

## EPSC 530 - Volcanology, Fall 2022

### Lab 4 - Using and interpreting volcanic gas monitoring data

All data are located here:

<http://www.eps.mcgill.ca/~courses/c186-530/Lab%20%20-%20volcanic%20gases/>

#### Introduction

This lab examines volcanic gases emitted at the surface through the crater of a volcano. The volcano in question is Yasur, located in Vanuatu. It is very interesting for a number of reasons. First, it is located on part of a resurgent dome which is actively inflating periodically, within a larger caldera called Siwi which was formed at <20 ka. Second, the volcano is almost continuously active, with frequent explosions. Third, Yasur is an arc volcano, and the volcano itself and the caldera are fairly mafic in composition.

For this lab, we will work in three groups. Two groups will analyze and calculate SO<sub>2</sub> fluxes from Yasur. These fluxes are important for two reasons. First, changes in the SO<sub>2</sub> flux can signal changes in eruptive activity. Second, the global SO<sub>2</sub> flux emitted by volcanoes is an important component of the global sulphur cycle.

The other group will look at gas ratios, specifically the CO<sub>2</sub>/SO<sub>2</sub> ratio. This ratio is important for two reasons. First, you can use it (with SO<sub>2</sub> fluxes) to calculate CO<sub>2</sub> fluxes. Second, increases in this ratio can signal renewed eruptive activity as the shallow system is replenished with new magma which is comparatively CO<sub>2</sub>-rich.

So a volcano which is undergoing renewed activity might show (a) increasing SO<sub>2</sub> fluxes and (b) increased CO<sub>2</sub>/SO<sub>2</sub> ratios.

#### SO<sub>2</sub> fluxes (Groups 1 and 2)

To calculate an SO<sub>2</sub> flux, use the following equation:

$$F = (pl) \times (\cos\theta) \times (d) \times (v) \times (cf)$$

where F = SO<sub>2</sub> flux in metric tonnes per day;

pl = average pathlength concentration for a given segment in ppm-m (use the calibration provided to convert your digital concentration values to ppm-m);

$\cos\theta$  = correction for segment deviation from perpendicularity relative to plume direction;

$d$  = length of the segment in meters;

$v$  = windspeed in meters per second;

$cf = 0.00023$  - this is a conversion factor.

When analyzing a traverse, it is best to split up the traverse into a series of linear segments. This can be easily done at Yasur, where a traverse comprises two segments each about 1 km long (see the Google Earth image).

When you do the calculation, do it for each of your segments, then add the individual fluxes for a total flux value.

You need to find the plume direction, which is controlled by the windfield. This can be done by locating the plume's peak value on the Google Earth image.

Group 1 will do  $\text{SO}_2$  fluxes for the first two traverses on 30 November 2017, while Group 2 will do the 3<sup>rd</sup> and 4<sup>th</sup> traverses for the same day. So each group can do two flux calculations.

How do the  $\text{SO}_2$  flux data from Groups 1 and 2 compare? How do these data compare with previous work? (see Bani and Lardy 2007; Métrich et al. 2011)

Now scale up your Yasur calculations and do a calculation for the total amount of  $\text{SO}_2$  emitted globally by volcanoes for a given year. When doing this, it is probably best not to use a single value. Instead, make a minimum and maximum estimate. Now compare these values to global anthropogenic  $\text{SO}_2$  released during 2017. How do these numbers compare?

### Windspeeds

30 November:

5 measurements at crater at 0902 hours:

8.4 m/s

8.8 m/s

9.0 m/s

11.9 m/s

12.0 m/s

5 measurements at crater at 1113 hours:

10.3 m/s

9.2 m/s  
6.4 m/s  
6.6 m/s  
8.7 m/s

Traverse data for 30 November 2017

Traverse 1: start at point 1 at 095620 hours  
stop at point 2 at 100105 hours  
vehicle travelling 30 km/hr

Traverse 2: start at point 2 at 100255 hours  
stop at point 1 at ~100730 hours (data are missing here, so I  
estimated the time)  
vehicle travelling 30 km/hr

Traverse 3: start at point 1 at 102145 hours  
stop at point 2 at 102610 hours  
vehicle travelling 30 km/hr

Traverse 4: start at point 2 at 102610 hours  
stop at point 1 at 103044 hours  
vehicle travelling 30 km/hr

PLEASE SHOW ALL YOUR CALCULATIONS IN YOUR LAB REPORT. THE LAB REPORTS ARE DUE ON 24 NOVEMBER.

**Gas ratios** (Group 3)

The gas concentrations are raw data expressed in millivolts. You need to convert these raw data to concentrations using calibrations (use the 6/12/2017 calibrations).

Once you have done this, make a single file with all the data. Use the program "ratiocalc" to determine the gas ratios. The program is in the "ratiocalc" folder; to install it, follow these three steps exactly: (1) run "setup.exe"; (2) shut down your computer completely; (3) restart computer and run "ratiocalc\_3\_1.exe". You need this program, because there is a small time offset between the different gas concentration measurements. I would recommend calculating 10 individual CO<sub>2</sub>/SO<sub>2</sub> ratios, in order to examine the variability. To get high-quality ratios, find the high-SO<sub>2</sub> peaks in the dataset.

In ratiocalc, to load a file, set the file type as "Delimiter ," then load SO<sub>2</sub> ppm and time into Ya and Yb to find places in the file with high SO<sub>2</sub>. To do ratios, load your ppm CO<sub>2</sub> and ppm SO<sub>2</sub> into Ya and Yb. Play around with "X a shift" and "X b shift"; "Ya

filter" and Yb filter" also can be useful. Try to get good  $R^2$  values of better than 0.7-0.8.

