Centre Sismologique
Euro-Méditerranéen

Final Report of the EMSC

for

the SCOR Foundation for Science

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I. ABSTRACT

The three-year agreement signed between the SCOR Foundation for Science and the EMSC had the objective of completely renewing EMSC's technical infrastructure and extending citizen seismology in order to improve the rapid assessment of the effects of earthquakes. The first two reports described in detail the technical developments that have occurred. For this last report, while still outlining the latest technical developments, the impetus is to illustrate how eyewitness data can replace dense real-time seismic networks for rapid impact assessment, using examples from the catastrophic M7.8 Kahramanmaraş, Turkey earthquake of 6 February 2023.

The technical refactoring of the processing system and communication tools has been finalized. After a new website for mobile devices and a new Twitter bot, the new smartphone app is available. The new desktop website has been online since the end of June 2023. The deployment of the new version of the app will be gradual, starting in September 2023.

The catastrophic M7.8 Kahramanmaraş earthquake in Turkey last February was a dramatic reminder of the destructive power of earthquakes and the difficulty of rapidly assessing their impact. The LastQuake system proved its value in a number of ways. More than 5,000 felt reports were collected in the first 30 minutes, providing a unique insight into the impact. The existence of collapsed structures was confirmed by crowdsourced geo-located imagery collected in the first few hours, despite the earthquake occurring at night. Felt reports were also used to determine the geometry of the seismic rupture within 10 minutes, dramatically improving estimates of the spatial distribution of shaking and damage. A new detector harvesting images from Twitter was also able to detect a triggered landslide blocking a road 12 hours after the earthquake.

Independently of this specific case, the felt reports are shown to be able to distinguish high-impact from low-impact earthquakes within 10 minutes thanks to a statistical analysis, especially for earthquakes of moderate magnitude and moderate damage levels, which are inherently complex to identify through impact modelling. Finally, we mention the recent development of an information and crowdsourcing bot on the messaging app Telegram to further extend the reach of the LastQuake system.

Taken together, these results demonstrate the ability of direct and indirect eyewitness observations to provide the necessary constraints for rapid and reliable impact assessment of global earthquakes.

II. TEAM

As on 1 April 2023, the EMSC team comprises the following members:

- Rémy Bossu, seismologist and team leader
- Jean-Marc Cheny, IT
- Laure Fallou, sociologist
- Simon Isartel, geophysicist and data analyst
- Matthieu Landès, seismologist
- Julien Roch, seismologist
- Frédéric Roussel, IT
- Robert Steed, data scientist and software engineer
- Guillaume Ucciani, seismologist

III. An Outline of Technical Developments

The main technical development concerns the data processing system. To provide information on earthquakes and their effects, it combines data from around 100 seismological institutes and crowdsourced data (Figure 1).

