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Corresponding Author:	Alberto Michelini Istituto Nazionale di Geofisica e Vulcanologia Roma, ITALY
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	Istituto Nazionale di Geofisica e Vulcanologia
Corresponding Author's Secondary Institution:	
First Author:	Dario Jozinović
First Author Secondary Information:	
Order of Authors:	Dario Jozinović
	Valentino Lauciani
	Sergio Bruni
	Licia Faenza
	Alberto Michelini
Order of Authors Secondary Information:	
Suggested Reviewers:	Bruce Worden, PhD cbworden@contractor.usgs.gov shakemap developer
	Carlo Cauzzi, PhD ETH - Zurich carlo.cauzzi@sed.ethz.ch expert shakemap user
	Nicos Melis, PhD NOA nmelis@noa.gr expert shakemap user
	Jennifer Taggart UC Berkelely jennifer.c.taggart@berkeley.edu IT web manager

ShakeMap4-Web: web application for ShakeMap 4 product visualization

Dario Jozinović[1,3], Valentino Lauciani[1], Sergio Bruni[1], Licia Faenza[2], Alberto Michelini[1]

1) Istituto Nazionale di Geofisica e Vulcanologia, via di Vigna Murata 605, 00143 Rome, Italy

2) Istituto Nazionale di Geofisica e Vulcanologia, Via Donato Creti, 12, 40128 Bologna

3) now at Swiss Seismological Service (SED) at ETH Zurich, Sonneggstrasse 5, 8092 Zurich, Switzerland

Corresponding author: Alberto Michelini (alberto.michelini@ingv.it)

Declaration of Competing Interests

The authors acknowledge there are no conflicts of interest recorded

Abstract

We present a web portal for the prompt visualization of the maps of ground shaking generated using the USGS ShakeMap 4 software (Worden et al., 2020). The web interface renders the standard products provided by ShakeMap dynamically (using Leaflet) and statically (standard shakemaps). The information included in the dynamic maps can be configured through different overlays. The dual view rendering modality allows presenting side-by-side maps of different intensity measurements. In addition, for each earthquake, it is possible to download all the data that contributed to the calculation, together with information on the seismological models adopted.

The appearance of the web portal is easily configurable by replacing the logo and banners. The software can be installed both on laptops and on server computers. The user can opt between the docker image or installation of the software after installation of a web server (e.g., NGINX or Apache).

Introduction

ShakeMap is open-source software (Wald et al. 1999), developed by USGS, which provides maps of ground shaking after an earthquake and is widely used worldwide. ShakeMap calculates maps of the ground shaking in terms of macroseismic intensity and of peak ground motions. It provides valuable information for disaster risk managers and civil protection authorities.

Until version 3 of the ShakeMap software, the package distributed by USGS consisted of a complete system that included both the generation of the maps of ground shaking and a website the users could adopt to publish the maps and other generated products. In 2016, the USGS developers started modernizing the software (version 4) by adopting the flexible python language (Worden et al., 2020). Version 4 of the software (SM4 here and thereinafter) adopts a new methodology for the interpolation of ground motions (Worden et al., 2018), ground motion models (GMM) from the Openquake library (Pagani et al., 2014), and many other new features. This new release of the package, however, does not include a website for the visualization of its products, leaving flexibility on how to present them to the users.

Since 2019, the "Istituto Nazionale di Geofisica e Vulcanologia", INGV, has implemented the SM4 (Michelini et al., 2020) and, in order to publish the resulting products on its dedicated website, has developed the software package described in this article. The software is publicly available on the shakemap4-web INGV GitHub repository and it has been designed to display the SM4 products specifically and it can be adopted by any interested users (institutions or individuals). At the time of this writing, the latest version of the software (or previous releases) have been implemented on the California Integrated Seismic Network website and to render the strong motion products of the EU supported projects SERA and RISE.

Methods

The website has been developed using Python, Bash, and Javascript. Python is used for two scripts:

1) *updateEventList.py* - a script that generates a table of events for which the ShakeMap data and products have been generated and are to be displayed on the website;

2) *runWeb.py* - a script that runs a web server to expose the web application.

