across two points like this is not good style. Complete a sentence and start a new sentence.

We have modified as:

"4. …lower part of the boundary layer.

5. The ATR-42 cruised back towards Barbados around 3 km a.m.s.l. (see Figure 3)."

26. Line 13 page 8: use of prototypical again. (See point 17 above.) I understand a prototype is a first version of something but in this case the question is whether the first version was actually flown or was the long description just an ideal plan that was never actually done.

We have replaced by:

" The flight strategy "

27. Line 7 page 9: Use of the word “onwards” not needed because there is no level above 3.

"For level 3 onwards that they are considered globally by flight segment to establish statistics."

has been replaced by:

" The statistics performed on Level-2 data are gathered in the Level-3 data. Statistics are computed for all flights for the aerosol Level-3 products and for the Phase 2 of the flights for the cloud products."

28. Line 7 – 8 page 9: I really don't know what this means: "For level 3 onwards that they are considered globally by flight segment to establish statistics." What does "considered globally by flight segment" mean?

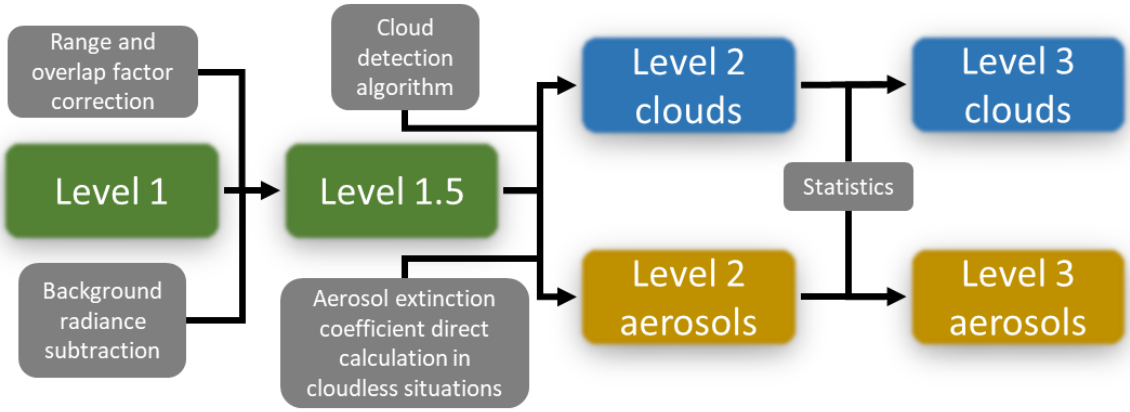
Agreed, we clarified by replacing the sentence. See previous answer.

29. Line 1 on page 10: The sentence "This section presents the physics of the measurement." should be removed. "…the physics of the measurement" is a huge and complex topic that would require several books to fully explain. Surely the manuscript is not covering all of it in this section. Maybe "This section presents the steps taken to derive data products."

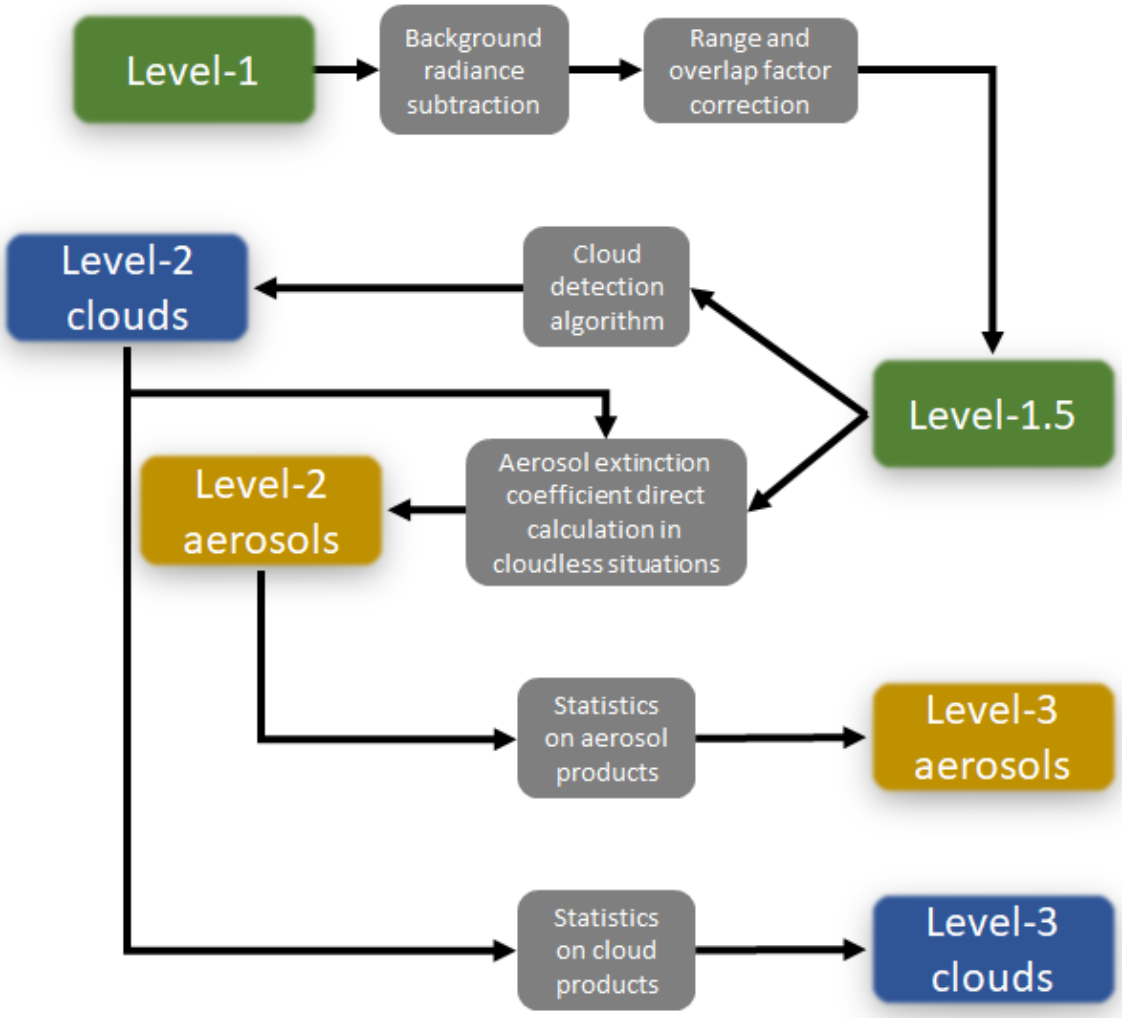
Thank you for the suggestion, we have replaced " This section presents the physics of the measurement." by "This section presents the steps taken to derive data products."

