Volcanic Clouds Products

(part of WP9)

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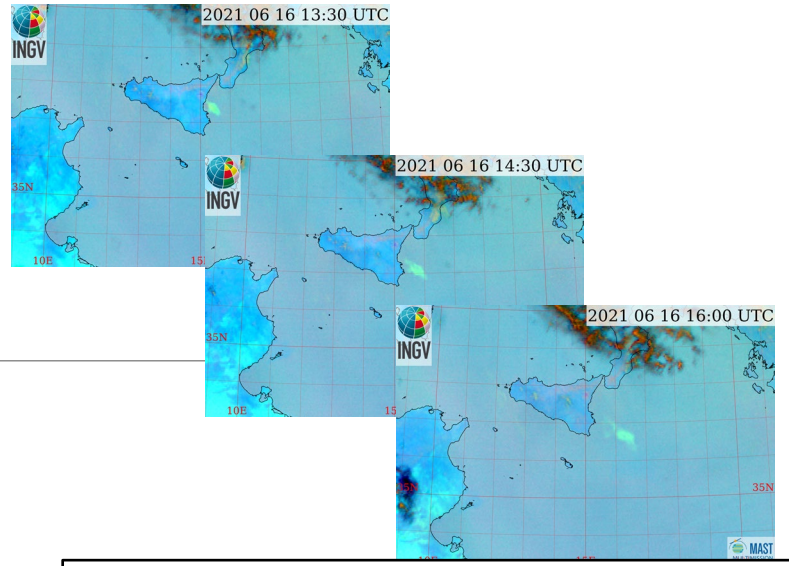
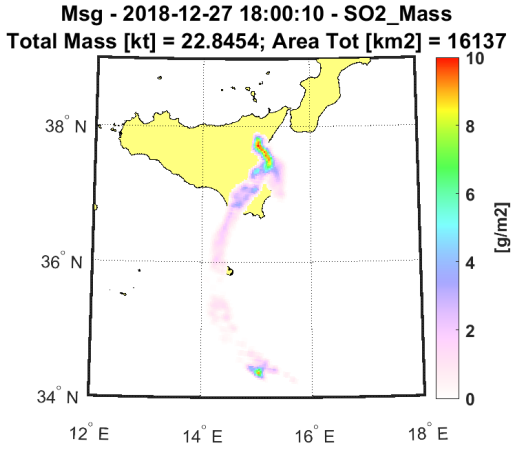
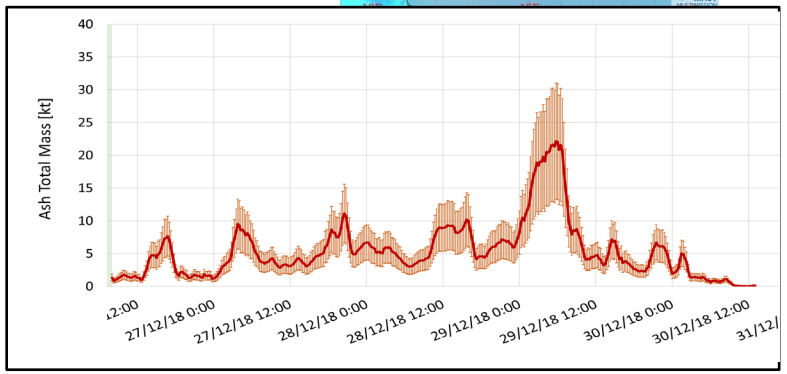
General Description (Objectives)



- **Detection and retrievals of volcanic clouds products**:
  - Volcanic Clouds *Detection* and *Height* retrievals
  - *Ash* and *Ice* characterization
    (*mass, optical thickness and effective radius*)
  - *SO_2 mass*





