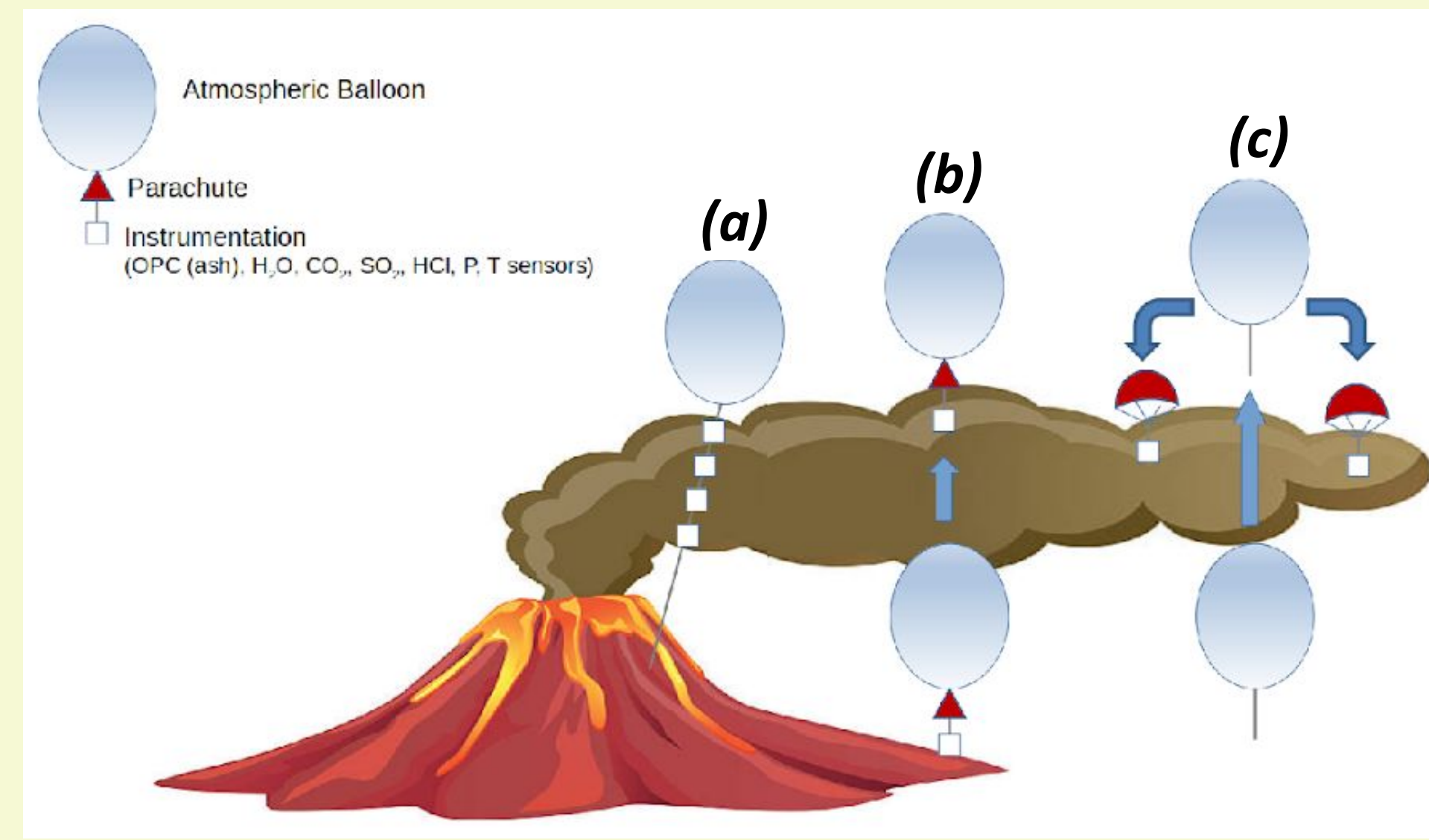


Volcanic plume gases and particles characterization using sounding balloons: the VOLANDO project



