Answers to Review1 of paper "First results of the Piton de la Fournaise STRAP 2015 experiment: multidisciplinary tracking of a volcanic gas and aerosol plume"

1/ Main remarks

Comments from Referee

This paper strongly emphasized the gas composition and flux measurements but results presented somewhat fail to fulfill expectations:
a) portable DOAS measurement is reported in the paper (L31 p4, L19 p7, L6 p9) but no corresponding result presented. Why? Figure 7 even present a transect across the plume. What is the corresponding SO2 flux? Table 1 indicates 6 series of DOAS measurements but why no preliminary results presented ?

Author's response

As indicated in Table 1, the dataset of portable DOAS measurements is much smaller in comparison to the NOVAC dataset, which is discussed in detail in the text. We have added to Table 1 the SO2 fluxes calculated using the Salerno et al., 2009 approach. The (few) available portable data are in reasonable good agreement with NOVAC data, as it can be seen in Figure RC1 below:

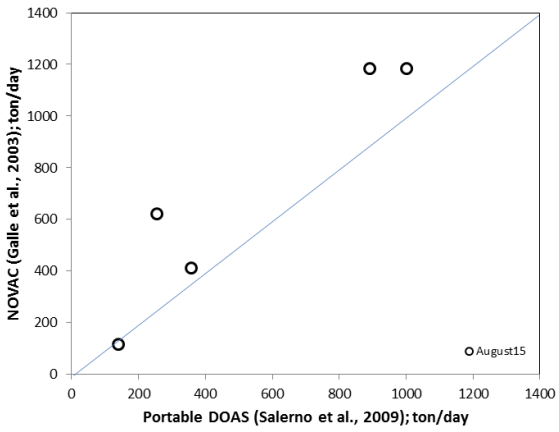

Figure RC1. Comparison of traverse mini-DOAS ('Portable DOAS') measurements with stationary scanning-DOAS ('NOVAC') measurements obtained on August 15 2015, evaluated with the methods mentioned in the manuscript. The correspondence is quite good and within the uncertainty of the measurements.

Comments from Referee

b) August 2015 eruption is described as following 3 different phases, based on results from DOAS stations (L2-6 p10). But the uncertainties associated to these results are significant (Fig.6).
- The eruption phase 1 described as associated to a progressive SO2 flux decreasing trend from 24/08 to 12/09 (L4 p10) is not convincing – this tendency is not clearly

decreasing (Fig.6). These gas flux results (Fig.5 and Fig.5) will gain more strength if portable DOAS results are associated.
- An “accelerating increase of SO2 flux between 13/09 and 18/10” is somewhat exaggerating. According to Fig.6 and accelerating tendency rather commenced in early October. Figure 6 indicates at least two strong degassing phases: from end august to mid-september and from early October to mid-October. Vigorous intermittent SO2 discharges were recorded between
and after these two strong degassing phases.

Author's response

The referee points out correctly that Fig. 6 shows large uncertainty ranges and that, based on this figure, the interpretation of changes of activity seems questionable. However, the best estimate of daily SO_2 emission, on which the interpretation of eruptive activity is based, is that of Fig. 5. The reason why they seem to differ, is that Fig. 6 shows the results of individual scan measurements that detected the plume. A careful uncertainty analysis was performed for each individual scan measurement, because of highly changing measurement conditions. For example, a plume can be observed completely above the horizon in one scan, and then decrease in altitude some minutes later affecting the accuracy of the flux measurement. Presenting all scans with their uncertainty makes look the plot dominated by those measurements with large uncertainty (notice that a single day may have up to ~50 scans), but we think the plot actually shows that the uncertainty varies among measurements and that some may indeed be quite large, presenting a challenge for interpretation. To compute a reasonable estimate of the daily mean value and its standard error (shown in Fig. 5), all valid scan measurements within a day are combined, weighting them according to their individual uncertainties, as explained succinctly in the caption of Fig. 6. By these approach, not only the mean value is more representative of the daily emission, but also the standard error accounts for the fact that the larger the number of validated measurements, the more representative the statistic. In any case, we have remake Fig. 6 changing scale and using scatter points instead of columns, for better readability.
Time evolution of SO_2 fluxes and their correlation with changes in magma bulk composition, lava flux, and other geophysical parameters during the August 2015 eruption has been discussed in detail in Coppola et al., 2017 (EPSL); eruptive phases have been defined using this multidisciplinary approach; their description has been partly modified in this manuscript.

Comments from Referee

c) MultiGAS measurements is outline several time in the paper (L32 p8, L33 p10, L1 p11, L6 p11, L13 p11, L31 p17,. . .) and table indicates a total of around 8h of recording from May to October 2015. But curiously only 2 ratios are provided : H2O/CO2 = 50-240 (L12 p11) and CO2/SO2 <0.6 (L13 p 11).

Author's response

Reported values correspond to the measured ranges, not to two values. Text has been modified accordingly, and mean compositional data for the 2 distinct eruptive phases are now provided.