30. Figure 4. This figure looks nice but I find it not very helpful because it is vague. For example, the following part of the figure is confusing. Are some arrow heads missing? It is not clear what is informing what. Where does "aerosol extinction coefficient direct calculation in cloudless situations" come from? Lidar data? What level?

The Figure 4



has been replaced by



31. Line 12 page 10: Volts should not be capitalized.

The correction has been done.

32. Line 12 page 10: Who cares whether they are in volts or digitizer counts? Isn't the voltage of backscatter data arbitrary? Really, why is data in volts important to note? Why is it in volts especially considering it uses a PMT? Shouldn't they be in counts?

It is not particularly important for the processing, but the detection is performed in analog and we record volts. It is the unit of the level 1 data. As explained in a previous response (reply to comment #14), there is no photon counting. The choice of analog is necessary to avoid saturation of the counting mode because of the strong signal, due to daylight and the presence of clouds that may be close to the lidar during flights.

33. Line 13 page 10. Resolution implies the ability to resolve. Given that the pulse length is 8 ns, I doubt you could distinguish two independent aerosol features that are 0.75 m apart. Perhaps the word "resolution" is a bit misleading. It is really more like spatial sampling along the beam. Whether those are truly independent samples or not is another question. It depends on the response time of the detector and amplifier. One could have 500 MHz sampling, but it doesn't provide value if the pulse length is long and the electronics are slow.

Indeed, and that is why we talk about “native” resolution, i.e. sampling rate. To ensure independence between each point of the profile, the signal is sub-sampled before analysis and the resolution along the line of sight is then 15 m. A sentence is missing in subsection 1.5 to explain this part, it was added as:

"To build level 1.5 data, the raw sampling along the line of sight has been degraded in order to ensure the independence of each point on the horizontal lidar profile. The final resolution is then 15 m. The ALiAS-derived level 1.5 data are then profiles corrected…"

34. Bottom of page 10. Just wondering: How many bits of dynamic range is in the detection subsystem on this analogue lidar? (Again, I am confused because Table 1 indicates it uses a PMT which tells me it is photon counting but it also lists analogue detection mode. What am I missing?) If it is analog detection, then the number of bits is important to understand how well resolved the dynamic range is.

It is possible to do analog detection with a PM, it is recommended in the UV/visible spectrum. Then, there is necessarily a digitization which is carried out. It is here on 12 bits. The digitalization noise is therefore negligible here. The number of bits has been added in Table 1. See remark 14.

35. Line 18 on page 11. I suggest replacing the word “verified” with “true”.

The correction has been done:

"…the heterogeneity is too strong for this hypothesis to be true."

36. Figure 5. Congratulations on achieving a flat background. However, many people who use this data will wonder why a description of this exercise is in the paper especially if it is not a problem. As having practiced lidar development I appreciate it and think it is worth keeping. But others will wonder. So, I think it would be helpful if the manuscript stated why this was investigated and why you bother to show it. Perhaps cite some examples where it was a problem? Without a good explanation, some may think it is just filler to fatten up the paper with technical stuff.

