EGU General Assembly

ChEESE

www.cheese-coe-eu

Center of Excellence for Exascale in Solid Earth

Probabilistic Tephra Hazard Assessment of Campi Flegrei, Italy

B. Martínez Montesinos (1) , M. Titos Luzón (2), L. Sandri (1), S. Barsotti (2), G. Macedonio (3), and A. Costa (1)

(1)Istituto Nazionale di Geofisica e Vulcanologia, Bologna, Italy
(2)Icelandic Meteorological Office, Iceland
(3)Istituto Nazionale di Geofisica e Vulcanologia, Napoli, Italy

EGU General Assembly 19-30 April 2021

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 823844

Outline

- Introduction
- Objectives
- Campi Flegrei
- Probabilistic Volcanic Hazard assessment (PVHA) Work Flow
- Preliminary hazard maps examples

Introduction

- Volcanic eruptions might introduce magmatic material into the atmosphere representing a risk for inhabited areas and airspace
- Hazards need to be estimated to provide decisions-makers with information to develop short- and long- term risk mitigation strategies
- Current operation forecast products do not always meet the requirements:
  - Time and space scales of current forecasts are coarse
  - High epistemic/aleatory uncertainties coming from the quantification of the eruption source term

Objectives

- Probabilistic Volcanic Hazard Assessment to:
  - overcome the limits imposed by the uncertainties in the volcanic phenomena
  - explore the natural variability of volcanic phenomena:
    - Eruption Source Parameters (ESPs)
    - Vent position
    - Meteorological conditions
- Show the feasibility and usefulness of HPC in PVHA

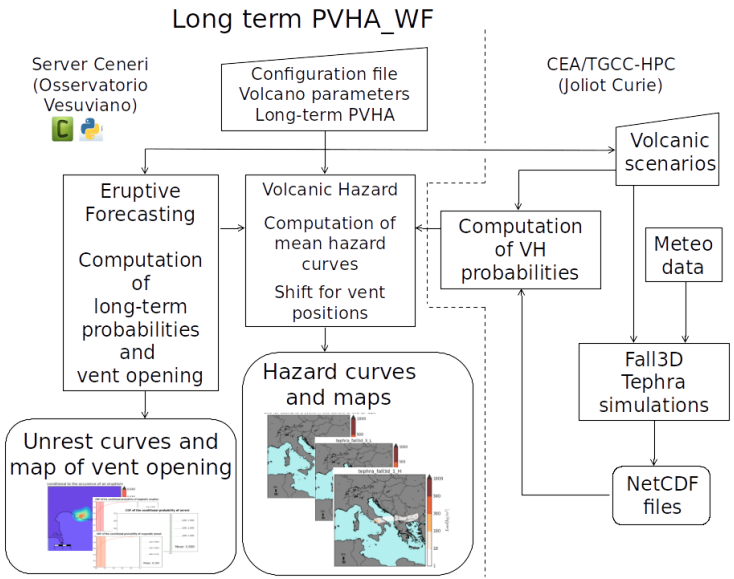
How?

