

## ***Interactive comment on “Volcanic SO<sub>2</sub> and SiF<sub>4</sub> visualization using 2-D thermal emission spectroscopy – Part 2: Wind propagation and emission fluxes” by A. Krueger et al.***

### **Anonymous Referee #3**

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The paper by Krueger et al. reports on a method how to estimate the source strength of a volcano from consecutive measurements of the 2D gas distribution in the volcanic plume. The method simultaneously derives information on the winds driving the plume. Krueger et al. apply the tool to mainly the SO<sub>2</sub> concentration field observed by thermal emission spectroscopy of the Popocatepetl volcanic plume as described in a precursor paper [Stremme et al., 2012].

The method - exploiting the continuity equation - is appealing because of its conceptual simplicity and its ability to estimate the winds simultaneously with the

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source strength. One might think of applying such a method to other source/sink questions in atmospheric sciences, e.g. to be addressed through geostationary satellites. The topic of the paper is well suited for publication in AMT.

The major shortcoming of the paper is the way how it is written up. The paper requires a major revision with some parts probably requiring a complete rewriting. My comments below point out some of the major issues but the whole paper is to be examined keeping in mind that the educated reader should be able to follow the rationale with adequate effort. I skip numerous issues concerning wording and typos.

## Comments

### Section 3.1:

\*The physical meaning of equation (3) is to be described in more detail. If I understand correctly:

- the 3rd dimension (along the line-of-sight) is neglected in a sense that the 2D wind speed vector is independent of the line-of-sight.
- the source term  $Q$  is not the true source strength of the volcano [units: mass/time/(area of the volcano)] but it is the source integrated along the line-of-sight [units: number of molecules/area perpendicular to the line-of-sight/time].
- the source term  $Q$  is estimated from the measured slant column densities. So,  $Q$  will also depend on retrieval sensitivity along the line-of-sight.
- chemical processing in the plume is neglected. This assumption should be justified based on some simple photochemical considerations.

\*The choice of “ **$c_l$** ” as a symbol for a scalar quantity is very confusing. Why not just “ $c$ ”?

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\*It could be helpful to expand “ $\nabla(v \cdot cl)$ ” (equation 3), because this is what the reader needs to understand equations (4), (6), (7).

\*It would certainly be helpful to explicitly introduce the discretization step “ $dcl \rightarrow cl_{t+1} - cl_t$ ” at the end of section 3.1 with  $t$  and  $t+1$  referring to the observation at time step  $t$  and  $t+1$ .

Section 3.2:

\*Choosing the state vector “capital, boldface  $V$ ” is confusing because capital boldface symbols typically refer to matrices. The letter  $V$  further hints at wind speeds ( $v$ ) but there is also source terms in the vector  $V$ .

\*It is very difficult to understand the rationale in this section with the state vector being introduced at the beginning and its components being listed at the very end.

\*If I understand correctly, the state vector contains the wind speeds and the source terms for each pixel  $(i,j)$  of the 2D image of the observed scene. The 2D scene is made a 1D state vector by chaining the pixels  $(i,j)$  into a column vector (while keeping the double indices). This process is to be described at the beginning of the section. Presently, the derivation of equation (6) and (7) is not understandable.

\*I do not understand the representation of “ $\text{div}_x^{mn}$ ” in equation (6).

\*Would it be useful to write out equations (4) through (8) for one of its components “ $dcl_{ij} = \dots$ ”?

Section 3.3:

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\*There is reference to section 3.3.1, but it does not exist.

#### Section 4.1:

\*Section 4.1 introduces the “cross-correlation” method. To a large extent, I was not able to follow the rationale in this section. I was not able to understand why you need the cross correlation method. Do you need it for an a priori estimate of the winds (p.4613,l.17)? Please rewrite this section:

- I suggest starting with a clear outline why you need the cross correlation method in addition to the method presented earlier.
- What is the first retrieval you describe in paragraph p.4612,l.7? Is it a cross correlation retrieval or the full retrieval? If it is the latter, it seems to be modified from the setup described in section 3. That is very confusing.
- paragraph p.4612,l.13: Suddenly, the images are treated separately. Do you start describing the cross-correlation method? If so, it would be good to add text that summarizes how the cross correlation method works conceptually.
- p.4612,l.17: What is the “final (third) retrieval”? There is no hint in the manuscript that actually three retrievals are performed.

#### Section 4.2:

\*The use of “boldface( $AK_{kl}^{ij}$ )” for the averaging kernel matrix is again confusing because the notation looks like a matrix multiplication of A and K.

\*p.4616,l.8: Is it really necessary to introduce “ $AK_{\theta}$ ” and “ $AK_{\phi}$ ”? The discussion would not suffer from just using “ $AK_x$ ” and “ $AK_y$ ”.

\*p.4616,l.21: Is there really non-zero averaging kernel diagonal elements in the vicinity of the volcano (lower panel of Fig. 6)? I cannot see it. Consider changing the

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color scale of Fig. 6.

Section 4.4.1:

\*Why do you need to estimate the distance  $r$  between the observer and the plume? Estimating  $r$  seems difficult because the method uses column densities integrated along the line-of-sight. Is it because you want to translate radial velocities (units angle/time) into Cartesian velocities (unit length/time)? Why do you need Cartesian velocities at all?

Section 5.2:

\*The paper gives emission estimates in units mass/time but the retrieval method yields emissions integrated along the line-of-sight (number of molecules/area perpendicular to the line-of-sight/time). What assumptions go into the conversion eg. relevant length of the line of sight/extent of the plume along the line-of-sight?

\*Fig. 1: Color scale missing. At least give a hint on “warm” colors meaning high SO<sub>2</sub>, “cold” colors meaning low SO<sub>2</sub> concentrations. Why does the figure caption say “the average wind vectors are sought”? My understanding is that the proposed method tries to estimate the wind vectors in all pixels.

\*Fig. 2: It might be useful to show the position of the volcano. I do not understand the last sentence of the caption.

\*Fig. 7: “SA<sub>inv</sub> Sources” has never been defined or discussed in the manuscript. The unit of the sources should be “per time”.

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