Earthquake Early Warning System in the Ibero-Maghrebian Region

Brief description

An **earthquake** is a sudden ground shaking caused by the release of energy from within the Earth. It is a natural phenomenon that occurs unexpectedly, without prior warning. Furthermore, earthquakes can have a high destructive potential, leading to significant human and material losses. Currently, it is not possible to predict the exact location and timing of an earthquake. Therefore, **prevention** is the most effective strategy to mitigate the damage earthquakes can cause. One of the most efficient tools in this regard are the **Earthquake Early Warning Systems (EEWS)**, whose effectiveness has been demonstrated during major seismic events, such as the Tōhoku earthquake (M_w 9.0) in Japan in 2011. EEWS enables real-time seismic monitoring and the issuance of early alerts for potentially damaging earthquakes, helping to reduce their impact and protect both infrastructure and local populations. These systems operate based on the principle that, within the first few seconds of the P-wave (the first seismic wave generated by an earthquake, which travels at the highest velocity), sufficient information is available to estimate its magnitude and destructive potential. allowing an alert to be issued before the more destructive waves (S-waves) reach the sites to be protected. A key aspect of EEWS is the **lead time**, which represents the time available from the moment an alert is issued at a given location until the arrival of the destructive seismic waves. This lead time ranges from a few seconds to several minutes and is crucial for implementing preventive actions (Fig. 1). For instance, with up to **5 s**, individuals can take self-protection measures; with 10 s, gas and electricity supplies can be shut off, and with a longer lead time, it is possible to reduce train speeds or stop industrial processes. Therefore, an EEWS will not avoid the effects of an earthquake, but it allows for their mitigation and enables anticipating them by taking preventive measures.

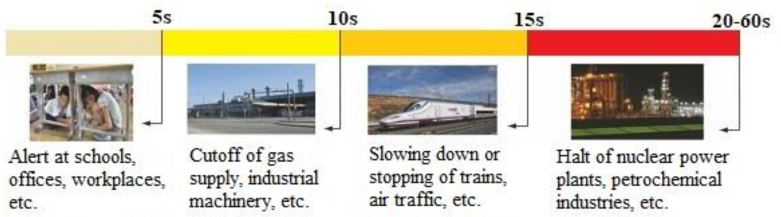

Figure 1: *Alert timing range of an EEWS (modified from Conte, 2013)*

How does it work?

The basic hypothesis used by an EEWS is that in the first few seconds of the P-wave (the first wave generated by the earthquake), there is already enough information to locate the earthquake and determine its size. This is the main difference compared to classical systems, which wait for the complete earthquake record to calculate its magnitude and, therefore, its destructive capacity. If the earthquake record (seismogram) at a station near the epicenter is transmitted in real time to the data receiving center via the internet, satellite, phone, etc., the information travels at the speed of light (300,000 km/s), thus faster than the seismic waves (6 km/s for the P-waves and around 4 km/s for the S and surface waves, which are the most destructive). These first seconds of signal are processed at the data receiving center, and the EEWS is able to estimate the alert parameters (Fig. 2). If these exceed a threshold value, the EEWS automatically generates an alert. One factor to consider in an EEWS is the size of the **blind zone**, which refers to the area around the epicenter where an alert cannot be issued. For an EEWS, to be effective, the blind zone must be as small as possible or not include the sites to be protected. The first step before implementing a SAST in a region is to study its feasibility.

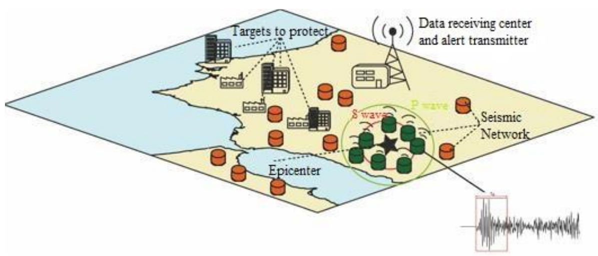

Figure 2: *Scheme of an EEWS. The star represents the epicenter, the cylinders represent the seismic stations (in green, those where the P-wave has already arrived and are calculating the alert parameters). A seismogram and the time window used are also shown (modified from Carranza, 2016).*

What problem does it solve?