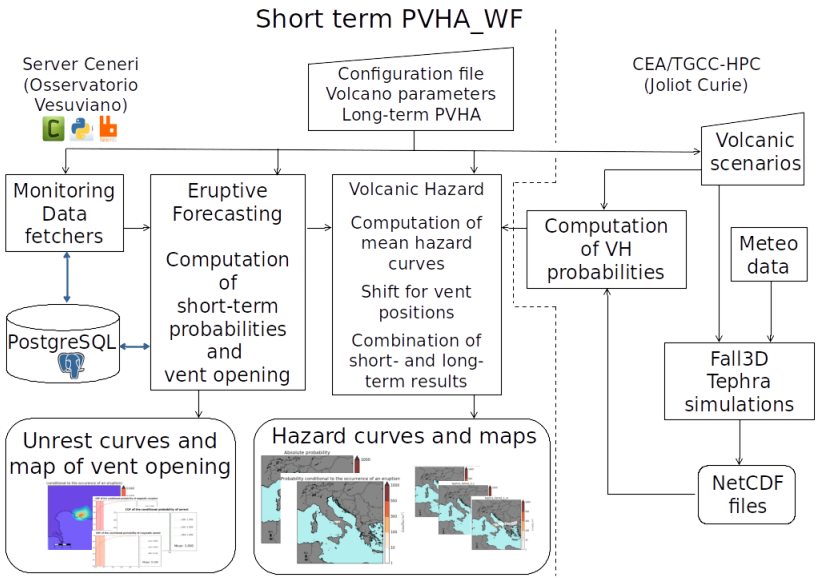
- Creating optimized codes and workflows to generate eruption probabilities and hazard maps for tephra deposition and airborne ash concentration
- Averaging thousand of numerical simulations (FALL3D model) in which eruption parameters are sampled within plausible ranges
- Delivering high resolution hazard maps over a 3D-grid covering a 2 Km-resolution 2000 km x 2000 km spatial domain for Campi Flegrei
- Considering hourly estimation of a large number of atmospheric, land and oceanic climate variables (from the surface up to 45 km altitude)

Campi Flegrei, Italy

- Campi Flegrei is an active volcano located in one of the most densely inhabited areas in Euro and under high traffic air routes
- The Vesuvius Observatory's surveillance system, which continuously monitors volcanic seismicity, soil deformations and gas emissions, highlights some variations in the state of the volcanic activity
- Potential impacts, on people, animals, assets and air-traffic

Probabilistic Volcanic Hazard Assessment Work Flow (*)





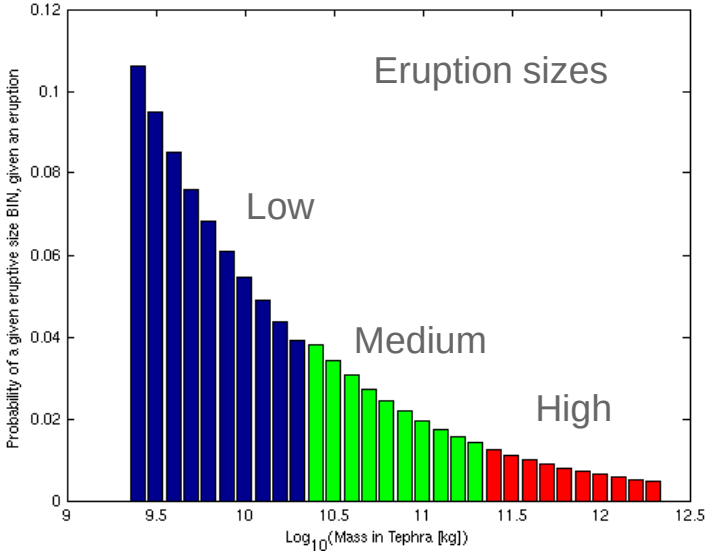
(*) based on the prototype tool BET_OV (Perfetti et al, 2021)

PVHA_WF applied to Campi Flegrei

Three “classical” eruption sizes (Low, Medium and High Explosive) for Campi Flegrei

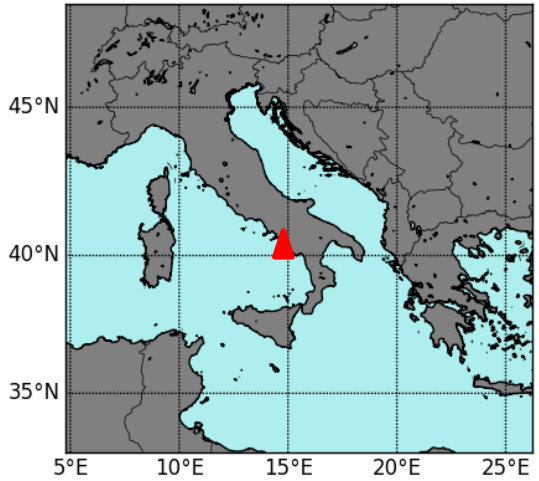
While usually synthetized in 3 representative scenarios with a fixed mass, neglecting the variability in mass around these scenarios, here we consider a wide range of volcanic scenarios taking into account even those of low probability but high impact

Size	**Scenarios for Long-term** (over 20 years of meteorological data)	**Scenarios for Sort-term** (corresponding to 5,6 and 7 Dec, 2019)
Low	1500	180/day
Medium	1500	180/day
Large	1500	180/day



Probability density function for the mass erupted in tephra for Campi Flegrei (Sandri et al, 2016).