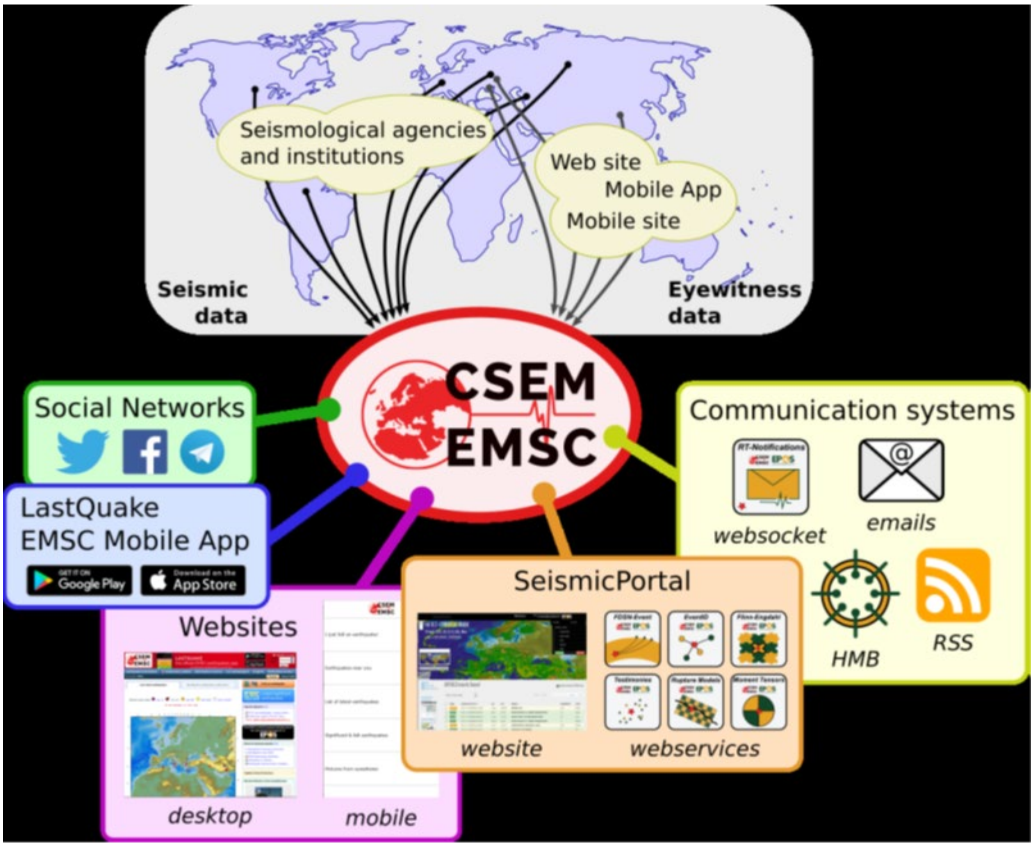


Figure 1 : Schematic view of data collection and distribution at EMSC

Having previously renovated the distribution component, EMSC has now finalized the data processing component, the main task being to upgrade the seismic data processing part. A new earthquake locator (iLoc) has replaced the old and now obsolete one. The data model, i.e., the different types of information stored and their interconnections, has been modified and extended. In particular, this enables better crediting of the different types of data contributions. The processing time has been reduced from one minute to one second. The production of maps and figures populating the services has been optimized. The new system was put online at the end of June 2023. A number of small improvements/corrections have been implemented since then. In 2022, the system processed 180,000 data contributions to derive the parameters of 90,000 earthquakes.

The latest development is the new version of the smartphone app. The first version was published in 2014. The ergonomics (Figure 2) were developed with the kind help of two Croatian professionals (pro bono). Apart from the ergonomics, the main change is the possibility of customizing notifications in terms of distance and size, a request from current users, and the use of WebSockets (updates are automatic and in real time).

The current version has been in operation for more than nine years and some users may not welcome any changes (this is what we observed with the new version of the website). To minimize the risk of a negative impact on users, the release will be gradual and accompanied by a communication campaign on social networks.

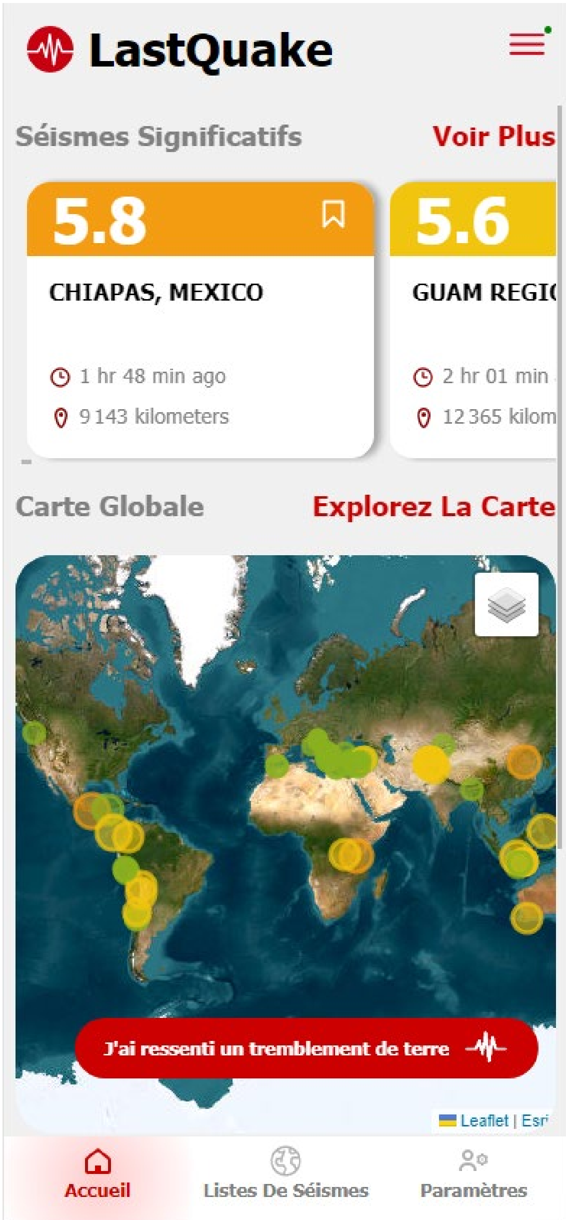


FIGURE 2 : SCREENSHOTS OF THE NEW VERSION OF THE LASTQUAKE APP, THE SPLASH SCREEN (LEFT) AND THE MAIN PAGE (RIGHT).

