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Interactive comment on “A comparison of DOAS observations by the CARIBIC aircraft and the GOME-2 satellite of the 2008 Kasatochi volcanic SO₂ plume” by K.-P. Heue et al.

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Review K.-P. Heue et al. “CARIBIC and GOME-2 comparison of the Kasatochi plume observations”

Paper describes near simultaneous sampling of the drifting volcanic SO₂/aerosol volcanic cloud by CARIBIC in-situ aircraft laboratory and satellite GOME-2 UV spectrometer. The aged cloud originated from August 8 2008 Kasatochi and the sampling occurred week later on August 15 over Europe at altitude ~11 km.

Aircraft encounters with volcanic clouds are quite rare; the previous one was of NASA DC-8 research aircraft inadvertently flown into aged volcanic cloud from Hekla eruption

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in 1999 [Rose et al 2003]. The DC-8 measurements were compared with satellite UV Total Ozone Spectrometer SO₂ and Aerosol Index measurements. The limiting factor in TOMS comparisons were high solar zenith angles and limited TOMS sensitivity to volcanic SO₂.

[Rose, W.I., Gu, Y., Watson, I.M., Yu, T., Bluth, G.J.S., Prata, A.J., Krueger, A.J., Krotkov, N., Carn, S., Fromm, M.D., Hunton, D.E., Viggiano, A.A., Miller, T.M., Ballentin, J.O., Ernst, G.G.J., Reeves, J.M., Wilson, C. and Anderson, B.E. 2003. The February-March 2000 eruption of Hekla, Iceland from a satellite perspective. In: Volcanism and the Earth's Atmosphere (eds. A. Robock and C. Oppenheimer), AGU Geophysical Monograph 139, pp. 107-132, 2003]

The Kasatochi eruption occurred at fortunate time when multiple research and operational satellite platforms were in operation (MetOp launched in 2006, EOS Aura launched in 2004 and EOS Aqua launched in 2002) carrying IR and UV satellite instruments capable of detecting volcanic gases and aerosols with unprecedented precision not possible just few years ago. On the other hand, the DOAS SO₂ measurements from aircraft platform are new and to my knowledge this is the first such measurement of the volcanic cloud. Authors specifically compare satellite DOAS SO₂ data from GOME-2 UV instrument with aircraft DOAS SO₂ measurements from CARIBIC platform, few hours after GOME-2 overpass. TRAJKS trajectory model was used to account of cloud advection and correct for the differences in observational times.

The observing conditions were quite favorable with solar zenith angle $\sim 73^\circ$. Good agreement between GOME-2 and CARIBIC DOAS SO₂ data is encouraging as it indirectly validates both retrievals. The only addition on my “wish list” would be adding in-situ SO₂ instrument to CARIBIC payload.

I recommend publishing the paper in ACP with minor corrections aimed at improving the text.

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- 1) I suggest adding in-situ SO₂ detector to CARIBOC payload, which would validate DOAS SO₂ measurements (e.g. Luke, W.T., 1997. Evaluation of a commercial pulsed fluorescence detector for the measurement of low-level SO₂ concentrations during the gas-phase sulfur intercomparison experiment. Journal of Geophysical Research 102 (D13), 16255–16265.)
- 2) The text is not always clear. English needs to be improved throughout. Some suggestions are given in detailed comments.
- 3) Radiative transfer model and calculation of box-AMFs (e.g. shown in figure 1) need to be described.
- 4) Specify the error in CARIBIC caused in SO₂ retrieval by constant temperature 273K (p.528) assumption. This temperature is not realistic for likely SO₂ plume altitude and is also inconsistent with ozone cross section temperatures in the DOAS fit (223K and 243K).
- 5) Do adjacent cross-track GOME-2 pixels overlap? If so, show actual GOME-2 pixel shapes in figure 8,9 and 11.
- 6) I found it surprising that GOME-2 AMF only increases by ~10% when thick cloud (COT~10) is placed just below SO₂ layer (p539, line 11-12). Suggest increasing cloud single scattering albedo (SSA) from 0.99 to 0.9999 and re-calculating AMF
- 7) I found surprising assumption of highly absorbing aerosols with SSA=0.8 in volcanic cloud. The predominant aerosol component in week old volcanic cloud should be sulfuric acid droplets with SSA=1. Provide more evidence supporting this assumption.
- 8) To achieve good agreement between trajectory shifted CARIBIC SO₂ columns and GOME-2 SO₂ spatial distribution, the wind speed in trajectory model has to be locally enhanced by 25%. To test this hypothesis I suggest forward project trajectory for the next 3 hours and compare with OMI overpass at ~12UTC (see OMI figure). Perhaps, comparing GOME-2 and OMI spatial SO₂ patterns would help constrain local wind