Figure 1 schematizes the structure of the codes underlying the ShakeMap website. The script *updateEventList.py* generates the *events.json* file (a list of events with their associated parameters) that is used as input by the Javascript files which are served through *runWeb.py*. Subsequently, through Javascript, the events are shown on the dedicated web page. Bash is used for a script (*crontabScriptToUpdateEvents.sh)* that inspects the ShakeMap data folder to find all new events to be processed by *updateEventList.py* and generates the *events.json* file. The processed events include only those that either featured changes of the input parameters or that have been added in the previous 2 days.

To keep the web application as simple as possible for distribution and use for other users, all the development of the web pages has been done using client-side programming in javascript (barring the Python scripts mentioned above, which use Python libraries already installed by SM4).

The interactive maps have been developed using the Leaflet Javascript library. Leaflet is an open-source Javascript library that allows the development of powerful dynamic maps, with many plug-ins available that extend the possibilities of Leaflet. It is especially suited for *GeoJSON* data, which are also the type of files generated by ShakeMap 4. The website can be installed by copying the GitHub repository to an arbitrary directory and specifying the ShakeMap *data* folder in the *config.js* file.

Dockerization

To simplify the installation and to increase the portability, the package can also be deployed using *docker* (Merkel, 2014). Docker, as reported in the main docker overview web page, "is an open platform for developing, shipping, and running applications. Docker enables you to separate your applications from your infrastructure so you can deliver software quickly".

We built two separate docker containers (see Fig. 2):

- *nginx* is open-source software, an alternative to *runWeb.py* for web serving. It is used to expose the web application based on Javascript. We preferred this solution since *nginx* is more efficient and stable; in any case, for users, the *runWeb.py* option remains available on our repository.

- *workspace* is based on *Debian bookworm-slim* and implements a *crontab* file to run every minute the script *crontabScriptToUpdateEvents.sh*.

Both *nginx* and *workspace* containers are run using *docker-compose*, which is a tool for defining and running multi-container Docker applications.

Results

The developed website features several pages. The *home* page contains the table that shows the latest N number of events, where N can be easily modified in the *config.js* file. The table contains the following columns: *Event ID, Year, Month, Day, Time (HH:MM), Location, Depth, Magnitude*. The rows are clickable and lead to the interactive event map *Leaflet page*. The *Archive page* (Fig. 3) is similar to the home page but the events listed are all those in the selected year to be chosen through a dropdown list above the table. In addition, the user can select the events according to a minimum and maximum magnitude and sort the events by magnitude in ascending or descending order. Above the table, some buttons allow the user to choose whether to show the events dynamically through the interactive Leaflet maps or to display the static maps generated by SM4. There exists also a version of the archive page for *Historic events*, accessible from the dropdown menu at the top of the page.

The *Leaflet page* (Fig. 4) shows the dynamic map of the event with a set of layers that can be turned on or off using a control panel. The available layers consist of contours of values for different intensity measures: PGA, PGV, PSA 0.3s, SA 1s, SA 3s, Macroseismic intensity.

In addition to the shaking parameter layers, the portal can show additional information. This concerns the stations used in the calculation, colored according to the recorded shaking, the macroseismic intensity overlay, the DYFI observations, and the surface projection of the fault when available. This additional information can also be entered through the control panel and is clickable. The bottom left corner displays the legend that associates with the shaking recorded the degree of damage potentially suffered.

Layers can be queried. By placing the cursor on the epicenter and clicking, information about the event such as location, depth, and magnitude appears. Similarly, by clicking on stations, the tooltip appears with essential data about the station: station name, network name, and the Vs30 at the site, but also data about the earthquake such as the distance from the source, the PGA and PGV values recorded, and the corresponding intensity value. Furthermore, if the data come from macroseismic questionnaires, the tooltip shows the intensity data and its conversion to ground motion. Finally, the layers also display contour lines of the ground motion value and its unit of measurement when clicked.

Another page, which is accessible from the *Leaflet page*, is the *Double view page* (Fig. 5) which shows two side-by-side leaflet maps of the chosen event, allowing the user to compare different ground motion parameter layers of the same event. Each of the two maps of the *Double View* mode can be customized independently and with the same functionality as the *Single View* display. The maps shown in Leaflet mode allow the user to zoom in to detail particular areas of interest.

