

Nat. Hazards Earth Syst. Sci. Discuss., author comment AC2
<https://doi.org/10.5194/nhess-2021-264-AC2>, 2021
© Author(s) 2021. This work is distributed under
the Creative Commons Attribution 4.0 License.

Reply on RC2

Manuel Titos et al.

Author comment on "Long-term hazard assessment of explosive eruptions at Jan Mayen (Norway) and implications for air traffic in the North Atlantic" by Manuel Titos et al., Nat. Hazards Earth Syst. Sci. Discuss., <https://doi.org/10.5194/nhess-2021-264-AC2>, 2021

We would like to thank Reviewer#2 for the careful reading of this manuscript and the thoughtful comments that have improved its quality. In the new version, the manuscript has been widely modified. Besides the modifications suggested by the reviewer, some others have been carried out in order to speed up the reading and the understanding of the manuscript. Amongst them, authors would like to stress: 1) the usage of Flight Level (FL) instead of feet for the specific height at which the model results are calculated and shown. Thus, the references to 5000 and 25000 feet along the text have been changed to FL050 and FL250, 2) Figures 9 -10, 11-12, as well as D1-D2 in the Appendix D have been merged into a single figure (3 in total), in order to facilitate the comparison of results between eruptive classes, 3) considering that the results for the different airports in U.K (London) do not show significant differences in the expected impact, the references to London Luton airport have been omitted along the manuscript (also figures), keeping only those to London Heathrow since it is the airport with the highest number of passengers in the country.

The answers to the questions raised by the reviewer have been carried out taking into account these modifications. Furthermore, below are those comments that need more clarification.

Summary

This paper deals with an unexpected eruption scenario, i.e. the resumption of volcanic (explosive) activity at Jan Mayen Island in the North Atlantic, a location unknown to most but whose eruptive historical record would suggest focusing on in the future.

The topic is certainly interesting and the possibility that an eruption from this so distant island could affect busy flight airspaces is largely proved. I think that the paper is an important contribution to the hazard assessment to air traffic in North Europe. The manuscript shows that much work has been done and that a lot of original data are presented.

The topic of the paper is addressed clearly and the introduction section gives the context to the research well enough and the motivation for doing the work. I have also suggested to add some references in some points. The analytical methods are very rigorous with regard to the probabilistic hazard assessment approach, allowing to compare in detail the

different tephra dispersal simulations. The same thing unfortunately cannot be said for the description of the eruption scenarios, which is crucial for the right comprehension of the obtained results. This made it difficult for me to review this article due to several ambiguities in the selection of eruption categories. Moreover, several imprecisions are reported throughout the paper (both in the text and in the figures) that in my opinion need correcting.

However, my main criticism concerns the assumption of the representivity of a few eruptions to infer on the features of the studied explosive eruption classes. I think that the possible limits of such a characterization could be better discussed (much more and earlier than in the few lines in the conclusion section), reporting for example also the potential and limits of considering only a few eruptions, to validate and make the study more "robust". See my comments in detail.

Finally, I suggest having the paper read by a mother tongue reader because although English is not my first language, I found several inaccuracies.

Overall, my view is that the paper may be deemed appropriate for possible publication in NHESS after reviewing the main critical issues. In the following, I set out some of my considerations and possible suggestions to improve the paper.

General comments

The paper needs to improve some descriptions to avoid misunderstandings and also to be more readable.

C1: The main problem is the first line of section 3.1 Eruption scenarios: "The possible eruptive scenarios at JM are based on 5 historical and prehistorical known eruptions". The Cumbre eruption at La Palma is an excellent case of comparison with past eruptions which now doesn't always seem coincident for the style, while, for example, we have to wait until the end of the eruption for some ESP such as the duration comparison. For example, at lines 101-102 you write that "Based on historical occurrence, this scenario can last for about 35-40 hours": if the possible eruptive scenarios are 5, how many small eruptions are there? I think you should discuss these poor statistics much better because few eruptions may not be representative of the whole eruptive story in terms of ESP (plume height, duration, intensity and so on) and forcing/constraining the assessment toward a prevalent eruption type.

