SO_2-flux measurements and BrO/SO_2 ratios at Guallatiri volcano, Altiplano, northern Chile

Jonas Gliß[1], Kerstin Stebel[1], and Helen Thomas[2]

[1]NILU - Norwegian Institute for Air Research, Kjeller, Norway, [2]Nicarnica Aviation, Kjeller, Norway

I Introduction

Sulphur dioxide (SO_2) fluxes were measured recently at Guallatiri volcano using two UV SO_2-cameras[1] and one IR camera[2]. Furthermore, measurements of reactive halogens (e.g. BrO, OClO) were investigated using a high performance DOAS (Differential Optical Absorption Spectroscopy[3]) instrument. Guallatiri (18° 25' 00'' S, 69° 5' 30'' W, 6.071 m a.s.l.) is situated in the Altiplano in northern Chile, close to the Bolivian border. The last known eruption of Guallatiri was in 1960. The measurements were performed during a short-term field trip on three days in November 2014 (20.11.-22.11.2014). During that time, the volcano showed a quiescent degassing behaviour from the summit crater and from a fumarolic field on the southern flank. Here we present preliminary results from one UV camera and from the DOAS spectrometer. Fig. 1 gives an overview of the measurement locations (21. and 22.11.2014) and the topography.

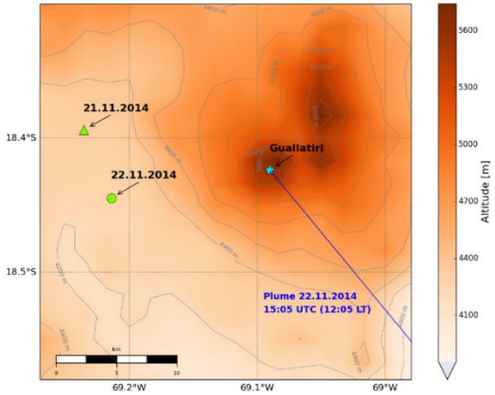

Fig. 1: Topography and measurement locations on 21. and 22.11.2014. The blue line indicates the wind direction on 22.11.2014.

Fig. 2: Photo from the measurement site showing 2 UV SO2 cameras (blue), the DOAS instrument and an IR SO2 camera (white, left side).

II Technical setup

Two UV SO_2 cameras as well as one IR camera were used in order to study SO_2 emissions at Guallatiri. The UV cameras are equipped with a spectrometer for spectral analysis of SO_2. In addition a high performance DOAS instrument with a temperature stabilised Avantes spectrometer was used to collect UV plume spectra. We discuss preliminary results from one of the UV cameras and from the DOAS instrument, technical details of these two instruments are summarised below.

III Camera retrieval details

SO_2 optical density images (τ_{SO2} images) were determined from consecutively recorded on and off-band images using the following equation:

$$\tau_{SO_2} = \ln\left(\frac{I_0}{I}\right)_{\text{on}} - \ln\left(\frac{I_0}{I}\right)_{\text{off}}$$

Here, I corresponds to the light intensity after penetrating the volcanic plume and I_0 to the corresponding initial light intensity before entering the plume. A 2D polynomial fit of an background image was used as an estimate of the background sky (I_0) in the on and off-band images in each image pixel. The τ_{SO2} images were then calibrated using the cell calibration curve shown in Fig. 3. All images were dark and offset corrected beforehand.

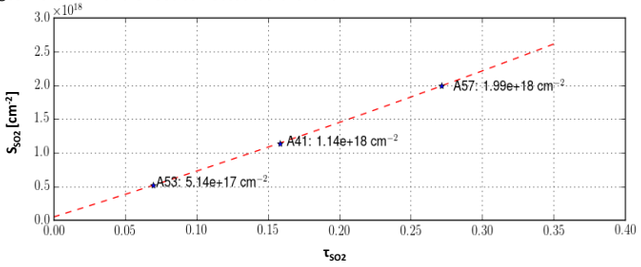

Fig. 3: Camera calibration curve (cell calibration)

Technical details UV camera	
Optics	50 mm lense f/8.0
Camera type	Hamamatsu C8484-16C
Detector size	1344 x 1024 px
Pixel size	4.65 µm
λ_0 on-band filter	310 nm
λ_0 off-band filter	325 nm
A/D converter (bit depth)	12 bit
Embedded spectrometer	Ocean Optics USB 2000+

Technical details DOAS instrument	
Spectrometer	Avantes AVA AvaSpec-ULS2048x64
Wavelength range	287.5 - 454.0 nm
FWHM slit function	0.58 nm
Temperature controlling	Supercool PR-59 + Peltier element
Operational temperature	15°C
Focal length optics	100 mm

IV Spectral analysis

The spectra were evaluated in a standard DOAS fit[3] regarding BrO and SO_2. BrO could only be significantly retrieved in 17 spectra and in these, an average BrO/SO_2 ratio of 9.77±3.76 x 10^{-5} was found. The spectra were evaluated against a clear sky spectrum (I0) recorded close in time. SO_2 was retrieved between 314.8-326.8 nm, two Ring spectra and one O_3 absorption cross section were additionally included in the fit. BrO SCDs were retrieved between 331.6-352.7 nm (additional absorbers: O_3, O_4, SO_2 and two Ring spectra). A pre-analysis showed no indications of HCHO or NO_2 abundances in the spectra, thus these species were excluded in the final evaluation scheme for the BrO retrieval of the Guallatiri data.