As an alternative to the dynamic version of the maps, the site allows the static visualization of the maps. This type of visualization is very familiar to those who have interfaced with the previous ShakeMap site because the *Static view* shows the maps of the six shaking parameters as the ShakeMap code generates them as *JPEG* images. Each map shows the contouring for the ground motion variable, the stations used in the calculation, colored according to the level of shaking, the epicenter with a star, the surface projection of the fault when available, and a legend that associates the degree of potentially suffered damage to the shaking recorded.

Other pages for an event include the *Metadata, Analysis view, Station list, and Download products page*. The *Metadata page* allows the user to access the information associated with the selected event. It includes the models selected for the events, such as the ground motion models, the ground motion to intensity conversion equations, the intensity prediction equation, and the spatial correlation. On the *Analysis view* page (Fig. 6), the user can view and compare the regression curve of the ground motion model implemented for the macroseismic intensity, PGA and PGV. The graph shows the regression curve as a function of distance from the source, also indicating with a gray banner the limit of uncertainty with +/- one standard deviation and the stations, colored according to the recorded shaking. It is possible to display the graph by representing the data on rock soil or including soil effects.

A list of all the seismic stations that comprised the input to the ShakeMap for a certain event, with information about them and the ground motions recorded at the stations, is available on the *Station list page*. The stations are sorted as a function of distance and again colored according to the recorded level of shaking. All the products generated by ShakeMap, for the selected event, are available for easy download on the *Download products page*. This section makes it possible to download the ShakeMap files as a map (in different formats such as PDF and JPG) and in forms that can be integrated into other visualization and calculation platforms, such as GIS Shapefiles, ESRI Raster files, or GeoJson files. Alternatively, ground motion values and their uncertainties are downloadable in two files in XML format. Together with the processed products, in this section of the website, we make available to the user other files used as input for the calculation of the ShakeMap. These include the file with the geometry of the rupture (*rupture.json*) and the stations' data (*stationlist.json*), both in GeoJSON format.

Some pages (*home, archive, information pages*) contain by default a logo image above the menu bar, a banner image immediately below the menu bar, and an image with the logos of the contributors at the bottom of the screen, which can all be changed in the *config.js* file. In the same file, the user can change the number of events shown on the home page and V_{s30} grid file location (if available). The file *bbox.txt* allows the user to select the latitude and longitude of the bounding box used for selecting earthquakes to show on the website (by default it shows the events from the whole world).

In addition to the pages dedicated to events, the website has a general section providing information on the website itself or the ShakeMap calculation process. The *Information section* opens with a drop-down menu, and it is possible to select three pages in the menu: *Disclaimer*, *Scientific Background*, *Historic Events*. In the *Disclaimer section*, we have included text specifying the preliminary and automatic nature of the ShakeMap, informing the user that the input data is raw and not checked by a seismologist before calculation. We also specify the intensity maps' meaning and how they are calculated. This page can be customized according to the needs of the institution responsible for calculating the ShakeMap. The *Scientific Background section* provides bibliographic indications of the ShakeMaps and their configuration. In this page, we also provide the link to the V_{s30} file in

GRD format used for the analysis. Finally, the *Historic Events* section leads to the ShakeMap generated for past events of particular interest.

Conclusions

We have developed a website to render the ShakeMap 4 products. The maps can be visualized both dynamically, with the user selecting the sought zoom level, and statically by displaying the maps generated by the USGS ShakeMap package. Maps can be also visualized side by side dynamically (e.g., intensity and PGA maps) facilitating the comparison between the different types of parameters used to represent the ground shaking. In addition, the website has been designed to provide other pages for easier access to the ShakeMap products. These include stations listed according to the epicentral distance and highlighted with colors consistent with the recorded ground shaking, all the relevant metadata associated with the generated maps, the graphs of GMM regression curves displayed together with the recorded data, and a list of all the products that have been produced and that can be downloaded. The idea behind the designed site is to show the shakemaps for the different parameters, together with a first visual analysis of the shaking at the stations that recorded the earthquake, through the *Analysis View* and *Station List* sections. In parallel, we provide users with all the information (metadata) related to the generated maps. This choice allows for complete transparency of the results and their reproducibility. The site can be easily personalized with logos and banners of the institutes participating in the projects, and the notice in the *Information section*.

The website is dockerized so it is highly portable to different environments. The developed website is easily used on any computer (either local or server). Users can modify the parameters of the website through the configuration files; more information about the configuration is given in the README file available in the project repository. The website is developed using primarily javascript, and python is used to select the events to be displayed. This setup allows for flexible modifications and updates without requiring users to install additional dependencies.