How do your  $\text{CO}_2/\text{SO}_2$  ratios compare with previous data at Yasur? (see Métrich et al. 2011) At other volcanoes? (see slide 32 of Turrialba from Lecture 1 – fast and slow volcanoes)

With your gas ratios, now calculate the  $\text{CO}_2$  flux from Yasur using previously published  $\text{SO}_2$  fluxes (Bani and Lardy 2007; Métrich et al. 2011):

$(\text{SO}_2 \text{ flux}) \times (\text{CO}_2/\text{SO}_2) \times (44/64) = \text{CO}_2 \text{ flux in metric tonnes per day}$

The (44/64) term is a conversion factor to convert the molar values of the ratios to mass values for the  $\text{CO}_2$  flux (44 is the molecular weight of  $\text{CO}_2$ , 64 is the molecular weight of  $\text{SO}_2$ ).

Group 3 will do ratios for 30 November 2017.

Now scale up your Yasur calculations and do a calculation for the total amount of  $\text{CO}_2$  emitted globally by volcanoes for a given year. When doing this, it is probably best not to use a single value. Instead, make a minimum and maximum estimate. Now compare these values to global anthropogenic  $\text{CO}_2$  released during 2017. How do these numbers compare?

PLEASE SHOW ALL YOUR CALCULATIONS IN YOUR LAB REPORT. THE LAB REPORTS ARE DUE ON 24 NOVEMBER.

### References cited

Bani P, Lardy M (2007) Sulphur dioxide emission rates from Yasur volcano, Vanuatu archipelago. *Geophys Res Lett* 34: L20309, doi:10.1029/2007GL030411

Métrich N, Allard P, Aiuppa A., Bani P, Bertagnini A, Shinohara H, Parello F, Di Muro A, Garaebiti E, Belhadj O, Massare D (2011) Magma and volatile supply to post-collapse volcanism and block resurgence in Siwi caldera (Tanna Island, Vanuatu arc). *J Petrol* 52: 1077–1105, doi:10.1093/petrology/egr019

## APPENDIX 1 - ANALYZING SO<sub>2</sub> FLUX DATA

In all SO<sub>2</sub> flux measurements, the SO<sub>2</sub> emission rate is determined by calculating the emission rate for each segment, which is then summed to determine the total SO<sub>2</sub> emission rate for a given traverse. In the case of airborne or boat-mounted measurements, only one emission rate calculation per traverse is generally performed, as it is rarely necessary to divide the traverse into multiple segments. The SO<sub>2</sub> emission rate (E) in metric tonnes per day is calculated using the following equation:

$$E = \frac{C_F}{C_F} [\text{SO}_2]_{\text{pl}} \cdot \cos\theta \cdot d_{\text{col}} \cdot v_{\text{wind}} \quad (14)$$

where  $[\text{SO}_2]_{\text{pl}}$  is the average path-length concentration of SO<sub>2</sub> (ppm·m) in the plume for the segment,  $\theta$  (°) is the deviation from perpendicularity of the segment of road with respect to the gas plume and  $d_{\text{col}}$  is the length (m) of a particular segment. For ground-based mobile measurements, the segment width is determined from a map. The term  $v_{\text{wind}}$  is the average windspeed (m s<sup>-1</sup>) and  $C_F$  is a conversion factor changing ppm·m<sup>3</sup> s<sup>-1</sup> into metric tonnes per day (t d<sup>-1</sup>). One ppm·m of SO<sub>2</sub> is one cubic centimetre of SO<sub>2</sub> gas uniformly mixed in one million cubic centimetres of air and viewed by the instrument over an optical path of one metre at a pressure of 101.325 kPa and a temperature of 20°C. Thus, the conversion factor ( $C_F$ ) is derived as follows:

$$C_F = \rho_{\text{SO}_2} \cdot C_{\text{fSTP}} \cdot 0.001 \cdot 10^{-6} \cdot 86,400 = 0.00023 \quad (15)$$

where  $\rho_{\text{SO}_2}$  is the density of SO<sub>2</sub> gas at standard temperature and pressure STP (2.8579691 kg m<sup>-3</sup> at 0°C and 101.325 kPa),  $C_{\text{fSTP}}$  is a correction factor ( $273.15/293.15 = 0.9317755$ ) to change the SO<sub>2</sub> gas density from 0°C to 20°C (273.15 K to 293.15 K), 0.001 converts the kg term in the density to tonnes,  $10^{-6}$  converts ppm to mass units, and 86,400 are the number of seconds in one day. Thus,  $C_F$  is equal to 0.00023008194, with units of t s m<sup>-3</sup> d<sup>-1</sup> ppm<sup>-1</sup>.

The average concentration of SO<sub>2</sub> for the segment ( $[\text{SO}_2]_{\text{seg}}$ ) is calculated from:

$$[\text{SO}_2]_{\text{seg}} = \frac{P_{\text{seg}}}{P_{\text{cal}}} \cdot [\text{SO}_2]_{\text{cal}} \quad (16)$$

where  $[\text{SO}_2]_{\text{cal}}$  is the concentration of the appropriate calibration gas cell in ppm·m,  $P_{\text{cal}}$  is the peak height of the appropriate calibration gas cell in arbitrary units and  $P_{\text{seg}}$  is the average peak height for the segment.

If the average segment peak height is lower than the low calibration peak height, then the low calibration cell should be used in the above calculation. If the average segment height falls between the high and low calibration, then use the average of the two. If average segment height is greater than the high calibration peak height, use the high calibration.