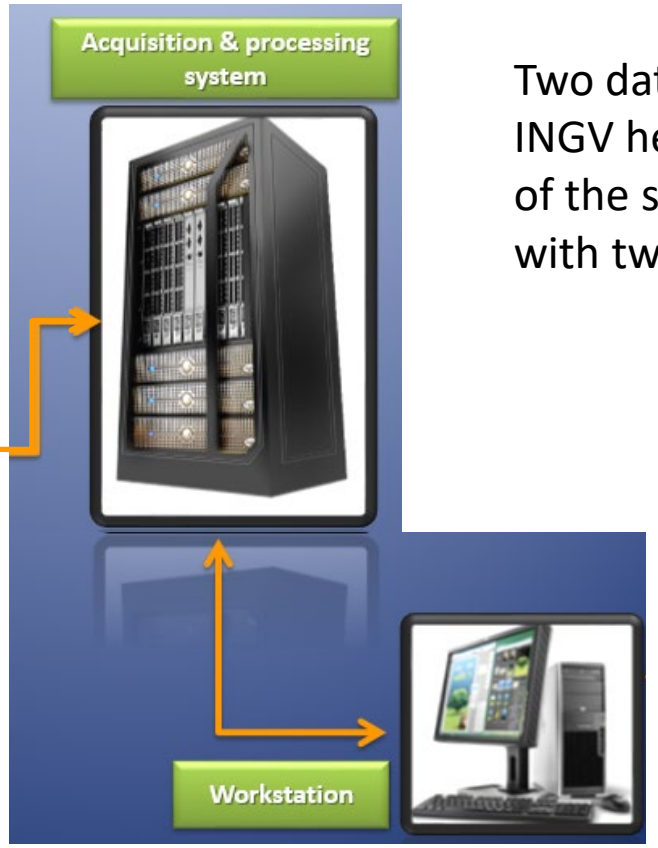
- **Satellite systems considered:** geostationary (SEVIRI) and polar (MODIS, VIIRS, SLSTR)
- The quantitative retrievals are achieved using the **Volcanic Plume Retrieval (VPR) approach** *[Pugnaghi et al, 2013; Guerrieri et al, 2015; Pugnaghi et al. 2016]* which, exploiting the use of **infrared channels centered at 8.6, 11 and 12** μm, allows the monitoring of volcanic clouds both day and night
- Currently, the products are generated on demand for internal (INGV) and external (DPC) users.

Progress Description (State of the Art)

The satellite data are acquired, in real time, from the Multimission Acquisition SysTem (MAST). MAST has been improved by the complete redundancy.

MAST MULTIMISSION ACQUISITION SYSTEM

(Stelitano et al., 2020)



Two data archiving servers were installed at the INGV headquarters in Rome and the installation of the second antenna was completed together with two other satellite receivers.

MAST is now ready for the acquisition and processing of data from the instruments on board the Meteosat Third Generation (MTG) geostationary satellite launched the 13 December 2022.

Data Assimilation of Volcanic Ash Clouds

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General Description (Objectives)

Development of an automated **VONA-based** workflow for **probabilistic real-time ash forecasting** including **Data-Assimilation (DA)** of satellite retrievals of volcanic clouds.

Workflow structure:

1. Activation in case a **RED VONA** reporting ash emission is issued.
2. **Ensembles** of numerical simulations are performed based on the information from the VONA (eruption time and column height) and predefined eruption scenarios.
3. **Probabilistic forecasts** of ash dispersal and fallout are produced and released in real time.
4. Forecasts are **updated** in real-time if:
   - **satellite retrievals** of the volcanic ash cloud are available. In this case algorithms of DA are applied to improve the quality of the numerical forecasts,
   - **new VONAs** (RED and ORANGE) with updated information on the eruption activity (e.g. a change in column height or end of ash emission) are released.

Progress Description

- A prototype of a DA scheme was developed and tested at Mt. Etna case study [1].
- The VONA-based real-time workflow was developed and tested during the 2020-2021 eruption activity of Mt. Etna [2]
- We are working on merging the two workflows into one tool

References

1 Pardini, F., Corradini, S., Costa, A., Esposti Ongaro, T., Merucci, L., Neri, A., ... & de'Michieli Vitturi, M. (2020). Ensemble-based data assimilation of volcanic ash clouds from satellite observations: application to the 24 December 2018 Mt. Etna explosive eruption. *Atmosphere*, *11*(4), 359.

2 Pardini, F., de'Michieli Vitturi, M., Andronico, D., Esposti Ongaro, T., Cristaldi, A., & Neri, A. (2022). Real-time probabilistic assessment of volcanic hazard for tephra dispersal and fallout at Mt. Etna: the 2021 lava fountain episodes. *Bulletin of Volcanology*, *85*(1), 6.

Volcanic hazard monitoring from space (part of WP9)

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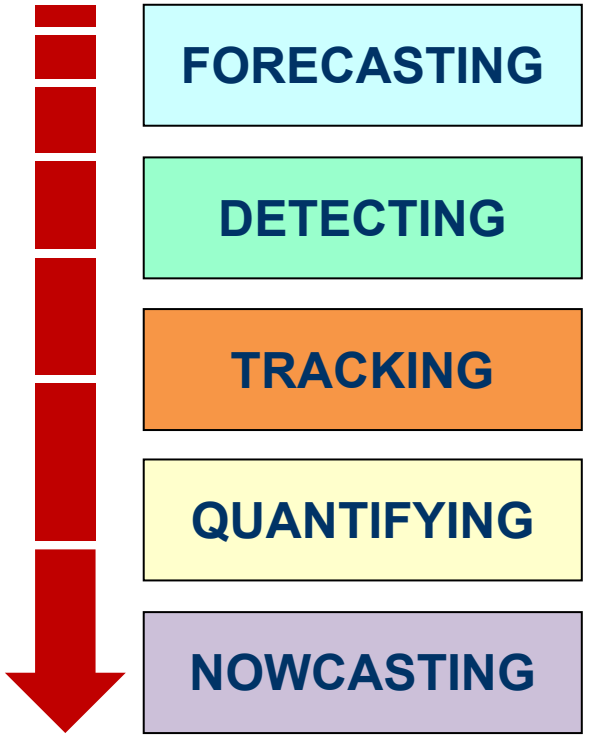
INGV – ETNA VOLCANO OBSERVATORY (EVO), LABORATORY OF TECHNOLOGIES FOR VOLCANOLOGY (TECHNOLAB)