The website can be thus implemented by any institution (or individual user) that requires visualization of the SM4.0 products.

Data and resources

The project repository is available at https://github.com/INGV/shakemap4-web. The USGS ShakeMap 4 software is available at http://usgs.github.io/shakemap/sm4_index.html. The Leaflet Javascript library (https://leafletjs.com/) software is available at https://github.com/Leaflet/Leaflet. The shakemap4-web software available at https://github.com/INGV/shakemap4-web. The data and the implementation of the software are available at the INGV shakemap website http://shakemap.rm.ingv.it/shake4/. The shakemap4-web software has been implemented on the https://www.cisn.org/shakemap.html website of the California Integrated Seismic network, and on the http://shakemapeu.ingv.it as result of activities carried out in the EU funded Horizon-2020 SERA and RISE projects. The Docker software is available at https://docs.docker.com. Nginx is available at https://nginx.org/en/. The screen shots of Figures 3-6 were all taken on 11/10/2021 at the following urls http://shakemap.ingv.it/shake4/archive.html, http://shakemap.ingv.it/shake4/viewLeaflet.html?eventid=8863681, http://shakemap.ingv.it/shake4/viewLeaflet2.html?eventid=8863681 and http://shakemap.ingv.it/shake4/viewAnalysis.html?eventid=8863681&eventyear=2016#pga, respectively.

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References

Merkel, Dirk. "Docker: Lightweight Linux Containers for Consistent Development and Deployment." Linux Journal 2014, no. 239 (2014): 2.

Michelini, A., Faenza, L., Lanzano, G., Lauciani, V., Jozinović, D., Puglia, R., & Luzi, L. (2020). The new ShakeMap in Italy: Progress and advances in the last 10 yr. Seismological Research Letters, 91(1), 317-333.

Pagani, M., D. Monelli, G. Weatherill, L. Danciu, H. Crowley, V. Silva, P. Henshaw, et al. "OpenQuake Engine: An Open Hazard (and Risk) Software for the Global Earthquake Model." Seismological Research Letters 85, no. 3 (May 3, 2014): 692–702. https://doi.org/10.1785/0220130087.

U. S. Geological Survey. "ShakeMap – Earthquake Ground Motion and Shaking Intensity Maps." U.S. Geological Survey, 2017. https://doi.org/10.5066/F7W957B2.

Wald, D. J., Quitoriano, V., Heaton, T. H., Kanamori, H., Scrivner, C. W., & Worden, C. B. (1999). TriNet "ShakeMaps": Rapid generation of peak ground motion and intensity maps for earthquakes in southern California. Earthquake Spectra, 15(3), 537-555.

Worden, C. B., Thompson, E. M., Baker, J. W., Bradley, B. A., Luco, N., & Wald, D. J. (2018). Spatial and spectral interpolation of ground-motion intensity measure observations. Bulletin of the Seismological Society of America, 108(2), 866-875.

Worden, C.B., E. M. Thompson, M. Hearne, and D.J. Wald (2020). ShakeMap Manual Online: technical manual, user's guide, and software guide, U. S. Geological Survey. http://usgs.github.io/shakemap/. DOI: https://doi.org/10.5066/F7D21VPQ.

Authors' postal address

Dario Jozinović: Sonneggstrasse 5, 8092 Zurich, Switzerland (dario.jozinovic@sed.ethz.ch)

Valentino Lauciani: Via di Vigna Murata 605, 00143, Roma, Italy (valentino.lauciani@ingv.it)

Sergio Bruni: Via di Vigna Murata 605, 00143, Roma, Italy (sergio.bruni@ingv.it)

Licia Faenza: Via Donato Creti, 12, 40128 Bologna (licia.faenza@ingv.it)

Alberto Michelini: Via di Vigna Murata 605, 00143, Roma, Italy (alberto.michelini@ingv.it)

