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## **Comment on nhess-2021-264**

Anonymous Referee #2

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Referee 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-RC2>, 2021

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**Review of the paper "Assessing potential impact of explosive volcanic eruptions from Jan Mayen Island (Norway) on aviation in the North Atlantic" by Titos et al., submitted for possible publication in NHESS.**

### **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.

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/constrain the assessment toward a prevalent eruption type.

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.

Medium and large are terms mainly used for category, class, eruption, size and so on. They are sometimes in capital letter, 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 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).

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?

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?

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?

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"?

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

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

## **Specific comments and technical corrections**

### **Introduction**

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.

Line 23 - Replace "remainder" with "reminder".

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".

Line 27 - Add a space after "flights" and remove a space after "(".

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.

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?

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”.

### **Jan Mayen Volcanism**

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

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

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.

### **Methodology**

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.

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

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.

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

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 ( $10^{8.7} \text{E} \square 10^9$ ).

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

Line 140 – weighting or weighing?

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

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

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

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.

Line 156-157 – What do you mean for “densities in the range of 250 and 350 kg/m<sup>3</sup> and diameters between 100 and 250 μm”? Not clear to what you refer.

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?

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?

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

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?

## **Results**

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.

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

Line 211 – How do you choose the selected ash concentration thresholds (0.2, 2, and 4 mg/m<sup>3</sup>)? By following international standard/guidelines on aviation safety or other considerations? Please specify.

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).

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

## **Discussion**

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.).

Line 259 - Replace "ten" with "10".

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?

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/m<sup>3</sup>. No airport shows exceedance probabilities for this critical threshold in ash concentration above 25%." Can you refer clearly?

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.

Line 284 - Insert "occur" after "when large size eruptions".

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.

Line 287 - "similar" or "similarly"?



Line 290 – Add “s” after “represent”.

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).

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.

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.

## **Conclusions**

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.

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

## **Appendixes**

Line 336 – Write Fall3d in capital letters.

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”).

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

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  $10^5$  and not  $10^6$ ? Should they be consistent with those in table B1 or not?

Line 374 – Add a dot at the end.

Line 402 – Correct the space in “(X,Y ,Z)” between Y and “,”.

**Competing interests:** change “uthor Giovanni Macedonio” to “author Giovanni Macedonio”.

## References

Check if “economics, 2010” is correctly reported or if it is better to write “Oxford Economics, 2010”.

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

## Figure Captions

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.

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

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/m<sup>3</sup>?

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

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).

In the title of the Figures where it occurs, use always the same format for mg/m<sup>3</sup> – mg m<sup>-3</sup>.

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.

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

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?

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?

Figure 16 – Cut "of" after "above".

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

Figure D2 – You lost "feet" after 25000.

### **Table Captions**

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.

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