

# ***Interactive comment on “Model-based aviation advice on distal volcanic ash clouds by assimilating aircraft in-situ measurements” by G. Fu et al.***

## **Anonymous Referee #1**

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The subject of the article is to apply EnKF to a distal ash plume problem, using real observations. The authors include a cross validation that demonstrates improved forecasts within a short-range region of interest several hours after the observation time. This is an important work for devising improved aviation advice during volcanic eruptions, one that may inform future assimilation and aircraft campaigns. The paper however suffers from poor grammar (particularly towards the end), some extraneous figures, a thin discussion of model error and forecast improvement, and is also a bit thin in terms of background on the use of aircraft data for EnKF. While we are not requesting any further calculations, discussion of these issues and others as outlined below constitutes minor revisions prior to publication.

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Comments: 2.10: This should be clarified to also acknowledge that some satellites provide very detailed vertical information on plumes (e.g., CALIOP) but are thus spatially sparse.

2.16: Actually, LIDAR gives gives profiles of e.g. aerosol extinction. I think the point the authors are trying to make here is that optical measurements are only an indirect constraint on concentration, which require further modeling and assumptions to translate into concentration estimates.

2.21: “These kinds of observations” is rather vague and potentially overly broad, as there have been many previous studies that have used EnKF to assimilate aircraft observations other than the authors’ previous work. It seems that the background on the use of EnKF with satellite data for air quality forecasting could be expanded.

3.19: Splitting hairs on semantics, but this type of model can be evaluated but never really “validated”, see Oreskes et al., Science, 1994.

3.22: It’s not really clear how aerosols are treated based on this description. What does it mean “average particle size are implemented”? Perhaps a brief summary using customary descriptions of aerosol modeling theory would be helpful (internal or external mixture? fixed size, modal or sectional scheme? etc.).

Section 2.3. Add numbers to equations. I think the apostrophe is being used to represent transpose, which is a bit odd. Superscript T would be much more standard.

Page 4, Line 1; Page 5, Lines 2 and 21: Comment: The 10% measurement uncertainty is repeated in three places. Consider including it only in Section 2.2 or 3.1. At the very least, the first time this is mentioned it should be explicitly stated that it includes an estimate of the model error as well. But later, in section 3.1, perhaps it needs to be explained further how the value of the model transport error is quantified. Usually this takes some work, and properly identifying the horizontal and vertical correlation in the model error is rather critical tuning of a robust EnKF.

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Figures 1b and 1c are unnecessary.

6.16 Bringing the analysis members into agreement in locations where there are no observations is only a sign of consistency, not accuracy. Independent measurements that are not assimilated are the only way to evaluate the forecasts away from the assimilation data.

7.26. This strikes me as a somewhat optimistic conclusion. It seems the evidence presented is that for some locations the forecast is improved, but in other it is not. Given the sparsity of the data used for assimilation, more often it is not. Rather, one might conclude that significantly more observations are required to completely constrain the ash plume across the domain. Extensive aircraft observations, or some combination of detailed aircraft measurements as used here with more broadly available remote sensing data may be useful.

7.10. An approach that combines adjustments to state variables as well as eruption parameters may perform better.

Section 5 and Figure 5. seem a bit flawed, in that they are presented in terms of an “Improvement rate”, but all I see is a difference, without and with assimilation. Either a comparison to actual measurements needs to be included (or if that was actually the case, this needs to be made clear), or these need to be presented quite differently in terms of “impact rate”, rather than “improvement rate”.

6.16: “This tells us that assimilating aircraft measurements effectively reduce the error of the whole distal ash plume, not only at measurement locations.” Comment: There could be some confusion in using the phrase “error of the whole distal ash plume”, because there are not measurements to extract the model residual at all locations. Ensemble “spread” and “variance” are reduced.

9.17: “This is mainly because...” Comment: Do you know that “this is mainly because” or is it “probably because” or “possibly because”? There was no detailed process study

to ascertain all sources of error.

9.18: “Whereas...approach, the model’s deficiencies can be compensated.” Comment: Although they can be compensated, underlying deficiencies remain. The evidence lies in the failure to match cross validation data far away from assimilated measurements.

Corrections:

2.22: “It has been shown...” -> “It was shown...”

2.24: “In this study...” -> “In that study...”

6.20: “due to assimilation” -> “due to the assimilation”

8.18: “Note that areas with ash concentration higher than this value are classified as No Fly Zone (NFZ) ...” Comment: It would be beneficial to mention this fact before Page 6, Line 21, where the concentration is mentioned. Give the context first.

7.2-3: Comment: This sentence needs revision for grammar.

7.24-26: Comment: This sentence needs revision for grammar.

7.30: Please correct to read as follows: “benefit has an effect. Firstly...impact in the downwind...directions is considered.” Page 8, Line 2: “PM10 ... evaluated.” Comment: This sentence is grammatically confusing.

8.9: “we can find” -> “we find” 8.8-13: Comment: There are three sentences in a row about wind direction. Consider revising.

8.14: “measurements have the ability” -> “measurements has the ability” 8.15: “assimilation has impact” -> “assimilation has an impact”

8.17: “direction of distal” -> “direction of the distal”

8.20-23: “This aviation...forbidden area.” Comment: This sentence has a lot of clauses and is confusing. Consider revising.

8.23-25: “In contrast. . .all lower than 3000ug/m<sup>3</sup>.” Comment: This sentence has a lot of clauses and is confusing. Consider revising.

8.31: “changes of the forecast differences between without and with assimilation” Comment: This phrase is very confusing. Consider revising.

8.31: “Since, there are” ->“Since there are”

8.34: “detected” ->“visible” or “noticeable” Comment: “detected” implies a physical observation.

8.34: “Actually we also examined the assimilation impact in the forecast of the next day, the difference was shown to be very small.” Comment: This is a run-on sentence. Either add a conjunction or appropriate punctuation.

9.7-15: Combine these two paragraphs as they both relate to assimilation accuracy

9.24: “This phenomenon is due to the wind direction and the transport process during the continuous assimilation.” Comment: This line is copied verbatim from Page 8, Line 12.

9.26: Please correct to read as follows: “The computer experiment. . .” 9.26-28: “Based on this. . .regional measurement tasks.” Comment: Clean this up a bit to distinguish whether “the aircraft campaign” is a specific plan or any in the future that might be planned.

9.30: “Actually these data also contain uncertainties which have an influence on ash cloud transport.” ->“These data also contain uncertainties that influence ash cloud transport.”

9.30-31: “In future work, . . . into account.” Comment: This sentence needs editing for grammar.

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