Volcanic clouds monitoring: a systematic review

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Introduction

Volcanic Clouds impose a serious risk to air traffic, as well as to public health, infrastructures and various economic sectors [1,2]. Therefore, the determining eruptive source parameters (*e.g.* erupted volume, plume height, mass eruption rate) is crucial to the characterization of eruption dynamics and the assessment of associated hazards [3].

There is a considerable number of EO satellites carrying sensors with the capability of detecting and measuring volcanic clouds and in recent times, EO sensors have become a regular tool tom monitor and track of volcanic clouds as well retrieve their physical parameters provide alert information.

This works purpose is a literature review to understand how Earth Observation (EO) satellite sensors are used to detect, monitor and track ash and SO2 plumes during volcanic eruptions. This review seeks to characterize the different sensors and algorithms advantages, and limitations.

Methodology

To identify the relevant scientific work already published on volcanic clouds detection, monitoring , was carried out a systematic literature review of academic articles indexed on the Web of Science using the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement as a guideline (fig.1) [4].The search parameters used were keywords chosen based on the review topic.

They were combined as follows: "Volcanic cloud" OR "Volcanic plume" OR "Volcanic Column" AND "Ash plume" OR "Ash cloud" OR "plume" AND "Remote Sensing" OR "Satellite" AND "Monitoring" AND "Eruptive Source Parameters" OR "SO2 mass Flux" OR "SO2 Flux". Only articles published in peer-reviewed journals between January 1st, 2010, to September 30th, 2022, were analyzed.

Knowing the goal of this work is to examine remote sensing approaches for detecting and monitoring volcanic clouds in order to estimate eruption parameters, only articles that included the following criteria were chosen: (1) Articles containing only ash plume retrievals, SO2, or a combination of the two; (2) Articles that use satellite remote sensing data retrieval methods for volcanic cloud monitoring.

Based on this parameterization, the selection presented in figure 1 was made, resulting in a total of 53 articles for the final analysis.

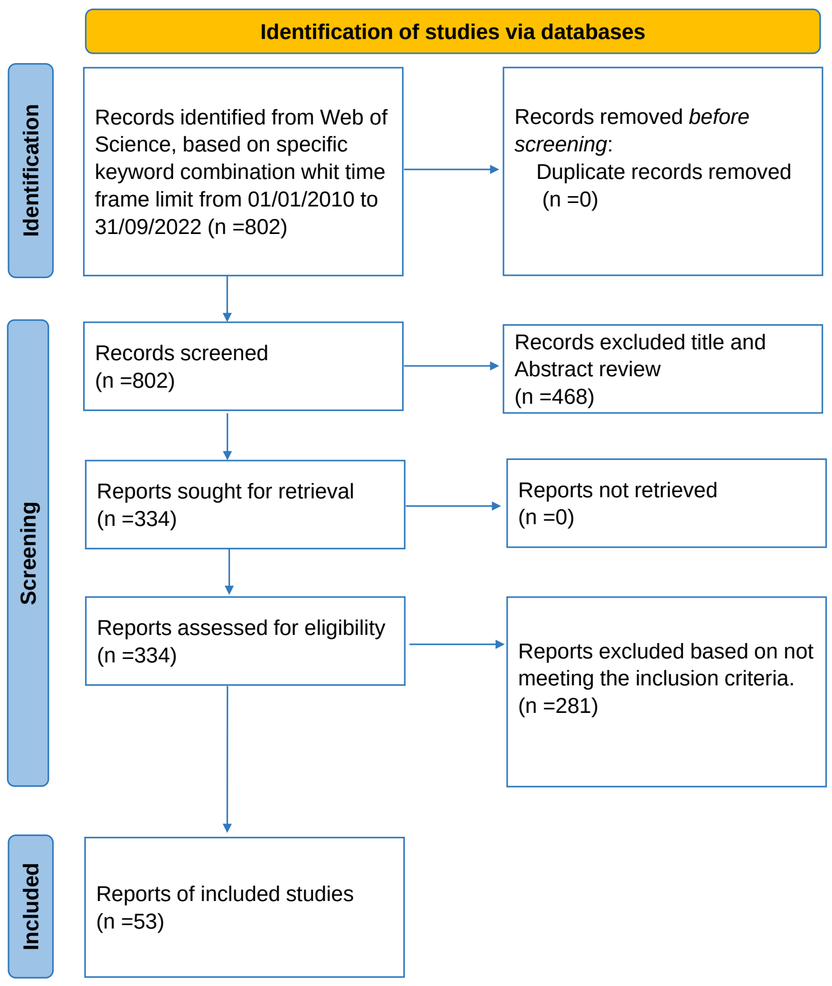

Figure 1. Systematic review procedure for article.