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speeds.

Specific comments:

524, 11 “A comparison of the [satellite] spatial pattern with . . .”

14 “[Emitted] and secondary particles, . . . “ - Emitted volcanic ash particles should have fallen out after a week of travel.

17 suggest re-wording: The main remaining sources of error are uncertainties in local wind speed . . . and effects of aerosols on DOAS retrievals.

20. I suggest adding SO₂ in-situ instrument to CARIBIC payload

525 11 “several satellite [UV spectrometers] , e.g. “ – explain abbreviations, provide references

17 remove [here]

20 Suggest re-wording: “Because of slight inconsistency between GOME-2 and CARIBIC SO₂ retrievals a more detailed study of local wind pattern was performed, which resulted in better agreement”

24. Why is O₄ slant column mentioned here? What is O₄ relation to SO₂ column ?

526 6 Why in-situ SO₂ is not measured?

7 [in] real time

25. “pointing starboard” – not clear. Are telescopes pointing toward or perpendicular to the flight direction? Will be nice to have photo of the telescopes on the aircraft.

527, 4 “full width [at] half maximum”

10 “which” -> “that are “ 10 “weighted average light path” – weighted with what?

13 Suggest re-wording: “The sensitivity [of the measured spectral radiance] to a trace gas concentration at certain altitude is commonly known as box air mass factor (box-

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AMF) or weighting function (WF)”.

25. What was the SZA during plume encounter?

26 “For comparisons with other observations [and models] the vertical column density is used”

29 “is called air mass factor [or column weighting function] “

528, 1 Box AMF also depends on clouds and aerosols. Suggest re-wording: “. . . but also on the gas vertical profile shape”

6 “O4 observations are often used as proxy to estimate cloud properties” – This statement is not clear: what O4 observations (in-situ density or absorption, etc) are meant and what cloud properties (e.g. optical or physical) can be estimated? Also why O4, but not for example O2 observations are used?

12. “ultra violet” – one word, often UV

20 For SO2 the same cross section (273 K) as for the GOME-2 data retrieval is used”
- This is certainly not correct temperature for the CARIBIC cruise altitude, so absolute SO2 column density will be incorrect. Specify the systematic SO2 error.

531, 2 Suggest additional reference here “In such cases this non-linearity has to be corrected for [Yang et al 2009] , or . . . “

Yang, K., N. A. Krotkov, A. J. Krueger, S. A. Carn, P. K. Bhartia, and P. F. Levelt (2009) Improving retrieval of volcanic sulfur dioxide from backscattered UV satellite observations, Geophys. Res. Lett., 36, L03102, doi:10.1029/2008GL036036.

18. Add web link for NRT SO2 data from both OMI and GOME-2 .

<http://satapsanone.nesdis.noaa.gov/pub/OMI/OMISO2/>

21 suggest: “. . . are shown”

23: suggest re-wording: “. . . an eastern edge of the volcanic cloud has reached West-C450

ern Europe stretching from Western Mediterranean to the Baltic sea”

532, 23 Explain how COT was determined. 25 How single scattering albedo value 0.99 was chosen?

