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Rapid Multi-Risk Needs Evaluation and Planning Platform

101193586 - EMERGE - UCPM-2024-KAPP-PV

CBR Ground Shaking Map

Executive summary of Near-real-time ShakeMap Module

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CBR Ground Shaking Map

Near-real-time ShakeMap Module

WP-04 | D.4.4

Gjorgjiev I., Salic Makreska R., Stojmanovska M., Poposka M., Filipovski D., Vitanova M., Riga, E., Amendola, C., Anastasiadis, A., Pitilakis, D., Ktenidou, O.-J., Nikas K., Papageorgiou A., Boukouras K., Plessa A., Qiriazi, G., Muceku, Y., Baballëku M., Dushi, E., Quaroni D., Bozzoni F., Di Meo A., Borzi B.

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Executive summary

This document presents the Executive Summary of the Near-Real-Time (NRT) ShakeMap Module developed within EMERGE Work Package 4 (WP4). The module provides a unified framework for the near-real-time generation, visualization, and exchange of cross-border seismic shaking information within the Cross-Border Region (CBR).

The primary objective of the module is the generation, and visualization of Near-Real-Time ground shaking map based on strong-motion recordings collected from integrated seismic networks operating within the CBR. The system utilizes seismic data acquired through the ORFEUS-EIDA infrastructure, the National Observatory of Athens (NOA) regional node, and dedicated direct data-sharing connections established among the participating institutions. The generated ShakeMap outputs provide input for the rapid needs assessment procedures integrated into the EMERGE Web-Based Platform (WBP).

The implemented solution is based on the ShakeMap4-Web framework developed by the National Institute of Geophysics and Volcanology of Italy (INGV) and adapted to the operational requirements of the EMERGE project, enabling automated data acquisition, processing, visualization, and dissemination of seismic shaking information.

The implemented system was validated through offline case-study analyses and online verification procedures using seismic data streams acquired through the integrated UKIM-IZIIS server environment. The performed tests confirmed the capability of the platform for operational ShakeMap generation and rapid output data dissemination.

Interoperability between the ShakeMap Module and the EMERGE Web-Based Platform was also successfully verified through the automated transfer of ShakeMap outputs for rapid needs assessment procedures within the EMERGE WBP within WP2.

1. Introduction

The near-real-time ShakeMap Module (web platform), developed within EMERGE WP4, represents the main outcome of this work package and an important step toward strengthening cross-border seismic monitoring, rapid earthquake impact assessment, and interoperable data exchange among the participating countries. Its main objective is the development of a web-based module for the generation and visualization of near-real-time ground shaking maps by integrating strong-motion data from North Macedonia, Greece, and Albania into a unified operational environment.

The module utilizes strong-motion data collected because of direct data-sharing connections established within the project framework. The generated ShakeMaps provide near real-time (NRT) estimation of ground shaking distribution following seismic events (Wald et al., 2003) and are intended to serve as input for the NRT needs assessment algorithms integrated into the EMERGE Web-Based Platform (WBP), developed within WP2.

The implemented platform enables the automated collection and processing of strong-motion seismic data in near real time, supporting faster and more reliable generation of ShakeMaps for regional earthquake events. Through the customization and implementation of the ShakeMap4-Web platform developed by INGV, the generated outputs are made accessible through a dedicated web interface. The access to the platform and user functionalities is described in Deliverable D4.3.

This document presents a high-level overview of the developed module, including its general architecture, operational workflow, and core functionalities, while avoiding disclosure of sensitive technical and security-related implementation details.

The platform underwent an extensive testing and validation phase through continuous collaboration among the participating institutions. Activities implemented within WP4 included the establishment of institutional cooperation mechanisms for cross-border seismic data exchange (signing of a Memorandum of Understanding), the integration of selected CBR strong-motion stations into the operational platform, and the development of technical solutions supporting ShakeMap generation and interoperability with the EMERGE WBP. In addition, the module was evaluated through case-study analyses and simulated real-time earthquake scenarios to assess its operational reliability, robustness, and applicability for rapid emergency-response support.

2. Framework for Cross-Border Strong-Motion Data Exchange

The North Macedonian Strong Motion Network initiated the integration process with the EIDA@NOA infrastructure in 2023. NOA hosts the regional node of EIDA (EIDA@NOA; https://eida.gein.noa.gr/; Evangelidis et al., 2021) distributing data from seismic stations located in Greece and the southeastern Mediterranean. EIDA stands for the European

Integrated Data Archive (https://www.orfeus-eu.org/data/eida/), is run by ORFEUS (https://www.orfeus-eu.org/) and is a federated European data center that archives and provides access to seismic data from European research infrastructures. Such data includes waveforms (raw, i.e. unprocessed, not in physical units and not ready for use in engineering applications) and their metadata including station inventory, and quality parameters

In support of this integration process, the data management and sharing framework between Institute of Earthquake Engineering and Engineering Seismology (IZIIS) and EIDA was formalized through the signing of two Memoranda of Understanding (MoUs) and cooperation agreements between IZIIS, the National Observatory of Athens (NOA), and the Institute of Geosciences (IGEO) (Annex 1 and Annex 2 of Deliverable 1: Evaluation of CBR Strong Motion Capacities and ORFEUS-EIDA Integration).