IV. An illustration of Citizen Seismology benefits from the M7.8 Kahramanmaraş earthquake in Turkey

LastQuake is based on citizen seismology. It collects direct and indirect data from earthquake eyewitnesses to improve rapid impact assessment. The dramatic February 2023 earthquake in Turkey and Syria is used here to illustrate the different products and information.

1. Crowdsourced detection

Crowdsourced detections are the detection of felt earthquakes based on the online reactions of eyewitnesses to the shaking. The Kahramanmaraş earthquake was detected in 70 seconds (Figure 3) using this technique, and this was the first indication of the existence of this earthquake, well before the first seismic detection (5 minutes). Crowdsourced detection is used to engage with eyewitnesses and invite them to share their felt experiences. In this case, the crowdsourced detection was due to the large increase in tweets (messages published on Twitter) containing "deprem", the Turkish word for earthquake, originating from southeast Turkey.

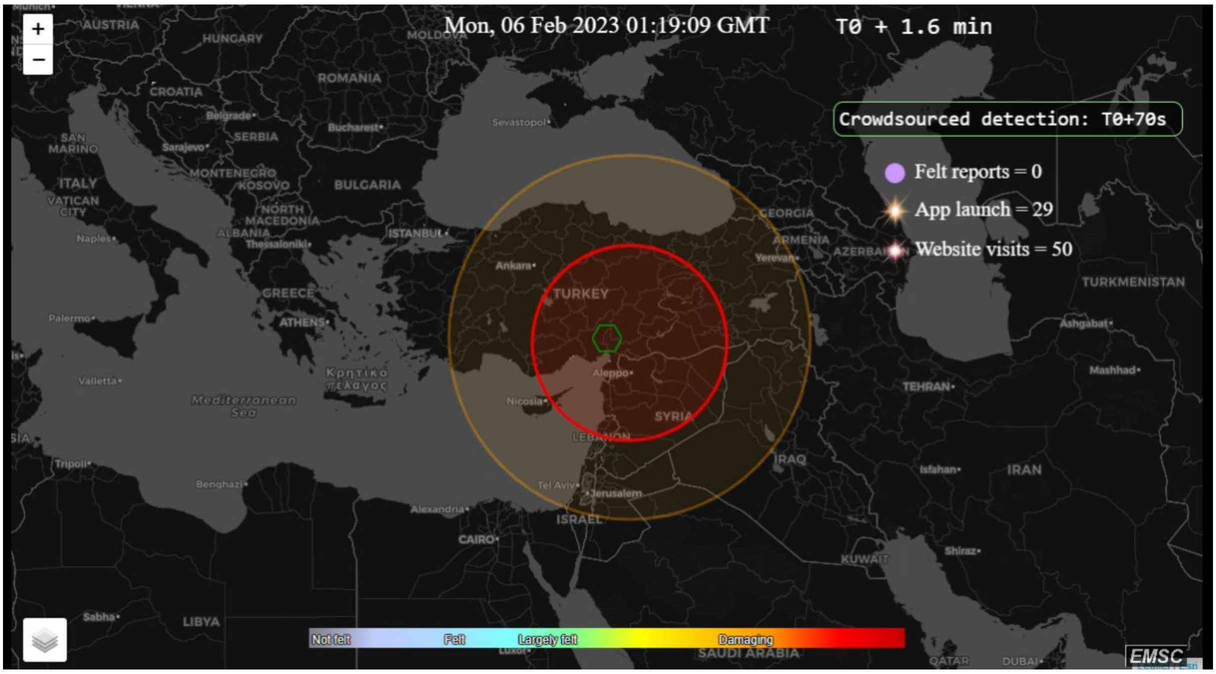


Figure 3 : The Kahramanmaraş earthquake was crowdsourced detected 70 seconds after its occurrence (green hexagon). The yellow and red circles represent the P and S seismic wavefront at the time of detection.