Corradini S.^(I), Marcuccio S.^(II), Biondi R.^(III), Ciancitto F.^(I), Filippeschi A.^(II), Giudice G.^(I), Gemignani M.^(II),
Guerrieri L.^(I), Marsili I.^(II), Merucci L.^(I), Naranjo C.^(I), Scollo S.^(I), Stelitano D.^(I)

[1] Volcanic plume characterization using sounding balloons The PRIN-VOLANDO project



- (a) Tethered Balloon
- (b) Free-flying balloon
- (c) Free-flying balloon with dropping volcanosondes

VOLANDO is a PRIN (Progetti di Rilevante Interesse Nazionale) project financed by European Union – Next generation EU (Missione 4 Componente 1 CUP D53D23004910006). It started in September 2023 with a duration of 2 years.

In this project, three balloon borne systems, equipped with different instrumentations for ash and gas measurements, are developed. A customized “volcanosonde” sensor package is designed, manufactured and airlifted by sounding balloons to provide a vertical profiles and time series of the species present in the volcanic plume. This will allow us to make a precise characterization of the volcanic cloud structure, ash and gases content, thus to improve and validate satellite, ground based and dispersion models products.

[2] Volcanosonde Development

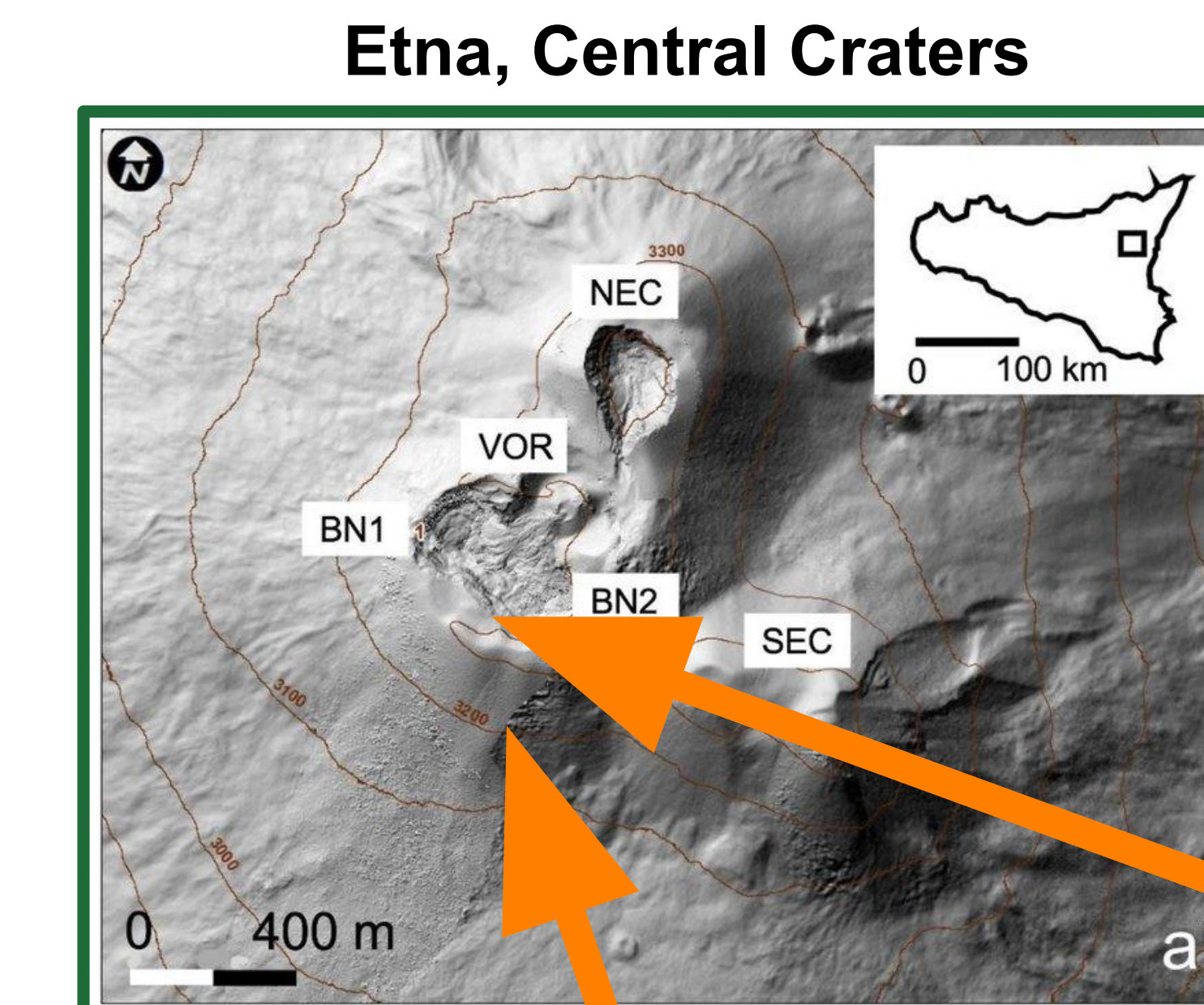
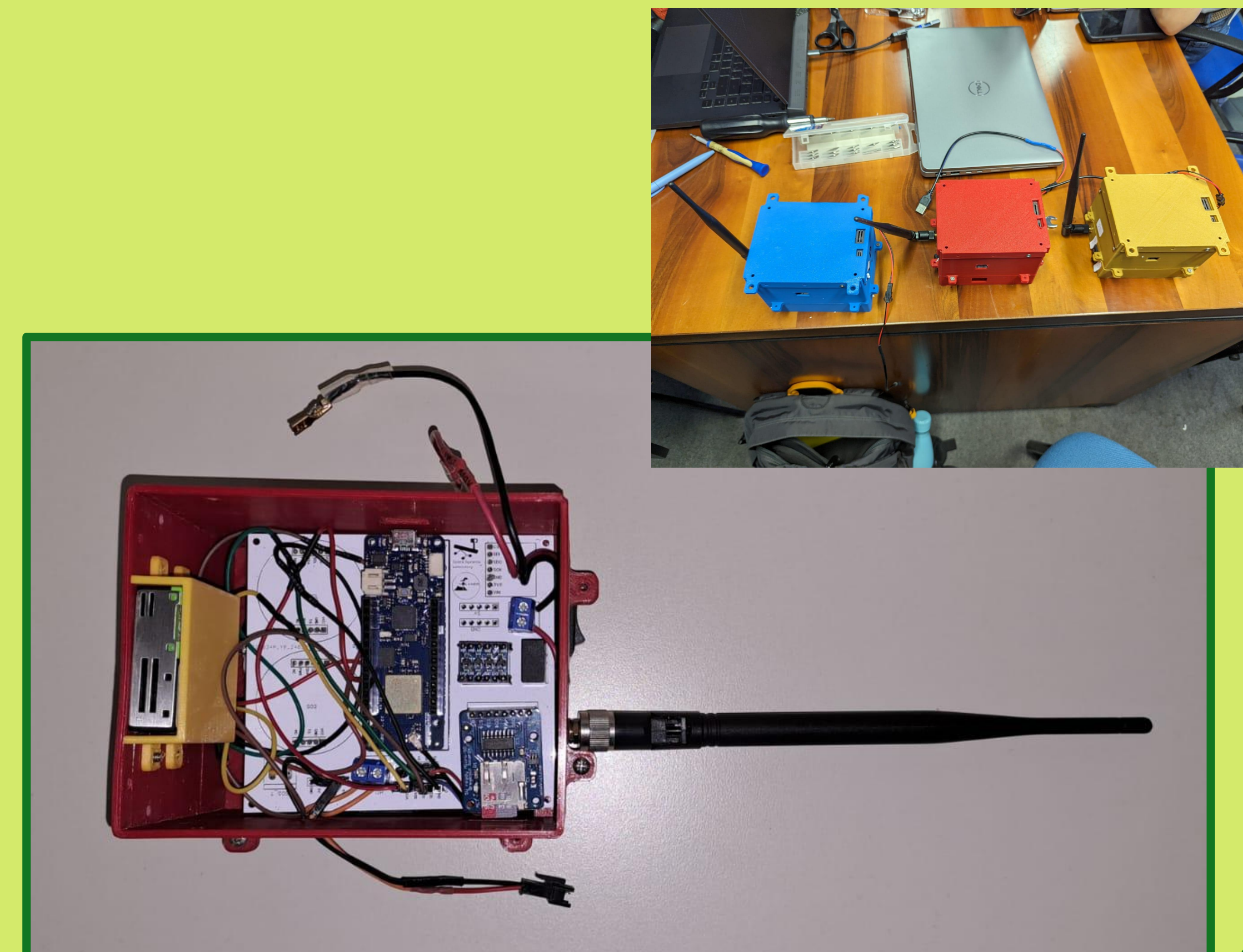
The “volcanosonde” package includes sensors for ash (concentration and Particle Size Distribution-PSD), gases (H_2O , CO_2 , SO_2 and HCl) and atmospheric parameters (pressure and temperature) estimations and telemetry. A dedicated software has been developed for the real time analysis of the collected data.

