Review of "Data Assimilation of Volcanic Aerosols using FALL3D+PDAF"

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General comments:

This paper presents the implementation of the coupling between the FALL-3D dispersion model and the Parallel Data Assimilation Framework to create an ensemble data assimilation method suitable for the assimilation of volcanic ash and sulphur dioxide. The new system is applied to two scenarios:

1. A hypothetical eruption of Etna with synthetic volcanic ash satellite retrievals assimilated
2. The assimilation of sulphur dioxide retrievals following the 2019 eruption of Raikoke

Although the initial implementation of the Local Ensemble Kalman Filter may lead to non-physical solutions, the authors show that a truncated version of this filter leads to a dramatic improvement in the location of ash/SO2 compared to a free running simulation without assimilation.

The paper is generally well written, scientifically sound and interesting. I recommend that is published subject to some minor revisions that I have outlined below.

Specific comments:

The introduction could benefit from the addition of a discussion of inversion modelling that can be used to constrain emission rates and plume height. Also, there is no mention of data insertion which is the simplest form of data assimilation.

The authors motivate the study by citing the impacts of volcanic ash on aviation, but the second set of experiments focus on the assimilation of sulphur dioxide. What was the reason for this? There are satellite retrievals of ash available for this eruption or are they too patchy? Is the fact that the satellite can only "see" the distal ash plume a problem?

I am unsure how Figure 1 enhances the readers understanding of the method – how is the ensemble constructed? Also, does the assimilation of the satellite retrievals take into account their uncertainty?

L150 You refer to something in the appendix – does this part of the appendix to be worked into the main body of the text?

The authors show that the prior pdf associated with the ensemble forecast tends to be skewed possibly leading to the unrealistic posterior estimate as the Gaussian assumption in Kalman filter theory is not satisfied. Can the prior pdf be modified by different parameter sampling strategy or constructing the prior in a different way?

Figure 6 and the comparison of observations, free run and analysis of the Raikoke eruption – are the distributions shown for the free run and analysis the ensemble means? In panel G, is the southern branch of ash missing due to the presence of meteorological cloud?

Figure 9 I really like panel C as you can see the ascent in the cyclone. It would be nice to see a similar plot for the free running ensemble. This might help explain the large differences between the free running simulation and observations seen in Figure 10. Can FALL-3D represent diabatic heating which can also cause ascent?

Assimilation is expensive - can anything be gained/lost from more/less frequent assimilation?

Technical corrections:

L2 and 25 Unsure what is meant here by "infrastructures"

L67 Change "enabled to quantify model uncertainties" to "enabled the quantification of model uncertainties"

L123 Unsure what is meant here by "embarrassingly (or perfectly)". The same on L244.

L136 Is there a reference for the "realistic results" you mention?

L146 Is the local range referred to here the same as L_R? Can you expand on the inflation factor that is referred to?

Table 2 caption last line – change if to of

Table 2 WRF-ARW needs to be defined

Equation 4 What does tr mean? Is n the number of ensemble members?

Table 3 Change grid size to resolution, Domain size to number of grid points, expand TGSD

Figure 3 This seems to be a very complex column height profile. Is it representative of what might be used in operations?

L279 It would be nice to remind the reader that it is a 36-hour forecast being performed here

L280 Why is the flow rate fixed? Could this also be perturbed or determined from the perturbed plume height?

L296 Is there a reference for the "notorious degradation"?

L326 What was the motivation for using a top hat vertical mass distribution? How was the MER and wind components perturbed?

L335 What was the start time of the GFS forecast that was used?

L375 Change "on this metrics" to "in this metric"

L376 Change "metrics" to "metric"

Figure labels seem to switch between capitals and lower case – these should be consistent.