Results

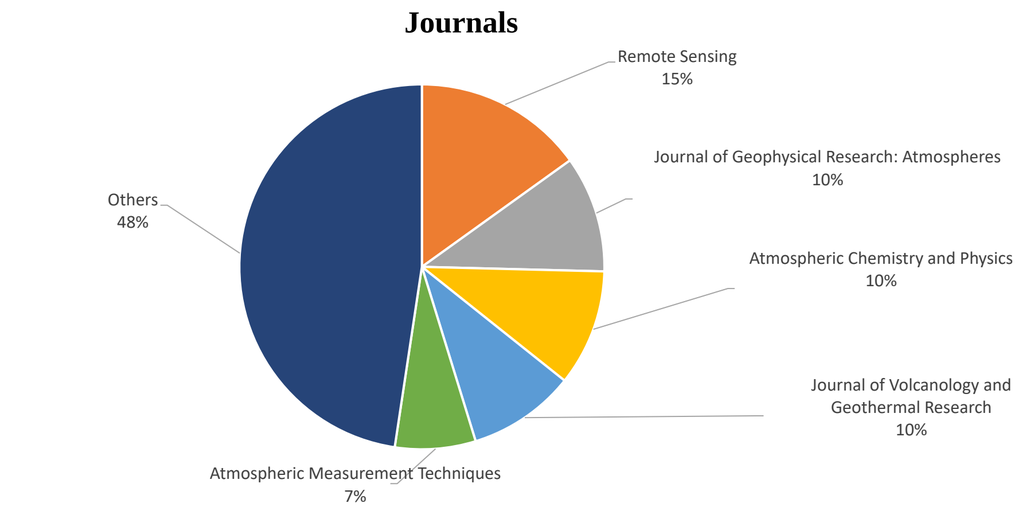

Figure 2. Distribution according to scientific peer-reviewed journals (top 5 highlighted).

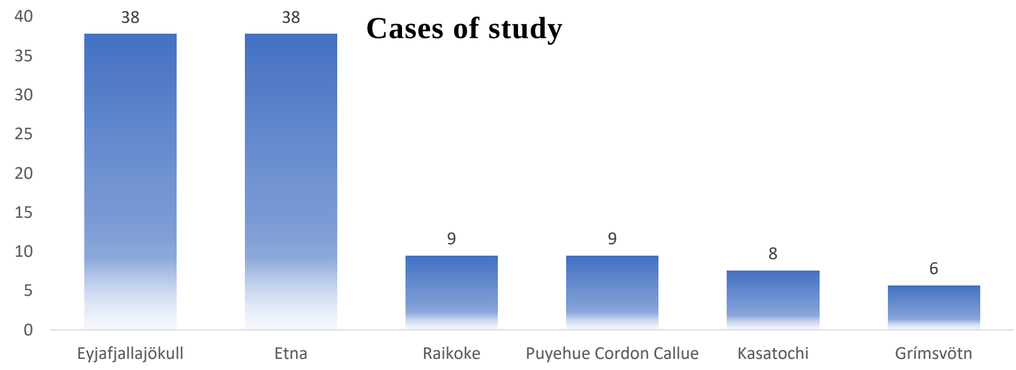

Figure 3. Total percentage (%) of each volcano is mentioned (top 6 highlighted).

