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Estimation of the vertical profile of sulfur dioxide injection into the atmosphere by a volcanic eruption using satellite column measurements and inverse transport modeling

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An analytical inverse modeling method has been developed to estimate the vertical emission profile of SO_2 resulting from volcanic eruptions using satellite-observed total SO_2 columns and an atmospheric transport model (FLEXPART). It utilizes the fact that winds normally change with altitude and, thus, the plume position and shape depend on the altitude of the emissions. The method finds the vertical emission distribution with which the model can optimally reproduce the shape and horizontal position of the observed SO_2 plume. We have used the eruption of Jebel at Tair on 30 September 2007 for which a comprehensive observational data set from various satellite instruments (AIRS, OMI, SEVIRI, CALIPSO) could be compiled. Using satellite data from the first 24 hours after the eruption for the inversion, we found an emission maximum near 16 km above sea level (asl) and a secondary maximum near 12 km asl. Based on this inversion result, the overall plume dispersion over the following week as observed by OMI could be simulated very well. Also, the altitude of the simulated plume is in agreement with CALIPSO observations of stratospheric aerosol. The inversion result was rather robust. Even when using only SEVIRI data from the first 15 hours after the eruption, the emission profile was reasonably accurate. Using our method, the emission altitudes of volcanic eruptions can be estimated with great accuracy. Therefore the method would be suitable for real time predictions of the threat posed by volcanic ash for commercial air traffic.