We thank the Reviewer#2 for this comment that gives us the opportunity to clarify some key points of our work.

Firstly, according to Gjerl w et al., (2016), Jan Mayen volcano tephrochronology reveals at least 8 eruptive periods over the last 600 years, 5 of them concentrated in the last 200 years, however, its Holocene eruptive history is basically unknown. It comprises only a very few distal sediment cores as well as lava flows and tephra deposits from eruptions on the ice-free parts of the Beerenberg volcano. Then, due to the lack of a complete geological record (composed of chronological and statistical data) and considering both the natural characteristics of the volcanic system itself (underlying geological framework, presence of ice / water, geothermal activity, vents location, etc.) as well as the existing historical reconstruction works (Larsen et al., 2017; Gjerl w et al., 2016), we described the conditional probability of different eruptive magnitudes based on fixed mass ranges and historical relative frequency using a Weibull Probability Density Function (Figure 2).

We fully agree with the reviewer that the recent eruption of Cumbre Vieja, La

Palma, it is an excellent case of comparison with past eruptions which now doesn't always seem coincident for the style. However, considering other eruptive scenarios would also bias the results. In this sense, as we have said before, we agreed to categorize the different eruptive types based on the volume of tephra emitted in DRE (Dense Rock Equivalent) based on historical studies. This information is detailed in both Section 2 and 3.1.

C2: You often talk about estimation of "different flight levels" but actually, in the paper you always show only 2 levels (5000 and 25000 feet). Maybe can you explain this apparent incongruity once and for all? Can you explain on what basis you select the 2 flight levels of 5000 and 25000 feet? You should also indicate which are the most important flight levels to consider at that latitude and both close to and distant from the airports.

All references to "at different flight levels" along the manuscript have been changed to "at FL050 and FL250". Regarding the choice of these two specific flight levels, they correspond to cruise altitude and maximum risk actions altitudes like takeoff or landing. In this sense, the following description has been included in the manuscript, section 4 lines 212-215:

"Although our method allows analyzing any desired FL, in this work, only FL050 and FL250 will be analyzed. Such FLs were motivated considering cruise (FL250) and maximum risk actions altitudes like takeoff or landing (FL050). Finally, three selected ash concentration thresholds (0.2, 2, and 4 mg/m³) were selected based on the impacts of volcanic ash on jet engines summarized in Figure 7 and the considerations included in the Volcanic Ash Contingency Plan published by the International Civil Aviation Organization (ICAO and VACP, 2016)."

C3: Medium and large are terms mainly used for category, class, eruption, size and so on. They are sometimes in capital letters, sometimes not. It would be better to make them uniform, or use them always in capitals, for example before "category". When possible, avoid different terminology, such as medium/large size eruption class, Medium size eruptive class, Medium ERUPTIVE class ERUPTIONS (?).

The correction has been addressed. We made these terms uniform along the manuscript.

C4: The moderate eruptions at line 103 seem to correspond to the future "Medium" class. You should describe these two terms (Medium and Large) better in a table to give more clarity on the terms about medium, moderate, large (eruption or magnitude size eruption, or class or category) and to better correlate the Table 1 with the two study cases (Medium and Large), or alternatively improve Table 1.

It is not clear even if the eruption scenario is coincident with the different eruptive magnitudes, namely if Table 1 correlates with Figure 2, because if so the terminology should be made uniform (e.g. small eruption with scenario effusive category and Moderate with Medium).

The term Medium has been included and correlated in Table 1 and Section 3.1.

C5: Also, the geographic framework is often not too clear and the reader (especially if not familiar with this area of the world) needs to consult internet to find some simple but lacking information crucial to follow properly the obtained results and the related discussion. For example, can you add a table with the airport locations, azimuth and especially distance from Jan Mayen?

