# Response letter

"Spatial variability of Saharan dust deposition revealed through a citizen science campaign" (essd-2023-16)

## Referee #1 (minor revision)

General comments:

The manuscript by Dumont et al. discusses a new dataset which consists of Saharan dust samples collected over the Pyrenees and European Alps by several research laboratories and citizens. The analysis of the samples consisted of mass, particle sizes with distance from the source along the transport path, and elemental composition. The manuscript is within the scope of the journal and can be published after minor revision by the authors. Before that, the authors should, however, provide the critical information on the data set on the following questions, to ensure the usability of these valuable and unique data:

We thank the reviewer for this careful evaluation of our work and the relevant suggestions to help other researchers make good use of the data. As explained below, we can provide most of the missing information in a revised manuscript. The reviewer's comments are reported in black below, our replies are in blue and the changes in the manuscript are highlighted in bold blue. A detailed point by point response is provided below.

1. whether your 152 samples were from 152 different locations or is there more than one sample from one location (e.g., from Fig. 4 it is hard to say how many locations you have);
2. which samples and how many were from citizens and which and how many were from research laboratories;
3. how these sample collections by citizens and professional differ from each other by sampling or any other property related (altitude, accessibility to sample, slope, etc any other);
4. how citizen/professional samples might affect the gained results (e.g., any bias in results due to any differences);
5. Also, it remains unclear for the reader, which samples (and how many) were used for which analysis, why, and how that affected the gained results. A summary table could help to give that information.

   Here we provide a response to comments 1 to 5 since they are related. We believe adding a summary table for all the samples is a very good idea and will clarify the paper. We added the table below in section results (p 9) :

| Analysis | Total analyzed | Regions | Source | Reference | Comments |
|---|---|---|---|---|---|
| Dust mass | 113 | 87 locations Pyr., French Alps, Swizterland | Citizens (95) Res. Labs (19) | circles on Fig. 4 Sec. 2.3, Sec. 3.3.1 | 152 samples collected 138 of the first dust event 27 with problems |
| Size distribution | 95 | 87 locations Pyr., French Alps, Swizterland | Citizens (79) Res. Labs (16) | circles on Fig. 4 Sec. 2.3, Sec. 3.3.2 | taken among the 113 samples for mass |
| Elemental composition | 70 | 70 locations Pyr., French Alps, Swizterland | Citizens (54) Res. Labs (16) | circles on Fig. 4 Sec. 2.4, Sec. 3.4 | taken among the 113 samples for mass |
| Additional samples | | | | | |
| Radionuclides | 3 | Pyr., French Alps. | Res. Labs (2) Citizens (1) | Triangles on Fig. 4 Sec. 2.6, 3.6 | need higher mass than the common samples |
| Optical Properties | 2 | Pyr., French Alps | Res. Labs (2) | Sec. 2.5, Sec. 3.5 | need higher mass than the common samples |

**Table 1.** Overview of all the dust samples analyzed in this study

The table summarized the number of samples and locations used for each analysis. Out of the 152 samples collected only 138 contains the first dust event only and out of these 138, corresponding to 87 different locations, only 113 of the 136 samples were analyzed as explained p12 since 27 had issues (9 labeling issues, 4 leaking, 4 mass outliers and 8 with missing information). Most of the samples were collected by citizens, except the ones from Switzerland that were collected by the network of professional snow observers. We believe that there is no systematic difference between the ones collected by citizens and the ones collected by research labs since the sampling protocol was new to both the public and the professional practitioners. However, since the swiss samples were collected in well sealed plastic boxes, none of them were leaking.

We added all this information in the text as well as the reason why some analysis rely on additional samples (need for higher mass of dust, as explained in the text and in the new table) and why some analyses were done only for a part of the samples. Here is the list of the modifications in the new version of the manuscript :

Page 1 line 5 now reads : “This somewhat improvised campaign triggered wide interest since 152 samples were collected in the snow in the Pyrenees, the French Alps and the Swiss Alps in less than four weeks. **Among the 152 samples, 113 in total could be analyzed, corresponding to 70 different locations. The** analysis of the samples showed a large variability in the dust properties and amount.”

Page 9 line 176 : “**Table 1 indicates the number of samples used for each type of analysis.** ”

Page 9 line 189 : “A total of 114 sample-derived masses were obtained over the Alps and the Pyrenees. The missing values (approximately 16\%) were due to leaks, which made the samples unusable. **These 113 samples correspond to 70 different locations and were mostly sampled by citizens except for the swiss samples (Tab. 1). We believe that there is no systematic difference between the samples collected by citizens and the samples collected by research labs since the measurement protocol was new to both the public and the professional practitioners.**”

Page 12 line 206 : ‘ **Most of the samples analysed for mass could be analysed for size distribution (Tab. 1).** A total of 95 samples …..”