The MoU between IZIIS and IGEO was signed in October 2025 with an indefinite duration, while the MoU between IZIIS and NOA was signed in February 2026 for an initial period of five years, with the possibility for renewal through an additional agreement upon its expiration. These agreements establish the framework for data sharing and integration of selected seismic stations belonging to the North Macedonian UKIM-IZIIS Network (MA), the Hellenic Seismic Network (HL) and the Albanian Seismological Network (AC) (IZIIS, 1972; NOA, 1975; IGEO, 2002).

In accordance with the signed agreements and to support the established data-sharing framework, a dedicated UKIM-IZIIS SeisComP (Helmholtz Centre Potsdam GFZ and gempa GmbH, 2008) server was installed as the central platform for integrating strong-motion stations from the participating seismic networks and enabling their utilization for near-real-time ShakeMap generation. Figure 1 presents the current status of the strong-motion stations from the three participating countries incorporated into the UKIM-IZIIS server. The green triangles represent the Albanian strong-motion stations, the purple triangles indicate the North Macedonian stations, and the blue triangles represent the Greek stations.

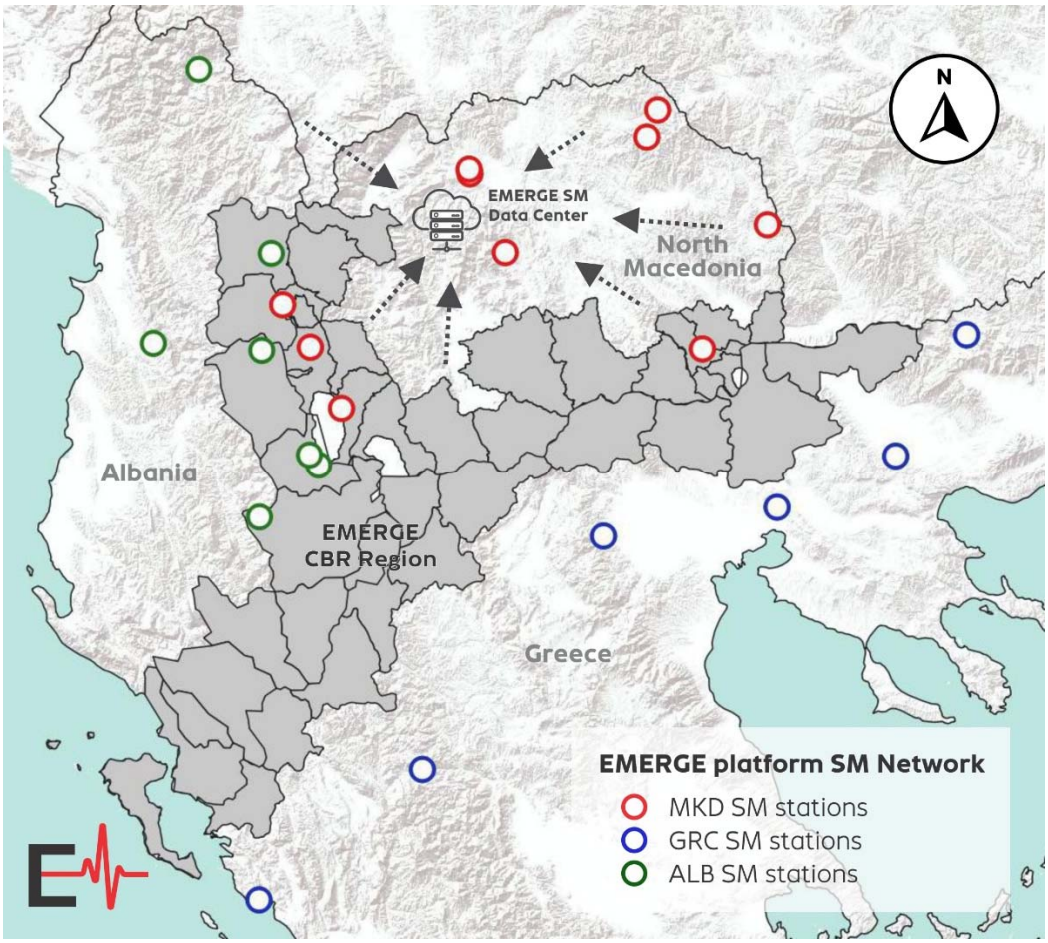


Figure 1. Current status of the strong motion stations incorporated into the UKIM-IZIIS server for ShakeMap generation

3. Development of Web GIS module

The ShakeMap web interface developed within the EMERGE project is based on the ShakeMap4-Web framework (Faenza et al., 2008) created by INGV and publicly available through its GitHub repository (https://github.com/INGV/shakemap4-web). This framework provides a modern web-based environment for the visualization, management, and dissemination of Near-Real-Time (NRT) ShakeMap products generated following seismic events.

