Specifications of EMSC moment tensor services: Interactive access and EPOS Thematic Core Service

Version 1.3.0
Status Final

Authors Matthieu Landès (EMSC)

Dissemination level Public
Related project EPOS, Grant agreement n°676564, WP 8.5
Keywords EPOS, Moment tensors, Services, Seismic Portal

Document history

Date	Version	Author	Object
09/06/2016	0.1	Matthieu Landès	First draft
24/06/2016	1.0	Matthieu Landès	Update
07/07/2016	1.1	Matthieu Landès	Update with F. Haslinger comments
12/12/2016	1.2	Matthieu Landès	Parameter update
14/04/2022	1.3	Matthieu Landès	Quality Assurance

Acknowledgment

This Moment Tensor Service is made within the EPOS project. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676564.

Summary

I. Aim of the document

The aim of this document is to describe the specifications of all functionalities the EMSC will develop in order to give access to the moment tensor data of seismic events. This includes the interactive access through the Seismic Portal website and the EPOS Thematic Core Service associated to moment tensor data.

The second section describes the data we receive at the EMSC and the parameters chosen to characterize moment tensor data.

The third section gives specifications of the new functionalities of the seismic portal allowing users to access moment tensor data. This includes visual representation of moment tensor, a web service and an interactive web search of moment tensor data.

Note about "moment tensor"

In this document, moment tensor data refers to all information describing the source mechanism of an earthquake following tensor, double couple or axe representation.

The Seismic Portal

The Seismic Portal has been developed within the NERIES FP7 project. This web site is now operational and is a single point of access to explore and download earthquake information. It's available at the url www.seismicportal.eu. Future development of EPOS services will be integrated into the Seismic Portal.

II. Description of moment tensor data and their association

This section describes moment tensor data and its association with EMSC earthquakes. The issue of whether or not the seismic event is in the EMSC database.

1. Data contributors

Moment tensor data hosted at EMSC comes from data received in near real time from seismological institutes and from catalogs such as the Earthquake Mechanisms of the Mediterranean Area (EMMA) database from Vannucci and Gasperini, 2004 (Described below).

Near real time moment tensors collected at the EMSC comes from:

- National Research Institute of Astronomy and Geophysics -- Helwan, Egypt
- Laboratoire de Détection et de Géophysique -- Pamatai, French Polynesia
- GEOSCOPE, Institut de Physique du Globe de Paris (SCARDEC method) -- Paris, France
- GeoAzur -- Nice, France
- W-Phase CMT -- IPGS/EOST and CALTECH -- France and USA
- GEOFON -- Potsdam, Germany
- National Observatory of Athens -- Athens, Greece
- University of Athens -- Athens, Greece
- Aristotle University of Thessaloniki -- Thessaloniki, Greece
- University of Patras -- Patras, Greece
- QRCMT INGV -- Bologna, Italy
- Instituto Geografico Nacional -- Madrid, Spain
- SED Moment Tensors -- ETH Zuerich, Switzerland
- Kandilli Observatory and Earthquake Research Institute -- Istanbul, Turkey
- Earthquake Research Department -- Ankara, Turkey
- USGS Fast Moment Tensor Solutions -- Denver, Colorado, USA
- Global CMT - Lamont-Doherty Earth Observatory (LDEO) -- Palisades, NY, USA
- Jascha Polet (Cal Poly Pomona) -- Pomona, California, USA

These moment tensor contributors are not restricted to EMSC members and additional institutes can be integrated into the collection process. All moment tensors are collected via email and PDL, the USGS messaging system (Product distribution layer) and are stored on the EMSC database. Formats used by contributors are custom text and xml format, Global CMT and ISOLA format. Depending of the inversion method, we may receive the full moment tensor, or only the double couple solution (IPGP for instance). Table 1 summarizes the data from each contributor.

Geographical coverage of different data contributors may overlap and if it is the case the EMSC will collect several moment tensors for one event (for example 12 moment tensors were collected for an event in Agean Sea the 24th May 2014).

The EMMA database. Alongside the data contributors, the EMSC stores the EMMA database and we explore the possibility to distribute their data. The Earthquake Mechanisms of the Mediterranean Area (EMMA) database is a project to collect focal mechanisms published in the literature of earthquakes in the Mediterranean area. It represents more than 6000 mechanisms of events since 1905 (Vannucci and Gasperini, 2004). The quality and the consistency of the data are checked and the authors defined a preferred mechanism among those available.

