

Remote sensing of exceptional winter aerosol pollution events and representativeness of the surface – column relationship over Paris metropolitan area

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In the following, *reviewers' comments are in italic blue*. Responses are in normal black font. **Changes in the text are in black bold**. The numbers of the most **major comments** are highlighted in red.

Response to Anonymous Referee #1 – RC2

We are very grateful to Referee #1 to have reviewed the manuscript and submitted helpful comments and suggestions to improve both the study and the text. Here we respond to the reviewer point by point.

1) P.1 L.19

Planetary boundary layer height (*PBL*). Changes have been made in the text:

“These two major aerosol pollution events share very low **planetary** boundary layer (**PBL**) heights”

2) P.1 L.20

Under the same weather condition. Changes have been made in the text:

“However, they did not take place **under identical anticyclonic** weather conditions”

3) P.1 L.21

Aerosol lidar ratio. Changes have been made in the text:

“they are associated with significantly different **aerosol** lidar ratios”

4) P.2 L.3

Anthropogenic. Changes have been made in the text:

“**Anthropogenic** contributors”

5) P.2 L.9

Extend. Changes have been made in the text:

“**extend** from regional to global scale”

6) P.2 L.21

Concerned. Changes have been made in the text:

“is often **concerned** by air pollution issues.”

7) P.2 L.27

Time. Changes have been made in the text:

“mainly during summer and ...”

8) P.2 L.31

~~Top~~. Changes have been made in the text:

“the PBL height ...”

9) P.3 L.1

The use of *in situ* sounding, or *lidar remote sensing techniques to obtain increased vertical and temporal resolution* can *provide valuable data to air pollution models*.

Changes have been made in the text:

“The use of *in situ* sounding, or **lidar remote sensing techniques to obtain increased vertical and temporal resolution** can **provide valuable data to air pollution models**.”

10) P.3 L.7

~~Planetary boundary layer (PBL) PBL~~ [...] ~~dinitrogen~~. Changes have been made in the text:

“the winter **PBL**.” The end of the sentence has been removed due to a significant modification of the sentence asked by the third referee.

11) P.3 L.14

~~Such as~~. Changes have been made in the text:

“aerosol optical properties, **such as** the lidar ratio”

12) P.3 L.15

~~Depolarization ratio (LPDR)~~. Changes have been made in the text:

“the linear particle depolarization ratio (LPDR)”

13) P.3 L.16

The meteorological situation ~~is examined to assign the~~ origin of pollution. Changes have been made in the text:

“the meteorological situation **is examined to assign the** origin of pollution”

14) P.3 L.18

~~Links~~. Changes have been made in the text.

“the link between”

15) P.3 L.20

~~Instrumentation~~. Changes have been made in the text:

“Section 2 presents the **instrumentation** and datasets”

16) P.4 L.31

~~Lidar ratio (LR)~~. Changes have been made in the text:

“also called **lidar ratio (LR)**.”

17) P.5 L.4

LPDR. Changes have been made in the text:

“(LPDR)”

18) P.5 L.8

SNR is defined P.4 L.19: “To obtain a sufficient signal to noise ratio (SNR)”

19) P.5 L.13

LPDR. Changes have been made in the text:

“(LPDR)”

20) P.7 L.3

CATS has been recently evaluated by ground-based lidar measurements from the EARLINET network (Proestakis et al., 2019). The sentence and reference have been added.

21) P.10 L.11

Low-pressure system. Changes have been made in the text:

“A low-**pressure system** coming from the South”

22) P.10 L.15

The Paris *area*. All the occurrences of “the Paris Area” have been changed in “the Paris **area**”.

23) P.15 L.2

It is well established that the LR. Changes have been made in the text:

“**It is well established that** the LR varies with the types of aerosols”

24) P.15 L.10

“Indeed, mechanical processes inducing abrasion (tires, breaks ...) linked to human activity decrease during the night. Yet, they are the main source of coarse particles with aerodynamic diameters larger than 2.5 µm.”

Comment: How the authors are sure about these statements?? Other PM local sources are also present. We know that in Paris area garbage burning industries are located, emitting coarse particles >PM2.5. Could this increase also linked to external sources (advected PMs)? The authors should investigate and comment on these issues.

It is true that we cannot be affirmative on this particular aspect. To us, the underlying cause of the diurnal variations of both the LR and the PM_{2.5}/PM₁₀ ratio could be the resuspension processes more active during daytime. In particular, resuspension of aerosols was identified as a possible cause of discrepancies between models and daytime observations during ESQUIF project (Hodzic et al., 2006).

However, to our knowledge garbage burning industries are no longer coarse particles emitters in the Paris surroundings. Moreover, external sources (e.g. advected particles) are excluded due to the weather and atmospheric structuration conditions (anticyclonic situation, weak winds, and free troposphere and mixing layer un-correlated).