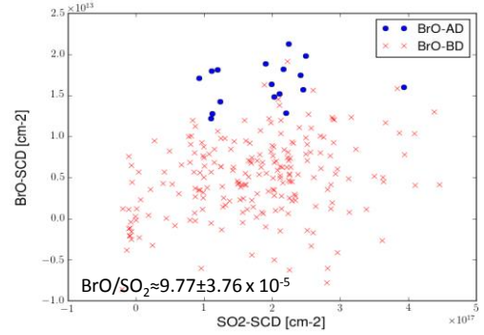

Fig. 4: BrO SO_2 scatter plot for the whole dataset. Spectra with significant BrO detections are marked in blue, measurements below the detection limit with red crosses.

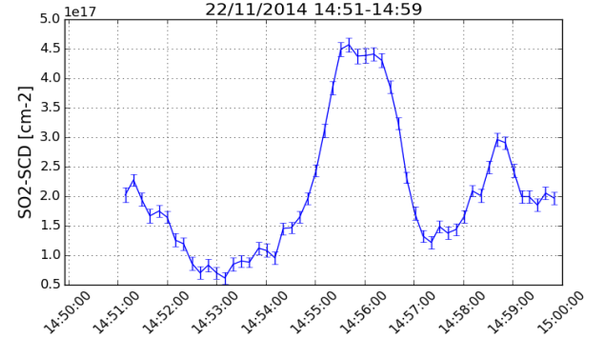

Fig. 5: DOAS SO_2 retrieval for the selected time window also shown in Fig. 7.

V Preliminary flux estimates from the UV camera

In a preliminary evaluation, a suited time window of 8 minutes between 14:50 and 14:58 UTC on 22. November 2014 was analysed. The camera calibration (Fig. 3) was performed close in time (~15:20 UTC) using three calibration cells. SO_2 fluxes of the order of several hundred grams per second were retrieved. The flux was estimated for two cross section, one only including the central plume (red dashed in Fig. 6 and Fig. 7) and one of the total emissions including also the fumarolic field emissions from the southern flank (blue lines in Fig. 6 and Fig. 7).

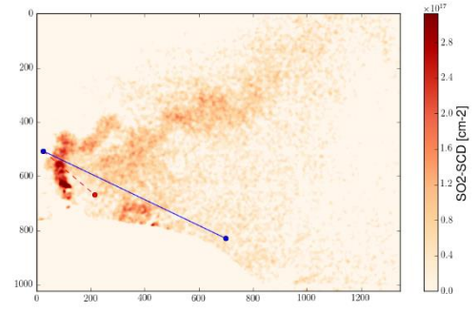

Fig. 6: Exemplary SCD image of the analysed time series and cross sections used for individual flux estimates (red and blue lines in Fig. 7).

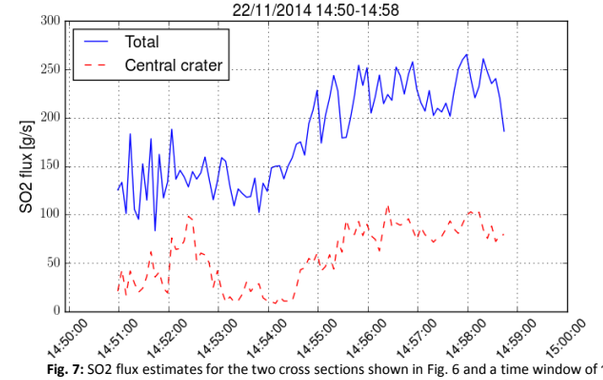

Fig. 7: SO2 flux estimates for the two cross sections shown in Fig. 6 and a time window of ~8 min between 14:50 and 14:58 on 22th Nov. 2014. Fluxes of up to 260 g/s were found.

VI Conclusions and outlook

In this setup, SO_2 emissions of Guallatiri were monitored using three cameras (two UV and one IR) between 20.-22.11.2014. Further-more, three spectrometers collected spectral data during the measurements pointing in the FOV of the cameras. In this preliminary evaluation only a short time window of the data of only one of the three cameras was analysed. Furthermore, the calibration of the camera was performed using calibration cells. This will be reanalyzed using the spectral SO_2 retrieval of the three spectrometers for the camera calibration. Furthermore, potential impacts due to light dilution will be investigated due to the comparatively large distance to the plume (~13 km). So far, BrO was analysed regardless the plume age range (i.e. young plume / aged plume). Since BrO is rather expected in the ageing plume (see e.g. [4]), a more detailed analysis will be performed in order to elaborate the BrO retrieval as a function of plume age. We furthermore attempt to separate SO_2 emissions from the two main sources (central crater and fumarolic field) and aim to study variations in these individual contributions to the total SO_2 flux of Guallatiri volcano.

VII References

[1] Kern C, Lübcke P, Bobrowski N, Campion R, Mori T, Smekens J-F, Stebel K, Tamburello G, Burton M, Platt U, Prata F (2014) Intercomparison of SO2 camera systems for imaging volcanic gas plumes. J Volcanol Geotherm Res. doi: 10.1016/j.jvolgeores.2014.08.026

[2] Prata, A. J. and Bernardo, C.: Retrieval of sulfur dioxide from a ground-based thermal infrared imaging camera, Atmos. Meas. Tech., 7, 2807-2828, doi:10.5194/amt-7-2807-2014, 2014.

[3] Platt, U. and Stutz, J.: Differential Optical Absorption Spectroscopy: Principles and Application, *Springer, doi:10.1007/978-3-540-75776-4*, (2008).

[4] Gliß, J.; Bobrowski, N.; Vogel, L.; Pöhler, D. & Platt, U. OClO and BrO observations in the volcanic plume of Mt. Etna - implications on the chemistry of chlorine and bromine species in volcanic plumes *Atmospheric Chemistry and Physics Discussions,* (2014), *14*, 25213-25280

***Acknowledgements**: we acknowledge the financial support received from UNIK, the University Graduate Centre, Kjeller, Norway.*