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Source mass eruption rate retrieved from satellite-based data using statistical modelling

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Ash clouds emitted during volcanic eruptions have long been recognized as a major hazard likely to have dramatic consequences on aircrafts, environment and people. Thus, the International Civil Aviation Organization (ICAO) established nine Volcanic Ash Advisory Centers (VAACs) around the world, whose mission is to forecast the location and concentration of ash clouds over hours to days, using volcanic ash transport and dispersion models (VATDs). Those models use input parameters such as plume height (PH), particle size distribution (PSD), and mass eruption rate (MER), the latter being a key parameter as it directly controls the amount of ash injected into the atmosphere. The MER can be obtained rather accurately from detailed ground deposit studies, but this method does not match the operational requirements in case of a volcanic crisis. Thus, VAACs use empirical laws to determine the MER from the estimation of the plume height. In some cases, this method can be difficult to apply, either because plume height data are not available or because uncertainties related to this method are too large. We propose here an alternative method based on the utilization of satellite data to assess the MER at the source, during explosive eruptions. Satellite-based techniques allow fine ash cloud loading to be quantitatively retrieved far from the source vent. Those measurements can be carried out in a systematic and real-time fashion using geostationary satellite, in particular. We tested here the relationship likely to exist between the amount of fine ash dispersed in the atmosphere and of coarser tephra deposited on the ground. The sum of both contributions yielding an estimate of the MER. For this purpose we examined 19 eruptions (of known duration) in detail for which both (*i*) the amount of fine ash dispersed in the atmosphere, and (*ii*) the mass of tephra deposited on the ground have been estimated and published. We combined these data with contextual information that may influence the statistical relationship such as the magma composition or the existence of phreatomagmatism. In order to infer the relationship between ash content in the atmosphere and the amount of tephra on the ground, we used advanced statistic modelling using model selection, with AIC-type (Akaike Information Criterion) penalization, and classification. First we show that a reliable statistical relationship does exist between atmospheric fine ash and tephra fall deposits. Then we show that magma composition does have an effect on this relationship. It follows a power function in the form $S_1 = c_0 {S_2}^{c_1(P_n)} H^{c_2}$ having a coefficient of determination r^2=0.91 and a prediction error of 2.16 at a confidence level of 95%. S_1 is the mass of tephra fall deposits and S_2 is the fine ash cloud mass as retrieved from satellite measurements. H is the plume height, c_0 and c_2 are constant coefficients while c_1 is variable and depends on the magma composition type ($P_{n=1:3}$). This method greatly improves the prediction capability of the source MER as compared to the one based on the plume height solely. If available in real-time, satellite data might be advantageously used as a proxy by the VAACs, to derive key source parameters such as the MER.