Page 12 line 220 : ‘ **From the 113 samples analyzed for mass, 70 were analysed for the elemental composition since only the filters with a smooth surface could be used for this analysis (Tab. 1)**. ”

Page 20 line 334 : “We present data from **113** dust samples …”

6. which samples were dry deposition and which were wet deposited? What effect that might have on the results?

Unfortunately we cannot provide a sound answer to these questions due to a lack of direct observations.

7. In addition, for the future usage of these valuable data by others, identification of the sample locations (coordinates or numbering the samples in the map) should be used. Unfortunately, I could not find this information from the current version of this manuscript nor in the dataset related to the manuscript (ref. p. 27, Data availability, “Data presented in this study are available at ttps://doi.org/10.5281/zenodo.7464063 (Dumont et al., 2022)”. If that information exists there, it should be presented more clearly in the manuscript. For example, from an individual section, it appears that only 2 samples were used for optical properties, and elsewhere, e.g., it is said that 136 samples out of 152 samples (152 is mentioned in the Abstract) were used for some of the analysis. This all would need to be clarified for the reader to easily see what analysis was made form which samples and where the sample locations are. Figure 6 is a great illustration of the particle mass, but there also is an open question if these numbers where produced using 3 closeby locations (as stated in p.3, line 3).

The sample locations (coordinates) and the corresponding analysis for each individual samples (mass, size, elemental composition) was provided in the dataset (https://doi.org/10.5281/zenodo.7464063), in the file named : DATA_Location_Mass_Size_ElementalComposition.csv . To clarify that, we extended the description of the dataset, and the Data availability statement now reads:

“Data presented in this study are available at https://doi.org/10.5281/zenodo.7969515 \ citep{dumont_2022_data}. **The dataset contains the mass and size data for each sample, as well as the exact coordinates for each sample. It also contains the elemental composition of the samples, and the calibration function of XRF. A data file is also provided for the optical properties (MEE and extinction) and for the radionuclides analysis.**”

Hence, a careful clarification of these valuable data is needed to ensure the best possible usability of these data by others.

We hope that the clarification provided above would increase the usability of the data by others.

Specific comments:

We reply to each specific comment below. We will incorporate all these clarifications into the revised manuscript.

Page 2 line 44-45. It could help the reader, if you clarify here that your data set presents results for the first Saharan dust event of 4-8 Feb 2021.

Page 2 line 44-45 has been modified as follows : "four weeks. The samples **resulting from the first deposition event** were analyzed …."

Page 3, 2.1 and Figure 1. The sample collection described in 2.1 is not the same as shown in Fig. 1. In page 3, you say "We asked participants to collect a snow sample of 10 x 10 cm2 area (or any known area)" and in Figure 1 you show a cylinder. A small correction of adding "appr. 10 x 10 cm2" would already improve this. Are there other clarifications on the sampling and sample area that you could provide? For example, if you had different sampling instructions to public and to researchers, it should be mentioned, too. Furthermore, did you use the sampling area information to calculate the dust deposition as mass per area, e.g. as g/m$^2$? It could be mentioned what was critical in citizen sampling for the quality of the samples for this purpose. Did you ensure the quality of the area estimate from citizens, and how did you do that? What was the container the citizens used and how did they get the dust into that container?

We recommended to collect an area of approximately 10 x 10 cm$^2$ as a general guideline. but participants used different types of containers to collect the samples (box, jar). For every sample we have noted the actual sampling area, as measured by us or as reported by the participant, when the shipping container was not the same as the sampling one. The instructions were the same to public and researchers. Yes, the sampling area information was used to calculate the dust deposition as per area. For the last question, two cases exist: the first one described above where the snow was directly sampled with the container as shown on Figure 1 and the second case, where an area of 10*10 cm$^2$ was sampled and then put in a container using a little plat.