533, 7 “The sensitivity to local SO₂ concentrations [at flight altitude] is enhanced 14 suggest re-wording “the difference in [SO₂] SCD peak heights can be explained by different SO₂ columns”

22. cloud cover “ -> cloud layer

29 “gives reason to assume” -> suggests

534, 4 re-word: “we assume the plume altitude between 11 and 12 km”

20 “by which” -> therefore

537, 7 re-word “A good agreement between the trajectory projected SO₂ timeseries and GOME-2 measurements is found with an 25 % increased wind speeds ”

11-12 remove “the spatial patterns of”

538, 16 “ . . . with single scattering albedo [SSA=0.8]. . . ’ - How the SSA was estimated?

539, 11-12 “the sensitivity for GOME-2 increases from 2.19 to 2.4 for nadir when the dense cloud is assumed, instead of the optically thin one” - The satellite AMF should increase more for an SO₂ layer just above dense cloud with COT=10. What cloud fraction was assumed in AMF calculation?

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 523, 2010.

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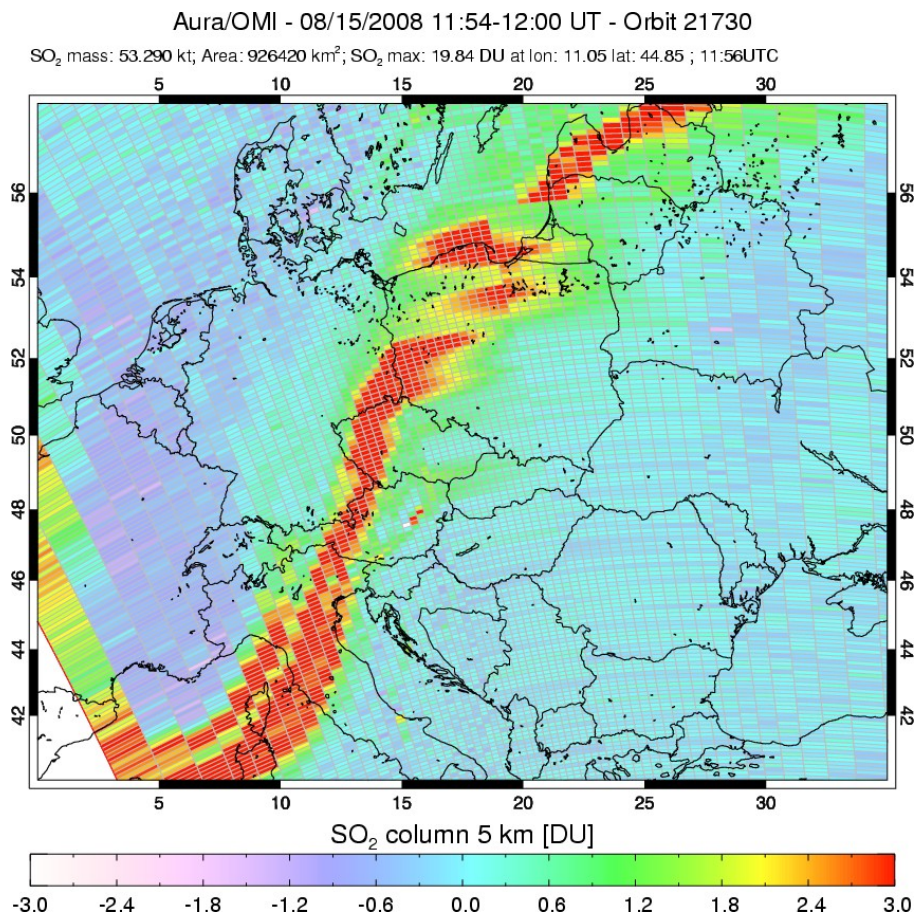
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Fig. 1. OMI SO₂ operational retrievals on August 15 at 11:54-12:00 UTC assuming center of mass altitude 7km. Maximal column SO₂ $\sim 5 \cdot 10^{17}$ molecules/cm²

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