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Ground-based radar monitoring of volcanic ash: a novel approach for the estimation of the bulk microphysical parameters

Gianfranco Vulpiani (1) and Maurizio Ripepe (2)

(1) Department of Civil Protection - Presidency of the Council of Ministers, Rome, Italy (gianfranco.vulpiani@protezionecivile.it), (2) Department of Earth Science, University of Florence, Florence, Italy

The detection and quantitative retrieval of ash plumes is of significant interest due to the environmental, climatic, and socioeconomic effects of ash fallout which might cause hardship and damages in areas surrounding volcanoes, representing a serious hazard to aircrafts. Real-time monitoring of such phenomena is crucial for initializing ash dispersion models. Ground-based and space-borne remote sensing observations provide essential information for scientific and operational applications. Satellite visible-infrared radiometric observations from geostationary platforms are usually exploited for long-range trajectory tracking and for measuring low-level eruptions. Their imagery is available every 10–30 min and suffers from a relatively poor spatial resolution.
Moreover, the field of view of geostationary radiometric measurements may be blocked by water and ice clouds at higher levels and the observations' overall utility is reduced at night. Ground-based microwave weather radars may represent an important tool for detecting and, to a certain extent, mitigating the hazards presented by ash clouds. The possibility of monitoring in all weather conditions at a fairly high spatial resolution (less than a few hundred meters) and every few minutes after the eruption is the major advantage of using ground-based microwave radar systems. Ground-based weather radar systems can also provide data for estimating the ash volume, total mass, and height of eruption clouds. Previous methodological studies have investigated the possibility of using ground-based single- and dual-polarization radar system for the remote sensing of volcanic ash cloud.
In the present work, methodology was revised to overcome some limitations related to the assumed microphysics. New scattering simulations based on the T-matrix solution technique were used to set up the parametric algorithms adopted to estimate the mass concentration and ash mean diameter. Furthermore, because quantitative estimation of the erupted materials in the proximity of the volcano's vent is crucial for initializing transportation models, a novel methodology for estimating a volcano eruption's mass discharge rate based on the combination of radar and a thermal camera was developed. We show how it is possible to calculate the mass flow using radar-derived ash concentration and particle diameter at the base of the eruption column using the exit velocity estimated by the thermal camera. The proposed procedure was tested on four Etna eruption episodes that occurred in December 2015 as observed by the available network of C and X band radar systems. The results are congruent with other independent methodologies and observations . The agreement between the total erupted mass derived by the retrieved MDR and the plume concentration can be considered as a self-consistent methodological assessment. Interestingly, the analysis of the polarimetric radar observations allowed us to derive some features of the ash plume, including the size of the eruption column and the height of the gas thrust region.