To ensure operational stability, reproducibility, and simplified maintenance, the application was implemented using a container-based deployment environment. This approach enables automated deployment, efficient system management, and seamless integration with the ShakeMap processing workflow. The implemented architecture supports the automatic ingestion, updating, and visualization of newly generated ShakeMap solutions with minimal manual intervention, thereby improving the responsiveness and operational reliability of the platform.

The modular design of the system also allows future expansion through the implementation of additional functionalities and supporting services. Within the current framework, the platform architecture supports implementation of automated notification procedures and interoperability with external modules and decision-support components integrated into the EMERGE WBP.

The webGIS interface provides several interactive visualization layers corresponding to different ShakeMap products and intensity-related parameters. These include macroseismic intensity distribution, Peak Ground Acceleration (PGA), Spectral Acceleration (S_A), and other ground-motion parameters relevant for rapid earthquake impact assessment. Through these visualization tools, users can obtain a comprehensive overview of the spatial distribution and severity of ground shaking associated with a seismic event.

Overall, the developed webGIS module represents a central component of the EMERGE Near-Real-Time ShakeMap system, enabling efficient visualization, automated updating, and user-oriented access to seismic shaking information within the cross-border monitoring framework.

For operational reasons, the platform is currently deployed within controlled access. This configuration ensures reliable system performance, data integrity, and operational continuity, particularly during periods of increased seismic activity or limited external network availability.

4. Integration with EMERGE Web-Based Platform (WBP)

Following the generation of the ShakeMap products, the resulting ground-motion intensity measures are automatically transmitted to the EMERGE Web-Based Platform (WBP) to support rapid needs assessment calculation developed within WP2. Figure 2 illustrates the overall operational workflow, beginning with seismic data acquisition and continuing through ShakeMap generation, data exchange, and needs assessment processing.

The implemented workflow consists of the following main steps:

- The UKIM-IZIIS SeisComP server continuously collects, processes, and analyzes strong-motion data acquired from the integrated CBR seismic networks;
- Following the detection of a seismic event, the system automatically initiates the ShakeMap generation procedure and transfers the required input parameters to the ShakeMap processing environment;
- The generated ShakeMap outputs including associated intensity measures, are transmitted to the EMERGE WBP;

- Based on the generated shaking distribution, additional parameters such as Permanent Ground Displacement (PGD) are calculated for the CBR region and transmitted to the EMERGE WBP through dedicated REST API communication services as supplementary GeoJSON layers associated with the corresponding event identifier;
- The EMERGE WBP, developed by EUCENTRE, utilizes the received ShakeMap outputs and derived parameters to perform Near-Real-Time needs assessment calculations for the detected seismic event.