In the new version of the manuscript a new table with the airport locations, azimuth and especially distance from Jan Mayen (complementing the visualization already done in Figure 1 where the airports considered in this work are plotted using black circles) has been added.

C6: The height of the volcano is important to better evaluate the scenario of the volcanic plumes (3-11 km or more than 10 km) and compare them with the flight levels. Are these heights all above sea level?

For the sake of clarity we have added a reference explaining that all these heights are above ground level (a.g.l) along the manuscript.

C7: At 5000 feet, the output maps in the different type of presented data seem to assign more hazard to the Medium category than to the Large one, while the opposite pattern (and much more clearly) occurs at 25000 feet. Can you explain the first, apparent contrasting result (the larger the eruption, the lower the hazard)? Can it be justified by the modelling used for the pulsating eruptions? If so, do you not think that the proposed methodology could have altered the magnitude (in terms of tephra emission and dispersal) of the Medium category?

As Section 3.1 and Table 1 explain, both eruption classes (Medium and Large) are mainly characterized by duration, plume height and total volume emitted. Then, considering that Medium eruption class generates volcanic plumes between 3 and 11 km above ground level (a.g.l) lasting between 4 and 40 days, both concentration and persistence probability maps should show greater exceedance probabilities at lower heights than Large eruption class. As the reviewer has pointed out, this can be easily seen in Figures 9, and 11-12.

From Figure 9, we can see that although at FL050 the area affected is approximately the same in both eruptive sizes, the probability of reaching ash concentrations at the given thresholds is greater in medium size eruptions. This is mainly due to the sustained duration of the pulses injecting ash at this height and nearby regions for long periods of time. The same conclusions can be obtained from Figures 11-12. Given the sustained ash emission into the atmosphere in Medium eruptive size, both the probability and the area affected increase when measuring persistence for concentrations of 2 mg/m³.

Regarding FL250, from Figure D1 it can be seen that the probability of reaching ash concentrations at the given thresholds increases in Large eruption, as well as the area affected and the persistence. Unlike Large eruptions where the plume height is obtained from the Mastin et al. (2009) formula from mass flow rate, in Medium size eruptions the height plumes are sampled from a triangular distribution centered around 6 km a.g.l. Therefore, many of the proposed scenarios do not inject ashes at FL250, affecting the final result.

Finally, answering the question if the proposed methodology could have altered the modelled impact of the Medium class, we want to highlight that this class includes different eruptive styles, so impact couldn't result simply in the rescaling of the Small and Large classes on the basis of the magnitude only. The choice of the classes and eruptive styles is based on previously published works supported by field analysis is explained in Section 2.

C8: Concerning some figures and partially the text, when you write "probability of reaching or exceeding ash concentration above at some time during the eruption up to 48 hours after its end", do you mean "at some time from the onset of the eruption up to 48 hours after its end"?

For the sake of clarity this sentence has been modified along with the manuscript. In the new version, we use "at some time from the onset of the eruption up to 48 hours after its end"

C9: Finally, Figures should be better presented so that they can be self-readable.

In the new version of the manuscript, figure captions are brief, but self-explicative.

In the following, my detailed comments and technical corrections on the text and figures.

Specific comments and technical corrections

Introduction

C10: Lines 22-23 - The eruption at Grímsvötn (Iceland, 2011) does not seem correlated to any of the following references. If so, please add at least one reference about this eruption. "economic, 2010" is not correct.

Correction performed

C11: Line 23 – Replace "remainder" with "reminder".

Correction performed

C12: Line 25 – I am not sure that "covid-19" is the right way to write this pandemic; probably it is better "COVID-19" in capital letters or "Covid-19".

Correction performed

C13: Line 27 – Add a space after "flights" and remove a space after "(".

Correction performed

C14: Line 32 – According to the standard guidelines, "(Gjerløw et al., 2016)" becomes "Gjerløw et al. (2016)". Please check this point carefully because eventually there are many other similar mistakes, e.g., line 44 "(Sandri et al., 2006)", line 62 "(Kandilarov et al., 2012)", and also in the caption of Figure 1 where some parentheses are not correctly inserted.