2. Felt reports collection

Crowdsourced detections are published on the various components of the LastQuake system (Twitter bot, smartphone app, websites) to initiate engagement with eyewitnesses and collection of felt reports. Once the earthquake has been seismically located (in this case, five minutes after occurrence), a notification about the earthquake is sent to LastQuake app users beyond the felt area. For this event, more than 5,000 felt reports (representing different local shaking and damage levels) were collected in the first 30 minutes (Figure 4).

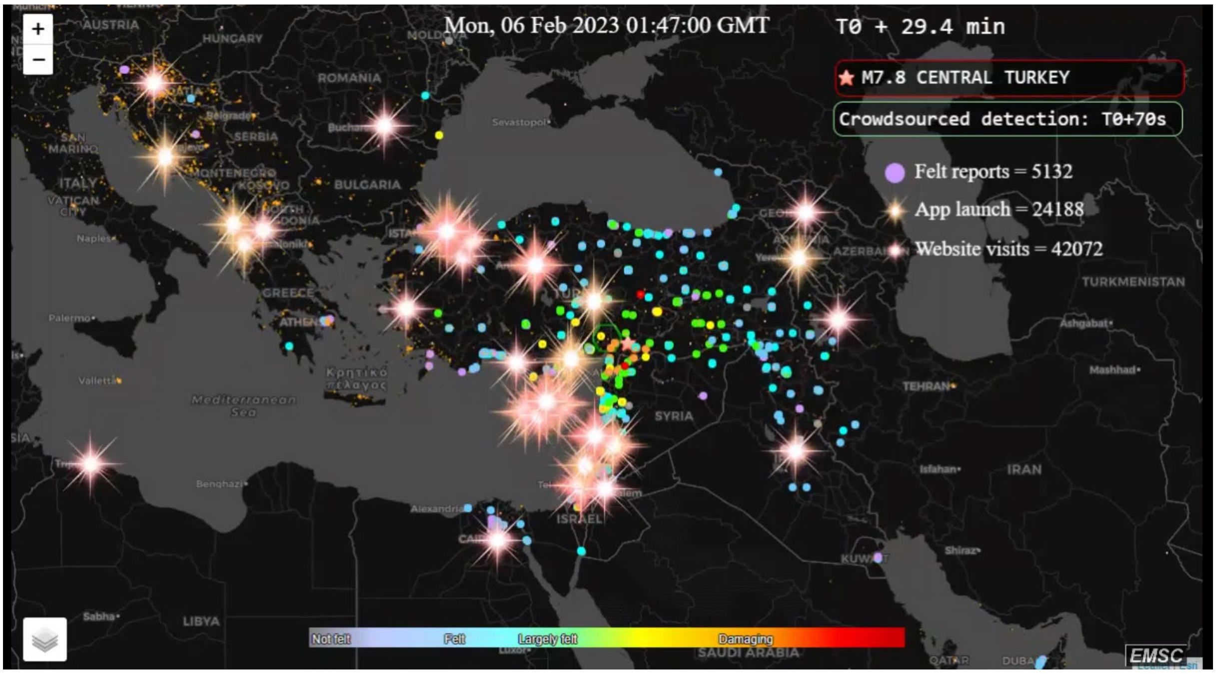


Figure 4 : More than 5,000 felt reports (coloured dots) were collected during the first 30 minutes.

3. From felt reports to intensity evaluation

For the same epicentral distance, the felt reports show significant variability. However, simple statistics show how damage varies as a function of epicentral distance (Figure 5). Initially, people who witness damage are less likely to report their observations, leading to an initial underestimation of the maximum damage (the so-called "doughnut effect"). After three hours, modelling the earthquake as a point source could estimate that more than four million people had been exposed to "moderate/heavy" shaking, resulting in several thousand deaths.

