An inter-disciplinary Virtual Research Environment to study the Amatrice-Norcia Italian seismic sequence 2016

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In this work, we present the preparation of a Virtual Research Environment (VRE) for analysing the Amatrice-Norcia Italian seismic sequence 2016 using a multidisciplinary and multiparametric approach.

A VRE can be implemented by Jupyter Notebooks, which, thanks to the ability to combine code, outputs and text documentation, can help other researchers reproduce the scientific investigation. In addition, users may modify some of the code's parameters and have immediate interactive visual feedback (e.g., graphs, images), which makes notebooks excellent candidates for creating VRE where earthquake parameters can be adjusted to let the final user implement the system on potentially any earthquake.

The developed VRE leverages the European Plate Observing System (EPOS) platform (Bailo et al., 2023), one of the key outcomes of the EPOS European Research Infrastructure Consortium (ERIC). EPOS platform integrates multi-disciplinary data from more than ten thematic disciplines, providing access to almost 300 different data services. In this framework, the Jupyter-based VRE will use the EPOS platform APIs to access the integrated datasets, such as the earthquake catalogue from the European-Mediterranean Seismological Centre (EMSC). Potentially, in the future, it could become available on the same system as software deployed in the portal.

The case study

The Italian seismic sequence started on 24 August 2016 in the Central Appenin was used as a reference case study. The main two events were the Mw = 6.0 Amatrice earthquake, which occurred on 24 August 2016 at 1:33 UT, and the Mw = 6.5 Norcia earthquake, which occurred on 30 October 2016 at 6:40 UT. Epicentre locations, together with a foreshock that occurred on 26 October 2016 close to Visso town, are represented in Figure 1. The main active faults are overlaid on the same map, taking advantage of the integrated visualisations of the EPOS Data Portal (https://www.epos-eu.org/dataportal, last access 18 Dec 2024). One can see that the earthquakes occurred in a very dense region of faults dominated by extensional tectonic stress. The focal mechanisms of these events are in agreement with a normal focal mechanism solution. A

multiparametric study of this seismic sequence was provided by (Marchetti et al., 2019). The paper also involved previous investigations of specific parameters (e.g., Piscini et al., 2017). Collecting analyses from the lithosphere, atmosphere and ionosphere, it was possible to detect a chain of phenomena that preceded the start of the seismic sequence of Amatrice-Norcia 2016.

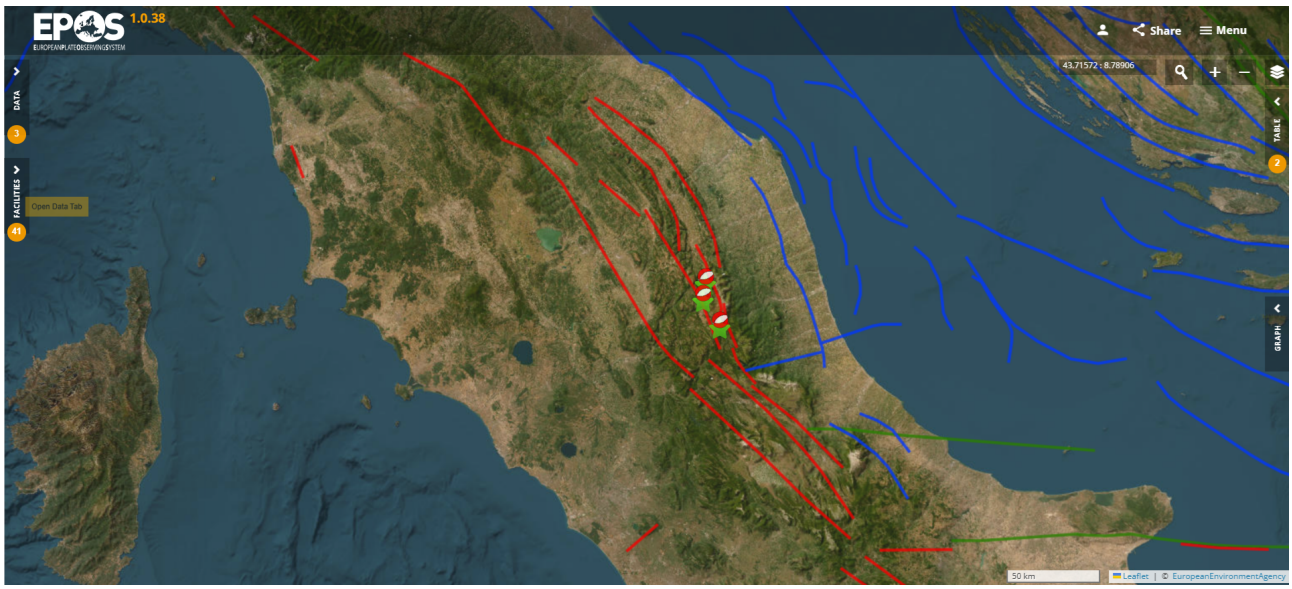

Fig. 1 – Localization of the seismic events (green stars) with magnitude equal to or greater than 6.0 using EPOS Platform version 1.0.38. The focal mechanisms of the larger events in the seismic sequence (M ≥ 6) have been overplotted using the EPOS Service "Moment tensor data for modern earthquakes (2013-present)" provided by TCS Seismology. The active faults have also been shown on the same map, and their colour indicates the tectonic mechanism (red = extensional, blu = compressional, green = transcurrent).

