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Satellite-based assessment of global volcanic degassing

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Satellite observations by hyperspectral ultraviolet (UV) and infrared (IR) sensors over the past decade have afforded tremendous insights into the spatial and temporal variability of global, subaerial volcanic degassing. Commonly cited volcanic emissions inventories are still largely based on infrequent ground-based gas measurements and have not been updated in recent years. We use ~10 years of operational sulfur dioxide (SO_2) measurements by the Ozone Monitoring Instrument (OMI) on NASA's Aura satellite to assess the spatial and temporal variability of volcanic SO_2 degassing between 2004 and 2014. We focus on passive (lower tropospheric) degassing, which is the major component of total volcanic emissions to the atmosphere on a time-averaged basis, but poorly constrained. Synergy between OMI and infrared (IR) satellite sensors (e.g., Aqua/AIRS) in the A-Train satellite constellation provides constraints on the vertical distribution of SO_2, which is critical for assessing the potential climate impacts of volcanic emissions. OMI measurements are most sensitive to SO_2 emission rates on the order of ~1000 tons/day or more, and thus the satellite data provide new constraints on the location and persistence of major volcanic SO_2 sources. Time-averaging of OMI SO_2 data provides information on weaker SO_2 degassing. We find that OMI has detected non-eruptive SO_2 emissions from at least ~60 volcanoes since 2004. Results of our analysis reveal the emergence of several major tropospheric SO_2 sources that are not prominent in existing inventories (Ambrym, Nyiragongo, Turrialba), the persistence of some well-known sources (Etna, Kilauea) and a possible decline in emissions at others (e.g., Lascar). The OMI measurements provide particularly valuable information in regions lacking regular ground-based monitoring such as Indonesia, Melanesia and Kamchatka. We describe how the OMI measurements of SO_2 total column, and their probability density function, can be used to infer SO_2 emission rates for compatibility with existing emissions data and assimilation into chemical transport models. The satellite-derived SO_2 emission rates are in good agreement with ground-based measurements from frequently monitored volcanoes (e.g., from the NOVAC network), but differ for other volcanoes. We conclude that some ground-based SO_2 measurements may be biased high if collected during periods of elevated unrest, and hence may not be representative of long-term average emissions. Overall, the satellite data suggest that currently accepted estimates of the total global volcanic SO_2 flux are the correct order of magnitude, but likely show significant temporal variability. Our analysis underlines the critical role of hyperspectral UV satellite observations in assessing global volcanic degassing rates, particularly for remote and/or unmonitored volcanoes.