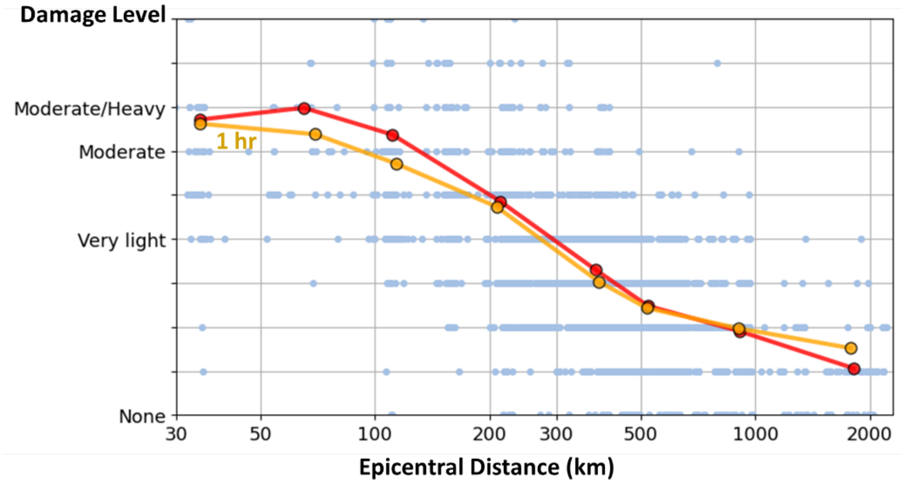


Figure 5 : Intensity curves as a function of epicentral distance are automatically determined from individual felt reports (blue dots). The maximum intensity determined after one hour (orange curve) underestimates the final value (red curve).

4. From felt reports to fault geometry

The point source approximation is not valid for an earthquake of large magnitude. The Kahramanmaraş earthquake had a rupture of 300 km (Figure 6).

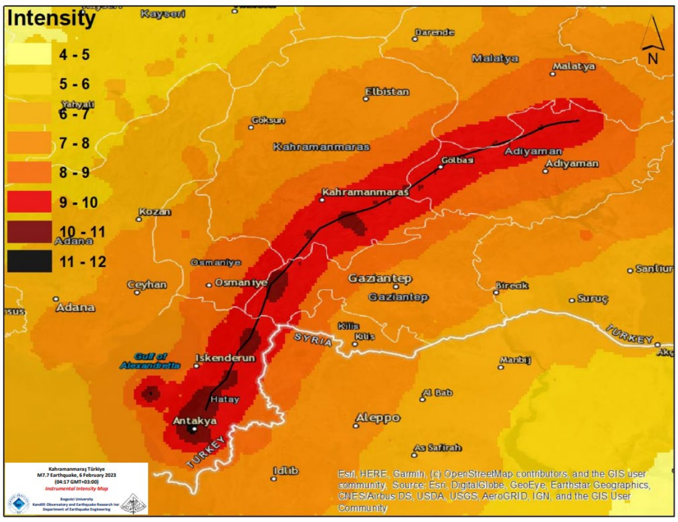
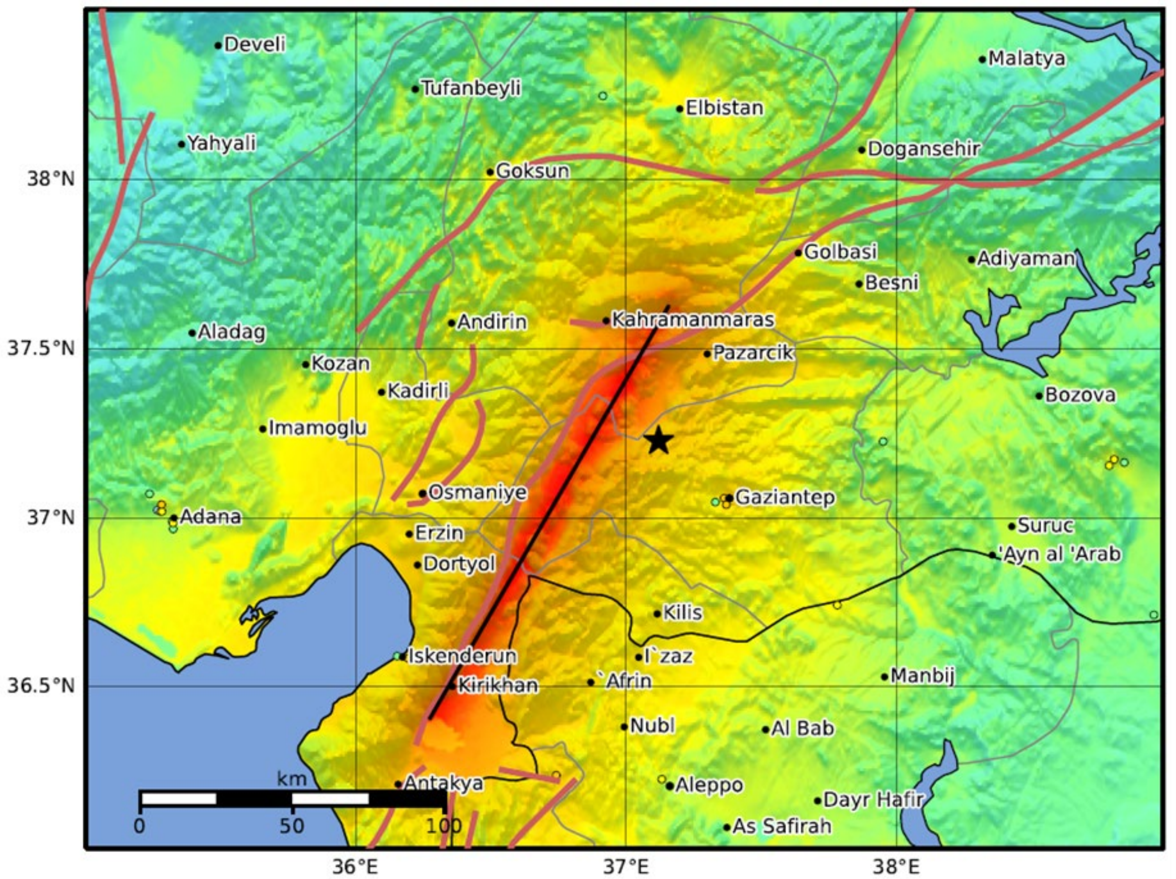


