An integrated study of sulphur dioxide emissions from Tungurahua volcano, Ecuador

Brendan T McCormick[1], Michael Herzog[2], Jian Yang[2], Marie Edmonds[1], Tamsin A Mather[3], Simon A Carn[4], Silvana Hidalgo[5], Baerbel Langmann[6]

[1]Department of Earth Sciences, University of Cambridge, United Kingdom, [2]Department of Geography, University of Cambridge, United Kingdom, [3]Department of Earth Sciences, University of Oxford, United Kingdom, [4]Department of Geological and Mining Engineering and Sciences, Michigan Technological University, United States, [5]Instituto Geofisico, Escuela Politecnica Nacional, Ecuador, [6]Institut fur Geophysik, Universitat Hamburg, Germany

E-mail: mccormickb@si.edu

Tungurahua is a stratovolcano in Ecuador, with a long-term mean SO2 output of 1458 $\pm$ 2026 t/day. Since 2006, SO2 emissions have been continuously monitored by UV DOAS spectrometers of the NOVAC programme. Tungurahua's SO2 emissions have also been observed by the satellite-based UV spectrometer OMI (Ozone Monitoring Instrument). Tungurahua is therefore an ideal location for comparing ground- and satellite-based estimates of volcanic SO2 emissions. Although OMI SO2 retrievals for continuous tropospheric degassing are not yet validated, the dataset represents a large and mostly untapped resource for volcano monitoring, particularly in remote or inaccessible regions.

This study aims to improve agreement between the DOAS and OMI SO2 datasets for Tungurahua, and gain new understanding of why differences arise. Uncertainties affecting comparison between the datasets include: the different natures of the quantities typically measured (flux vs column concentration); the impact of local atmospheric and meteorological conditions (e.g. clouds masking volcanic plumes; humidity and temperature promoting rapid loss of SO2 via oxidation to sulphate or by various wet/dry deposition processes; wind dispersal of plumes); and differences in the spatial/temporal resolution of measurements. We present a novel numerical modelling-based study of volcanic SO2 emissions from Tungurahua using the atmospheric chemistry/transport model REMOTE, which has already been used to investigate post-emission SO2 dispersion from volcanoes in Nicaragua and Indonesia. We also investigate the use of derived fluxes from instantaneous satellite scenes to provide better agreement with ground-based gas emission measurements, and a detailed assessment of the principal errors in each dataset is presented.

Much better agreement between satellite- and ground-based observations of SO2 emission are found when using OMI derived fluxes, rather than mass burdens, for comparison to DOAS-measured fluxes. Where possible therefore, these derived datasets should be used in assessing volcanic SO2 output. Simulations of plume dispersal by the REMOTE model agree broadly with OMI observations. Simulations of daily SO2 mass burden in the model domain record significant variability in the extent of atmospheric plume processing, and this variability shows limited agreement with the OMI mass burden time series. This suggests that simulations of processing may be able to predict days on which potential for satellite-based detection of SO2 is improved or limited. Further simulations are proposed to address this further. Calculated SO2 loss rates are in agreement with previous work at similar volcanoes, and the relative importance of oxidation, deposition and transport processes in the removal of SO2 are assessed. Diurnal variations in these processes do not appear to be significant.