	Name of the institute	Region	Min Mw	Type of data	Comments
HARV	Global CMT - Lamont-Doherty Earth Observatory (LDEO) -- Palisades, NY, USA	Global	4,2	tensor	
USGS	USGS Fast Moment Tensor Solutions -- Denver, Colorado, USA	Global	3	tensor	
GFZ	GEOFON -- Potsdam, Germany	Global	3,2	tensor	
IPGP	GEOSCOPE, Institut de Physique du Globe de Paris (SCARDEC method) -- Paris, France	Global	5,3	DC *	
PPT	Laboratoire de Détection et de Géophysique -- Pamatai, French Polynesia	Global	4,8	tensor	
AZUR	GeoAzur -- Nice, France	Global	3,9	DC	stopped since 2015
INGV	QRCMT INGV -- Bologna, Italy	Mediterranean area	3,9	tensor	
NOA	National Observatory of Athens -- Athens, Greece	Greece	3,1	tensor	
KAN	Kandilli Observatory and Earthquake Research Institute -- Istanbul, Turkey	Turkey	2,9	DC	
IGN	Instituto Geografico Nacional -- Madrid, Spain	West mediterranean area	3,9	tensor	
ETHZ	SED Moment Tensors -- ETH Zuerich, Switzerland	Europe	4,4	tensor	stopped since 2009
THE	Aristotle University of Thessaloniki -- Thessaloniki, Greece	Est mediterranean area	2,9	DC	
ERD	Earthquake Research Department -- Ankara, Turkey	Turkey	3,3	tensor	
UPS	University of Patras -- Patras, Greece	Greece	3,3	tensor	
UOA	University of Athens -- Athens, Greece	Greece	3,4	tensor	stopped since 2015
EOST	W-Phase CMT -- IPGS/EOST and CALTECH -- France and USA	Global	8,2	tensor	only one event
NRIAG	National Research Institute of Astronomy and Geophysics -- Helwan, Egypt	Est mediterranean area	4,6	tensor	only one event
CPPT	Jascha Polet (Cal Poly Pomona) -- Pomona, California, USA	Global	5,3	tensor	stopped since 2014

Table 1 : List of all EMSC contributors sending source mechanisms in near real time and a short description of their data. * DC means double couple.

2. Association of moment tensor data with an EMSC event

In seismology, the moment tensor is a representation of the source for a given event. The association between moment tensor data and EMSC events will be performed through the UNID parameter. The UNID is the unified identifier of events in the EMSC database.

To associate moment tensor data with an EMSC event, we simply search for the first event where the time difference between the origin time and the centroid time is less than one minute and where the difference location is less than 4 degrees. When many events match, we choose the closest in time.

For the specific situation of the addition of an external catalog, the event associated to the moment tensor may not be in the EMSC event database. In that case, the event will be added to the EMSC database and the UNID will be created. This management of event ID issue is strongly related to the event ID services developed for EPOS (See the incoming event ID service document).

3. Preferred moment tensor mechanisms

As long as no authoritative rule exists to define a preferred moment tensor solution for one event, we have chosen the following criteria arbitrarily:

1. First of all, we consider currently available services having a global coverage and providing moment tensors. If possible, the preferred solution will be firstly from Global CMT, then from USGS, then from GFZ and then from INGV.
2. If no solution is found, we choose the moment tensor having the centroid location the closest to the EMSC event location referenced by the UNID, which is determined following the rules regarding authoritative locations established at the EMSC.

These criteria are arbitrary and will be applied until we have a validated method. This may be done with the future test platform where we plan to test the authoritativeness of moment tensors.

4. Quality Assurance

The earthquake data distributed by the service are collected by the EMSC in real-time. Once received by the EMSC internal system, these data are then published on the Seismic Portal. The Quality Assurance is done in the internal system with the following actions:

- Daily Feedbacks from users that compare with other seismological apps and from contributors that check the data they have sent.
- Global study of seismicity
- The majority of earthquake origins composed by many contributions are reviewed by seismologists.

More details are available in the Annex V.