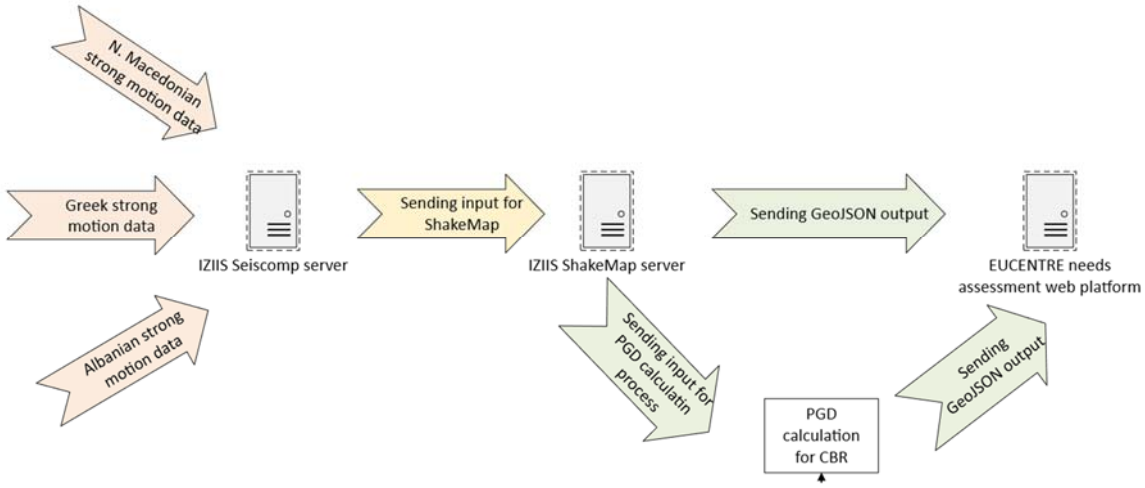


Figure 2. WP4 system architecture

5. Testing of Ground Shaking Module (case – study analysis)

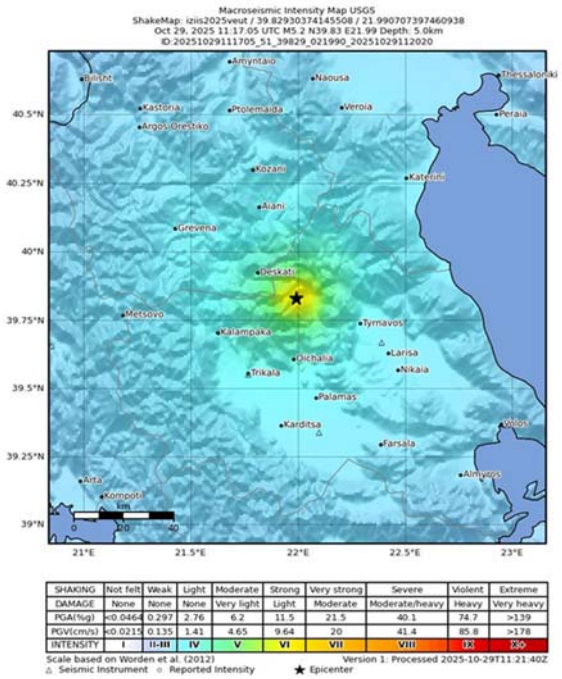
5.1. Verification of ShakeMap based on NOA seismic network data

To evaluate the operability, stability, and functional performance of the implemented software environment and its supporting extensions required for ShakeMap generation, a dedicated offline validation test was conducted.

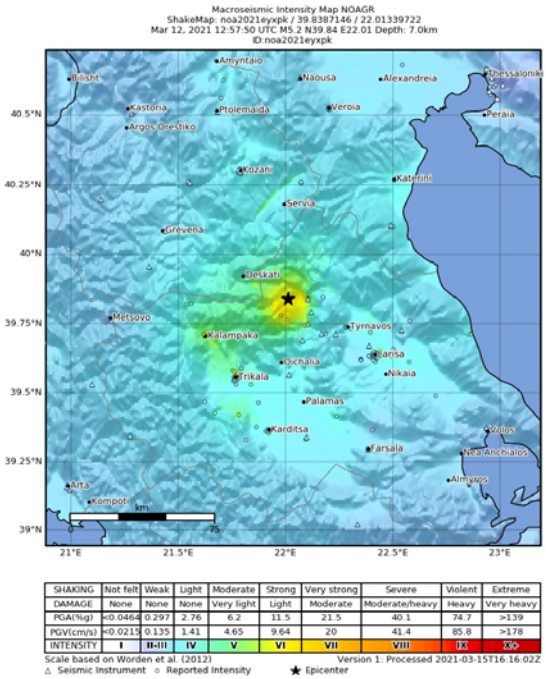
For this purpose, strong-motion data from the NOA seismic network corresponding to the earthquake event of 12 March 2021 at 12:57:51 (Mw = 5.6) were utilized as input for the testing procedure. The selected dataset included recordings from all available stations, which were incorporated into the ShakeMap generation workflow in order to assess the flexibility and robustness of the implemented processing chain.

The test confirmed the successful operation of the processing environment and the proper generation of ShakeMap products. The resulting maps included macroseismic intensity distribution, Peak Ground Acceleration (PGA), and Spectral Acceleration values for a structural period of T = 1.0 s. The output generated are presented in Figures 3a, 4a and 5a. For the sake of comparison and completeness, Figures 3b, 3c, 3d, 4b, 4c, 4d and 5b, 5c, 5d respectively show the same maps generated by standard sources, namely NOA (https://accelnet.gein.noa.gr/noa_sites/noa.shakemaps.gr/public/index/126701), ITSAK

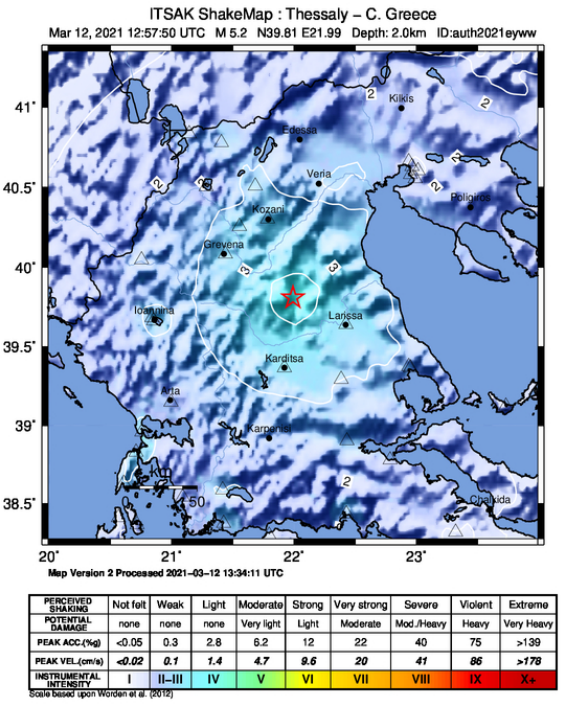
(https://shakemaps.itsak.gr/auth2026eyrm/intensity.html), and ShakeMapsEU (Michelini et al., 2023; https://shakemapeu.ingv.it/#event/20210312_0000107).



