ChEESE

ChEESE-2P in Mexico's National Earthquake Drill: Technical Results and Communication Impact

Funded by the European Union. This work has received funding from the European High Performance Computing Joint Undertaking (JU) and Spain, Italy, Iceland, Germany, Norway, France, Finland and Croatia under grant agreement No 101093038.

ChEESE-2P

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Document Information

Contract Number	101093038
Project Website	https://cheese2.eu
Activity	WP6-WP7
Dissemination Level	PUBLIC

Abstract

This report summarises the ChEESE-2P participation in Mexico's National Earthquake Drill 2025, presenting both the technical execution and the communication impact of the activity. The technical section describes the setup, workflows, and outcomes of the urgent computing trial jointly coordinated by the Barcelona Supercomputing Center (BSC), the Mexican National Seismological Service (SSN) - a member of the ChEESE Industry and User Boards (IUBs) - and the National Autonomous University of Mexico (UNAM).

I. Copyright

II. Delivery Slip

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III. Version control

Version	Date	Description of change	Author/Partner
V1	07/10/2025	Initial draft	Aerton Guimarães
V2	14/10/2025	Revised version	Josep de La Puente
V3	15/10/2025	Final version	Leonarda Isabel Esquivel Mendiola

CASE STUDY: Urgent computing for Mexican Earthquake annual drill TRIAL CASE #	
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Overview of the Trial	

Mexico is one of the most seismically active regions in the world due to its location at the convergence of several major tectonic plates: the North American, Pacific, Cocos, Rivera, and Caribbean Plates. This complex tectonic setting leads to frequent earthquakes, particularly along the subduction zones off the western and southern coasts. In this context, the **Mexican National Earthquake Drill** (Simulacro Nacional) represents an essential annual preparedness exercise coordinated by national civil protection authorities to enhance the population's awareness and response capacity to large seismic events.

The 2025 edition of the drill, held on **19 September 2025**, carried exceptional national relevance, marking the **40th anniversary of the 1985 Michoacán earthquake (Mw 8.1)** - a catastrophic event that caused thousands of fatalities and deeply shaped Mexico's seismic risk management policies.

In collaboration with the **National Seismological Service (SSN)** of Mexico, part of the **Institute of Geophysics** of the **National Autonomous University of Mexico (UNAM)** and a member of the ChEESE Industry and Users Board (IUB), this event served as an opportunity to demonstrate advanced high-performance computing (HPC) technologies developed under the **ChEESE Centre of Excellence (CoE)** and **DT-GEO** projects, coordinated by the **Barcelona Supercomputing Center (BSC)**.

The trial aimed to simulate an operational urgent computing service during the national drill, using two HPC-based workflows designed to support rapid seismic analysis and impact forecasting in near-real time. This collaboration bridged scientific research, computing innovation, and national emergency preparedness, showcasing how European HPC technologies can contribute to global resilience efforts.

This activity aligns directly with the **objectives of the ChEESE-2P project**, which seeks to advance and operationalize HPC-based workflows for natural hazard forecasting, response, and mitigation. By embedding these workflows into a real operational context, the exercise demonstrated how scientific and computational advancements can transition from research to societal application. Furthermore, the trial functioned as a **ChEESE-2P trial**, focused on the **urgent computing use case for seismic events**. It validated the interoperability, scalability, and efficiency of the developed workflows when integrated with local seismic observation networks and decision-making structures in Mexico.

The main objectives of the trial were to test the operational readiness of HPC-based urgent computing workflows, assess the performance of real-time seismic simulations, and evaluate data integration between the SSN and BSC's HPC infrastructure. On the technical side, the trial pursued specific goals such as verifying workflow performance under operational constraints, testing real-time data ingestion, and producing near **real-time scenario simulations** that could inform rapid impact assessment during a seismic emergency.

On the societal, dissemination and communication side, the activity aimed to increase public awareness of the role of computational science in disaster preparedness, foster trust in science-driven emergency management tools, and highlight the benefits of international cooperation between Europe and Mexico in advancing seismic resilience.

Overall, this trial demonstrated how cutting-edge HPC infrastructures and urgent computing frameworks, when coupled with national observatories and emergency response systems, can play a transformative role in reducing seismic risk and improving disaster response capacity. The 2025 Mexican National Earthquake Drill thus served as both a national exercise in preparedness and a near-real world testbed for next-generation scientific and technological capabilities developed within the ChEESE-2P and DT-GEO projects.