Here, by means of a Jupiter notebook, we are providing a VRE to reproduce the previous study and even potentially extend it to the other disciplines/datasets available within the EPOS framework (e.g., GNSS). Figure 2 shows the sketch of the undertaken approach. The main data source is the EPOS platform. it offers a single point of access to almost 300 datasets in the domain of Solid Earth science. This is done both through a Platform user interface and through APIs. The Jupyter Notebook VRE accesses EPOS datasets through the platform APIs and then analyses them together with datasets taken from other sources. Finally, the VRE provides an output with text and graphs of the analysed case study, i.e., the Italian Seismic sequence 2016 occurred in Central Appennine.

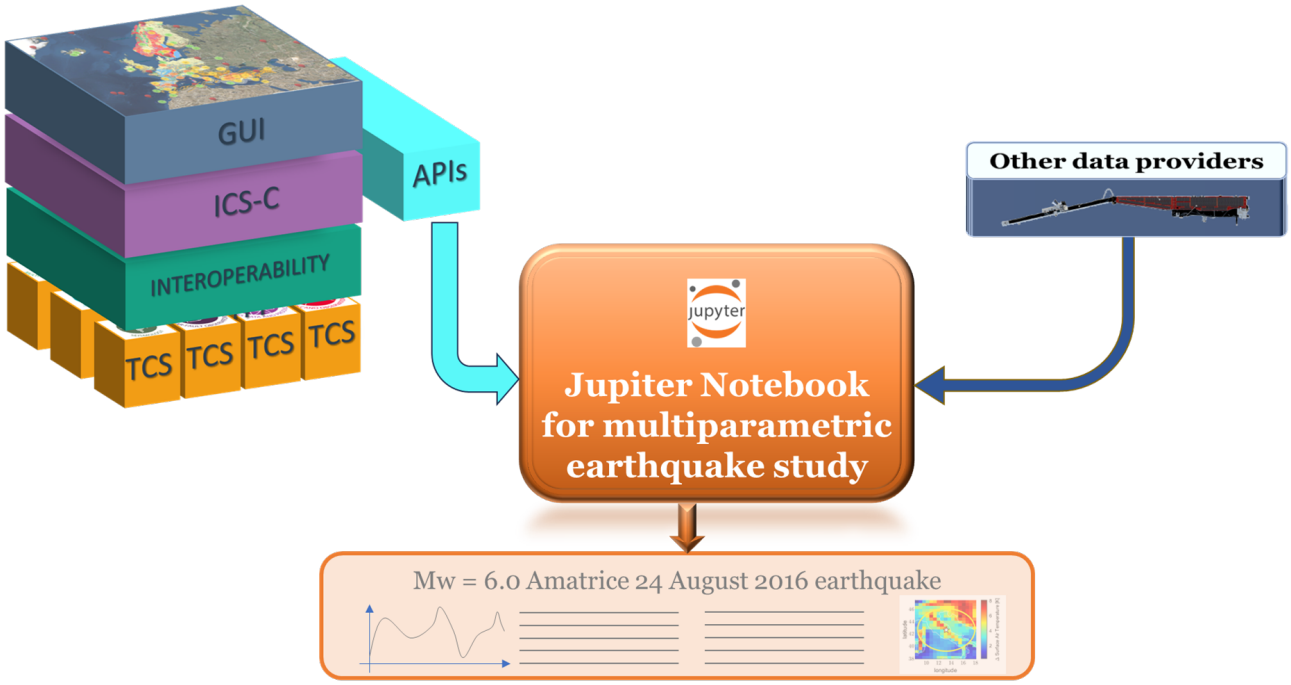

Fig. 2—Sketch of the VRE. The core of the VRE is the Jupiter Notebook. It retrieves most of the data (e.g., the earthquake catalogue) from the EPOS platform via APIS and integrates it with other external data sources, such as Swarm satellite geomagnetic data. It provides an output report with information on the Italian Seismic sequence 2016, graphs, and analyses of the retrieved data.

These preliminary studies provide strong evidence that a multidisciplinary and multiparametric approach could open new prospects on the relations between geo-layers in our Earth's system. Furthermore, this VRE paves the way for approaching the earthquake investigation in a programmatic way, enabling users to perform multi-dimensional analysis of a natural hazard using different data sources in a VRE, leveraging on the wealth of data of the EPOS Platform.

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