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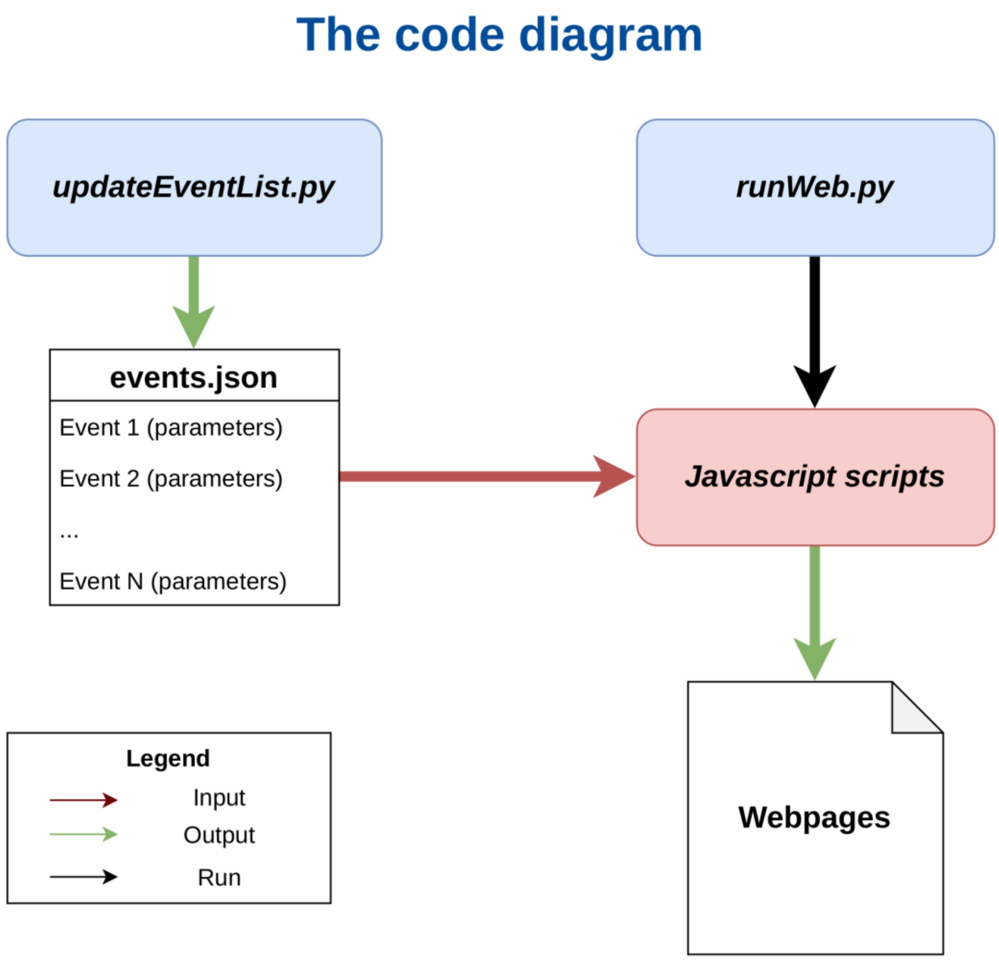

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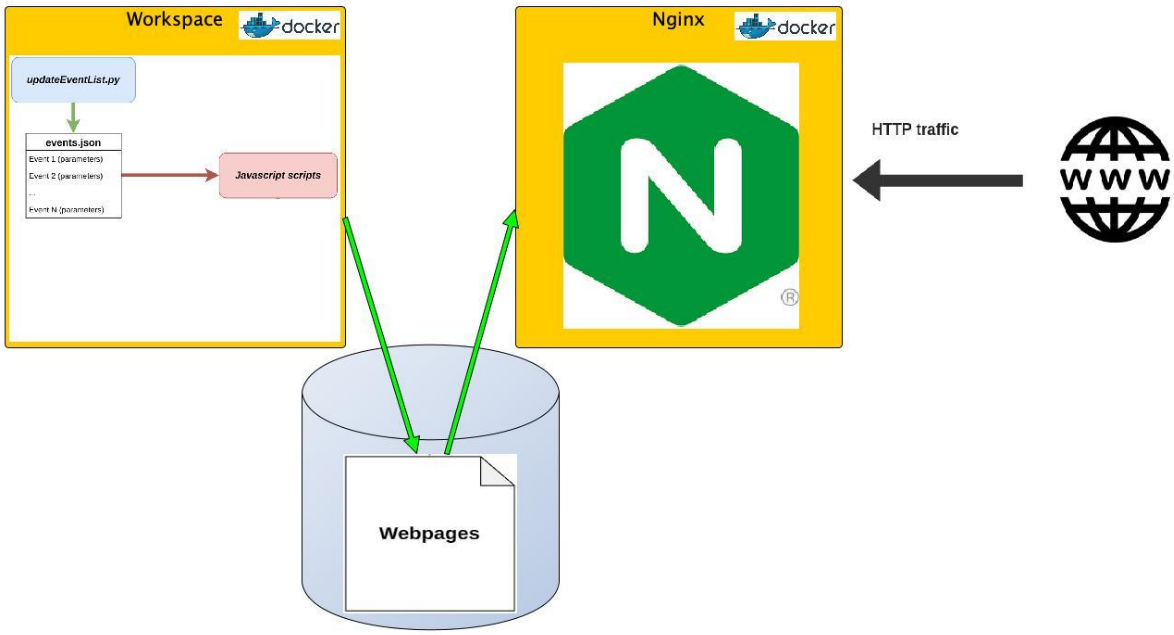