1. Technical Execution

The preparation for the 2025 Mexican National Earthquake Drill trial was the result of over **six months** of coordinated technical and operational planning between the Barcelona Supercomputing Center (BSC), the National Seismological Service (SSN) of Mexico, and the Institute of Geophysics of the UNAM, together with the Salvus development team from Mondaic, and the BSC operations and ChEESE-2P technical teams.

Several bilateral and joint meetings were held to define the workflow configuration, data exchange procedures, and the execution plan for the urgent computing demonstration. This long preparation ensured that both the scientific and computational components were fully aligned with the objectives of the national seismic drill.

During the trial, computations were executed on the MareNostrum 5 (MN5) supercomputer at the BSC, a Tier-0 European HPC system. A total of **140 compute nodes were used** - 70 nodes from the accelerated partition and 70 from the general-purpose partition - for approximately two hours at maximum priority, marking a pioneering example of Urgent Computing queue activation on a European Tier-0 system. This achievement positioned BSC as a frontrunner in developing and testing operational urgent computing workflows for natural hazard response within Europe.

The technical workflow implemented was the Urgent Computing Integrated Services for Earthquakes (UCIS4EQ), designed to perform rapid, large-scale seismic simulations. During the exercise, UCIS4EQ executed **50 parallel simulations** using the Salvus code to model different possible earthquake source scenarios, accounting for uncertainties in source parameters such as location, depth, and rupture mechanism.

A particularly demanding aspect of the trial was the modelling of the Mexico City basin, a region characterized by complex sedimentary structures that strongly amplify seismic waves. Accurately capturing this amplification required high-resolution post-processing and careful calibration of material properties, posing additional computational and numerical challenges that tested the limits of the workflow and HPC infrastructure.

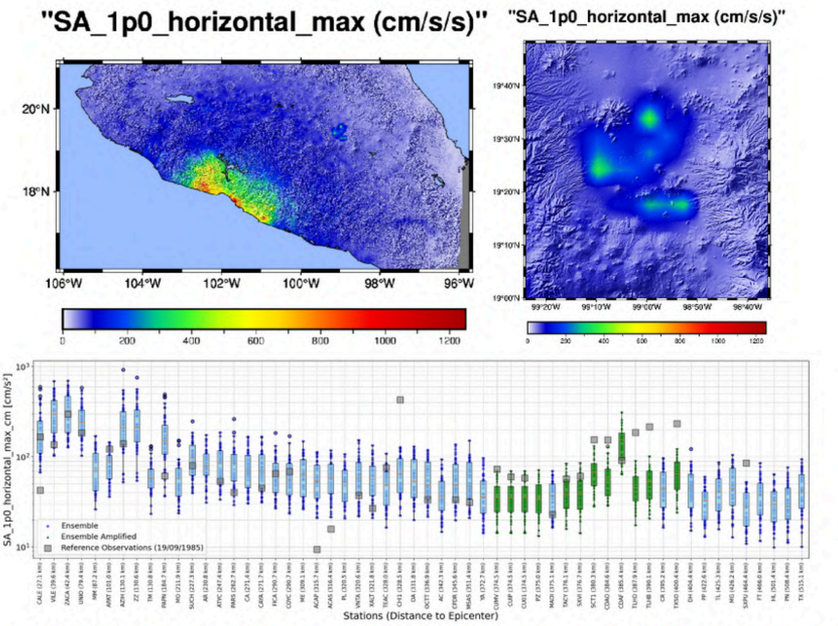
One of the main technical challenges faced during the preparation phase was optimizing the pre-processing and post-processing stages of the UCIS4EQ workflow to meet the strict timing constraints of urgent computing scenarios. These bottlenecks were mitigated through code profiling, improved data management strategies, parallelization strategies through PyCOMPSs, and tighter integration between Salvus and the UCIS4EQ orchestration layer. The exercise also **represented the largest ever execution of Salvus** by Mondaic, serving as a stress test for both software scalability and operational readiness.

The outcome of this joint effort not only validated the technical feasibility of urgent computing for seismic scenarios but also reinforced the operational collaboration between European and Mexican institutions in advancing scientific computing for disaster response.

