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Atmospheric Measurement Techniques Discussions

Interactive comment on "Volcanic SO_2 and SiF_4 visualization using 2-D thermal emission spectroscopy – Part 2: Wind propagation and emission fluxes" *by* A. Krueger et al.

Anonymous Referee #1

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The authors describe a method which uses consecutive images recorded by a scanning IR Fourier transform spectrometer to calculate wind speed and emission rate of the volcano Popocatepetl near Mexico city. This paper is consecutive to Stremme et.al. (2012) who describe and validate the scanning IR Fourier transform spectrometer which is used to record the column density fields which are used as a base for this work.

The approach is interesting and offers the possibility to measure the wind and emission strength of a volcano during day and night.

However, the paper is difficult to read and lacks important information. Sometimes the choice of terms seems questionable to me (e.g. emission flux for what I understand to be the emission rate). Because the journal is directed at a wider audience such terms should at least be defined.

I therefore suggest publication but only after a major rewriting considering the issues raised below. In particular please make clear what you are actually trying to get and what you are using for it. Because it introduces a new method it should carefully be explained what you gain compared to other methods and a proper error analysis should be made. Also show the limits of the method and where to start if you want improvements.

General

What is the main goal of this research? Getting the wind speed or the amount of the emitted gases from the volcano? The authors describe at length the retrieval of the wind speed. The calculation of the emission flux (meaning the amount of the emitted gases?) is only described in the section 4, labeled "Diagnostics and errors". But it seems to me, that at least one main result of the paper, the calculation of the amount of emitted gases is this calculation.

The authors often mention the wind speed, which is retrieved. But the method is only suitable to retrieve the component of the wind speed which is perpendicular to the line of sight. Please clarify this throughout the whole article.

How has this been dealt with in the calculation of the emission flux? The authors give an error for the miscalculation of the distance of the plume in section 4.4.1. They do not mention the direction of the wind. If it does not matter, please state so and justify. I consider this crucial, because the method is not very useful if the wind direction cannot be dealt with appropriately.

An example: If the wind is 45° to the line of sight. How does it influence the result of

the emission flux? How large is the error. How do I decide if there is no wind, weak wind or the wind direction is more or less parallel to the line of sight.

The method seems to consist of three steps, a retrieval of the wind field, a measurement of the wind strengths and a final retrieval which uses the results of the first steps to retrieve the source distribution. I found it rather difficult to find that out, especially because the second and third step is described in what appears to be the error section.

I would suggest an overview of which steps are calculated at which time using which previous results and which constraints is provided in section 3.1. Also an overview of the determination of the constraints, which sometimes uses results of one of the steps would be very helpful.

The error discussion is very rudimentary. No statement is made on the error of the wind speed and wind direction. The conclusion of the error on the emission flux can only be believed but it is not conclusively derived.

The statement regarding the independence of the source strength and the wind field is at least questionable. In any case, it has to be proven, that this statement is valid.

It is common that the pictures are in the order of their first reference in the text (Page 8, but more places). I would recommend to stick to this custom, because it makes reading more easy.

Section 3.1.

The fact that the method can only retrieve the component of the wind speed projected to the plane perpendicular to the line of sight should already mentioned here, not partially and every now and then in the paper.

Equation 2 and 3 can only be regarded equal if the velocity has been projected to the plane perpendicular to the line of sight (LoS).

Eq. 3.2.

As I understand the principle so far, cl is a scalar field and v is a vector field. The style of the variables in eq. 3.2. should show this difference (please refer to the guide lines of the AMT journal on how to do that).

Section 3.2.

The calculation of the forward model seems rather strange to me: How is the gradient of the column density distribution been calculated, from the difference of the two consecutive images which also forms the measurement (dcl)?. If this is the case I wonder if this is circular. It seems to me that either the wind field or the source distribution and strength must be known in order to get the other one. Please explain this in detail.

Please state the structure of the solution vector already at this place. It makes it really difficult and confusing to get this information later in the paper.

In this section two different symbols for div (sometimes also $\nabla\cdot$) and grad (sometimes ∇) are used. Please use one of those and stick to it consistently throughout the paper.

Equation 5 and 6 What is x and y? The axis of the plane in which the wind retrieval takes place? If so, please state it.

What is the partial derivative of x and why is it necessary?

What is cl in equation 6? The column density field of the first or the second image, or a mean thereof?