Correction performed.

C15: Lines 49-50 – "A novel strategy has been developed to treat and describe the styles of pulsating eruptions, characterized by a series of discrete short-lived events followed by occasional interruption of the tephra emission.": this is very interesting and also very common although not always properly considered. Can you correlate some real deposits or eruption observations of Jan Mayen to this eruption style?

We thank the reviewer for the interesting comment. We think it should be possible to correlate tephra deposits at Jan Mayen to this eruption style by analyzing volcanic products in the field but we believe that a discussion about this point would go well beyond the scope of this paper. Moreover the mapped deposits in Jan Mayen are pretty poor and this would require a much deeper investigation. However, we have included the reference (Gjerløw et al., 2015) addressing the interpretation of the deposits, field reports and historical sources of the Eggøya explosive eruption (1732) (emplacing approx 0.3–0.4 km³ (VEI 4)

of tephra up to distances of at least 100 km from Jan Mayen and covering a minimum area of around 500 km² within the 2-cm isopach) and presenting Surtseyan eruption with activity shifting between tephra jetting, continuous uprush and more magmatic phases as possible eruption scenario.

C16: Lines 58-59 – Replace “;” with “,” and “volume and address” with “volume, addresses”, and add “s” to “describe”. Alternatively, rewrite better the whole sentence “Section 3..... pulsating eruptions”.

Correction performed

Jan Mayen Volcanism

C17: Lines 66-67 – Insert the reference(s) which shows “at least five eruptive periods”.

Correction performed

C18: Line 70 – Can you give a rough estimation of how many km are these “Distal records”? From tens/hundreds to thousands?

According to the sentence: “Distal records as trachytic tephra found in Ireland (Hunt ,2004) and basaltic tephra found in older sediment-records in the North-Atlantic (Lacasse and Garbe-Schönberg, 2001; Brendryen et al., 2010; Voelker and Haflidason, 2015) or in Greenland ice-cores (Abbott and Davies, 2012) have shown the potential for explosive ash-forming eruptions whose size, frequency, and potential impact are, however, uncertain”, and based on table 2, these distal records correspond to hundred to thousand of km from Jan Mayen.

C19: Line 76 - Can “Beerenberg central volcano” and “Midt- and Sør-Jan volcanic ridge” be located on the map in Figure 1? Due to their importance in the subsection, you should eventually add an inset with a small-scale map showing these important volcanic structures. At the same time, to get a picture of the position of the study area it is necessary to go to Figure 4, while it should be useful to have a geographic outline in the first figure of the paper.

Following other suggestions an improved version of Figure 4 in Section 2 has been included in order to show Beerenberg central volcano and Eggoya crater as well as a general overview of the location of the Jan Mayen island and the study area.

Methodology

C20: Line 97 – This is the first time you present “JM”. It is easy understand what you mean, but you should define it before and afterwards use the acronym when possible.

Correction performed

C21: Line 99 – Write “sub-Plinian” with the lowercase initial according to all the other citations.

Correction performed

C22: Line 100 –You are using eruption magnitude and VEI parameters without defining them somewhere (reference, table, other?). Especially the magnitude is a parameter not well known even among volcanologists and similar.

Correction performed. In the new version of the manuscript, references describing both magnitude and VEI terms have been included.

C23: Line 103 – Probably you should use the term “Surtseyan” with the capital (or not) letter everywhere.

Correction performed

C24: Line 122-123 – You are reporting a sub-Plinian type I eruption... I can imagine that someone defined at least two different types of sub-Plinian eruptions, but you should cite them and eventually define or characterize some features of this type (if necessary also in Table 1).

Line 122 and other lines – You reported wrongly the hyphen between the two values (108.7–109).

Correction performed

C25: Line 129 – Can you add a reference or more discussion about the methodology based on the “representative eruptive scenario”?

