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A showcase of HPC workflow for long-term Probabilistic Volcanic Hazard Assessment: the case of tephra hazard from three active volcanoes in the Azores

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Explosive volcanic eruptions, especially those of Plinian and sub-Plinian styles, are among the most hazardous natural phenomena due to their potential to affect vast areas of land, ocean, and airspace. These eruptions are characterised by the ejection of large amounts of tephra and gases into the atmosphere, forming buoyant eruption columns that disperse downwind.
Tephra fallout is the most common product of such eruptions, with the potential to locally generate hazardous loads on buildings and disrupt critical infrastructure. Fine ash can be transported by wind over thousands of kilometres and persist in the atmosphere for several days or weeks, with severe consequences for aviation and far-reaching socioeconomic impacts.
On volcanic islands, such as the Azores Archipelago (Portugal), these impacts are amplified by geographic isolation, limited land area, and rugged topography. Sao Miguel Island, the largest and most populated of the Azores, is one such case, hosting three active central volcanoes (Sete Cidades, Fogo, and Furnas) that have produced a large variety of tephra-producing eruptions in the last millennia, including in historical times.
Here, we develop the first Long-term Probabilistic Volcanic Hazard Assessment (PVHA) for tephra fallout and airborne ash generated by explosive eruptions at the three central volcanoes of São Miguel, taking advantage of the High-Performance Computing (HPC) capabilities and workflow provided by the Geo-INQUIRE Transnational Access. The workflow implements a probabilistic approach based on the Bayesian Event Tree (BET) method, coupled with large ensembles of FALL3D simulations designed to capture the full range of eruptive and atmospheric variability.
To perform this assessment, a set of eruptive scenarios was devised for VEI 3, 4, and 5 events. Eruptive parameters were sampled with an Orthogonal Latin Hypercube Sampling method to ensure highly uniform and space-filling sampling. To account for variability in meteorological conditions, 30 years of ERA5 reanalysis data were incorporated into the simulations.
The simulations were performed over two different computational domains: a regional grid (4x8 degrees approximately, 2-km resolution) to assess tephra load and impact on the Azores Islands, and a continental domain (70x50 degrees approximately, 10-km resolution) to evaluate the

airborne ash concentration, arrival times, and atmospheric persistence affecting Europe and North Africa.
For the probabilistic hazard calculations, tephra footprints were produced for each simulation and dropped in the Simulation Data Lake developed by the Geo-INQUIRE project for convenient storage, allowing open access and post-processing by other users.
Overall, the outcomes of this work enable the generation of long-term hazard maps for different eruptive scenarios, including tephra fallout (load) and ash concentration at specific flight levels, and the evaluation of the associated uncertainty.
Furthermore, the combination of these results with an equivalent effort in progress within the ChEESE-2P project relative to Spanish, Italian, and Icelandic volcanoes will contribute to the definition of the first European Tephra Hazard Map and a preliminary long-term hazard assessment for European airspace.

TA Project description: https://eur02.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwww.geo-inquire.eu%2Ftransnational-access%2Fproject-reports%2Ftephrazor&data=05%7C02%7CSimone.C.Aguiar%40azores.gov.pt%7C680b5094c8fb4458ec4708de52994528%7C14ab77183e714019890a54ed9b92f98a%7C0%7C0%7C639039015408152164%7CUnknown%7CTWFpbGZsb3d8eyJFbXB0eU1hcGkiOnRydWUsIlYiOiIwLjAuMDAwMCIsIlAiOiJXaW4zMiIsIkFOIjoiTWFpbCIsIldUIjoyfQ%3D%3D%7C0%7C%7C%7C%7C&sdata=fGhjDRxzs5aSEiDSmHvbil6oM4ZU7Bt6wTFOpHxpGJY%3D&reserved=0