2. Outputs and Deliverables

The trial generated a variety of scientific and technical outputs that contribute both to the ChEESE-2P objectives and to the broader seismic research community. Among the main deliverables produced were the simulation datasets and models resulting from the fifty parallel runs of the UCIS4EQ workflow, capturing multiple earthquake source scenarios and their effects across the Mexico City basin.

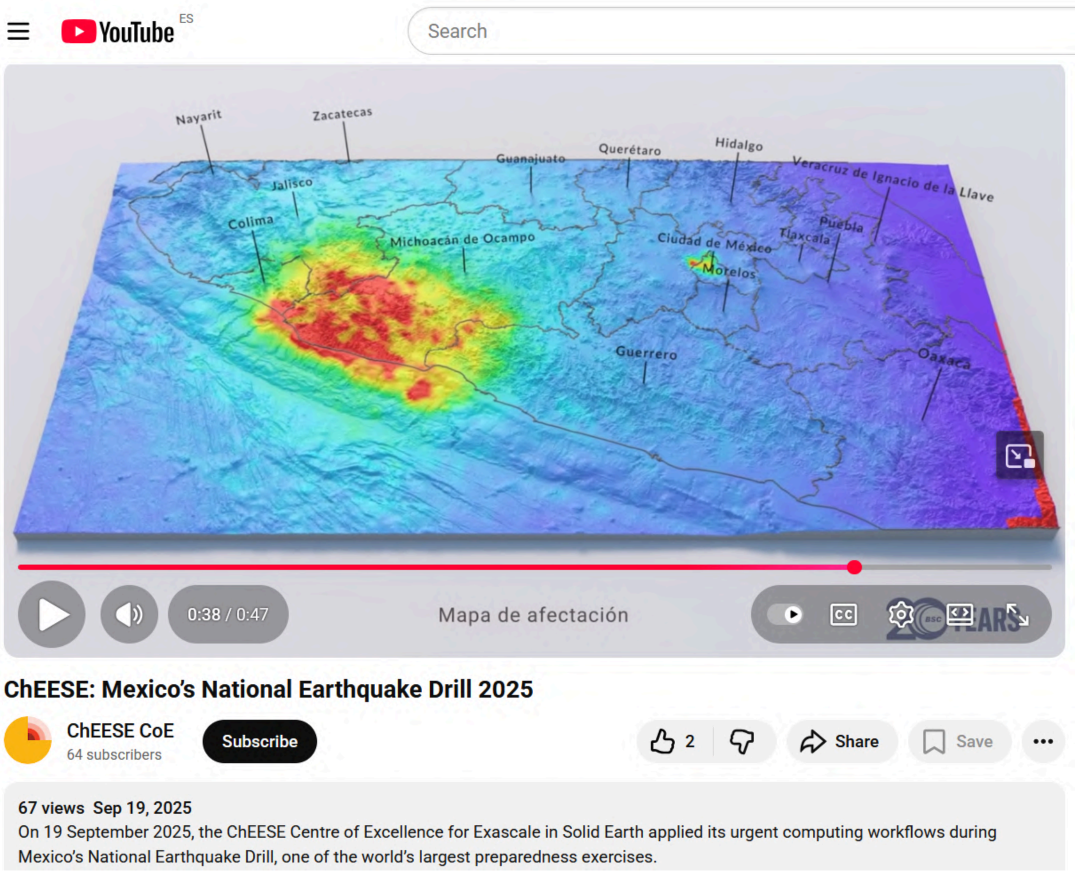
All resulting simulation data, metadata, and workflow configurations **have been made publicly** available through the official ChEESE-2P GitLab repository and its linked Zenodo archive, ensuring transparency, reproducibility, and open scientific access. The UCIS4EQ workflow itself is open source, providing the research community with an operational example of a fully integrated urgent computing system for earthquakes.



Figures: Spectral acceleration (SA) maps of the hypothetical earthquake simulated on 19 September 2025. The left map shows the full area of estimated SA values, while the right focuses on potential intensities in Mexico City. The lower chart compares the maximum SA values from the simulations with records from different stations during the 19/09/1985 earthquake. Produced by the Barcelona Supercomputing Center in collaboration with the Mexican National Seismological Service.