5. Parameters describing moment tensors

To describe moment tensors, we select a set of parameters based on the information provided by contributors. These parameters are listed on the following tables are fully compatible with the elements defined in the quakeML format. This set includes collected and computed parameters. The unid parameter corresponds to the ID of the event from which is associated moment tensor data.

Event information			
unid			UNified ID used at the EMSC to identify events

The following parameters are provided by the different contributors. Some of them, such as the IPGP, don't provide the full tensor but instead double couple information.

Focal information			
source_catalog		string	Contributor reference (GFZ, IPGP, EMMA…)
source_id		string	Internal ID
centroid_time	datetime	datetime	Centroid date/time UTC
longitude	degrees	float	Longitude of the centroid
latitude	degrees	float	Latitude of the centroid
depth	km	float	Depth of the centroid
region		string	Flinn-Engdahl region name[1]

Moment information [2]			
m0	Nm	float	Value of m0
m0_exp		integer	Exponent of m0
mw		float	Magnitude Mw

Double couple information		
First nodal plan		
strike	degrees	float
dip	degrees	float
rake	degrees	float
Second nodal plan		
strike	degrees	float
dip	degrees	float
rake	degrees	float

Tensor information [2]		
tensor_exp		integer

[1] Flinn, E.A., Engdahl, E.R. and Hill, A.R., 1974, Seismic and geographical regionalization, Bulletin of the Seismological Society of America, vol. 64, p. 771-993.

[2] All values in Nm are described by an exponent and by the coefficient according the scientific notation. For instance the number 1.3E15 has a coefficient of 1.3 and an exponent of 15.

mrr	Nm	float
mtt	Nm	float
mpp	Nm	float
mrt	Nm	float
mrp	Nm	float
mtp	Nm	float

These four parameters may be collected if they are given by the contributor. Otherwise, they are computed with the tensor coefficients.

additional information			
per_iso		float	Percentage of isotropy
per_dc		float	Double couple percentage
per_clvd		float	CLVD percentage of the tensor

Axe information are computed from tensor or from double couple parameters.

Axe information[3]			
axe_exp		integer	
tval	Nm	float	value of T axis
tplung	degrees	float	plunge of T axis
taz	degrees	float	azimuth of T axis
pval	Nm	float	value of P axis
pplung	degrees	float	plunge of P axis
paz	degrees	float	azimuth of P axis
nval	Nm	float	value of N axis
nplung	degrees	float	plunge of N axis
naz	degrees	float	azimuth of N axis

[3] All values in Nm are described by an exponent and by the coefficient according the scientific notation. For instance the number 1.3E15 has a coefficient of 1.3 and an exponent of 15.

III. Interactive access and Moment Tensor services

The different ways to access moment tensor data will be developed as extensions of the existing Seismic Portal with interactive access and a web service. Three new functionalities are identified:

1. Complete the event page (called the “eventdetails” page) of the Seismic Portal to display moment tensor information of EMSC events;
2. Give access to all moment tensor data available at the EMSC via a web service;
3. Add an interactive query search on the Seismic Portal.

1. Moment tensors on the event page of the Seismic Portal

The aim is to add moment tensor information (when they are available) into the “eventdetails” page of the Seismic Portal (see Figure 1). This functionality is considered as a new section like the existing “origins” and “arrivals” sections. The idea is to have a “moment tensor” item listing for all entries (see Zone B, Figure 1).