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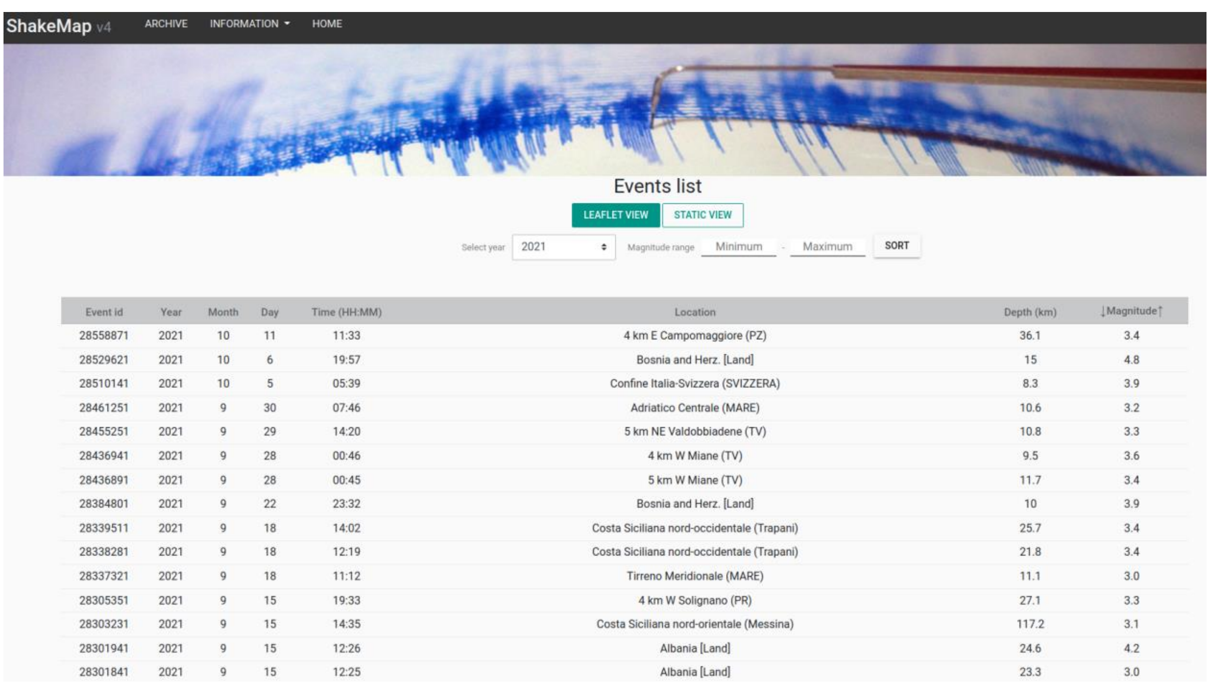