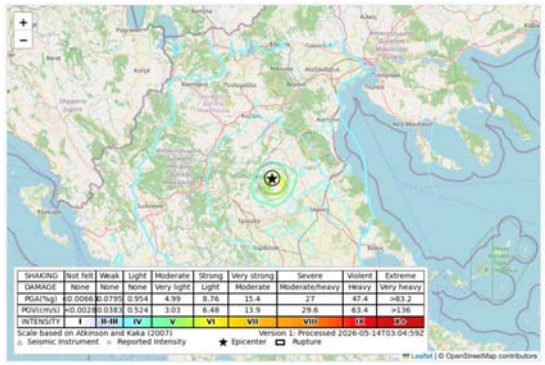
a) Generated by EMERGE WBP



b) Macroseismic Intensity Maps by NOA standard source

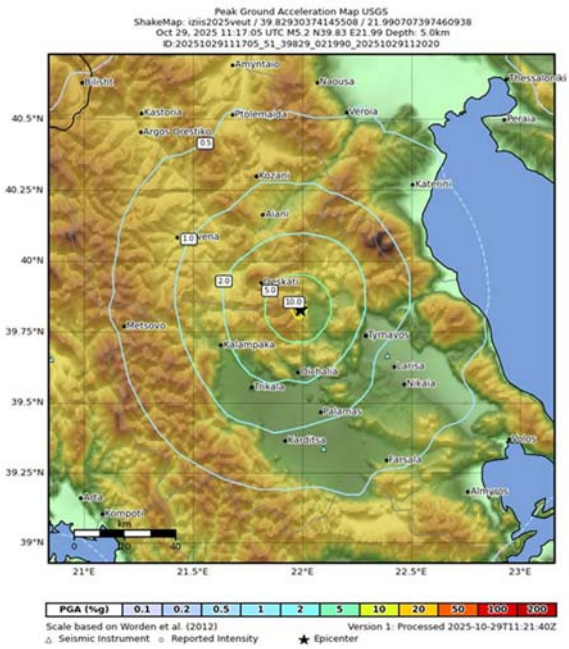


c) Macroseismic Intensity Maps by ITSAK standard source

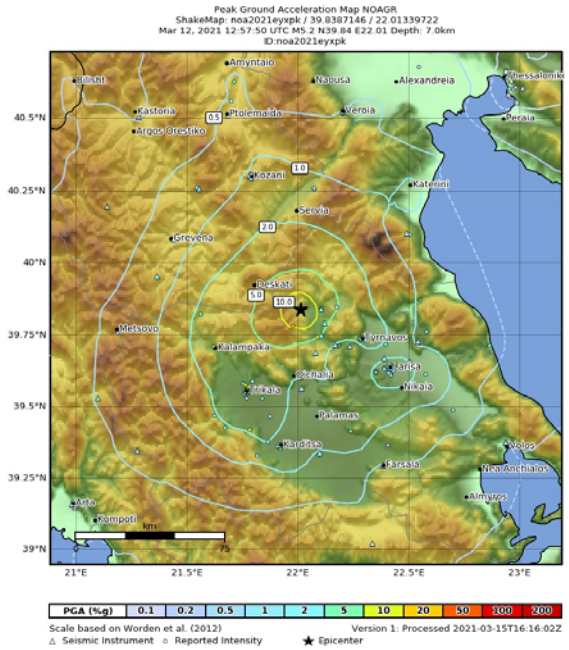


d) Macroseismic Intensity Maps by ShakeMapsEU standard source

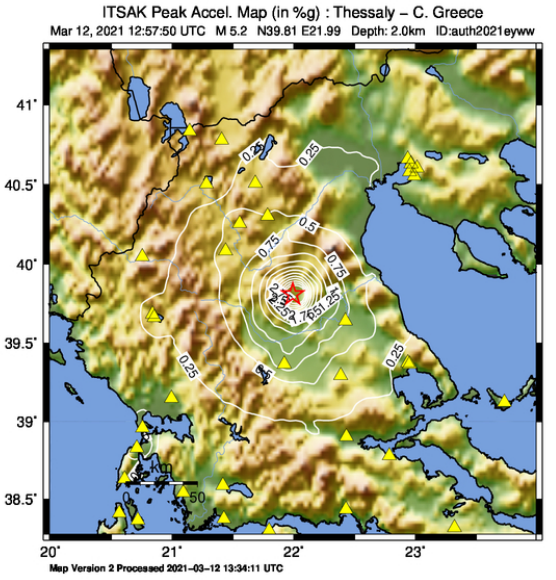
Figure 3. Macroseismic Intensity Maps (12 March 2021 at 12:57:51, Mw = 5.6)