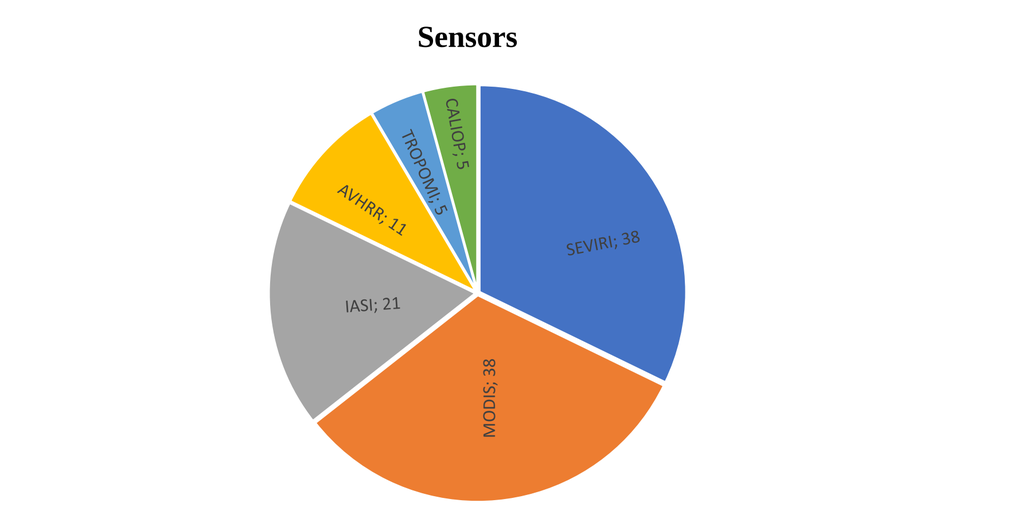

Figure 4. Distribution according to Sensors (top 6 highlighted).

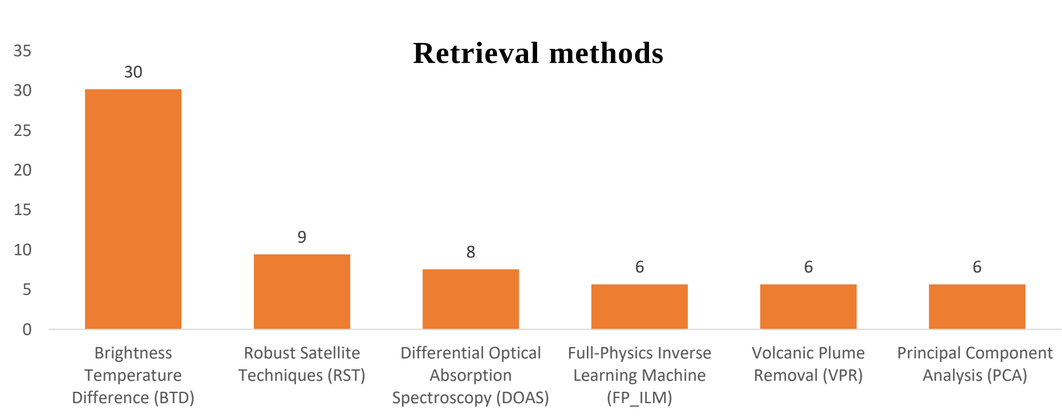

Figure 5. Retrieval algorithms for ash and SO_2(top 6 highlighted).

From this search, 53 papers were chosen based on the use of satellites to detect and monitor volcanic clouds . The top-5 journals account for 52% of all papers published, with Remote Sensing being the one with more publications. The Eyjafjallajökull 2010 eruption alone was on represented 38 of the study cases and is one of the most well-documented eruptions. Etna studies represent several eruptions and account also 38 of the total case studies.

This review revealed that optical sensors SEVIRI and MODIS (fig.4) are commonly used sensors because of their availability and near real-time capabilities. CALIOP is always used when available because of his high spatial and vertical resolutions The traditional brightness temperature difference (BTD) [5] is the most used approach to detect and retrieve volcanic clouds parameters despite its limitations (fig.5) More recent methods such RST [6] and PCA [7] can overcome some of the limitations of BTD eliminating the need for fixed thresholds and showing better accuracy.

Hyperspectral sensors, such as IASI and TROPOMI, are commonly utilized for SO_2 detection and estimation. Limitations related to scattering, which occur during cloudy conditions, make accurate measurements difficult or impossible under extreme cloudy conditions. Even though DOAS [8] is one of the most used methods, other methods like as FP_ILM [9] and COBRA [10] have produced excellent results, particularly in terms of scattering reduction.

Conclusions

- Etna and Eyjafjallajökull eruptions are important case studies for volcano cloud monitoring.
- Satellites are crucial for cost-effective and efficient monitoring of remote areas in near-real-time, improving the accuracy of the input parameters of the dispersion models.
- Despite advancements in retrieval techniques and equipment, ash parameters determination such as particle size distribution, is one of the biggest limitations of the methods.
- To overcome the limitations and increase the efficiency of ash and SO2 retrieval in remote sensing applications, more research and development are necessary.

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