This additional information was added in the text page 9 in section 3.1 (citizen campaign) that now reads :

"In total, in less than four weeks, 152 samples were collected: 84 in the French Alps, 9 in the Jura Mountains (France), 1 in the Massif Central (France), 26 in the French and Spanish Pyrenees and 32 in the Swiss Alps (Fig. \ref{location}). **Most of the samples were stored in the same container that was used for sampling as shown Fig. \ref{fig:protocol}, so that we could verify the sampling area ourselves. Some samples were provided in a container (e.g. a zipper bag) that was not originally used for sampling. In this case, we relied on the information provided by the person who collected the sample to determine the sampling area (e.g. the diameter of the jar).**"

Page 3, line3. You say: "average of the three closest samples for each site (see Sect. 2.3)." Please specify what was the distance of these three closest samples? How representative this makes the combined sample dust mass deposition estimate per one location? How many locations were combined for the purpose? The whole sample set or some samples, how many samples/location and if so, how did you select these samples/locations? Were some masses determined per sample, too?

We selected the three samples closest to the MOCAGE sites and averaged their measured mass. The distance for the 3 samples ranges between 6 to 10 km for the Queyras location, 0.5 to 4 km for the Chartreuse location, and between 67 to 74 km for the Pic du Midi location.
MOCAGE simulations are performed over a grid size of 10 km (Josse et al., 2004). Therefore, the location chosen is representative of a 100 km2 area. For the Queyras and

Chartreuse locations, the 3 samples chosen are located within this 10 km grid size. For the Pic du Midi, the 3 samples are located further and results might be taken with more caution. Otherwise, to ensure the representativity of the grid size, we ensured that samples covered different aspects (i.e. from 126, 258, and 274°N for the Queyras location, 9, 222, and 310°N for the Chartreuse location, and 5, 125, and 180°N for the Pic du Midi location; aspects computed based on a 250m DEM resolution)
Finally, the mass of the 3 samples chosen is 5.2, 4.7, and 6.6 g $m^{-2}$ for the Queyras, 2.1 2.52, and 2.34 g $m^{-2}$ for the Chartreuse and 11.6, 6.2 and 24.4 g $m^{-2}$ for the Pic du Midi. For both Queyras and Chartreuse locations, the 3 samples are close to each other in terms of mass while for the Pic du Midi the values of the 3 samples are more diverse, showing here, again that the MOCAGE evaluation for this point should be taken with more caution.

These informations have been precised in the revised manuscript as follow:
*(In section Meteorological conditions):*
"**We further evaluated the accuracy of the total dust mass deposition from MOCAGE by comparison with the averaged mass measured of the three closest samples for each site. For the Chartreuse and Queyras locations the three samples are within the grid size resolution of MOCAGE (i.e. 10 km). For the Pyrenees, samples are located 60 to 70 km away and results might be taken with more caution. The three samples taken for each location covered different slope aspects. The three samples close to Pic du Midi also exhibit a larger spread in mass values that the samples for the two other locations.**"

Page 3, line 70. You say "poor counting statistics above a certain size (example shown in Fig. 2).". It would be helpful if you could say instead "a certain size" the same giving a value, then refer to Fig 2 for more details.

The section was clarified and we now explicitly refer to figure S3, together with figure 2. The section now reads:

"Dust size distributions were measured **with a Coulter counter (multisizer IIe) following protocols adapted from Delmonte et al. (2004). The main adaptation concerns the measured size range, which was set to 4 – 120~$\mu$m by choosing a 200~$\mu$m measuring aperture. However, above $\tilde$40-60 $\mu$m, depending on the sample's concentration, the size distributions measured with the Coulter counter suffer from poor counting statistics, as shown in Figure ~\ref{cut_diameter}. We thus determined for each sample a so-called cutoff diameter, as the lowest diameter where no particle was detected in any of the three individual replicate measurements (See Fig.~\ref{cut_diameter} for an example). This cutoff diameter (see Fig. ~\ref{small_and_big} for values distribution) separates a lower part of the distribution, well measured (typically better than 10\% uncertainty), and a tail, which is highly uncertain although it may represent a significant portion of the measured distribution (Fig. ~\ref{cut_diameter}).**"

Page 3, line 70-71. The same as above: could you give a value for what is lower part of the distribution, when you say: "We thus separated the distribution in a lower part, usually well measured (typically better than 10% uncertainty), and the tail of the distribution, which is highly…"

Please see response to previous comment and modifications listed there.

Page 4. Figure 1. It is a bit confusing for me that the French text font is so big, it is almost 1/3 of the image. Could you make the same figure with English text (or reduce the French

text font size)? The figure could then be “Sampling protocol…” instead “Original sampling protocol”.

This is the original picture that was posted in the social media. We chose a large font size to facilitate the reading of the guidelines on a smartphone. We will change the figure caption to “**Original picture of the sampling protocol as** posted on Twitter (in French).” We have also reduced the figure size to avoid this disagreement.