The sensors used are:

- Sensirion OPC
- Semeatech HCl and SO_2 sensors
- COZIR-LP CO_2 sensor
- Pressure temperature and humidity sensors

The sensors are integrated directly on a Printed Circuit Board (PCB), enclosed in a 3D-printed structure.

The acquisition rate is one data packet a second. The data are stored on an on-board SD memory card and, at the same time, transmitted through Long Range (LoRa) communication protocol to the ground station, consisting of a receiver and a rugged tablet. The electrochemical sensors are placed with the membrane on the bottom of the system, in order to interact with the ascending plume directly impinging the membrane of the sensor. The OPC is placed on top to avoid high air intake velocity from the plume below.



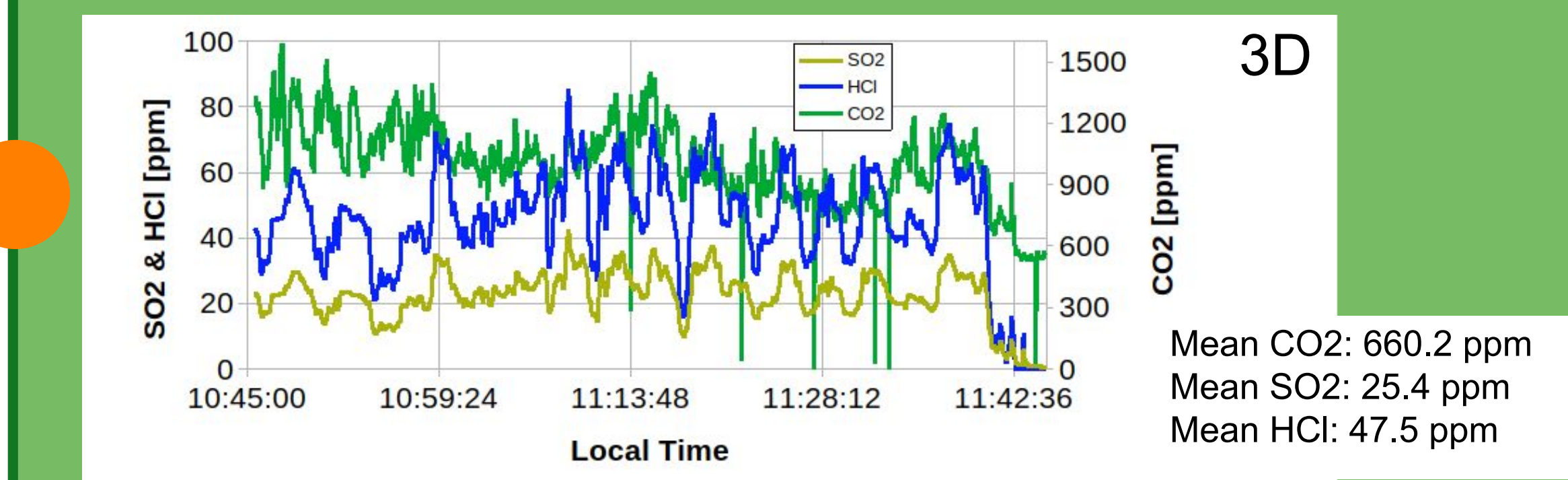
Pioli et al., 2022



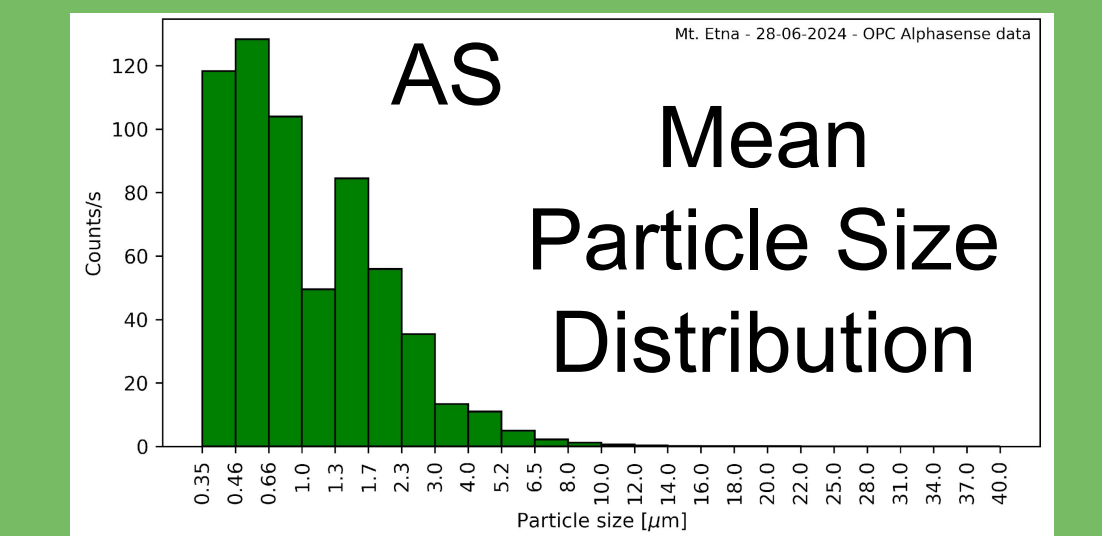
[3] Etna - June 2024 Volcanosondes test measurements at Bocca Nuova (BN) crater



The measurements were made at Etna on the rim of Bocca Nuova crater (3350 m asl). The 28th of June different continuous measurements were conducted to evaluate the response of gas and particle sensors to volcanic emissions, the volcanosonde remote connection and the internal data storage. The data have been collected by using three volcanosondes: the first two (named 3D and 7D) containing all gas sensors and a Sensirion OPC, while the third with only the Alphasense OPC (named AS).



