EGU22-10650, updated on 19 Aug 2022
https://doi.org/10.5194/egusphere-egu22-10650
EGU General Assembly 2022

Volcanic cloud satellite retrieval: an infrared and millimeter-wave multisensor approach using statistical and machine learning methods

Francesco Romeo[1], Luigi Mereu[3,4], Simona Scollo[4], Mario Papa[2], Stefano Corradini[4], Luca Merucci[4], and Frank Silvio Marzano[2,3]
[1]I3S Sapienza University of Rome, Rome, Italy
[2]DIET Sapienza University of Rome, Rome, Italy
[3]Centre of Excellence CTEMPS, University of L'Aquila, L'Aquila, Italy
[4]OE – Istituto Nazionale di Vulcanologia e Geofisica (INGV)

Volcanic eruptions are one of the most impressive natural phenomena to which our planet is subjected and which over the years have influenced human life. During explosive eruptions a great amount of volcanic particles are ejected in atmosphere and can remain suspended for days, also creating aviation traffic impairments.

Orbiting satellite observations can provide a large amount of daily data. The global perspective offered by Geosynchronous Earth Orbit (GEO) and Low Earth Orbit (LEO) satellite systems is of vital importance for the monitoring of volcanoes, especially those in remote and inaccessible areas. Data from LEO satellite visible-infrared (VIS-IR) spectroradiometers (e.g., VIIRS, AVHRR), but also from microwave radiometers (MHS, ATMS), can be used. Although the LEO thermal-infrared (TIR) data analysis represents the classic approach in the study of volcanic eruptions, given their remarkable spatial resolution and sensitivity to ash clouds, their brightness temperature (BT) difference signatures saturate because of large amount of tephra mass as well as the presence of volcanic particles having sizes bigger than 10 μm within the expanding plume.

Microwave (MW) and millimeter (MMW) passive sensors can be also exploited because they are more sensitive to larger tephra particles (i.e., sizes bigger than 10-100 μm) so that the near-source plume does not typically extinguish the MW and MMW signals, especially in the first hours after the eruptive event. Satellite-based detection of volcanic eruptions, using infrared radiometric data from LEO spectroradiometers, may lead to an ambiguous detection in the proximity of the volcanic vent during sub-Plinian volcanic events. The thermal-infrared (TIR) brightness-temperature difference signatures saturate because of the large tephra particle within the expanding plume. In this respect, the use LEO spaceborne millimeter-wave (MMW) radiometric observations can help since plumes at millimeter wavelength are less optically opaque than at micron ones.

In order to demonstrate this MMW-TIR synergy, we show the analysis of the 2014 Kelud and 2015

Calbuco eruption case studies, considering LEO radiometric measurements and algorithms based on physical-statistical approaches as well as machine learning techniques. Eruptions of the Etna volcano in 2018 and 2021 are also considered to evaluate the detection capability of TIR methods. Results are compared with literatures in terms of volcanic cloud mapping as well as with available other validated satellite estimates for the tephra columnar loading in the near source and distal areas. Detection split windows approaches are compared with random forest (RF) models. During the learning phase, the RF models were trained to give more importance to the false alarms. The mass loading retrieval is done by inverting the forward problem. Effective radius and mass loading are two related quantities. Due to this aspect, a neural network model is developed to solve a multiple regression problem.