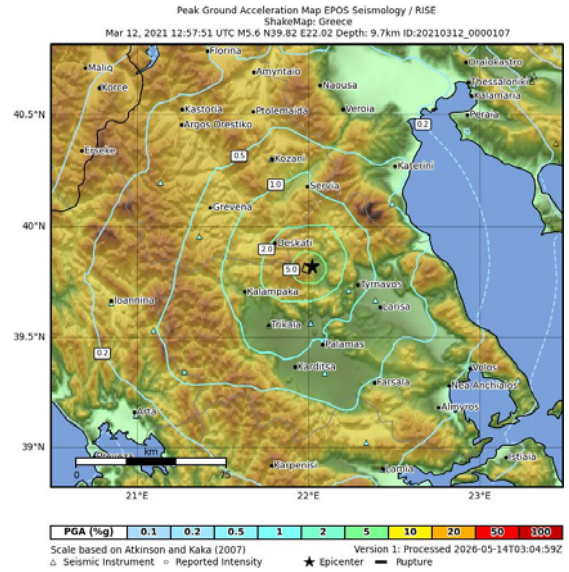
a) PGA map generated by EMERGE WBP



b) PGA map by NOA standard source

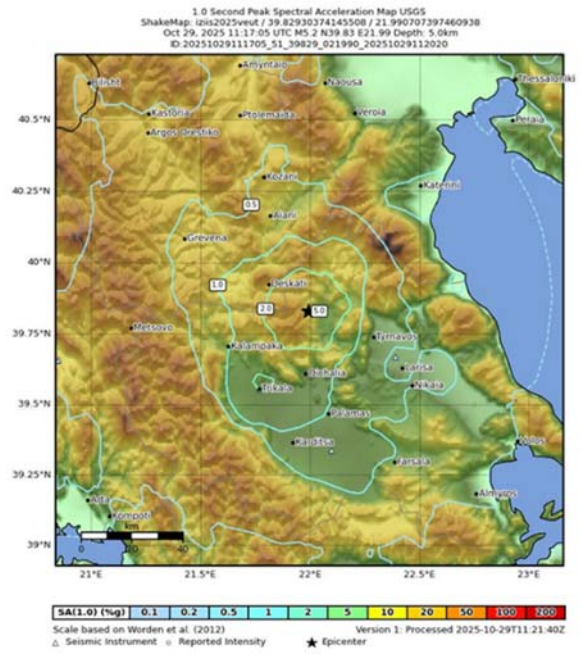


c) PGA map by ITSAK standard source

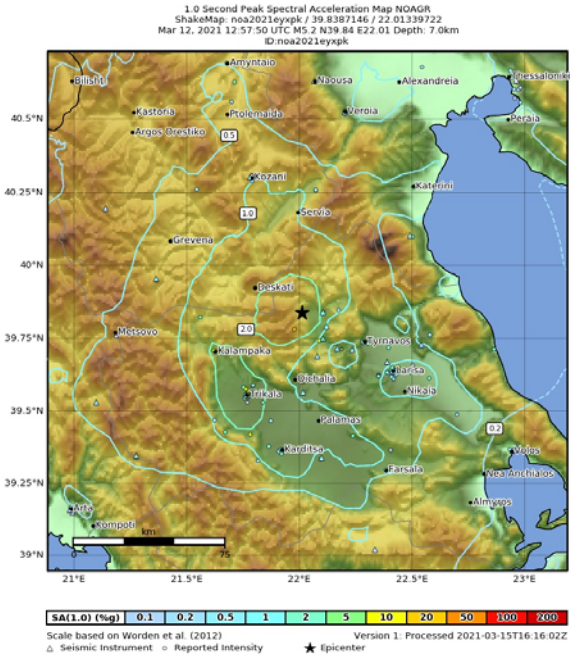


d) PGA map by ShakeMapsEU standard source

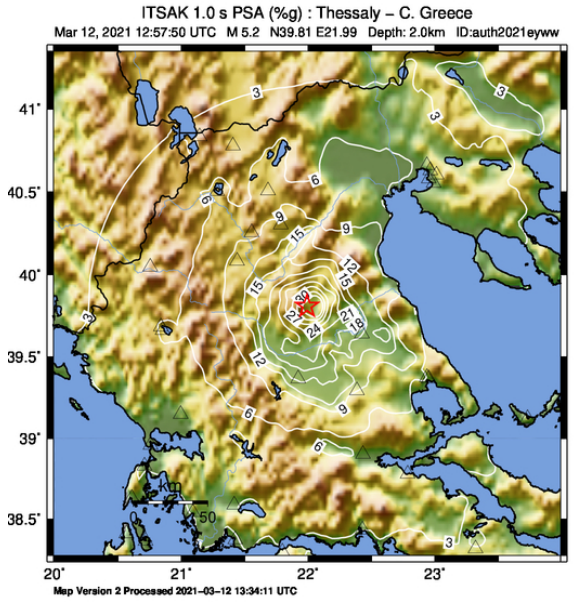
Figure 4. Peak Ground Acceleration (PGA) Maps (12 March 2021 at 12:57:51, Mw = 5.6)