We have clarified the interest of this figure:

The sentence:

" From level 1 data, the eventual shift of the lidar signal baseline is checked for each flight in order not to introduce any bias during data processing, mainly in the far field, i.e. beyond 4-5 km."

has been replaced by

"Baseline distortion can significantly increase the rates of non-detection and/or false detection of cloud structures. Hence, in Level-1 data, potential drifts of the lidar signal baseline are checked for each flight, in order not to introduce any bias during data processing, mainly in the far field (i.e. beyond 4-5 km)."

37. Isn’t a plot of a single waveform for level 1 data more important than a scatter plot showing the flat baseline? (Just wondering why there is not a figure to show a typical return from 1 pulse of level 1 data.)

After years of practice, we consider that a scatter plot allows providing more robust data verification on the dependency of the baseline drift on the sky background level, as well as helps visually averaging out noisy data. In addition, a typical return is given as an example in Figure 10.

38. How much averaging (temporal or spatial) is ever done to the data. I don't recall reading anything above smoothing and it might be worth pointing this out,

Agreed, we have modified the sentence:

"The native resolution of the lidar profiles is therefore 0.75 m along the line of sight."

by

"The raw sampling of the lidar profiles is 0.75 m along the line of sight and an average over 50 shots is performed during the acquisition, corresponding to about one recording every 5 s (2.5 s averaging time and 2.5 s recording time)."

39. Same question as above for level 1.5 data. Why not make a plot that shows how data processing transforms a given waveform from level 1 to level 1.5? Then people can see a plot of the actual data. This is helpful so that when they read the data they can check to make sure they see the same thing. They can attempt to recreate the plot on their own and be sure they are looking at things correctly.

This kind of plot is not very graphical because of the difficulties to find an adapted scale when correcting for the solid angle. As seen in remark #33, only the resolution along the line of sight is degraded at 15 m. The temporal resolution remains unchanged.

40. In fact, I am thinking of a plot that shows the progression of going from level 1 to level 1.5 etc all the wave up to the final product: cloud boundaries. That would be nice.

We already have some of this in Figure 10. There is not really much interest in showing raw data profiles, it is more the ABC that is interesting (solid angle correction).

41. Figure 6 panel b shows the "apparent backscatter coefficient" close to the aircraft (< 1 km range) tend to be more orange than the data out at 2 or 3 km which tends to be yellow. Is this the result of attenuation that is not corrected? I think it is worth explaining this in the manuscript.

The apparent backscatter coefficient is corrected for the molecular transmission, but not for the aerosol and cloud transmission as shown in Equation (3).

Indeed, it becomes more yellow away from the plane because of attenuation by aerosols and clouds.

We have added the sentence:

"The ABC decreases away from the plane because of attenuation by aerosols and clouds (passing from orange to green on Figure 6a)."

42. Please state (it may require a new paragraph) the distribution of roll angles during a typical flight leg and the implications of aircraft roll on the altitude of the lidar beam as a function of range. For example, what happens to the altitude of the beam at 8 km range if the aircraft rolls off of perfectly a horizontal plane by 1 degree? Perhaps the flight data could be used to mark

each range gate in a lidar return with an estimated altitude. Also, can the authors please comment on the implications of variability in aircraft roll on what this means for the cloud location data? Is it possible that at one moment the lidar beam intercepts a small cloud but the next moment it misses the cloud because the aircraft rolled a little bit? Could this rolling (due to the turbulence) make the cloud results look less coherent and more noisy?

The effect of roll is taken into account in the quality indicator/flag. As explained above it is less than 1±0.5° during Phase 2 (subsection 5.3.1.c). We have considered it because indeed we can miss small clouds at great distance.

The Qflag parameter in Table 4 (subsection 5.3.1.c) contains this information via the vertical positioning with respect to the horizontal (Δz).

43. Line 8 and 9 of page 28: what means “altitude parameters”? This is vague. Is it altitude of the aircraft for each pulse? Is it altitude of the beam for each range gate?

Agreed, we have modified as

" flight attitude, localization and altitude".

44. Section 5.2.2: Many non-lidar scientists will not understand what overlap factor is. Perhaps one or two sentences to describe what this is and why it must be addressed?

Yes, we have added the sentence:

" The overlap factor corresponds to the overlap between the laser beam and the field of view of the telescope. It is equal to 1 when the two fields completely overlap and leads to a geometric attenuation of the lidar when the overlap is partial. It…"

45. Is the aircraft attitude (pitch, roll, yaw, etc.) data included any of the level 1, 1.5, etc data?

Yes, all data levels contain this information.

We have added the sentence:

" It should be noted that for Level 1 to Level-2, the location and attitude of the aircraft are also reported for each horizontal lidar profile."

in Section 5 (line 2 page 10).

46. Can the manuscript please state the size of the data files? For example, megabytes per file?

The sentence:

" The typical sizes of the different NetCDF files are: i) ~ 195-420 Mo for Level-1 data, ii) ~11-29 Mo for Level-1.5 data, iii) ~4-18 Mo for Level-2&3 cloud products, and iv) ~60-190 Ko for Level-2&3 aerosol products."

has been added at the end of subsection 6.2.