Geoscientific
Model Development
Discussions

Interactive comment on "Variational assimilation of IASI SO$_2$ plume height and total-column retrievals in the 2010 eruption of Eyjafjallajökull using the SILAM v5.3 chemistry transport model" *by* Julius Vira et al.

Anonymous Referee #1

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Review of

Variational assimilation of IASI SO2 plume height and total-column retrievals in the 2010 eruption of Eyjafjallajökull using the SILAM v5.3 chemistry transport model.

by Julius Vira et al.

Overview:

The paper describes the assimilation of SO2 total column and plume height retrievals from IASI with the SILAM 4D-VAR system in order to infer the vertical and temporal

variability of the volcanic emissions.

First, the authors present an observations operator for the assimilation of plume height retrievals, which are available in addition to the retrieved total column of volcanic SO2 obtained from IASI. This is an interesting aspect because the retrieved plume height is a single value representing the centre of the plume whereas observed volcanic SO2 plume often occur in complex profiles and even multiple layers.

Second, the authors present an effective regularisation approach of the 4D-VAR problem, which allows the inversion of the source term without a-priori information. This is also an interesting aspect because most retrieval studies rely on an a-priori estimate of the source term.

The new method is tested with an artificial data set and with a real-world application of the Eyjafjallajökull eruption 1-20 May 2010.

General remarks

The paper addresses two important aspects of the assimilation of IASI SO2 retrievals, which are very valuable to the scientific community. However, the paper misses a convincing evaluation of the results.

The evaluation should be carried much more thoroughly. Independent data should be used or - if these are not available - the improvement of plume forecast in a near-real time scenarios where future observations are not available for the source term estimate could be estimated. The quantitative comparison with ash plume observations is not satisfactory. Likewise a better comparison with emission flux (temporal variability and plume height) with the different estimates form the literature should be included.

In the current version of the manuscript, it remains unclear what the benefit of the assimilation of the plume height is. Given the overall uncertainty and judging from the pictures, it seems that the plume height assimilation does not lead to an improvement. If this is the case it should be mentioned more clearly.

The presented 4D-VAR approach does not take into account correctly the error statistics of the assimilating model as no model error co-variances are considered. This seems a simplification which should be better justified. Also, it seems that the SILAM model did not consider a chemical loss for SO2, which – if this was the case – would be an unnecessary simplification of the model.

The paper would benefit from a more detailed and thorough description of the experiments as well as a more detailed discussion and conclusion section.

Specific remarks

L 17: Clarify "vertical centre of mass" and "first moment"

L 20: Mention the relation of regularization with the a-priori estimate here.

L 50: Discuss the issue of the "single value" plume height retrieval and the observed complex SO2 profiles and the resulting challenges for the assimilation.

L 64: Clarify the differences between the "inversion type studies" using Lagrangian models, the 4D-VAR approach for the assimilation of only concentrations and the inclusion of the emission term in these 4D-VAR systems.

L 91: Say what the data set entails: TC and plume heights retrievals.

L 99: What is the effective plume height?

L 103: If this is the ash plume height - why the ash plume height?

L 155: What are inversion experiments. Please clarify the use of the terms "data assimilation" and "inversion" throughout the paper (see L64).

L 122: The "inversion" with simulated observations is discussed before the Eyjafjallajökull case. So please also mention them here before.

L 128: Is the conversion of SO2 to SO4 considered in the study ?

L 140: Please discuss that the standard 4D-VAR approach would include the model

error in form of the background error covariance matrix.

L 146: Spell out L-BFGS-B

L 156: Define also y and m_{ij}

L 160: Provide the formulae for centre of mass and 1st moment of mass

L 175: It is not clear if R also contains the error of the plume height retrieval. Is this error also provided and used?

L 204: This is not surprising given that the model/background error is ignored in equation (2)

L 209: Having only a diagonal model error covariance ignores the fact that the model advects the tracer.

L 219: Provide reference or explanation for the Tikhonov regularisation

L 252: Please describe the setting of the synthetic experiment better. What was period, region and meteorological data ? Is only the emission term synthetic ? What are the synthetic observations?

L 315: What is meant by "overall need"? Why is there an assumption about the source term? I thought regularizations is introduced to avoid an prior assumption for the source term? From which of the above are these generalisations deduced?

L 316: In which of the experiments there was no model error? Please clarify. Perhaps a table of all the synthetic experiments would be useful.

L 320: Say exactly which type of experiment you refer to.

L 322: Motivate this choice of the 9th and 13th iterate better. I thought that the L-curve needs to be examined for every case specifically.

L 324: Over plotting the observed ash plume height in Figure 7 is not really instructive. You should try to plot the time series of the averaged emission centre from the two

inversions together with the retrieved plume height (see Figure 13) in the vicinity of the volcano. This would show how much the plume height observations in the whole domain constrain the injection profile over the volcano. The observed ash plume height, which is basically the lower border of the ash plume, is less instructive.

Consider showing he difference between the two inversions in Figure 7b.

L 328: Stating the differences between the two inversions is not enough (see my general remark). Please say which of the two inversions is better. If this is no possible, say more clearly that this is the case.

L 337: Please discuss in more detail, why the total emission change despite that fact that the assimilated total columns are the same.

L 341: A plot of the difference with the base case would be clearer.

L 343: Check language ". . . as spread as . . ."

L 344: Again, it needs to be shown, that the results shown in Figure 10 are better or worse than the ones from Figure 7 before any conclusion can be drawn.

L 349: In line 337 you say it is about 10%. Why is this the case? Were the observations errors different for the assimilated TC in the two cases? The TC and the plume height retrievals are not independent,

L 350: Please provide more evidence and discussion.

L 355: I find it actually quite interesting that the additional assimilation of the plume height has so little influence.

L 357: Again, this is no proof that one inversion is better.

L 366: The differences between GOME-2 and IASI plume height retrievals should be discussed in more detail. The explanation is too short.

L 366 and L 370: Compare your results for both the injection height and the SO2 mass

with the results published in the literature, for example Boichu et al. 2013, Flemming and Inness, 2013. This would be an important result and should be mentioned in the conclusion or abstract.

L 376: Which other studies? Provide references.

L 380: This is all a bit unspecific. Please quantify the identified noise and how this could relate to the results from the 2010 case study.

L 390: 1000 days wall clock time or simulated days? How long does it need on a typical high performance computer architecture? What are the options for the parallelism of the application.

L 400: It think it is fair to say that the assimilation of the plume height only had a small influence on the results. Also, the paper provides not enough evidence that one option is better than the other.