Figure 6 : Fault rupture (black line) and damage level from field survey. The rupture has a length of 300 km.

As shown in the field survey, the rupture geometry dominates the spatial distribution of damage (Figure 5). Rapid determination of the rupture geometry is then essential for reliable impact assessment. Thanks to a collaboration with ETH Zurich and the USGS, felt reports collected within 10 minutes of the earthquake are analysed to automatically determine a fault line model of the rupture, which in turn is incorporated into the model for the spatial distribution of shaking, greatly improving its reliability compared to a simple point-source model, which in such a case significantly underestimates the earthquake impact (Figure 7).



SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0464	0.297	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.0215	0.135	1.41	4.65	9.64	20	41.4	85.8	>178
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Worden et al. (2012) Version 1: Processed 2023-03-16T13:45:03Z

△ Seismic Instrument ○ Reported Intensity ★ Epicenter ▭ Rupture

FIGURE 7 : FAULT GEOMETRY (BLACK LINE) DETERMINED FROM THE ANALYSIS OF FELT REPORTS COLLECTED WITHIN 10 MINUTES OF THE EARTHQUAKE. THE GEOMETRY IS THEN USED AS THE SEISMIC SOURCE TO RECALCULATE THE EXPECTED SPATIAL DISTRIBUTION OF SHAKING AND DAMAGE WHICH AGREES WELL WITH THE OBSERVED DAMAGE (FIGURE 5).

5. GEO-LOCATED PICTURES AND VIDEOS

LastQuake crowdsources not only felt reports, but also geo-located images and videos. These are manually validated before publication. Within the first few dozen minutes, the first videos were uploaded, taken from a great distance and typically showing swaying objects. A total of 32 were validated within the first three hours. Although the earthquake occurred at night, several showed actual damage, three of which are shown in Figure 8. Such submissions can help to constrain the actual extent of local damage.

FIGURE 8 : CROWDSOURCED IMAGES OF DAMAGE. THE TIME OF COLLECTION AND THE EPICENTRAL DISTANCE ARE GIVEN. THE IMAGE IN THE CENTRE REPRESENTS THE TOTAL COLLAPSE OF A BUILDING.

6. TRIGGERED LANDSLIDES

Even if they do not affect human settlements, triggered landslides need to be mapped, as they can block roads and hamper earthquake response. In collaboration with QCRI and BGS, we developed the Global Landslide Detector, which collects tweets containing an image and the keyword "landslide" in different languages. Artificial intelligence then rejects images not related to landslides. A landslide triggered by the Kahramanmaraş earthquake and blocking a road was detected 12 hours after it occurred (Figure 9).