Some changes have been added in the text:

“The LR is quite variable for the December APE, with values ranging from ~30 to ~90 sr and a mean value of 59 ± 18 sr. These temporal variations trace a diurnal evolution with smaller aerosol during night time, as highlighted on **Erreur ! Source du renvoi introuvable.b**, when the $PM_{2.5}$ to PM_{10} ratio slightly increases during the night (e.g. from 0.4 to 0.6 during the first night, 28th November). This increase **may** be explained by the diurnal variation of aerosol production in an urban area (Airparif, 2014). Indeed, mechanical processes inducing abrasion (tires, breaks ...) linked to human activity **and resuspensions processes decrease during the night. Yet, they are the main source of coarse particles with aerodynamic diameters larger than 2.5 μ m. Resuspension during daytime was highlighted as a possible cause of discrepancies between model and observation during the ESQUIF project in the Paris surroundings (Hodzic et al., 2004, 2006). This could be the underlying cause of the diurnal variations of both the LR and the $PM_{2.5}$ to PM_{10} ratio.** The fine fraction of AOT given by the AERONET operational product is also plotted in **Erreur ! Source du renvoi introuvable.b** (available only during daytime). It agrees with an increase of LR when the load of smaller particle increases from one day to the next.”

25) P.15 L.21

77 \pm 6 %. Changes have been made in the text:

“a ratio of $PM_{2.5}/PM_{10}$ of 77 ± 6 (Figure 8b).”

26) P.16 L.4

02:00. In all the paper, the time hours have been written in the format hh:mm.

27) P.16 L.10

I am not convinced that the CATS and CALIOP trajectories south of Paris area could be compared with data inside the Paris area, as the distance between these 2 sites is very big (>150 km).

Indeed, the distances between the ground-based lidar and the spaceborne lidars ground-tracks are substantial, ~200km for CATS, the farthest track.

However, according to the figure 9, we see in light blue with an AOT > 0.1 that the pollution plume is quite widespread south of Paris. Each track passes through this plume. According to ensemble reanalyses of chemical transport models available on the CAMS website (<https://atmosphere.copernicus.eu/>) and given the meteorological conditions discussed above the pollution plume seems to originate from the spreading of the urban haze.

Thus, we assume that the three lidars measured the same type of aerosol and that their data can be compared.

The sentence has been added in the text:

“Erreur ! Source du renvoi introuvable. **shows the CALIOP and CATS ground-tracks for the January APE. Within a 24-hour time interval, their tracks are crossing in the middle of France, along a south-north axis for CALIOP and a west-east axis for CATS. The distances between the ground-based lidar and the spaceborne lidars ground-tracks are substantial (~200km for CATS, the farthest track). However, according to ensemble reanalyses of chemical transport models available on the CAMS website (<https://atmosphere.copernicus.eu/>) and given the meteorological conditions discussed**

above, the pollution plume seen by MODIS (AOT > 0.1 in light blue South of Paris) seems to originate from the spreading of the urban haze. The distance separating the ground-based lidar and the farthest ground-track is inferior to the characteristic size of the dispersed plume. Thus, we assume that the spaceborne and ground-based lidars measured the same type of aerosol and that their data are comparable.”

28) P.21 L.6

PBL. Changes have been made in the text:

“the **PBL** height”

29) P.21 L.20

Found. Changes have been made in the text:

“may be **found** near the top of the PBL”

30) P.21 L.20

“here we find 358 ± 229 m as the averaged difference between PBL height and the altitude of AEC_{max} over all the available profiles”

Please comment on this very high value of the std.

This high value of the standard deviation of the distance between the AEC_{max} altitude and the PBL top can be explain by the wide range of variation of the PBL height in the dataset considered. Indeed, the AEC_{max} altitude is rather stable ($\sim 300\pm 90$ m AMSL, specified p.21 l.13) but the PBL height is not ($\sim 640\pm 250$ m AMSL).

Changes in the text:

“In the case of hydrophilic aerosols, as is often the case for Paris pollution aerosols (Randriamiarisoa et al., 2006), the AEC_{max} may be found near the top of the PBL. **Nevertheless, during winter, at low temperatures, aerosols are generally less acidic and therefore less hydrophilic (Jaffrezo et al., 2005).** Here we find 358 ± 229 m as the averaged difference between PBL height and the altitude of AEC_{max} over all the available profiles. **This mean distance is associated with a high standard deviation resulting from the high variation of the PBL height within the considered dataset ($\sim 640\pm 250$ m AMSL).**”

31) P.23 L.4

Investigated. Changes have been made in the text:

“In this paper we **investigated** the lidar-derived optical properties”

32) P.23 L.15

LPDR. Changes have been made in the text:

“(LPDR)”