In addition, a public outreach video summarizing the objectives, setup, and results of the trial was produced and disseminated through both the ChEESE-2P website and the official YouTube channel, aimed at enhancing public understanding of HPC's role in seismic risk mitigation.

The results and analysis from the trial were also included in the **official report** published by the National Seismological Service (SSN) as part of the documentation of the 2025 National Earthquake Drill, available to the public through SSN's communication channels (https://shorturl.at/Ihwbj).



https://www.youtube.com/watch?v=SIEP99J9mmM

From a technical standpoint, the trial successfully met all performance and accuracy requirements defined in collaboration with the SSN. Specifically, the system achieved the targeted response time for urgent simulations and the frequency resolution needed to accurately capture ground motion amplification within the Mexico City basin, in agreement with observed site effects.

Key performance indicators included the **successful execution** of 50 parallel simulations within a two-hour operational window, maintaining numerical stability and computational efficiency on 140 nodes of the MareNostrum 5 system. These results confirm both the scalability and readiness of UCIS4EQ for real-world urgent computing applications and position BSC and its partners as leaders in the development of operational HPC frameworks for seismic risk response.

2.1 Outputs

1. List of outputs
   - ☑ Simulation data: synthetic seismic records, ground shaking maps (Peak Ground Acceleration [PGA], Peak Ground Velocity [PGV], Spectral Acceleration (SA), Cumulative Absolute Velocity [CAV],

Arias Intensity [AI], and Significant Duration based on AI), and raw data of seismic hazard parameters.

- ☑ Scientific/technical reports
- ☑ Media reports: Media impact report, pre- and post-event press releases, and real-time event coverage.

2.2 Physical scenario definition

This TRIAL was developed in the framework of the annual Mexican National Seismic Drill on 19/9/2025. The Mexican tectonic setting has a high seismic potential with high-magnitude earthquakes. Therefore, we will consider the hypothetical scenario suggested by the Mexican government, a large earthquake located in the southwest Mexican subduction zone. km. The simulation considered a simulation frequency of 1 Hz and its domain covered an area of 1,074 km × 580 km, **with a depth of 150 km**, which represented the largest computational domain modeled with Salvus by Mondaic.

Challenges of this trial:

Large computational resources were required for this trial. However, it lacked high-resolution velocity models, which limited our validation and increased the level of "blindness." The high-magnitude earthquake generated ground-shaking maps with the highest ground accelerations concentrated in the epicentral region. Nevertheless, our resolution level allowed us to identify other towns or cities with a high potential for **strong ground shaking**.

2.3 Data integration workflow

Input data:

- Topography and Bathymetry grid obtained from the Global Multi-Resolution Topography Data Synthesis (https://www.gmrt.org/)
- Seismic velocity models obtained from (Solvi et al., 2024)
- Hypocentral location reported by SSN of Mexico (http://www.ssn.unam.mx/)
- Focal mechanism catalogs obtained from Global CMT (https://www.globalcmt.org/CMTsearch.html) and IRIS (https://ds.iris.edu/spud/momenttensor)
- Station Locations from the SSN and the Engineering Institute (UNAM) networks

Output data:

- Synthetic seismic records on the simulated grid.
- Measurements of Peak Ground Acceleration (PGA) and spectral Acceleration (SA) for each point in a grid.
- Maps of ground motion parameters.

2. List of Model Output Data (according to the EPOS data policy)

- ☐ Level 0 (raw or basic data)
- ☐ Level 1 (data products coming from (nearly) automated procedures)
- ☑ Level 2 (data products resulting from scientific investigations)
- ☑ Level 3 (integrated data products resulting from complex analysis)

- Simulation data feeding other workflow components
  - ☐ Data chain

2.4 Data Management Plan

3. Restricted access data
4. Open-access data (specify the access mode)

2.5 Workflow

5. Numerical simulation workflow
6. Trial workflow
7. Graphical representation

3. Communication and Dissemination

3.1. Actions taken before, during, and after the simulation

A comprehensive communication and dissemination plan was designed and implemented before, during, and after the Mexico National Drill (19 September 2025), turning a major scientific trial into a landmark case of knowledge exploitation and social engagement.

Before the event, the communication team prepared a detailed dissemination strategy aimed at both **visibility and impact**. This included pre-event announcements, coordination with Mexican and Spanish institutions, and the preparation of audiovisual and written materials explaining the role of ChEESE and its partners in the national simulation.