PVHA_WF computational domain and meteorological data



3D-Grid:

2000 km x 2000 km geographical area
0.025 degrees grid resolution (2 km approx.)
8 flight levels covering 40000 ft

Meteo data:

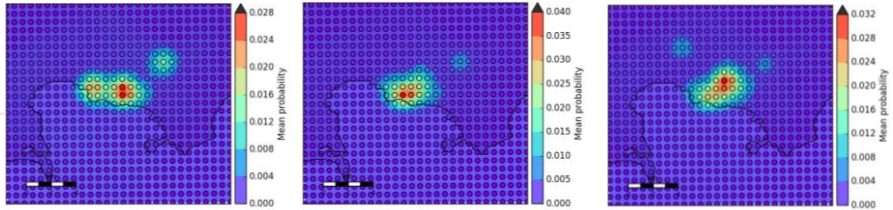
ECMWF ERA5 reanalysis
3-H temporal resolution
20 years (1999–2019) for the long term analysis

Preliminary hazard maps examples

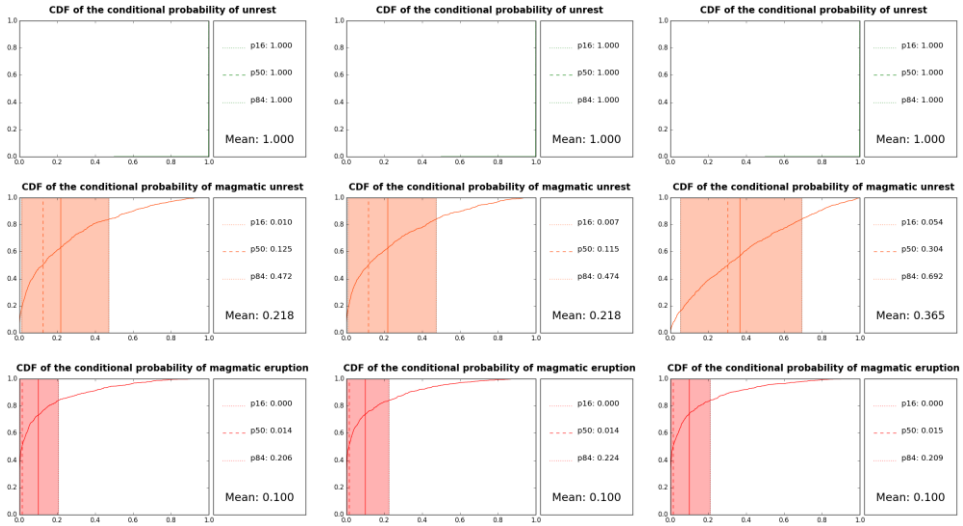
Short term assessment for Dec 5, 6 and 7, 2019

(when the Vesuvius Observatory's surveillance system detected abnormal activity)

Eruptive forecasting

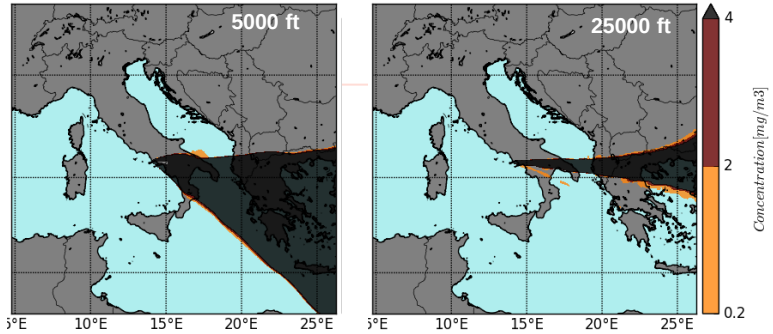


Vent opening probabilities conditional to the occurrence of an eruption during the days 5, 6 and 7 Dec 2019