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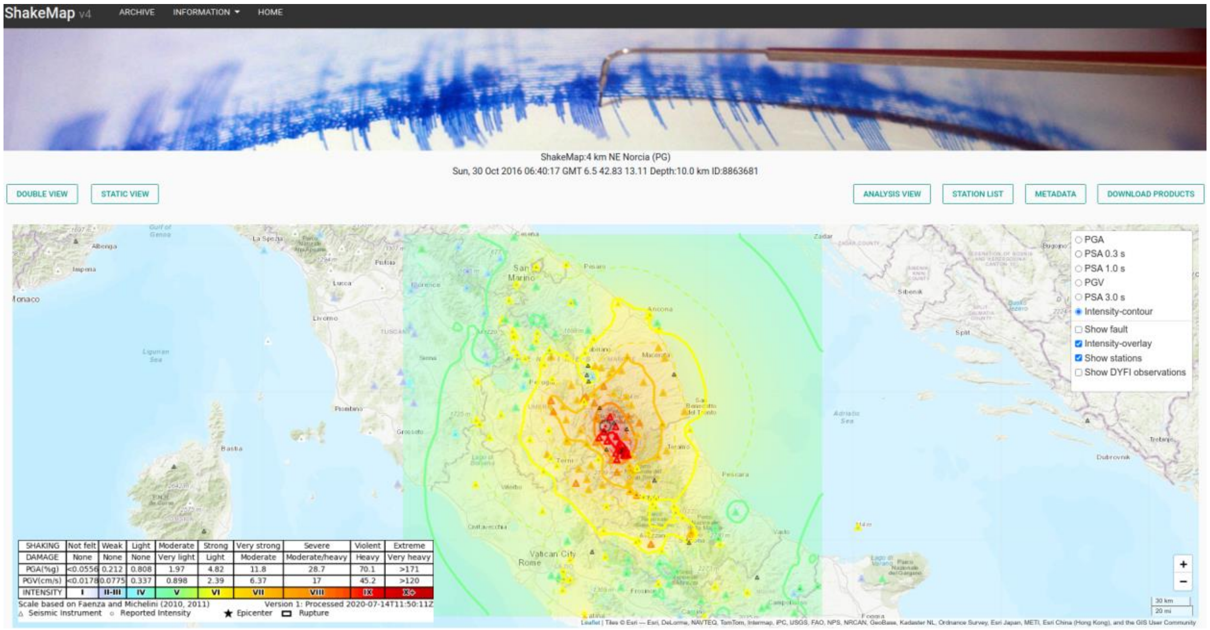

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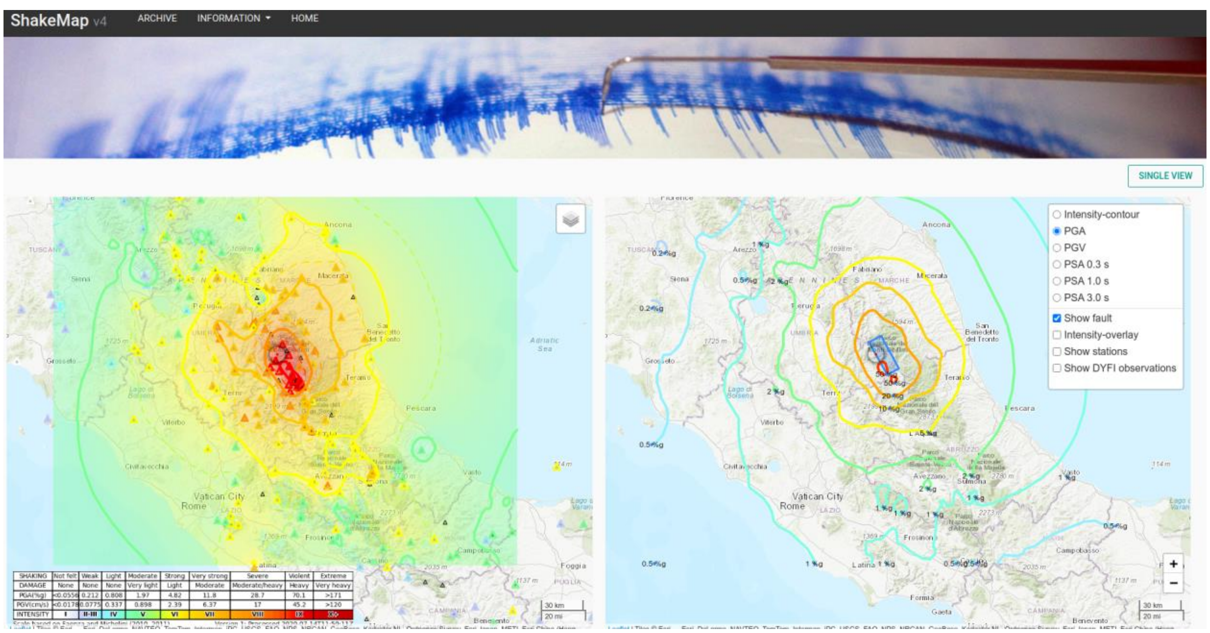