Some references addressing such methodology have been included in the new version.

C26: Line 140 – weighting or weighing?

Weighting. This correction have been fixed in the manuscript

C27: Line 143 – In Section 3.1 you have selected the possible eruption scenarios, not categories.

Correction performed

C28: Line 147 – Please, make uniform Section (capital or lowercase initial letter) everywhere throughout the paper.

Correction performed

C29: Line 150-151 –Can you give a short description and/or a reference about the “Akaike Information Criteria”?

2 references have been included.

C30: line 155 – You are talking about “Medium and Large classes”.. but in section 3.1 and Table 1 you define Moderate (“subaerial, sub-glacial and even surtseyan eruptions”) and Large (“expected to be initially subglacial and include moderate to sub-Plinian eruptions”). There is a little bit of confusion, are they classes, categories, or eruption scenarios as maybe provided by Table 1? See general comments.

Possible relative eruption scenarios on JM Island are based on the volume of tephra emitted in DRE. These scenarios can be splitted in Small, Medium, Large and subPlinian/Plinian (<http://icelandicvolcanoes.is/?volcano=BEE>; Gjerløw et al., 2016), however, according to the geological record (extending beyond Holocene), subPlinian/Plinian events are highly unlikely (1%). Because of this, they are not included in table 1. Each of these eruptive scenarios is based on different eruptive dynamics. Thus, for example, small magnitude scenarios are

mostly associated with small lava flows or small scoria cones, while medium ones are characterized by effusive and/or Vulcanian to violent Strombolian or Surtseyan eruptions.

C31: Line 156-157 – What do you mean for “densities in the range of 250 and 350 kg/m³ and diameters between 100 and 250 μm”? Not clear to what you refer.

We mean densities and diameters of the particle aggregates being sampled in these ranges. These particle aggregates are being used to complement the Total Grain Size Distribution of the eruptive scenarios.

C32: Line 158 – Pulsating eruptions: according to Table 1, they belong only to Surtseyan eruptions. Can you remind the reader of this also in this subsection? So that they do not include the Large category but only the (Moderate scenario)/Medium category, right?

Correction performed

C33: Line 169 – Is the column height above the hypothetical vent or above sea level? How high is Jan Mayen island or the area supposed for the possible vent opening?

In this work, column or plume height are considered above ground level (a.g.l). When referring to Medium class, we are supposing Surtseyan eruptions. In the case of Large class, Beerenberg volcano has an altitude of 2277 m. We added the term above ground level (a.g.l) along the manuscript for the sake of clarify.

C34: Line 170 – Mastin et al. is not reported in the reference list.

Correction performed

C35: Lines 180-180 – The wind patterns are overlapping each other at both sites. Which is the resolution of the wind data (i.e. the computational grid)? Is this a similarity real or artificial because the 2 sites result in the same cell?

The wind patterns were analyzed using ERA5 dataset. ERA5 dataset provides hourly estimates of a large number of atmospheric, land and oceanic climate variables. The data cover the Earth on a 30km (0.25° x 0.25° resolution) grid and resolve the atmosphere using 137 levels from the surface up to a height of 80 km. Considering that these 2 points are 55 km far away, we can conclude that this similarity is real because the 2 sites are in different cells.

Results

C36: In this section, you have only a subsection (4.1 Hazard maps and uncertainty quantification), so probably you can join the two titles or use only the second one.

Correction performed. Both sections have been merged into one single section titled: “Results: Hazard maps and uncertainty quantification”

C37: Lines 203 and 206 – Add “Island” after “in Jan Mayen”, while if you mean the volcano, change to “at Jan Mayen”.

Correction performed.

C38: Line 211 – How do you choose the selected ash concentration thresholds (0.2, 2, and 4 mg/m³)? By following international standard/guidelines on aviation safety or other considerations? Please specify.

