

Interactive comment on “Early in-flight detection of SO₂ via Differential Optical Absorption Spectroscopy: a feasible aviation safety measure to prevent potential encounters with volcanic plumes” by L. Vogel et al.

Anonymous Referee #2

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In their manuscript “Early in-flight detection of SO₂ via Differential Optical Absorption Spectroscopy: a feasible aviation safety measure to prevent potential encounters with volcanic plumes”, L. Vogel et al. report on airborne measurements of SO₂ from a volcanic plume using the DOAS method. Several approaches of the plume are documented and compared to stationary and mobile ground-based DOAS measurements. The airborne measurements are simulated by a radiative transport model and extrapolated to observations from larger distances to the plume. Some additional RTM cal-

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culations are made to investigate the impact of larger optical depths (from SO₂ and aerosols) on the observations. From their measurements and the simulations, the authors conclude that passive UV DOAS measurements could be used on aircrafts to avoid flying into volcanic plumes.

The paper is well written and reports on interesting measurements. The topic is within the scope of AMT and I find the test case and the idea of applying UV DOAS instruments to operational volcanic plume avoidance intriguing. However, while the test measurements and their comparison with ground-based data are sound if somewhat qualitative, the discussion of the application to volcanic plume avoidance is not convincing. In my opinion, additional RTM studies and discussion are needed to justify the title of this manuscript, and therefore I can only recommend publication after major revisions.

My main concern about this manuscript is that it claims to have shown that passive UV DOAS measurements from aircraft can be used for volcanic plume avoidance while in fact it has only demonstrated that SO₂ plumes from volcanic plumes can be detected at relatively large distance when flying exactly in the altitude of the plume. While this is a nice demonstration, it is not really surprising as SO₂ has been observed before from airborne DOAS instruments in volcanic plumes and in power plant emissions. To make such a system useful for volcanic plume avoidance, a couple of requirements must be met:

1) The system must tell the pilot at which distance and in which altitude a dangerous SO₂ plume is observed. It is not clear to me, how the distance to the plume can be estimated from the DOAS measurements alone, unless some kind of triangulation is applied which does not appear very realistic to me. Also, how is the altitude of an extended plume estimated from the measurements? This is crucial information for any attempt to avoid the plume. Measurements under different angles are potentially a method to estimate the plume altitude, but again this is complicated by the fact that the distance to the plume and also its SO₂ content are not known. Please ex-

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plain in the manuscript how plume height and distance can be determined from the measurements of the instrument.

2) The system must be sensitive enough to give a warning when there is still enough time to change course. While the paper contains some discussion on this, I think that an estimate of the smallest observable OD must include the dependence on illumination (flight altitude, solar zenith angle, solar azimuth angle) and also give some indication on how the background reference is to be taken in an automated system. Using a measurement from just after passing the plume is not an option in real world applications, and other alternatives (fixed background, zenith-sky observation from another telescope / instrument / stripe on CCD) have negative impacts on the detection limit. Considering that even with the rather optimistic assumptions made in the current manuscript, there only are a few minutes between the first measurement above detection limit and contact with the plume, this is a relevant discussion and should be included in the manuscript.

3) The system must be able to differentiate between a dangerous SO₂ plume at flight altitude and a harmless SO₂ plume above. As the light observed by the forward viewing telescopes is mostly scattered at flight altitude, any SO₂ layer above the aircraft will also create a signal (depending on SZA). To a much smaller extent this is also true for SO₂ at levels below flight altitude. I think that RTM calculations with plumes of similar SO₂ content but at different altitudes are needed to investigate their impact on the signal.

In addition, there are some obvious drawbacks of using passive UV DOAS instruments for volcanic plume detection which should be briefly mentioned in the conclusions, for example the fact that SO₂ is measured but ash is more dangerous, that measurements can only be performed at daylight, and that clouds can interfere with the observations.

Minor comments

P2834, l11: reported appears twice

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P2834, I26: shouldn't that be 1.730 Gg / day?

P2835, I14: a recent examples => recent examples

P2835, I23; as sketch => a sketch

P2836, I6: Why "thus"? This is a different aspect

P2837, I14: shouldn't this be 1.9 Gg / day?

P2845 I24: are observed are increasingly => are observed increasingly

P2848, I2: thus the all modelled => thus all modelled

P 2849, I25: what are the units of epsilon?

P2851, I11: I think that intensity is also very important for the detection limit

Fig. 3 4: please use the same scale

Fig 5: I assume this is the absorption cross-section and has units of $\text{cm}^2 / \text{molec}$

Fig 7: This is probably not intensity but differential optical density

Fig 13: caption: concentration is $\text{molec} / \text{cm}^3$, not molec/cm^2

Fig 14: Check first sentence in caption for grammar

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