EGU24-19255, updated on 20 May 2024
https://doi.org/10.5194/egusphere-egu24-19255
EGU General Assembly 2024

A digital twin for volcanic deformation merging 3D numerical simulations and AI

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At active volcanoes, surface deformation is often a reflection of subsurface magma activity that is associated with pressure variations in magma sources. Magma dynamics cause a change of stress in the surrounding rocks. Consequently, the deformation signals propagate through the rocks and arrive at the surface where the monitoring network records them.

It is invaluable to have an automated tool that can instantly analyze the surface signals and give information about the evolution of the location and magnitude of pressure variations in case of volcanic unrest. Inverse methods employed for this often suffer from ill-posedness of the problem and non-uniqueness of solutions.

To this end, we are developing a digital twin to use on Mount Etna volcano, combining the capability of numerical simulations and AI. Our digital twin is composed of two AI models: the first AI model (AI1) will be trained on multi-parametric data to recognize unrest situations, and the second AI model (AI2) will be trained on a large number (order 10^5 - 10^6) of 3D elastostatic numerical simulations for dike intrusions with the real topography and best available heterogeneous elastic rock properties of Mount Etna Volcano using a forward modeling approach. Numerical simulations will be performed on Fenix HPC resources using the advanced open-source multi-physics finite element software Gales.

Both AI modules will be developed and trained independently and then put into use together. After activation, AI1 will analyze the streaming of monitoring data and activate AI2 in case of a volcanic crisis. AI2 will provide information about the acting volcanic source.

The software will be provided as an open-source package to allow replication on other volcanoes. The tool will serve as an unprecedented prototype for civil protection authorities to manage volcanic crises.