General Description (Objectives)

Operational monitoring centers like the Etna Volcano Observatory (EVO) are nowadays heavily reliant on remote sensing data to provide time-critical hazard information. The major applications of satellite data are in identifying potential eruption indicators as an aid for **forecasting** unrest, **detecting** the onset of eruptive activity that is associated with increased hazards, and **tracking** the evolution of ongoing eruptions watching for changes in the conditions that may result in new hazards. The paroxysmal activity at Etna volcano during 2020–2022 offers an excellent example of the importance of remote sensing datasets for forecasting, detecting, and tracking eruptions.

We aim at extending the use of satellite data in volcanology for **quantifying** and **nowcasting** eruptive activity. For this task, we are building a Web platform to improve the volcano hazard monitoring using Artificial Intelligence (AI) applied to multispectral satellite imagery.

Currently, the products are generated on demand for internal (INGV) and external (DPC) users.



Flow chart of Web platform

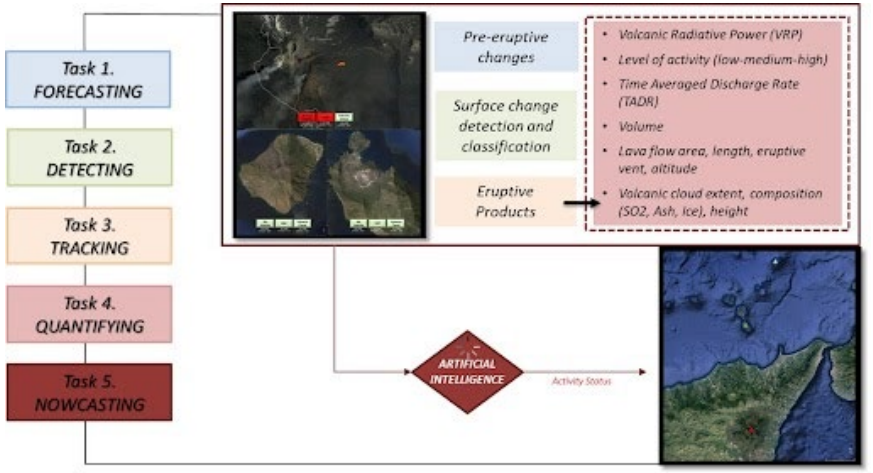
Progress Description

We are developing a Web platform based on AI techniques for satellite data processing to build a better understanding of volcanic hazards. The platform includes 5 modules:

FORECASTING - Deep Learning (DL) to extract pre-eruptive changes in land surface temperatures by using the spatial information over several decades.

DETECTING – Transfer Learning and Ensemble Learning to identify the onset and the type of volcanic activity with short training times and high accuracy.

TRACKING – Machine Learning (ML) to discriminate between the spectral features of volcanic products and the background.



Modular scheme of Web platform

QUANTIFYING – Super-resolution DL to improve the quantitative estimation of features characterizing volcanic products for hazard evaluation.

NOWCASTING - Data-driven models will capture spatiotemporal features for short-term prediction of the evolution of volcanic activity.

Remote Ground-based observation of volcanic degassing (part of WP9)

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1:ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA, OSSERVATORIO ETNEO