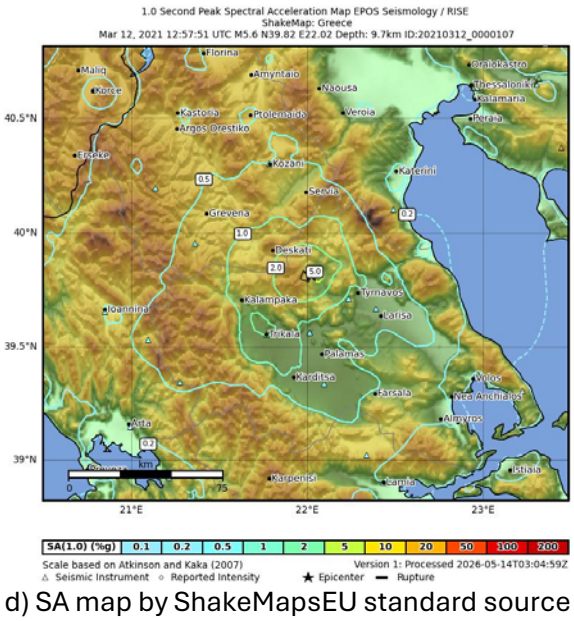
a) SA generated by EMERGE WBP



b) SA map by NOA standard source



c) SA map by ITSAK standard source



d) SA map by ShakeMapsEU standard source

Figure 5. 1.0 sec Spectral Acceleration (SA) Maps (12 March 2021 at 12:57:51, Mw = 5.6)

5.2. Verification of near-real-time ShakeMap using EMERGE WBP event data

Following the successful completion of the offline validation test, an additional verification procedure was conducted to evaluate the operational performance of the platform using data acquired through the integrated UKIM-IZIIS server environment.

For this purpose, strong-motion recordings corresponding to the earthquake event of 10 February 2026 at 21:05:28 (Mw 4.5) were processed using data streams collected from the stations integrated within the platform. The objective of this verification procedure was to assess the capability of the system to automatically retrieve, process, and utilize near-real-time seismic recordings for ShakeMap generation within the operational workflow.

The performed verification confirmed the successful integration of the incorporated stations and demonstrated the capability of the platform to support automated processing and generation of ShakeMap products using online seismic event data. Results from the ShakeMap online test are given in Figures 6, 7 and 8.

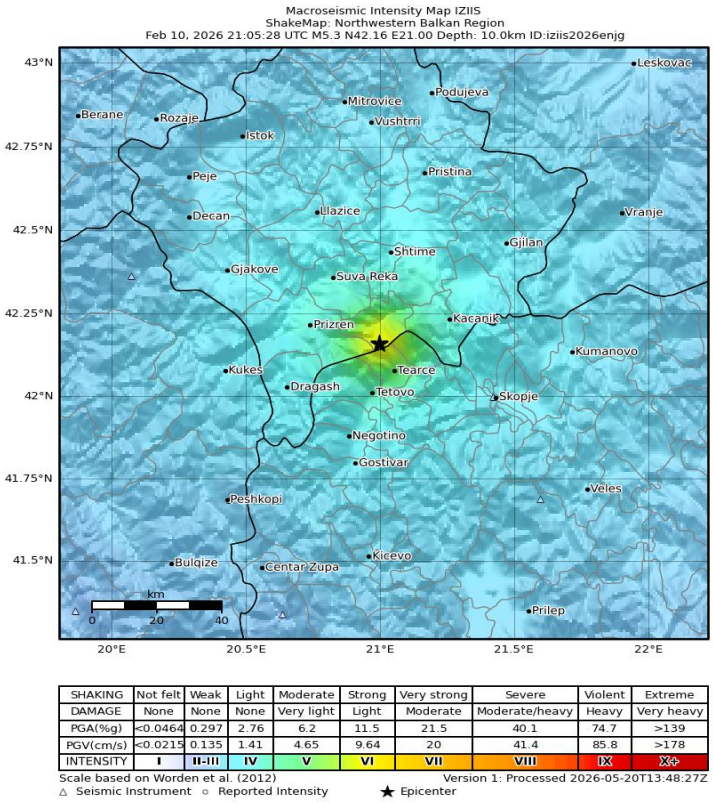


Figure 6. Macroseismic Intensity Map (10 February 2026 at 21:05:28, Mw = 4.5)