During the simulation, **real-time coverage** was carried out through social media, with posts featuring photos, short videos, and commentary from researchers in the field. A coordinated effort across multiple institutional channels ensured continuous communication in both Spanish and English.

After the event, **several press releases**, feature stories, and a short documentary were produced and disseminated through the institutional websites and social media channels of ChEESE, BSC, CSIC, and UNAM, highlighting the scientific contribution and cross-border collaboration.

This multi-phase communication approach helped transform a technical validation trial into a widely recognised public success story, connecting European HPC innovation with real-world societal impact.

The ChEESE team during the drill - which began at 12 p.m. in Mexico (8 p.m. in Spain).

3.2. Partners and institutions involved

The strategy was led by:

- Barcelona Supercomputing Center (BSC) and;
- Geociencias Barcelona (GEO3BCN – CSIC) at the Spanish National Research Council

In collaboration with:

- Universidad Nacional Autónoma de México (UNAM)
- Institute of Geophysics (UNAM)
- Servicio Sismológico Nacional (SSN, Mexico)

3.3. Materials created

The campaign used a mix of high-quality and accessible communication formats, including:

- Pre- and post-event press releases
- Feature stories for the ChEESE, BSC, GEO3CSIC and HPC Portal websites
- Real-time social media coverage (photos, short videos, technical highlights)
- Documentary and simulation video, showing the deployment and results
- Infographics explaining the workflow of the hazard models
- Researchers interviews

Many of these materials were produced in both Spanish and English to ensure broad accessibility and impact.

3.4. Communication reach and impact

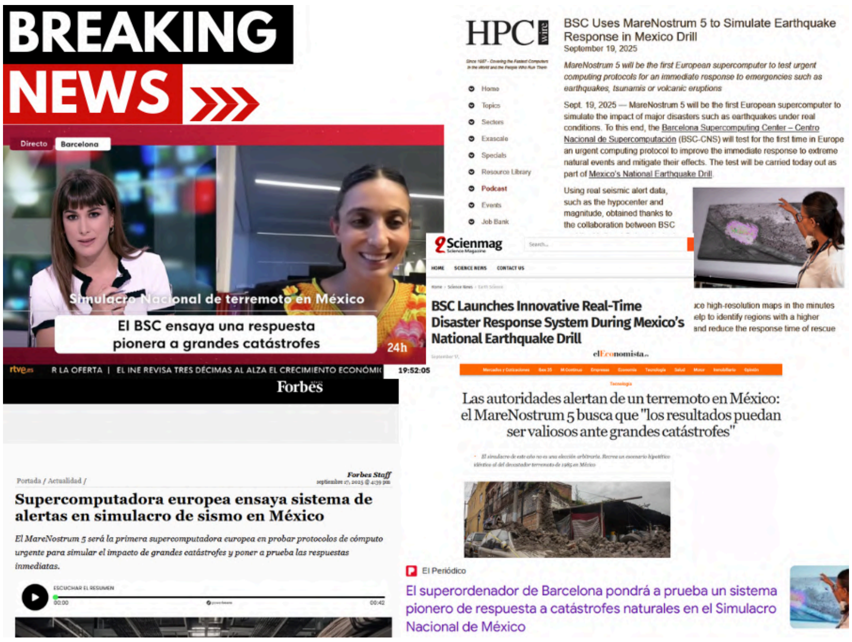
The communication effort generated over **130 publications** across media outlets, websites, and social media channels, reaching audiences in multiple countries and languages.

- Media appearances: 71 (including RTVE, El Periódico, Forbes México, HPC Wire, and Diario de México)
- ChEESE website and social media: 20 original posts
- BSC institutional channels: 21 publications
- SSN Mexico: 8 social media posts, including the official simulation video, and the mention in the special report prepared for the drill (http://www.ssn.unam.mx/sismicidad/reportes-especiales/2025/SSNMX_simulacro_20250919_Michoacan_M81.pdf)
- CSIC channels: 2 publications
- Total combined reach: Over 130 mentions and posts across all media and institutions and platforms

Coverage by **international media outlets** such as HPC Wire and national press in Spain and Mexico elevated the visibility of the ChEESE Project as a reference in urgent HPC applications and cross-border disaster preparedness.

