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Reconstruction of flux and altitude of volcanic SO_2 emissions from satellite observations: implications for volcanological and atmospherical studies.

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Volcanic sulphur dioxide (SO_2) degassing is a crucial indicator of the sub-surface volcanic activity, which is widely used today for volcano monitoring and hazard assessment purposes. Volcanic SO_2 is also important regarding atmospherical studies. More easily detectable from space, SO_2 can be used as a proxy of the presence of ash to anticipate air traffic issues caused by explosive eruptions. Moreover, volcanic SO_2 strongly impacts air quality but also climate following its conversion to radiatively-active sulphate aerosols. However, the accurate assessment of these various impacts is currently hampered by the poor knowledge of volcanic SO_2 emissions, which can substantially vary with time, in terms of flux and altitude.

To fulfil this need, we propose a strategy relying on satellite observations, which consequently allows for monitoring the eruptive activity of any remote volcano. The method consists in assimilating snapshots of the SO_2 load, provided by infrared or ultraviolet satellite observations, in an inversion scheme that involves the use of a chemistry-transport model to describe the dispersion of SO_2 released in the atmosphere. Applied on Eyjafjallajökull (Iceland) and Etna (Italy) eruption case-studies, this procedure allows for retrospectively reconstructing both the flux and altitude of the SO_2 emissions with an hourly resolution. We show the improvement gained in the simulations and forecasts of the location and mass load of volcanic SO_2 clouds using such a detailed reconstruction of emissions.

For calibration-validation purpose, we compared our satellite-derived time-series of the SO_2 flux with ground-based observations available on Etna. This comparison indicates a good agreement during ash-poor phases of the eruption. However, large discrepancies are observed during the ash-rich paroxysmal phase as a result of enhanced plume opacity affecting ground-based ultraviolet spectroscopic retrievals. Therefore, the SO_2 emission rate derived from the ground is underestimated by almost one order of magnitude. This result calls for the necessity to revisit currently available inventories of the global budget of sulfur released by volcanoes, because they heavily rely on ground-based observations. It also shows that volcano observatories cannot rely solely on ground-based spectroscopical observations for the monitoring of ash-rich explosive eruptions.