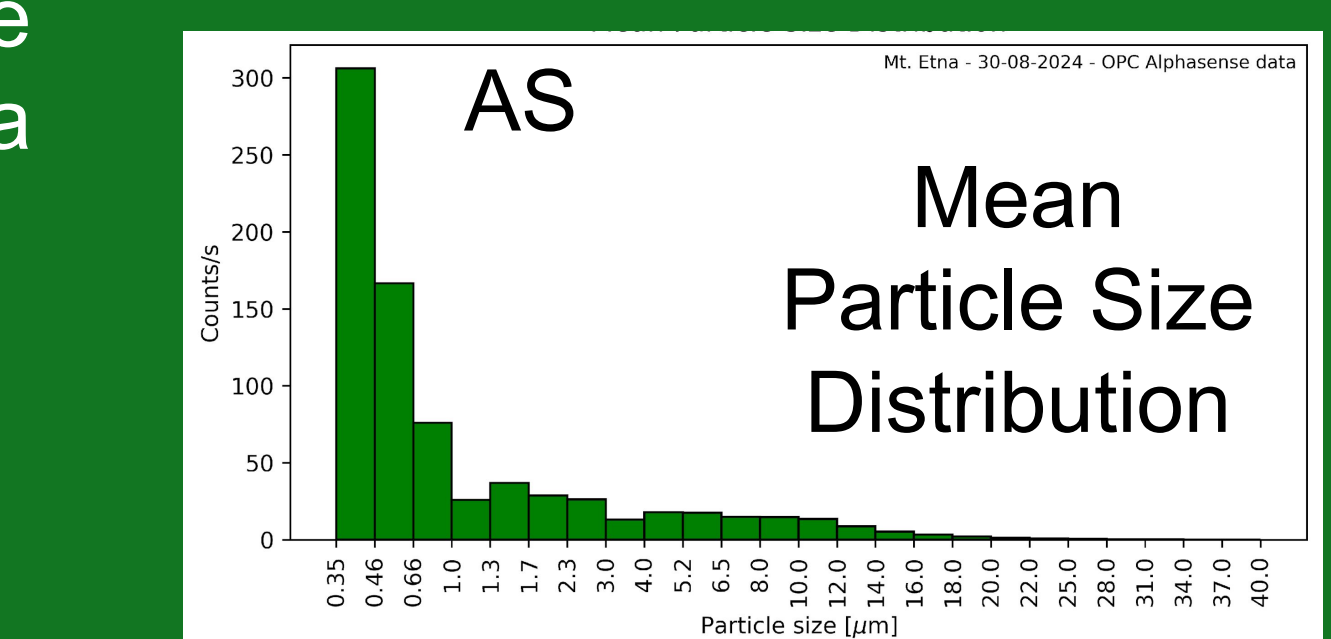
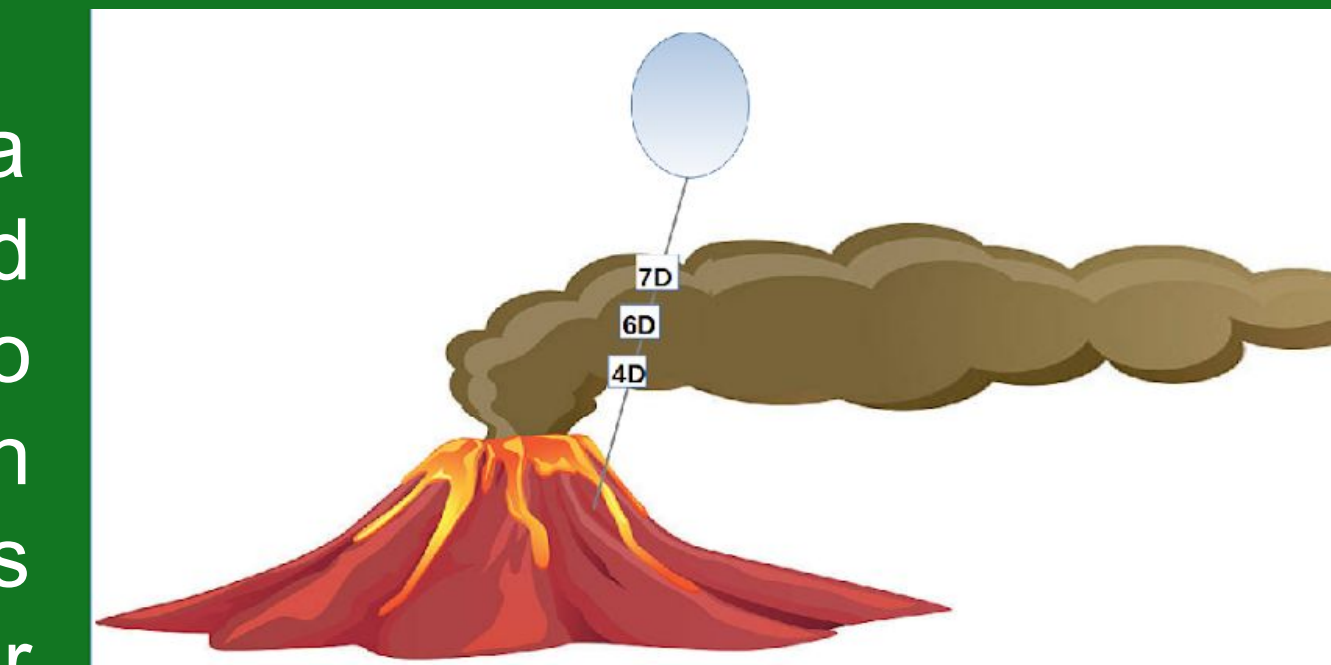
Real Time
Acquisition and
Visualization