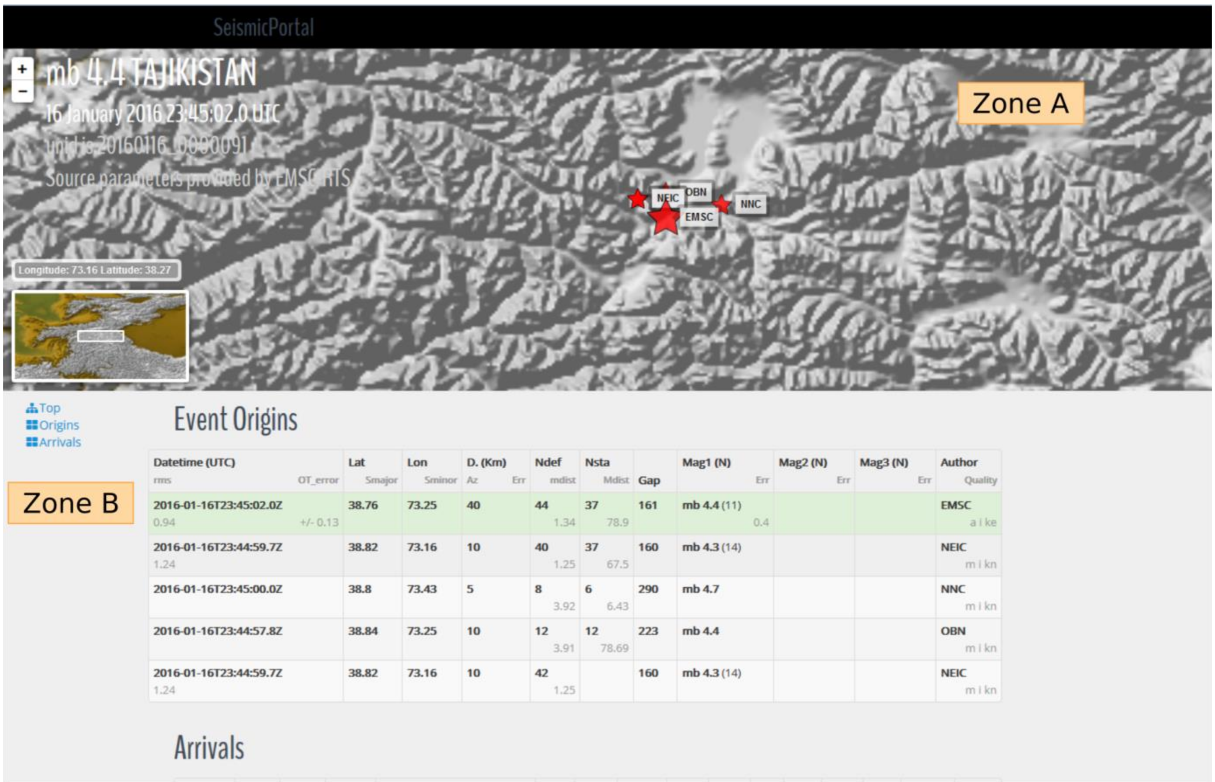

Figure 1 : Example of the “eventdetails” page of the Seismic Portal page. The two zones locate the two modification zones.

This section details the elements to be displayed on the "eventdetails" page of the Seismic Portal. For moment tensor associated to an event, we choose to show:

- Centroid information (date, time, longitude, latitude, depth);
- Author information (source_catalog);
- Moment information (Mw);
- Additional information (%DC, %ISO, %CLVD);
- Nodal plane information (strike, dip, rake for the two nodal planes);
- (if available) Moment tensor components;
- one beachball.

Moreover, on the map (Zone A, Figure 1) the user will have the possibility to switch between origin locations (current display) and the display of all beachballs associated to this event.

In addition to these visual features, the user will have the possibility to download the moment tensor information on the "eventdetails" page in quakeML, CSV or in JSON format.

2. Moment tensor web service

This service is a part of the EPOS Thematic Core Service and aims to give access to moment tensors via a web service integrated into the Seismic Portal. Since it's not possible to include moment tensor queries into the existing FDSN-event web service of the Seismic Portal, this moment tensor web service will be independent. However, the specifications will follow as closely those of FDSN-event.

This service aims to give access to all data hosted on EMSC servers and moment tensors from catalogs included later such as the EMMA database.

As for the FDSN-event, this service gathers data for a given request, which can be based on:

- a search by region, or
- a search by time period, or
- a search for a specific event defined by an ID.

The user may choose to add other filtering rules on depth, magnitude, plunge of T or N axis or by the data contributors (parameter catalog in the FDSN-event specifications).

Information used for queries. For location, time, depth and magnitude filtering, the parameters used are the source parameters provided by the EMSC earthquake catalog defined by the UNID (see Figure 2). The data provided by the service includes both the moment tensor data and the origin information of the associated event.

Figure 2 : Distinction of moment tensor information and information used for queries.

The output of the available data for a given request may be in quakeML, CSV or in custom json format.

Specifications of this service are very similar to the FDSN-event specifications. The description of all available parameters is listed below.