Why is the divergence given as an differential operator in equation 6 but not the gradient? How is the gradient calculated if not from two consecutive images?

Section 3.3.

The descrition of the retrieval is not very clear. The authors mix the concepts Optimal estimation and Thikonov regularisation in a very arbitrary way and use terms in their own fashion. I would strongly recomment to stick to the usual meaning of the terms and clarify the descritopn of the retrieval.

Examples: Thikonov-type smoothing constraint: Thikonov describes a method to solve an ill-posed problem using a weighted mean of the data norm and some constraint. In the more general Thikonov regularisation the form of the data norm and the constraint is left free as long as certain conditions are fulfilled.

As I understand the authors mean the L1 norm, which they also state later in the paper.

Bayesian approach

The Bayesian approach means that the ill-posed problem is tackled using Bayes theorem. A priori information is always used, also in the Thikonov regularisation, because one uses information which is known before the measurement took place (knowledge a priori) and is not restricted to the Bayesian approach. It only takes a certain form in the Optimal estimation method described by Rodgers (2000) and this is mainly because of tractability.

Please sort out your use of terms and concepts. A good starting point to do this is Rodgers (2000).

Page 9 line 1

I do not understand how the residual shows the impact of the chosen weighing. Is the residual calculated before or after the retrieval?

Page 9 lines 3ff

A few lines above the inverse S_e^{-1} is calculated from the residual, now some correlation coefficient comes in. The correlation coefficient is a quantity calculated from two random variables. What are those variables and what is correlated here? Why is the root mean square of the fit linear to (1-correlation)?

Please redo this section and make clear what you are actually doing.

Page 9 line 13.

I guess section 3.3.1 is the following section. Please change your numbering accordingly.

Page 12 line 21

Which equation is meant here?

Page 13 line 12

What is meant by adequat? How is the smoothing determined, manually, automatically?

Section 4.1.

Which series are cross-correlated and to what purpose? Please make this clear in the beginning of this section.

Page 14 lines 11-12

Using the method described above? Other method? Please provide examples of how the new constraint changes the retrieved wind field.

Equation 15, 16

Define latter and former. cl are scalars and v and j are vectors, please change your notation appropriately.

Page 14 line 17

Which trajectory?

Page 15 line 1

Emission flux seems is defined here for the first time. Please define this variable in the beginning of your paper, because it seems one of the major outcomes of this work. If not, why is it calculated?

Page 15 lines 14,15

What exactly is t_{shift} and what t_{frames}. I never found this variables again.

Section 4.2

Are the AVK only calculated from the third retrieval? If so, the statements made below, that the retrieval of the wind speed in x and y direction and sources are independent is wrong. Even if they would be so, please do actually show that the results for those three components are independent using the off-diagonal values of the AVK which are calculated for all steps. This can be used be a perturbation calculation if a analytic expression cannot be found.

Section 4.4

Rodgers (2000) distinguishes between forward model error and forward model parameter error. Described here are the errors in the forward model parameters, not in the forward model itself.

Page 20 line 2

Please cite properly which Part 1 you mean.

Page 20 line 9

What is meant by the velocity of the viewing angle $\frac{d\phi}{dt}$? Please define.

Section 4.4.2

If it is not possible to calculate a proper measurement noise matrix, you should provide an example using artificially created fields of column densities given a wind field and a source distribution.

Page 21 line 4

Rodgers (2000) defines it differently, pointing out that his first definition was wrong. In particular, the smoothing error is only accessible if the statistices of the original is known.

Page 22 line 9

Perpendicular to what?

Page 23 line 9

Please cite the paper which is part I.

Figure I

Which time is needed to take one image? Can they be considered as snapshots or are they taken continuously?

Figure 3

The "drawn trajectory" is almost invisible. Please make it stronger and put an arrow at it.

Rodgers, C. D.: Inverse methods for atmospheric sounding: theory and practice, Ser. Atmos. Oceanic Planet. Phys., 2, World Sci., Hackensack, N. J., 2000. 17, 19

Stremme, W., Krueger, A., Harig, R., and Grutter, M.: Volcanic SO2 and SiF4 visualization using 2-D thermal emission spectroscopy - 0 Part 1: Slant-columns and their ratios, Atmos. Meas. Tech., 5, 275 - 288, doi:10.5194/amt-5-275-2012, 2012. 2, 4, 5

Interactive comment on Atmos. Meas. Tech. Discuss., 5, 4599, 2012.