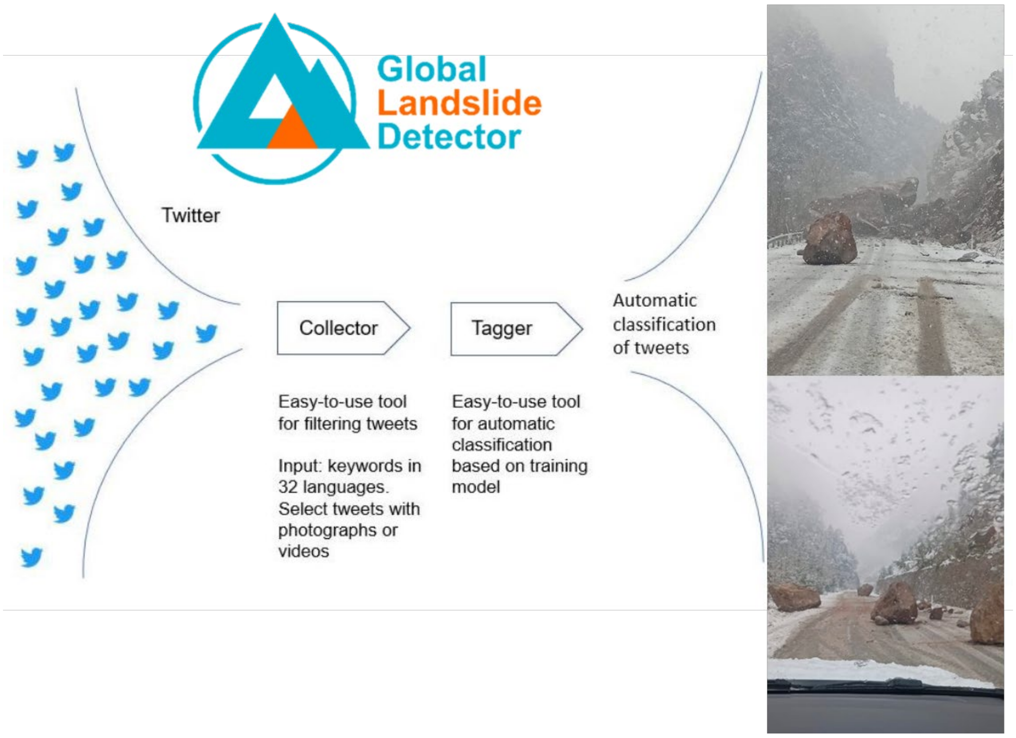


FIGURE 9 : THE GLOBAL LANDSLIDE DETECTOR COLLECTS TWEETS MENTIONING "LANDSLIDE" IN DIFFERENT LANGUAGES, THEN A MANUALLY TRAINED ARTIFICIAL INTELLIGENCE ENGINE REJECTS IMAGES NOT RELATED TO LANDSLIDES. A TRIGGERED LANDSLIDE (RIGHT IMAGES) WAS DETECTED 12 HOURS AFTER THE KAHRAMANMARAŞ EARTHQUAKE.

7. DISTINGUISHING HIGH-IMPACT FROM LOW-IMPACT EARTHQUAKES

There are two cases where impact assessment of global earthquakes can be particularly challenging: earthquakes of moderate magnitude (magnitude around 6) and earthquakes (of any magnitude) with limited impact. For moderate magnitude earthquakes, the potential damaged area (a dozen of kilometres from the epicentre) is comparable in size to the location uncertainty, leading to large uncertainties if the epicentre is close to a city, while moderate impacts are generally dominated by single accidents that cannot be predicted by statistical approaches.

The idea of the approach developed with GFZ is to statistically analyse the spatio-temporal characteristics of the felt reports collected in the first ten minutes and to determine the probability that the associated earthquake is a high-impact earthquake (Figure 10). It is proving effective in identifying non-damaging earthquakes and could be developed into a traffic light system by adding different types of crowdsourced data and obtaining a first-order damage estimate without calculating ground motion or exploiting seismic data (magnitude, locations).