Page 5, line 89. You say: “For the analysis of optical properties, two specific samples were taken to ensure that a sufficient dust mass was available.”. It could be helpful to mention the locations of these samples here.

The locations of the two samples were indicated in the following sentences : “For the analysis of optical properties, two specific samples were taken to ensure that a sufficient dust mass was available. We took two additional samples at a similar elevation of 2100 m near Pic du Midi de Bigorre in the Pyrenees and Col du Lautaret in the Alps.”

Page 6, line 120. You say “Some of the filters were analysed”. Which filters, how many, why these were selected, what were the sample locations?

Since the radionuclides analysis typically requires several g of dust, the analysis was tried only on the filters with the higher mass of dust (ca. 0.1-0.3 g). The results are given only for the most loader filter (page 6, line 124) since they are the most robust. The sentence was modified as follows :

**“The filters with the highest dust load (ca. 0.1-0.3 g)** were analysed using ultralow background Germanium HyperPure gamma spectrometry detectors installed in the underground facilities…”

p. 7 lines 130- 131. “in spring 2021”, what were the dates? So this was much later then? Is it possible that some other dust events (Asian dust?) could have transported dust elsewhere, too?

The samples were collected at the same period (early March 2021) and consist of dust samples from the two same dust episodes that took place in Feb. 2021. This information was added in the text :

“To obtain larger quantities of radionuclide fallout, we performed two specific samplings in regions with significant deposition levels in **early March 2021** (i.e., in addition to the samples from the citizen science campaign, **Tab. 1**). **The samples consist of dust from the two dust episodes that took place in February 2021.**”

p. 9, section 3.1. Here it is finally revealed that 136 samples were used for the analysis. Could you confirm here if these were from 136 different locations?

This has been clarified in response to the first general comment. Please see our answer and the proposed modifications in the text in the response to general comments 1-5 and the new Table 1.

p.9 Section 3.3.1. and Fig 6. Now in p. 9 it is revealed that 114 sample derived masses were obtained. But now is there a contradiction with what you say in p.3 line3 “average of the three closest samples for each site” So was the mass determined separately for 114 locations or not?

This has been clarified in response to the first general comment. Please see our answer and the proposed modifications in the text in the response to general comments 1-5 and the new Table 1.

p.3 line3 “average of the three closest samples for each site” : this is only for the comparison with the atmospheric model at 3 sites (shown by the blue stars on Fig. 4). Yes the mass was determined separately for the 113 samples (70 locations). We hope it is clearer now.

p.12 line 206 “A total of 95 samples”. Does this refer to 95 different locations?

This has been clarified in response to the first general comment. Please see our answer and the proposed modifications in the text in the response to general comments 1-5 and the new Table 1.

p.12 line 220 “105 samples were analyzed for the elemental composition”. Are these the same as for sample size distribution analysis and some additional ones (where from, why)?

This has been clarified in response to the first general comment. Please see our answer and the proposed modifications in the text in the response to general comments 1-5 and the new Table 1.

p.20 line 339. Please correct an error here when you say: “To our knowledge, this is the first time that such a large number of dust samples from a single dust event were collected and analysed with multiple analytical tools.”. Please correct to say, e.g., “To our knowledge, this is the first time that such a large number of dust samples from a single dust event **in the Pyrenees and the European Alps** were collected and analysed with multiple analytical tools. In another study for February 2021 (Meinander et al. 2022), Saharan dust citizen science samples from over 500 locations in Finland have been collected and analysed with multiple tools." Reference: Meinander, O., Alvarez Piedehierro, A., Kouznetsov, R., Rontu, L., Welti, A., Kaakinen, A., Heikkinen, E., and Laaksonen, A.: Saharan dust transported and deposited in Finland on 23 February 2021, EGU General Assembly 2022, Vienna, Austria, 23–27 May 2022, EGU22-4818, https://doi.org/10.5194/egusphere-egu22-4818, 2022.

The Finnish campaign was done on the second of the two dust events in February 2021 (the only one that reached Scandinavia). The Finnish campaign was thus posterior to the French one and if we remember correctly the discussion with our Finnish colleagues, it was inspired by the French campaign. However, we believe it’s relevant to add the reference. Page 20 line 339 now reads :

“To our knowledge, this is the first time that such a large number of dust samples from a single dust event **in the Pyrenees and the European Alps** were collected and analysed with multiple analytical tools. **A second citizen campaign was launched for the second of the two dust events late February 2021 in Finland (Meinander et al., 2022).**”