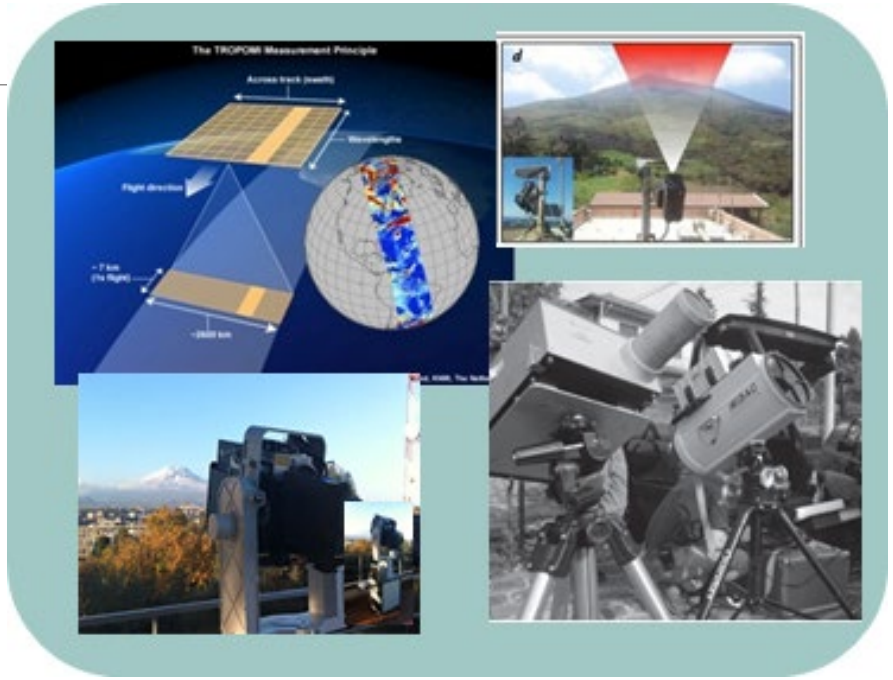
2:ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA, SEZIONE DI BOLOGNA

3:ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA, OSSERVATORIO NAZIONALE TERREMOTI

General Description

Data from Earth observation satellites (EO) is constantly increasing in both spatial and temporal resolution, underpinning their leading role in decision-making by institution such as monitoring and surveillance of natural hazards. Therefore, End-users need to be confident in the quality reliability, accurateness of the inverted products.

CALibration and VALidation (CALVAL) is quality control process, in which inverted data are aligned with physical standards as to deliver processing performance. CALVAL exploits the link between EO-derived data with those observed on the ground by sensors and infrastructures. A successful CALVAL process require a careful plan which involve several steps.

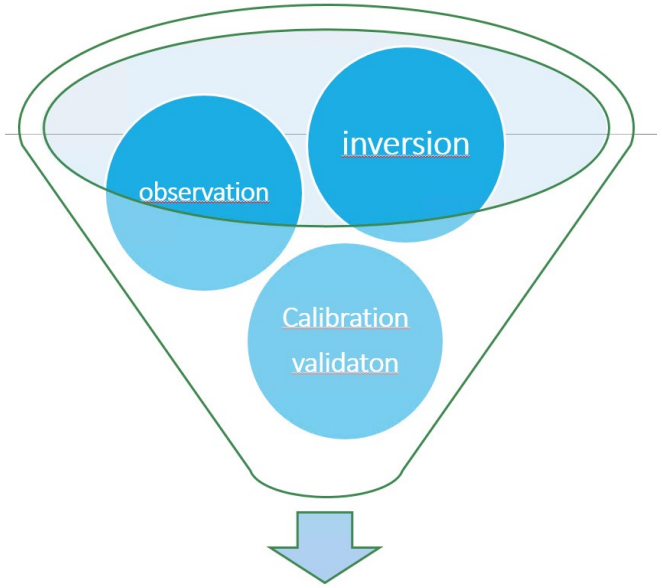


In this module, we carrying out CALVAL quality process of volcanic degassing and ash in volcanic plumes in both passive and active volcanic stages. This deliver the validation of algorithms, and models exploited to derive parameters and data of volcanic products.

Progress Description

CALVAL in volcanic plumes

- **OBSERVATIONS:**
  - multi-platform space-derived SO_2 with ground-based FLAME-DOAS networks and traverses method
  - Cross- integration of SO_2 observed from ground-based UV and TIR Cameras
  - Sulphate and Chlorine space-derived products with ground-based FTIR
  - Volcanic ash detection using ground-based RADAR and lidar systems
  - Plume height with visible camera arrays
- **INVERSION:** Retrieval procedures of observed data from space and ground
- **VALIDATION/CALIBRATION:** cross-integration and comparison of inverted data as to improve algorithms of both space and ground retrievals and calibrate procedure
- **ESTIMATION:** quantitative estimation of volcanic products for hazard evaluation and short-long term forecasting of escalating volcanic eruption and sin-eruptive style changes.



Volcanic products

ON GOING:

- Cross-validation of SO_2 observed during the 2021-2022 lava fountain of Mt. Etna from TROPOMI and SEVIRI with those measured from ground FLAME DOAS scanning spectrometers
- Cross-validation of SO_2 observed by ground UV and TIR cameras and TROPOMI at Sambacaya (Perù)
- Analysis of Lidar data collected during some Etna explosive events and field surveys in Stromboli
- Realization of a free-available database which includes calibrated visible images at Etna volcano