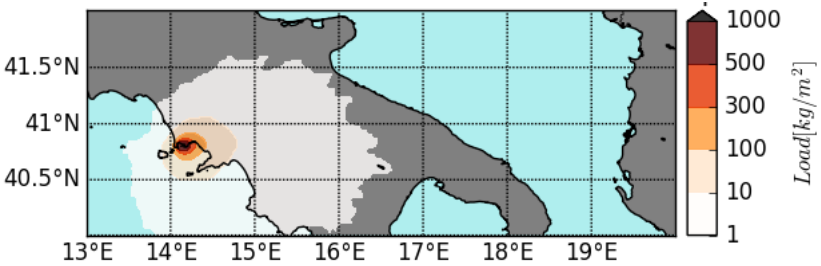


Conditional probability density function of unrest, magmatic unrest and eruption for days 5, 6 and 7 Dec 2019

Hazard maps



Area where the conditional probability of exceed labelled thresholds of ash concentration at 5000 ft and 2500 ft, at least once during an eruption, is greater than 5%

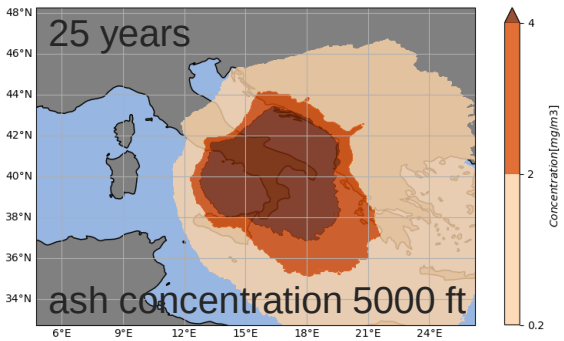


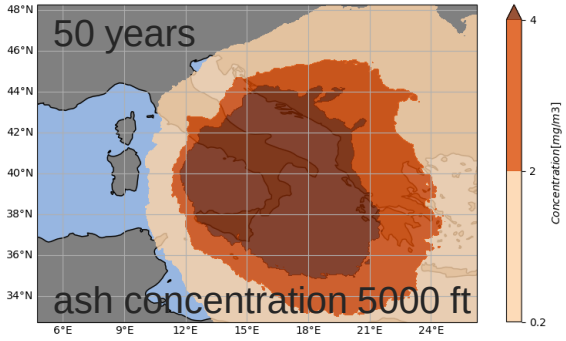
Area where the probability of exceed labelled thresholds of tephra load is greater than 5%

Preliminary hazard maps examples

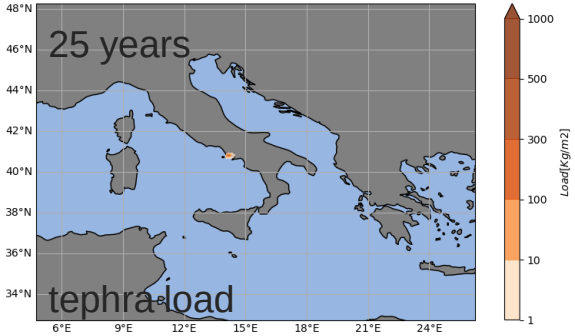
Long-term assessment for the next years

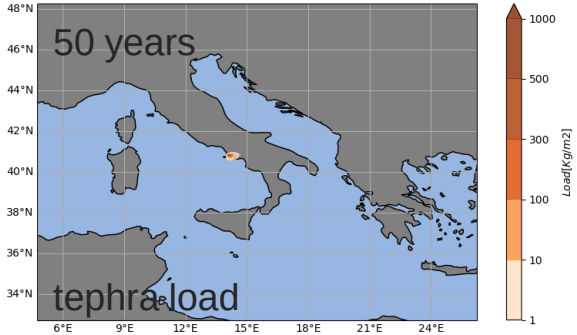
Absolute probability ≥ 5% of exceed critical thresholds