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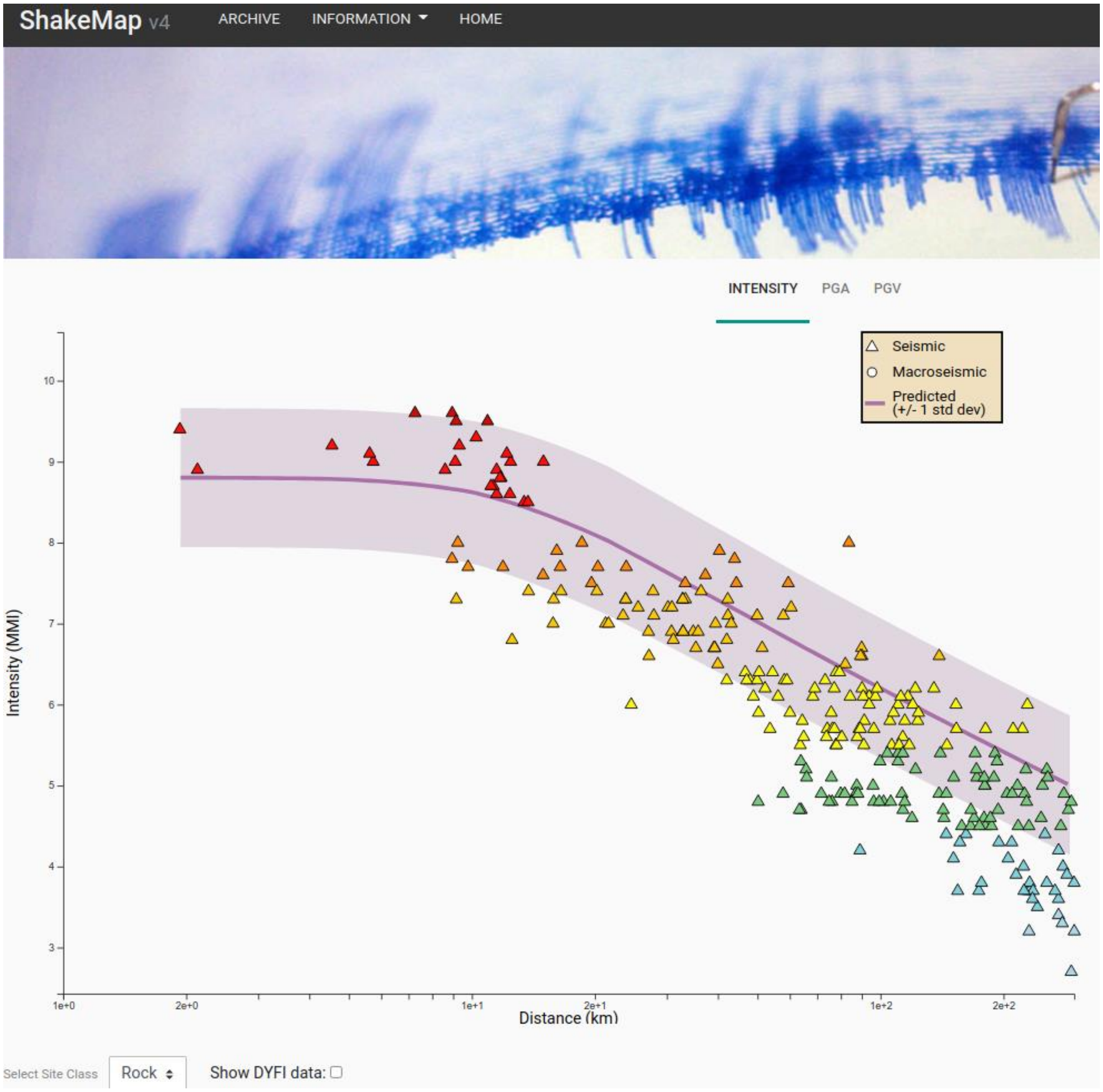

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