Comments from Referee

- It is well known that H2O and even CO2 are not easily measured in the plume. What is the error of this ratios ? A figure of the plots should be very informative. - Figure 7 gives concentration results which are not exploitable. The behaviour of H2O, CO2 and SO2 are totally different which may suggest no common source, that is surprising given that some of the measurement are performed close to the vent.

Author's response

Fig. 7 has been modified; in the original version, we wanted to emphasize the measurements of concentrations in situ by helicopter flight, which are informative for the meteorological community. We have now shown a typical ground based measurement performed closed to the vent, showing the occurrence of both correlated and uncorrelated peaks.

Correlated peaks are indicative of a common source (volcanic degassing), while H2O-CO2 peaks (with no corresponding SO2 peak) imply contributions from ambient air (H2O) and/or low-t degassing features (CO2). The error in derived H2O/CO2 ratios is <20% in dense plume conditions, while it can increase up to 50% in dilute plumes, where the volcanic signal becomes limited compared to ambient air levels.

Comments from Referee

- Should we understand that H2O/CO2 and CO2/SO2 ratios are unchanged over the eruptive period ? That would be very surprising given the dynamic of the eruptive activity. Authors should add more results of multiGAS measurements and check the ratio changes which might describe better the eruption dynamic than the SO2 flux from the stationary DOAS.

Author's response

As a general comment, we want to stress that the detailed volcanological interpretation of the full dataset is not the main target of this paper; several other papers (e.g. Coppola et al., 2017) are under preparation, and they permit a complete analysis of each part of the dataset. In this paper, multiGAS data are only presented to give a general idea of the plume composition near the vent and of the bulk fluxes; these parameters are fundamental to model plume ascent and dispersion; detailed discussion of the multiGAS dataset is the topic of a distinct paper (currently under preparation) which integrates a broader geochemical dataset.

Comments from Referee

- L32 p 4 indicates H2S was also measured. But curiously no result mentioned this gas. Is this suggest no H2S in the system ? That would be very surprising.

Author's response

H_2S makes an irrelevant fraction of the S budget in the high-T vent emissions studied here, and was essentially below detection.

2/ Minor remarks

Comments from Referee

- L25 p4: accumulation chamber for CO2 soil flux. Is this instrument deployed ? Not referring to in the rest of the paper. Add reference if developed elsewhere.

Author's response

As indicated in the text, CO_2 fluxes are part of the measurements routinely performed by the OVPF observatory and they are part of the rich dataset acquired during each eruption of Piton de la Fournaise. Their presentation is not relevant here, as in this paper we focus on gas plume emission and dispersion.

Comments from Referee

- L21 p6, delete 2 after August.

Author's response

Thanks, it has been done.

Comments from Referee

- L21 p6, the date format is e.g., 2 August 2015 whilst L22 p6 the format is e.g., August 24, 2015. Harmonize date format throughout the paper.

Author's response

Thanks, it has been done.

Comments from Referee

L21 p6, to the south-southeast ?. . ..to the north ? L22 p6, to the west-southwest? What are these direction referred to ?

Author's response

The previous sentence specified that directions are referred to the Bory crater, we think it is obvious as it is presented.

Comments from Referee

- L31-32 the output budget ? Not calculated in the paper, why? Do add reference if done elsewhere.

Author's response

Budget have been computed. We added new sentences in the new version to discuss these results.

Author's changes in manuscript

In section 3.3 : « Water is recalculated from hygrometric measurements.
Subtraction of the atmospheric background permits the quantification of the elemental molar ratios (e.g. H2O/SO2, CO2/SO2 molar ratios) in the volcanic emissions. Correlation of these ratios with the SO2 fluxes (4.8+/-1.1 kt in May and 33.8+/-7.4 kt in August; Coppola et al., (2017)) measured by DOAS permit here a first estimation of the syn-eruptive fluxes of H2O and CO2 released by the eruptive vent(s). »
In section
« The combination of DOAS and MultiGAS permits to estimate that the May eruption emitted a minimum of 258 kt H2O 4.8 kt SO2 and 0.8 kt CO2, while the August-October eruption erupted 2649 kt H2O, 33.8 kt SO2 and 9.3 kt CO2.»

Comments from Referee

- L12 p9, DOAS sessions are acquired with a high rate – what does it mean by high rate ?

Author's response

Thank you, we have specified the sampling rate of typically 5-10 min.

Comments from Referee

- L25-27 p9, 1870 t/d and 1840 t/d is that same if taking into account the errors. Thus not so sure that highest SO2 emission rate was observed on 20 May – maybe tone down this comparison.

Author's response

On the basis of our analysis, which treats carefully the uncertainty, we found that the mean flux measured on 20 May 2015 was indeed the highest in the record. Fig. 5 shows the respective standard errors for the interested reader.

Comments from Referee

- L31 p9, May SO2 fluxes are not in fig.6, but fig.5 – do modify the sentence.

Author's response

Thank you, the sentence was modified.

Comments from Referee

- L35 p9, add reference to the estimated 24-37 m3/s, or give further details if calculated in this work.

Author's response

The calculation has been performed in this work and the appropriate reference has been included.

Reference:been added.