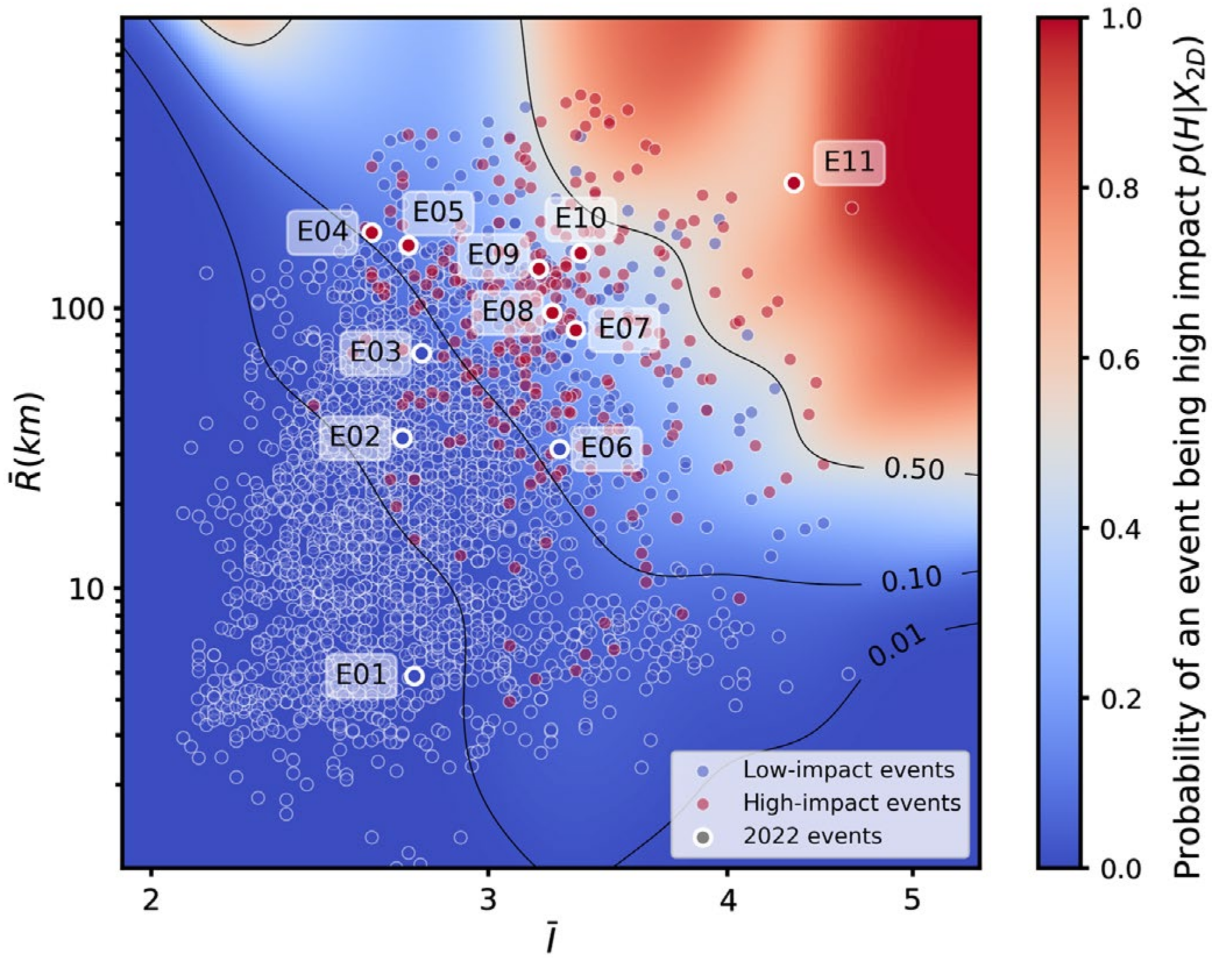


FIGURE 10 : PROBABILITY OF AN EARTHQUAKE BEING HIGH IMPACT. TRANSPARENT MARKERS REPRESENT EVENTS BETWEEN 2014 AND 2021 THAT WERE USED TO CALIBRATE THE MODEL. OPAQUE MARKERS REPRESENT VALIDATION EVENTS FROM 2022.

8. THE POTENTIAL OF MESSAGING APPS

The app is the most efficient crowdsourcing component of the LastQuake system. However, as it is mainly downloaded after the mainshock, the volume of crowdsourced data tends to be lower for the mainshock, where it is most valuable, than for strong aftershocks. We are consequently exploring the possibility of complementing the LastQuake system with bots on messaging apps such as Telegram or WhatsApp. The potential benefits are obvious: while a third to half of LastQuake app users have deleted the app a year after the mainshock, messaging apps are rarely deleted. They also have a penetration rate that a citizen science app like LastQuake cannot possibly match. If we can develop a bot that meets people's needs, and raise awareness of it, this could greatly increase the reach of the LastQuake system and further improve its performance.

V. CONCLUSION

Support from the SCOR Foundation for Science has been instrumental in improving the LastQuake system. It has also provided an opportunity to demonstrate that crowdsourced data can facilitate rapid impact assessments in the many regions where dense real-time seismic networks are not available. The data collected is attracting increasing interest from the scientific community, and new processing approaches are being developed. The LastQuake system itself continues to evolve and we are confident that it will play an increasing role in providing rapid public earthquake information and damage assessment in the future. Beyond earthquakes, LastQuake proves that constant dialogue with citizens, thanks to smartphones and social media, is essential for effective crisis management.

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