Currently, the growth of large cities and the high concentration of buildings in metropolitan areas increase vulnerability to earthquakes. The EEWS implemented in countries such as Japan, Taiwan, Mexico, and USA, have demonstrated their effectiveness in mitigating earthquake damage. However, the effectiveness of these systems is closely linked to the education and preparedness of the population on how to act during a seismic event. Without adequate action plans or knowledge of safety measures, alerts alone do not ensure complete protection. Therefore, it is crucial to combine the use of EEWS with proper training and public awareness to maximize safety and the effectiveness of responses during an earthquake.

What future products will it develop?

Since October 2015, an EEWS has been in operation at the Department of Earth Physics and Astrophysics (EPA) of the UCM, adapted to the Ibero-Maghrebian Region (IMR), using the software *PRESTo* (Probabilistic and Evolutionary Early Warning SysTem). It receives real-time data from 57 seismic stations in the IMR, belonging to the *Instituto Geográfico Nacional* (IGN, https://doi.org/10.7914/SN/ES), the Western Mediterranean network (https://doi.org/10.14470/JZ581150), and the *Instituto Portugués do Mar e da Atmosfera* (https://doi.org/10.7914/SN/PM). Since its installation, *PRESTo* has been the subject of various studies. The results show that, for 70-80 % of the detected earthquakes, the differences in origin time and epicenter compared to the IGN are less than 2 seconds and 20 km, respectively, and the differences in magnitude (M_w) are less than 0.3 for 60-65 % of the earthquakes. The EEWS is fully operational and is continuously subject to improvements in both methodology and functionality. Currently, an EEWS based on progressive temporal prediction of ground shaking is being implemented for the IMR. Unlike the current EEWS, which is based on the early determination of seismic source parameters (hypocenter and magnitude), this new system focuses on determining the Potential Damage Zone (PDZ), defined as the area where the Instrumental Intensity (I_{MM}), calculated from the Peak Ground Velocity (PGV) values predicted by the EEWS, exceeds a predefined threshold.

Competitive advantages compared to other research

In Spain, significant earthquakes have caused considerable economic losses and casualties. Examples include the 1755 Lisbon earthquake, the 1829 Torrevieja (Alicante) earthquake, and the 1884 Arenas del Rey (Granada) earthquake. Even small-to-moderate magnitude earthquakes, such as the 2011 Lorca earthquake, have caused extensive material damage and loss of life. Therefore, there is a significant risk of a large earthquake occurring in Spain, and having an EEWS would help mitigate and reduce the damage. The EEWS installed in the EPA department has proven that a system of this kind is feasible for the IMR and generates effective results. Implementing an EEWS based on the estimation of the PDZ would significantly increase the effectiveness of these systems in the IMR and provide highly useful information, not only for scientific purposes but also for society. It would enable the transmission of very specific alerts to emergency services, thus shortening response times and optimizing resources in the event of a seismic disaster.

Where has it been developed?

The research team that has implemented this technology is composed of members from the Department of Earth Physics and Astrophysics at the Faculty of Physical Sciences at UCM, together with RISSC-Lab at the *Università di Napoli Federico II* (Italy), the Real Instituto y Observatorio de la Armada de San Fernando, and the *Institut Cartografic i Geologic de Cataluña*.

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And moreover…

The Structure and Dynamics of the Earth, Seismicity, and Seismic Risk Group at UCM offers its expertise and knowledge for studies on seismicity (both historical and instrumental), damage assessment, intensity estimation, focal mechanism (point and extended sources), directivity studies, regional stress determination, seismotectonic models, and earthquake rupture processes.

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