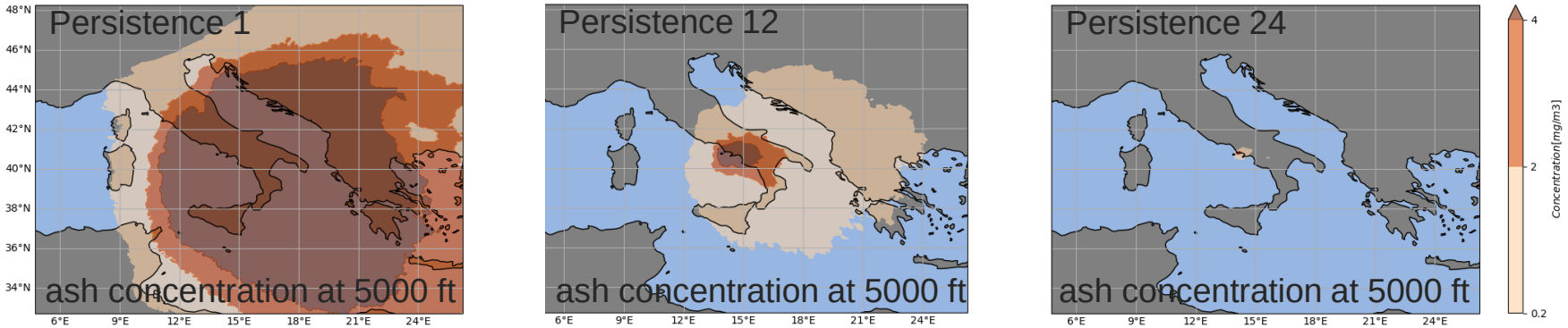
Area where the probability of exceed labelled thresholds of ash concentration at 5000 ft in 25/50 years, at least once, is greater than 5%



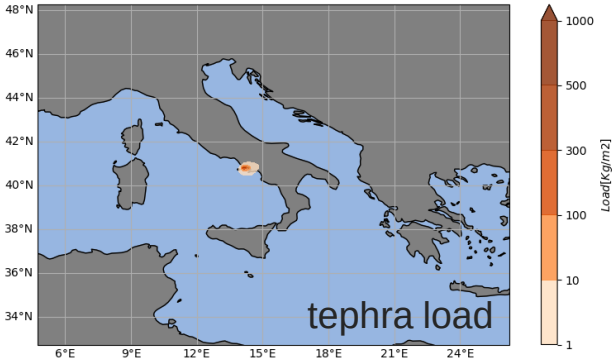


Area where the probability of exceed labelled thresholds of tephra load in 25/50 years is greater than 5%

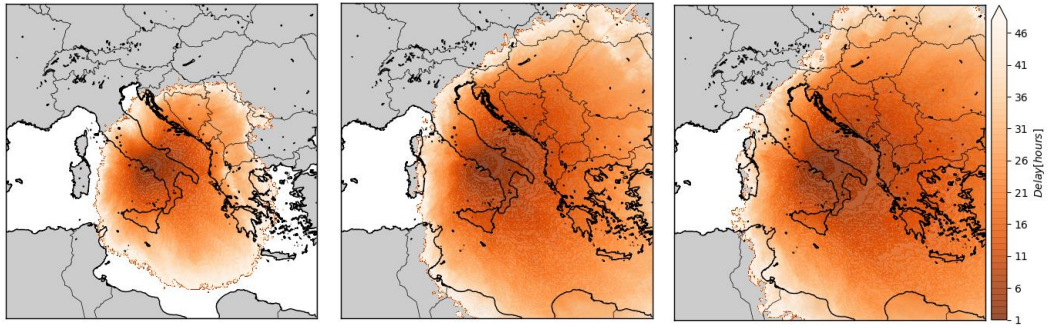
Conditional probability ≥ 5% of exceed critical thresholds



