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## **Comment on nhess-2021-97**

Anonymous Referee #2

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Referee comment on "Modelling the volcanic ash plume from Eyjafjallajökull eruption (May 2010) over Europe: evaluation of the benefit of source term improvements and of the assimilation of aerosol measurements" by Matthieu Plu et al., Nat. Hazards Earth Syst. Sci. Discuss., <https://doi.org/10.5194/nhess-2021-97-RC2>, 2021

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## **Review of "Modelling the volcanic ash plume from Eyjafjallajökull eruption (May 2010) over Europe: evaluation of the benefit of source term improvements and of the assimilation of aerosol measurements"**

Matthieu Plu, Guillaume Bigeard, Bojan Sičković, Emanuele Emili, Luca Bugliaro, Laaziz El Amraoui, Jonathan Guth, Beatrice Josse, Lucia Mona, and Dennis Piontek

### **General comments**

This paper outlines 3 strands of work related to developments in the system used to produce volcanic ash simulations for the Toulouse Volcanic Ash Advisory Centre, focussed on the case study of the 2010 Eyjafjallajökull eruption:

- A comparison of a simulation using parameterised ash source term with a simulation using a resolved source term by coupling MOCAGE with FPLUME.
- A comparison of simulations setup as in 1. but with additional assimilation of MODIS aerosol optical depth.
- MOCAGE simulations of the case study with continuous assimilation of ground based lidar profiles.

Equal space seems to be given to each strand although it seems that the assimilation of ground based lidar at two locations has the most unexpectedly large impact on this case study. As with all research/developments related to volcanic ash, there are only a few case studies to consider. It is unclear whether the authors intend to apply the approaches presented here to eruptions in different geographical locations or to create "synthetic" eruptions to study.

It is generally well written, although in places sentences are very long and should be revised for clarity. Maybe the manuscript would benefit from being read by a native English speaker?

All figures should have panel labels as per the submission instructions. This makes referring to figures in the text and writing concise captions much easier.

### **Specific comments**

Introduction:

L1-24 More information could be added about what is issued by the VAACs (e.g. flight levels). What is the impact of issuing concentrations on aviation operations? What was the motivation of moving to a concentration approach? Do other VAACs issue quantitative information (I wasn't aware they did)?

L25 You mention shortcomings of the models used to produce the ash dispersion forecasts, however you do not include the impact of driving meteorology (and potential uncertainty) on the output. The driving meteorology also impacts on the plume model that is used to determine the resolved source term and source inversion.

Case study:

Section 2.1 is rather brief and focusses mainly on listing the observations that are available rather than features of the case study. The observations then seem to be repeated in section 2.3.

L65 what ash properties are available from SEVIRI?

L86 What is the difference between 3D-VAR and 3D-FGAT? Which one is used in this study?

L96 I am unclear what an observation operator is. Can you define it?

L109 'rather good' is a subjective statement. Can you support this statement with some quantitative comparison?

I am not an expert in aerosol optical depth retrievals or data assimilation methods – When you assimilate AOD is this done at a specific height or does it somehow effect the whole column?

Figure 1 – it is not clear what is shown by the shading in the plot on the left. Is it the fraction of time in your simulations that ash is present in that location?

Representation of the emission and of the plume

L142 There are many more studies that are related to this issue e.g. Kristiansen et al. 2012, Harvey et al. 2020, Prata et al. 2021

L147 I am unsure what is meant here by 'regular'

L174 Is this value of 30% analogous to the distal fine ash fraction used by the London VAAC? This value seems quite high if this is the case.

L182 Is this the uniform distribution of ash in the parameterised case by design?

Figure 2 What is meant by the yellow shading in the bottom panel below the green line? Is it ash at the vent?

L187 The authors state that the 'plume has a realistic shape which goes in the right direction' but they don't say what evidence they use to come to this conclusion. Is it compared to the VACOS information?

Figure 3

- Qualitatively, the ash distributions in both simulations are quite similar and are both a reasonable match to the VACOS retrieved information. What is the additional cost of running with FPLUME?
- Along the plume axis, the high ash column loadings that are simulated are not reflected in the VACOS retrievals. Is there an upper limit on the value that can be retrieved?
- At 0900 on 16<sup>th</sup> May in the parameterised simulation there is a lot of ash to west of Ireland that isn't present in the FPLUME simulation. Is this ash at low levels?
- At 2000 on 17<sup>th</sup> May there are large parts of the simulated ash plume that are not evident in the VACOS retrievals. Do you have a hypothesis for why this is? Over the Netherlands there is no ash simulated in either simulation. Could this be due to errors in the meteorology?

L195 Remove this sentence

L200 This 12% error seems quite small? Is it from literature?

Figure 4 It is quite difficult to compare Fig 3 and Fig 4 as the differences seem to be very small. One way to make this easier would be to combine Fig 3 and Fig 4 to have all the simulations in one plot. Do the authors think that this small impact is a surprise? Is it just valid for this case study or a more general feature of assimilating this variable?

