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# A new $SO_2$ emissions budget for Anatahan volcano (Mariana Islands) based on ten years of satellite observations

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Satellite remote sensing offers great potential for the study of sulphur dioxide ($SO_2$) gas emissions from volcanoes worldwide. Anatahan is a remote volcano in the Mariana Islands, SW Pacific. Existing $SO_2$ emissions data from Anatahan, from ground-based UV spectrometer measurements, place the volcano among the largest natural $SO_2$ sources worldwide. However, these measurements are limited in number and only available from intervals of eruptive activity. Activity varies widely at Anatahan: over the past decade, records held in the Smithsonian Institution Global Volcanism Program Volcanoes of the World database describe the alternation of intense eruptions with long intervals of quiescence, where much lower intensity activity took place.

We present ten years of satellite-based measurements of $SO_2$ in the atmosphere over Anatahan, using data from the UV spectrometers OMI, GOME-2, and SCIAMACHY, and the IR spectrometer AIRS. We find Anatahan's emissions to be highly variable both within and between intervals of eruption and quiescence. We demonstrate a close agreement between trends in $SO_2$ emission evident from our remote sensing data and records of activity compiled from a range of other sources and instruments, across daily to annual temporal scales. Mean eruptive $SO_2$ emissions at Anatahan are $\sim$6400 t/d, and range from <1000 to >18000 t/d. Quiescent emissions are below our instrument detection limits and are therefore unlikely to exceed 150-300 t/d. Overall, accounting for both eruptive and quiescent emissions, we calculate a revised decadal mean $SO_2$ emission rate of 1060-1200 t/d. We further calculate a total decadal $SO_2$ yield from Anatahan of 4-5 Mt, significantly lower than the 17-34 Mt calculated if ground-based campaign data are used in isolation. The use of isolated measurements to extrapolate longer term emissions budgets is subject to clear uncertainty, and we argue that our satellite observations, covering a longer interval of Anatahan's history, are better suited to such calculations, and do not require widespread extrapolation. We propose that the use of multi-year satellite datasets, ideally in conjunction with key ground-based data and longterm records of activity, can make major improvements to existing emissions budgets at Anatahan and other volcanoes worldwide.