Yes, these 3 thresholds were selected based on the aviation safety considerations included in the Volcanic Ash Contingency Plan published by the International Civil Aviation Organization. The reference of this contingency plan has been also included in the new version of the manuscript (Section 4, line 212)

C39: Lines 224-225 – You don't report that Figure 9 is referred to Large eruptions and Figure 10 to the Medium eruptions. The different flight levels are only 2 (5000 and 25000 feet).

Correction performed. The sentence was modified: " Figures 9 and D1 in the appendix show the probability of reaching or exceeding ash concentration above 0.2 mg/m³, 2 mg/m³, and 4 mg/m³ at FL050 and FL250 at some time from the onset of the eruption up to 48 hours after its end, for Medium and Large eruption classes respectively."

C40: Line 228 - Does "It can..." refer to "predictions" (if so, it should be "They can") or "uncertainty quantification"?

Correction performed. For the sake of clarity "It can..." was modified by "Such UQ..."

Discussion

C41: Line 255 –At least in the first map at small scale (Figure 4), please write down the name of some places/countries (Jan Mayen, Iceland, Faroe Island, London, airports etc.).

Correction performed.

C42: Line 259 – Replace "ten" with "10".

Correction performed.

C43: Line 260 – The description of the "probability of exceeding the threshold at any airport ..." does not seem to fit with the Large eruptions (approximately 3 days) but also with the Medium eruptions (approximately 10 days). Can you check and eventually describe better?

Correction performed. The sentence was modified: "The probability at any airport is neglectable during the first hours (approx. 10 and 15 hours for Medium and Large classes respectively) and then increases until stabilizing after several days (approx. 7 and 5 days for Medium and Large classes respectively)".

C44: Lines 263-265 – Sorry, I do not understand clearly to which figures you relate the sentences: "We can also highlight that after 48 hours since the beginning of the eruption, only medium eruption class exceeds probabilities above 5% to reach the threshold of 2 mg/m³. No airport shows exceedance probabilities for this critical threshold in ash concentration above 25%." Can you refer clearly?

This sentence corresponds to Figure 13. In fact, the entire paragraph from line 265 to line 275, corresponds to the analysis of Figure 13.

C45: Line 275 – If you had defined 25000 feet in m as done for the 5000 feet level, it is easier for the reader to understand where an eruption plume of 11 km (or more) occurs.

Correction performed. The altitude in km has been defined in section 4, line 218, just when FLs in the results are presented.

C46: Line 284 – Insert “occur” after “when large size eruptions”.

Correction performed.

C47: Lines 285-286 – Why duplicate the same phrase: “For medium-size eruptive class, only polar routes above 25000 feet would be threatened. Then, we can conclude that for medium-size eruption class, only polar routes above 25000 feet would be threatened”? Eventually modify the first one and delete the latter one.

Correction performed

C48: Line 287 – “similar” or “similarly”?

The sentence was modified: “in a similar way to..”

C49: Line 290 – Add “s” after “represent”.

Correction performed

C50: Lines 300-304 – Not clear 1) if this sentence relates to a specific figure(s), and 2) if you find or not some differences depending on the eruption category; if so, please separate the description because it seems that you are talking about a unique, large/medium eruption category (that is, there is no difference between Large and Medium).

The sentence was modified for the sake of clarify. The information was splitted to show better the difference between Large and Medium eruption. We wrote: “However, when analyzing the spatial pattern for long-term persistence (more than 12 hours), we find some differences depending on the eruption class. For persistence above 12 hours, at FL050, an ash cloud has 2% to 10% probability to reach latitudes as low as 65° N and 62° N for Large and Medium eruption respectively. Such southernmost latitude increases for longer persistence values, meaning that (obviously) only closer to the source we may get long-persisting clouds”

C51: Line 307 – To give more clarity, I would delete the bracket before London and use a dot before, or a comma followed by “while” or similar word.