Main institutional publications:

- Supercomputadora europea simula un sismo de magnitud 8.1 en México
- ChEESE Project will test computing technologies for immediate emergency response at Mexico's National Earthquake Drill
- El BSC ensaya un sistema pionero de respuesta inmediata a grandes catástrofes en el Simulacro Nacional de terremoto de México
- ChEESE Completes Exercise in Mexico's National Earthquake Drill



Media coverage of ChEESE's work.

4. Impact Assessment

The immediate impact of the trial on the participating institutions and stakeholders was highly positive, strengthening both technical collaboration and institutional coordination between European and Mexican partners. For the National Seismological Service (SSN) and UNAM, the exercise provided valuable insights into how HPC-based urgent computing workflows can complement traditional real-time seismological monitoring, enhancing their capacity to perform rapid scenario simulations during seismic crises. For the Barcelona Supercomputing Center (BSC) and the ChEESE-2P consortium, the trial represented a near-real world validation of the UCIS4EQ workflow and **the first operational demonstration of an Urgent Computing queue** on a European Tier-0 system, setting a precedent for future emergency computing protocols within the European HPC ecosystem.

At an institutional level, the trial **reinforced collaboration** frameworks between BSC, SSN, and UNAM, creating a foundation for continued joint research and data exchange on seismic risk modelling. The experience also influenced internal operational prototype considerations and protocols at BSC, particularly regarding the rapid allocation of computational resources for time-critical simulations, and contributed to the ongoing discussion within EuroHPC and ChEESE-2P about integrating urgent computing capabilities into European HPC infrastructures.

Several key lessons were learned from this experience. First, the trial highlighted the importance of co-design between scientific teams, software developers, and HPC operators, ensuring that urgent computing workflows can adapt to operational requirements and infrastructure constraints. Second, it demonstrated that **real-world readiness** depends not only on computational speed, but also on data availability, workflow robustness, and institutional coordination. Finally, the exercise underscored the value of international cooperation in developing interoperable tools and protocols for rapid scientific response to natural hazards.

In the long term, the outcomes of this trial are expected to have a significant impact on both the European HPC ecosystem and global disaster management practices. The demonstrated feasibility of urgent computing at Tier-0 scale will inform future HPC resource management policies, promote the adoption of near-real-time simulation services for natural hazards, and contribute to the design of **resilient digital twins for critical regions**. Beyond the technical achievements, the collaboration also fostered stronger ties between Europe and Latin America in the field of computational geosciences, establishing a model for how advanced computing can directly support societal resilience and emergency preparedness worldwide.

5. Next Steps and Recommendations

Building on the experience and outcomes of this trial, several improvements and future directions have been identified to enhance upcoming collaborations and large-scale demonstrations. From a technical standpoint, future trials will focus on further optimizing the UCIS4EQ workflow, particularly by reducing pre- and post-processing times through better parallelization strategies, and adaptive load balancing across HPC nodes. Another proposed improvement is the integration of **real-time data ingestion** directly from national seismic services, enabling faster initiation of urgent computing simulations immediately after event detection. Extending the workflow to include multi-hazard coupling—for example, cascading effects such as landslides or tsunamis—has also been identified as a long-term development goal within ChEESE-2P and related DT-GEO initiatives.

On the communication and dissemination side, the trial demonstrated the effectiveness of open-access outreach materials, including the public video, datasets, and visualization products. These materials successfully connected scientific achievements with public awareness and institutional visibility. For future editions, the dissemination strategy could be scaled up through **interactive web dashboards**, and collaborative visualizations that allow decision-makers and the public to explore simulation outputs in real time. Closer coordination with civil protection agencies and educational institutions could also amplify the societal impact of these communication efforts.

Finally, the success of this activity has opened several opportunities for new collaborations and follow-up studies. Building on the strong partnership between BSC, SSN, UNAM, and Mondaic, future work may include joint development of basin-scale models for other Mexican and Latin American cities, comparative simulation campaigns using European and non-European HPC systems, and joint dissemination actions highlighting international cooperation in urgent computing. At the European level, the trial provides a valuable use case that can inform the **design of operational urgent computing services** within EuroHPC and inspire new cross-continental research initiatives aimed at enhancing global seismic resilience through open science and advanced computing.