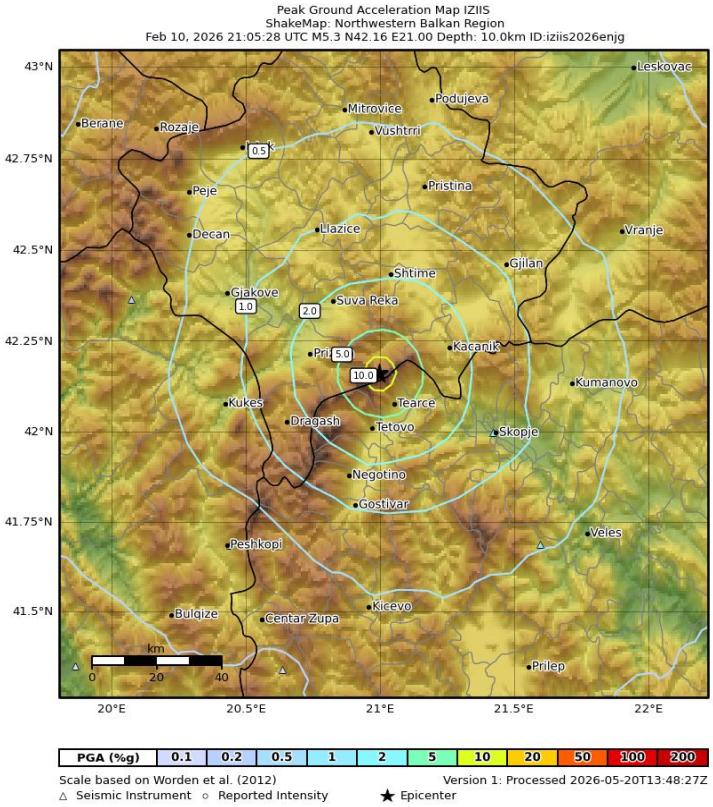


Figure 7. Peak Ground Acceleration Map (10 February 2026 at 21:05:28, Mw = 4.5)

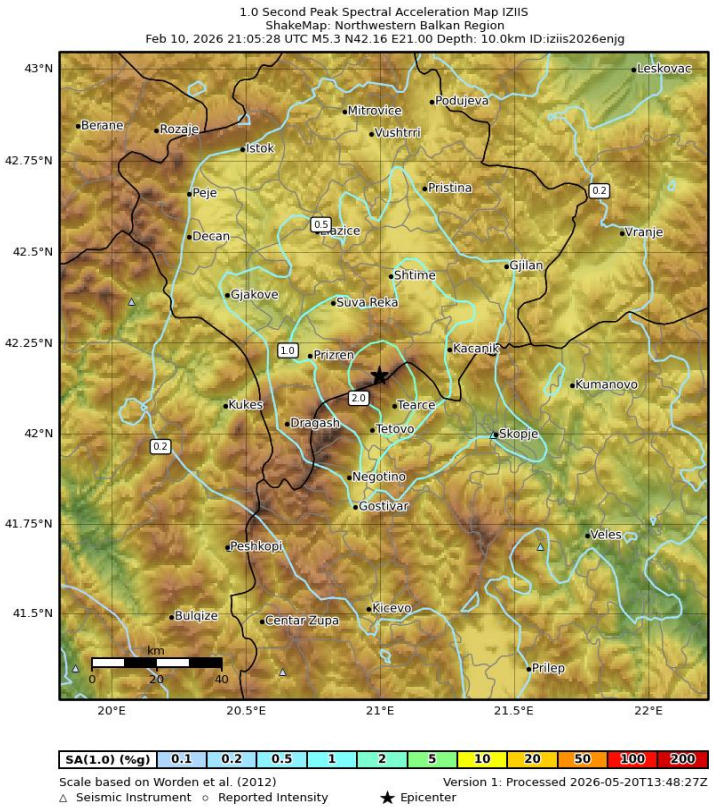


Figure 8. 1.0 sec Spectral Acceleration Map (10 February 2026 at 21:05:28, Mw = 4.5)

6. Concluding remarks

EMERGE WP4 has successfully delivered the design, development, testing, and implementation of the NRT ShakeMap Module as one of the main outcomes of the work package. The developed system represents an important advancement in regional capabilities for rapid assessment and contributes to strengthening cross-border seismic monitoring through the integration of strong motion data from North Macedonia, Greece, and Albania.

A key prerequisite for the successful implementation of the platform was the establishment of institutional cooperation mechanisms and operational data-sharing frameworks among the participating organizations. Therefore, Memoranda of Understanding and bilateral cooperation agreements were signed, providing the foundation for continuous seismic data exchange, interoperability, and long-term regional collaboration. In parallel, the deployment of a dedicated UKIM-IZIIS SeisComP server enabled centralized integration, processing, and management of strong-motion data required for near-real-time ShakeMap generation.

The developed web-based ShakeMap interface, implemented using the ShakeMap4-Web framework within a container-based deployment environment, provides a stable, reproducible, and maintainable operational solution. Automated processing procedures, real-time data integration, and support for additional notification and interoperability services further improve the operational efficiency, responsiveness, and usability of the platform.

The implemented system was validated through offline case-study analyses using recorded strong-motion data from participating seismic networks. In addition, an online verification phase was conducted using seismic data streams acquired through the integrated UKIM-IZIIS server environment. The performed tests confirmed the capability of the platform to automatically retrieve, process near-real-time strong-motion recordings from the connected CBR stations for operational ShakeMap generation and near-real-time data dissemination.

In addition, interoperability with the EMERGE WBP was successfully tested through the automated transfer of ShakeMap outputs and derived parameters used for rapid needs assessment procedures within the EMERGE platform.

Overall, WP4 delivers a scalable and operational Near-Real-Time ShakeMap solution that significantly advances regional seismic data integration, automated earthquake-response workflows, and cross-border cooperation in support of earthquake risk assessment, emergency response, and decision-support activities. The results achieved represent an important contribution toward the broader objectives of the EMERGE project related to rapid needs evaluation, and regional resilience enhancement.

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