Correction performed

C52: Lines 310-313 – The statement that “The sustained injection of tephra into the atmosphere related with a series of discrete short-lived events increases the probability of prolonged persistence scenarios” is important as well crucial, because it probably explains also that medium eruptions reach probabilities higher than large ones even in most (or all) of the previous plots. How can you support this? A pulsating event should disperse in the atmosphere much earlier than a continuous injection event of tephra, because single tephra pulses are not able to continuously “feed” a plume in the atmosphere as well and they singularly result dispersed more proximally than a continuous tephra emission.

First, Medium-sized eruptions can reach even greater mass flow rates (MFR) than Large eruptions, as long as the duration and eruption volume conditions provide it. This feature, coupled to the use of a mass fraction of 0.8 for Medium eruptions versus [0.05, 0.1] for Large one allows a greater injection of tephra into the atmosphere for the first case, thus increasing the persistence conditions for given concentration level.

Second, it is important to note that the duration of Medium-size eruptions (4-40 days) are much longer than Large-size ones (1-5 days), which, added to the aforementioned features, directly affects the persistence conditions. In addition, the rest period between pulses is computed considering the difference between the total duration of the pulses and the total duration sampled for the eruptive scenario (Figure 3), finding scenarios where there is no rest period between pulses, and having pulses with different duration and size, also directly affecting to the persistence conditions.

For these reasons and based on the results obtained, we conclude that the sustained injection of tephra into the atmosphere related with a series of discrete short-lived events increases the probability of prolonged persistence scenarios.

We hope now this point is clearer.

Conclusions

C53: Lines 314-315 – I think that you should have discussed the problem for the representivity of your data before describing the results i.e. in the methodology section, and discussing them there.

Correction performed. The problem of data representivity has been mentioned in the methodology section (lines 97-98) and discussion section (lines 261-264)

C54: Line 325 – Specify which are the low flight levels for better clarity. See also general comments.

Correction performed.

Appendixes

C55: Line 336 – Write Fall3d in capital letters.

Correction performed.

C56: Line 339 and 340 – large and medium are categories or classes?

Line 340 – “Since medium eruptive classes”: whatever you decide to use, I think medium can be related to a single “class” (or “category”).

We decided to use class or classes along the manuscript for the sake of clarity.

C57: Line 360 – The steps start in the section without describing what you are talking about. Please insert a short phrase preceding the workflow.

Correction performed.

C58: Line 366 – Add a “kg/s”. The upper size of the Large class is lower than the one for the Medium class... is that an error? Maybe 1.39 is elevated to the 105 and not 106? Should they be consistent with those in table B1 or not?

Correction performed. Regarding the limits of the mass flow rate ranges in both classes, the values are correct. They were obtained in accordance with the data proposed in this work. Large eruptions may have a lower mass flow rate than Medium size eruptions mainly due to the mass fraction of tephra in the

volcanic plume and the duration of the eruption.

These mass flow rates (MFR) ranges are computed from the total erupted volume (TEV) in the PDF of Figure 3. Thus, for example, the TEV for Medium-size eruptions will vary between 108 and 108.7m³, while for Large ones, this value will vary between 108.7 and 108.9 m³. To obtain the mean MFR range we need to compute the total erupted mass (TEM). This value corresponds to TEM = mass_fraction * density_average * TEV, where the density and mass fraction values are shown in Table B1, in the appendix, for both sizes.

Once the TEM is obtained, MFR is computed as MFR = TEM / eruption_duration. Thus, since the mass fraction in Medium category is much higher than in Large sizes, 0.8 against [0.05, 0.1] respectively, in the case of a medium eruption of short duration (4 days) and large TVE, the upper limit of the MFR may be greater than the upper limit of a Large one.

C59: Line 374 – Add a dot at the end.

Correction performed.

C60: Line 402 – Correct the space in "(X,Y,Z)" between Y and ",".

Correction performed.

C61: **Competing interests:** change "uthor Giovanni Macedonio" to "author Giovanni Macedonio".

Correction performed.

References

C62: Check if "economics, 2010" is correctly reported or if it is better to write "Oxford Economics, 2010".

Correction performed.