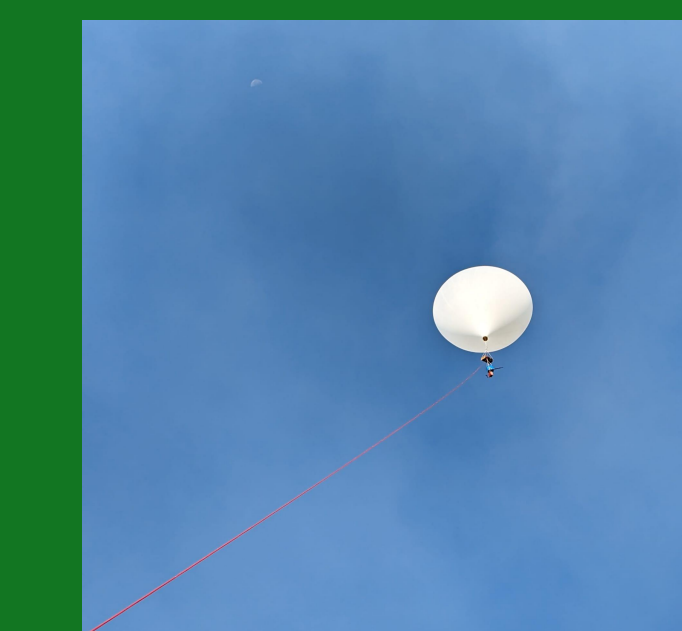
Mean
Particle Size
Distribution

[4] Etna - August 2024 Tethered balloon configuration test and measurements

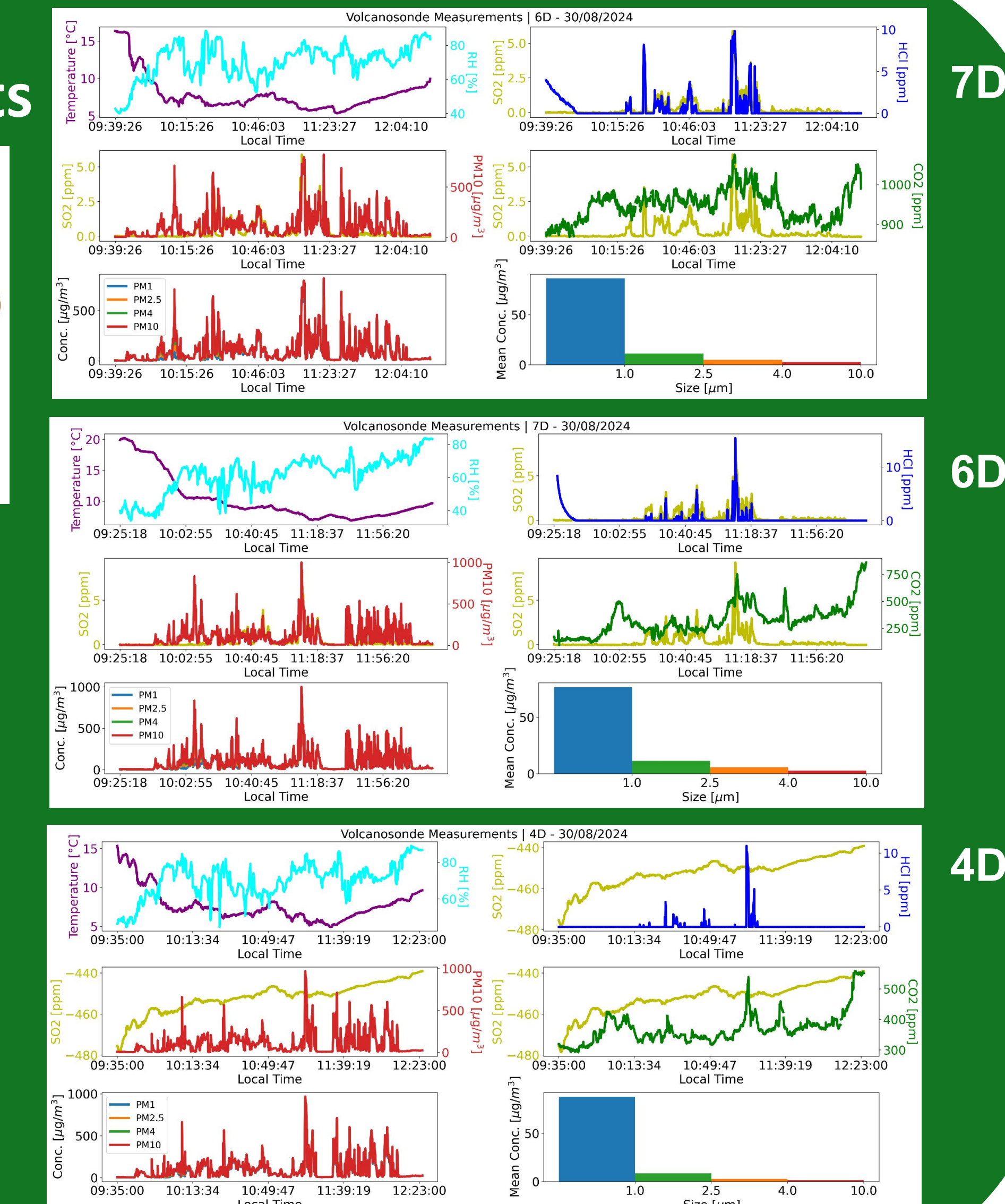
On August 30, a 1600 g balloon with a cable of about 400 m, was equipped with 3 volcanosondes (from bottom to top, 4D, 6D and 7D) 50 m apart and an Alphasense OPC (AS). The system was raised to an altitude of 3000 m in order to allow the volcanosondes to enter the volcanic plume generated by the Bocca Nuova crater



Mean
Particle Size
Distribution



- High correlation between CO_2 , SO_2 , HCl and particles concentration measurements
- Values of CO_2 and SO_2 indicate that 4D was not inside BN plume
- PSD bimodal with peaks centered at 0.4 and 1.5 microns



Conclusions

□ During the first year of the VOLANDO project:

- “volcanosonde” systems containing ash, gases, atmospheric parameters sensors and telemetry have been developed
- A dedicated software for the real time analysis of the data collected has been implemented
- During the June 2024 Etna field campaign, measurements have been realized to test volcanosondes response and telemetry
- During the August 2024 Etna field campaign the tethered balloon system with volcanosondes was tested and Bocca Nuova plume measurements carried out

□ June 2024 field campaign:

- high correlation between CO_2 , SO_2 and HCl measurements
- $HCl/SO_2 \approx 2$; $CO_2/SO_2 \approx 25$.
- PSD bimodal with peaks centered at 0.55 and 1.5 microns.

□ August 2024 field campaign:

- high correlation between CO_2 , SO_2 , HCl and particles concentration measurements
- PSD bimodal with peaks centered at 0.4 and 1.5 microns.

Future Activities

□ During the second year of the VOLANDO project:

- Gas sensors validation by using laboratory measurements and cross comparison with different sensors systems
- Field campaign at Volcano Island (Eolie, Sicily, Italy)
- Development of free-flying balloon with dropping volcanosondes
- Field Campaign on Etna volcano for the final test of systems and sensors
- Validation using satellite and ground based systems

