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Satellite-derived SO_2 flux time-series and magmatic processes during the 2015 Calbuco eruptions

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Quantifying time-series of sulfur dioxide (SO_2) emissions during explosive eruptions provides insight into volcanic processes, assists in volcanic hazard mitigation, and permits quantification of the climatic impact of major eruptions. While volcanic SO_2 is routinely detected from space during eruptions, the retrieval of plume injection height and SO_2 flux time-series remains challenging. Here we present a new numerical method based on forward- and backward-trajectory analyses which enable such time-series to be robustly determined.

Using this technique, we investigated the SO_2 emissions from two sub-Plinian eruptions of Calbuco, Chile, produced in April 2015. We found a mean injection height above the vent of 15 km for the two eruptions, with overshooting tops reaching 20 km. We calculated a total of 300 $\pm$ 65 kt of SO_2 released almost equally during both events, with 160 $\pm$ 30 kt produced by the first event and 140 $\pm$ 35 kt by the second one. From our satellite derived results, we inferred the presence of pre-eruptive exsolved SO_2 for both the eruptions, with the first event richer in pre-eruptive SO_2 than the second one. This hypothesis is supported by melt inclusions measurements of sulfur concentrations in plagioclase phenocrysts and groundmass glass of tephra samples through electron microprobe analysis. We propose that the overpressure caused by the pre-exsolved volatile phase (not only SO_2, but also probably H_2O and CO_2) may have triggered the two sub-Plinian eruptions.

This work demonstrates that detailed interpretations of sub-surface magmatic processes during eruptions are possible using satellite SO_2 data. These novel tools open a new frontier in space-based volcanological research, and will be of great value when applied to remote, poorly monitored volcanoes, and to major eruptions that can have regional and global climate implications through, for example, influencing ozone depletion in the stratosphere and light scattering from stratospheric aerosols.