C63: Budnitz et al. is not completed in the references list.

Correction performed.

Figure Captions

C64: Figure 1 – You are using the abbreviation or acronym "JMMC" without having written it in full here (in the caption). It is impossible to understand how the Jan Mayen volcano is related to the Jan Mayen island. You should insert at least an inset of the island showing the study area or how the volcano is located with respect to the island and how much the occupied area is approximately. This is also useful for better appreciating the related location of the wind pattern points.

Correction performed. Given the geological completeness of Fig 1, we considered it necessary to describe the geographical framework of the Island. Instead of modifying this image, Figure 4 has been improved and placed in section 2 in order to identify the location of both the island and those important volcanic structures such as Beerenberg and Eggoya (also described in this section). Following the reviewer's suggestions, some geographic references and scale bar to help the reader to follow the manuscript have been included.

C65: Figure 2 – In the caption you write “High” instead of “Large”.

Correction performed.

C66: Figure 7 – I don’t see the “Volcanic ash safety implications regions”, probably I don’t understand the colors or the shape of the boxes? Also, the meaning of the oblique dashed ellipses should be detailed. Can you add in the x-axis also the dashed threshold value of 4 mg/m³?

The figure comes from the Rolls Royce analysis on volcanic ash impact on RR engines and published as such. What they found is that the key factor is the dose, i.e. for how long an aircraft would fly within a specific concentration of ash. These concentrations are those used throughout the paper to analyze the potential impact on aviation. The ellipses represent events that have been documented and for which it is possible to prove the effects on engine functionality when exposed to such doses.

C67: Figure 8 - Change 1,5 to 1.5. At the first citation of this figure, the airports are not still cited.

Correction performed.

C68: Figures 9 and 10 – It seems that the Medium category has lower exceedance probability than the Large one: does it depend on the modeling of the pulsating (i.e. Medium) eruptions? Does it make sense? Can you discuss this result better?

Figures 13 and 14 – Similarly to the previous case, the Large category seem less impacting than the Medium one. Can you explain and describe better if true? The titles should report the term “map” as in the other similar (8-12) Figures (and Figures D3 and D4 as well).

Figures 9, 11 and 12 as well as their analysis have been addressed above in this text. Given the sustained character of the ash injection into the atmosphere in Medium eruptive sizes, both the probability and the area affected increase when measuring persistence for concentrations of 2 mg/m³. As a result, we conclude that eruption source parameters associated with Medium class and pulsating dynamics have an important impact on the results obtained.

C69: In the title of the Figures where it occurs, use always the same format for mg/m³ – mg m⁻³.

Correction performed.

C70: In the Figure captions where they occur, it should be reported that the isolines of the maps are the expected arrival times in hours or probability percentages.

Correction performed.

C71: In the captions of all the figures where it appears “(Large)” and “(Medium)”, adding category “(Large category)” and “(Medium category)” or other.

Correction performed.

C72: In the lowest isolines of some figures, some “spots” are related to small closed isoline.. if true, can you describe them in the text/caption?

We tried to soft the isolines and even reduce the resolution between grid-point. Unfortunately, these spots still appear in the figures. In the new version of the manuscript small closed lines have been removed using only values where the lines are well defined.

C73: Figures 15, 16, 17 – Don't you think that using the same range of values in the y-axis could give an immediate comparison between Large and Medium eruptions?

Correction performed.

C74: Figure 16 – Cut "of" after "above".

Correction performed.

C75: Figures 13, 14, D3 and D4 – You lost "18 hours" in the caption.

Correction performed.

C76: Figure D2 – You lost "feet" after 25000.

Correction performed.

Table Captions

C77: Table 1 – In the row "Eruption type", "volcanian" is erroneously written, moreover you should make it uniform with the other citations in the text with capital (or not) initial letter. Also, you should cancel "eruption" after Surtseyan to make it uniform with the other descriptions.

Correction performed.

C78: Table B1 – There is a "tephra" to correct.

Correction performed.