Figure 5

- What is meant by hits for VACOS? It is just the number of grid cells with ash in the retrievals?
- Are all the hits along the plume axis and misses around the edges?
- It seems all the simulations perform similarly in the hit metric, although there are obvious phases in the period considered.
- The caption mentions grey shading but there is none in the figure.

L224 Unsure what is meant by 'data spots' here

L225 Can the author's say something more quantitative here than 'rather good'?

L235 What is meant for by a 'meaningful' metric?

L244 Is a radius used or is it a square of a specified number of grid boxes as per the original FSS methodology?

Figure 6

- Why did you choose these neighbourhood sizes? 500km is a very large area.
- The differences between each of the simulations is quite small especially one you get to the larger neighbourhood sizes. Do the authors need to show 200km and 500km?
- Highlight the FSS=0.5 level on the plots
- What happens on 19 May? Skill drops off very quickly at all scales.
- Is it possible to show how much information is being assimilated at each time? This might be interesting to know.

The metrics that are used in this study consider the presence of ash above a column loading threshold. This analysis could be extended to determine the performance of the simulations regarding the magnitude of ash column loadings.

## Assimilation of ground-based lidar profiles

L262 I don't think that the signature is 'obvious' if you are not used to looking at this type of data. Also, the maximum at Hamburg really isn't that clear.

Figure 7 The x,y labels and legend are very small in all panels.

L288 A 10% error seems quite small? Is it from literature?

L305 -308 I don't really follow the argument here. If there is a negative bias of non-ash aerosols in MOCAGE then how can the ash concentrations decrease after assimilation on 18 May?

Figures 8 and 9

- Add units to color bar
- Is it possible to indicate the values of the insitu measurements on this Figure?

You only use a few snapshots of the insitu measurements. Is there more that can be used? (E.g. to create a plot that shows the impact of the assimilation more generally – maybe a scatter plot).

## Conclusions

L336 change 'look more realistic' to 'compare more favourably to insitu measurements'

L342 How general do you think that your findings are given that you have only run a small number of simulations for one case study? Do you intend to apply the approaches presented here to eruptions in different geographical locations or to create “synthetic” eruptions to study? Another approach to address some of issues used as motivation in this study is to use ensembles of simulations. Is this something your group has considered?

### **Technical corrections**

L34 eruption not eruptions

L34 I think that there is an – that is not required

L47 purposes rather than purpose

L47 can you expand out the acronym – I am not familiar with this project

L48 replace `,' with and so that it becomes `satellites and ground based....’

L52 `terms’ than `term’

L57 `are’ rather than `is’

L59 This sentence sounds rather odd – maybe change to `includes a discussion of possible future directions for this work’?

L62 change `ashes’ to `ash’

L63 'and fly over continental Europe' doesn't make sense. How about 'and impacted aviation operations over continental Europe'?

L63 This sentence is quite hard to follow too: 'During this period, lidar observations from EARLINET (Pappalardo et al., 2013) and airborne measurements (Schumann et al., 2011) of aerosols were acquired, that detected layers of significant ash concentrations.' Please revise.

L66 add 'the' between 'from' and 'SEVIRI'.

L78 change 'on' to 'over'

L93 replace 'So' with 'This means that'

L117 change 'hours' to 'hour'

L123 change 'has' to 'was'

L126 switch the words 'devoted' and 'database'

L130 remove 'used, to be'

L137 'which mass concentration of volcanic ash has been estimated' sounds odd. Replace with 'which insitu measurements of ash concentration were taken'.

L138 change 'meaningful....' to 'important as they provide observations which can be directly compared to simulated ash concentrations.'

L143 remove the word 'much'

L144 change 'size distribution' to 'particle size distribution'

L145 change 'scarce' to 'limited'

L153 change 'The plume rise models get increasingly sophisticated

' to 'These so-called plume rise models are becoming increasingly sophisticated'

L163 change 'done' to 'performed'

L165 remove 'MOCAGE fields'

L166 change 'issued' to 'taken'

L173 move 'however' to the start of this sentence

L185 change 'instants' to 'times'. This occurs in several places in the manuscript

L213 change 'capacity' to 'analysis'

L216 change 'every' to 'all'

L217 'meteorological cloud'?

L221 change brackets to say '(by approximately double)'

L225 change 'raw' to 'row'

L225 change 'much' to 'many'

L226 replace 'a noticeable, although low' with 'a small'

L247 remove 'besides'

L261 add 'The' before 'Signature'

L262 add in 'May' after '17'

L262-263 This sentence is quite difficult to read – please revise.

L264 change 'develloped' to 'developed'

L270 add 'mixing' after 'vertical'

L294 change 'along' to 'in'

L297 change 'mean' to 'min'?

L312 change 'high' to 'large'

L317 change 'instant' to 'time'

L351 change 'along' to 'in'

L348 change 'reach realistic values of ash concentrations' to 'simulate ash concentrations closer to those values obtained from in-situ observations'

L351 change 'along' to 'in'