Ash concentration at flight level 5000 ft with a persistence of 1, 12 or 24 hours in a time interval of two days after eruption starts



Area where the probability, conditional with the occurrence of an eruption, of exceed labelled thresholds of tephra load is greater than 5%



Delay in exceeding the threshold 2 mg/m3 at flight level 5000 ft in two days after eruption starts conditional on the occurrence of a L / M / H size (from left to right) eruption

Bibliography

Barsotti, S., Di Rienzo, D.I., Thordarson, T., Björnsson, B.B. and Karlsdóttir, S., 2018. Assessing impact to infrastructures due to tephra fallout from Öræfajökull volcano (Iceland) by using a scenario-based approach and a numerical model. Frontiers in Earth Science , 6 , p.196.

Folch, A., Mingari, L., Gutierrez, N., Hanzich, M., Macedonio, G., and Costa, A.: FALL3D-8.0: a computational model for atmospheric transport and deposition of particles, aerosols and radionuclides – Part 1: Model physics and numerics, Geoscientific Model Development,13, 1431–1458, 2020.

Sandri, L., G. Jolly, J. Lindsay, T. Howe, and W. Marzocchi (2012) Combining long- and short-term PVHA with cost-benefit analysis to support decision making in a volcanic crisis from the Auckland Volcanic Field, New Zealand, Bull. Volcanol., 74(3), 705–723.

Sandri L, Costa A, Selva J, Tonini R, Macedonio G, Folch A, Sulpizio R (2016) Beyond eruptive scenarios: assessing tephra fallout hazard from Neapolitan volcanoes. Sci Rep 6:24271, doi: 10.1038/srep24271.

Selva, J., Costa, A., Marzocchi, W., Sandri, L. (2010) BET_VH: exploring the influence of natural uncertainties on long-term hazard from tephra fallout at Campi Flegrei (Italy). Bull Volcanol 72, 717–733.

Selva J., Orsi G., Di Vito M.A., Marzocchi W., and L. Sandri (2012a). Probability hazard map for future vent opening at the Campi Flegrei caldera, Italy. Bull Volcanol, 74:497–510, DOI 10.1007/s00445-011-0528-2.

Selva J., Marzocchi W., Papale P., and L. Sandri (2012b). Operational eruption forecasting at high-risk volcanoes: the case of Campi Flegrei, Naples. J Applied Volcanol,1:5, DOI: 10.1186/2191-5040-1-5.

Selva J, Costa A, Sandri L, Macedonio G, Marzocchi W (2014) Probabilistic short-term volcanic hazard in phases of unrest: A case study for tephra fallout, J Geophys Res Solid Earth, 119, DOI:10.1002/2014JB011252..

Perfetti, Paolo, Tonini, Roberto, & Selva, Jacopo. (2021, March 26). perfettp/BET-Tephra: v0.2017.04 (Version v0.2017.04). Zenodo. http://doi.org/10.5281/zenodo.4638667

Acknowledgements

The research leading to these results has received funding from the European Union's Horizon 2020 research and innovation programme under the ChEESE project, grant agreement No. 823844

We acknowledge PRACE for awarding us access to Joliot-Curie at GENCI@CEA, France

SERENADE - SEismic Restful ENAbled DatabasE, Peluso R. 2017 for the provision of the seismic data of Campi Flegrei area

TSDSystem for the provision of the deformation data of Campi Flegrei area

Copernicus Climate Change Service (C3S) (2017): ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate . Copernicus Climate Change Service Climate Data Store (CDS), date of access. https://cds.climate.copernicus.eu/cdsapp#!/home for the access to the meteorological data

The authors of the prototype tool BET_OV Perfetti, Paolo, Tonini, Roberto & Selva, Jacopo