The specification column refers to:

- FDSN indicates that the parameter behaves the same way as for FDSN-event specification;
- 1 - "from starttime" time constraint allows querying all focal mechanisms with the event time between "starttime" and "dayafter" days.
- 2 - These filter constraints allows to select focal mechanisms with a range of plunge for the T and N axis (like GCMT, see http://www.globalcmt.org/CMTsearch.html) and having a given percentage of double couple (per_dc parameter).
- 3 – If set to true, this option actives the selection of the preferred moment tensor of each event. The rules defining the preferred solution are defined in section II.3. Otherwise, if this option is set to false, all data are selected and the user may get many moment tensors per event.

3. Interactive search of moment tensors

The interactive search is a web interface that should give the user the possibility to request moment tensor data with all filtering options defined in the web service specifications.

	parameter	abbreviation	min	max	type	Units	Specification
time constraints							
date range							
	starttime	start			time	UTC	FDSN
	endtime	end			time	UTC	FDSN
from starttime							
	starttime	start			time	UTC	1
	dayafter		1			integer	1
geographic constraints							
area-rectangle							
	minlatitude	minlat			float	degrees	FDSN
	maxlatitude	maxlat			float	degrees	FDSN
	minlongitude	minlon			float	degrees	FDSN
	maxlongitude	maxlon			float	degrees	FDSN
area-circle							
	latitude	lat			float	degrees	FDSN
	longitude	lon			float	degrees	FDSN
	minradius		0	180	float	degrees	FDSN
	maxradius		0	180	float	degrees	FDSN
specific event							
	eventid				string		FDSN
output control							
	format		quakeml, json, GCMT		string		FDSN
	nodata				string		FDSN
filtering constraints							
	mindepth				float	km	FDSN
	maxdepth				float	km	FDSN
	minmagnitude	minmag			float		FDSN
	maxmagnitude	maxmag			float		FDSN
	orderby						FDSN
	catalog						FDSN
	mintplung		0	90	float	degrees	2
	maxtplung		0	90	float	degrees	2
	minnplung		0	90	float	degrees	2
	maxnplung		0	90	float	degrees	2
	mindc		0	100	float		2
	maxdc		0	100	float		2
	preferred		true,false		boolean		3

IV. Annexes

- Interactive web interface to search moment tensors data as the ISC: http://www.isc.ac.uk/iscbulletin/search/fmechanisms/#quakemlfm

- Specifications of FDSN web services: http://www.fdsn.org/webservices/FDSN-WS-Specifications-1.1.pdf

- Specification of the QuakeML format: https://quake.ethz.ch/quakeml/docs/REC?action=AttachFile&do=view&target=QuakeML-BED-20130214a.pdf

- Specifications of the GlobalCMT interactive search and GCMT moment tensor format http://www.globalcmt.org/CMTsearch.html

V. Annex: EMSC Activity Report

Extract of the EMSC activity report of 2018 that describes the data collected ant its statistics.

I INTRODUCTION

The European Mediterranean Seismological Centre (EMSC), hosted by the LDG (*Laboratoire de Détection et de Géophysique*, Bruyères-le-Châtel, France), is a non-profit and non-governmental scientific international organization which provides rapid earthquake information in coordination with the national seismological institutes in the Euro-Mediterranean region. 81 seismological institutes are members from 56 countries covering the whole Euro-Med region.

The main scientific activities of the EMSC are the real time information services which are presented in this report. These services are operated thanks to the operational and technical support of the LDG and of the IGN (Madrid, Spain) by compiling the real time parametric data provided by 96 seismological agencies, in the Euro-Med region but also worldwide.

The real time catalogue is available on various media: websites, smartphone App, Twitter, Browser add-ons, FDSN webservice etc.

In addition to seismological data, the EMSC collects rapid in-situ data thanks to the eyewitnesses who provide felt reports, comments and/or geo-located pictures of earthquake effects. Seismic data along with in-situ data allow the EMSC to quickly detect felt and potentially damaging earthquakes and to rapidly publish information on these significant earthquakes through various media: websites, email services, Twitter, smartphone App, etc.

The different earthquake information services and the publication media are presented in this report as well as their performance's evolution over the last few years. The report also presents recent developments carried out by the EMSC.

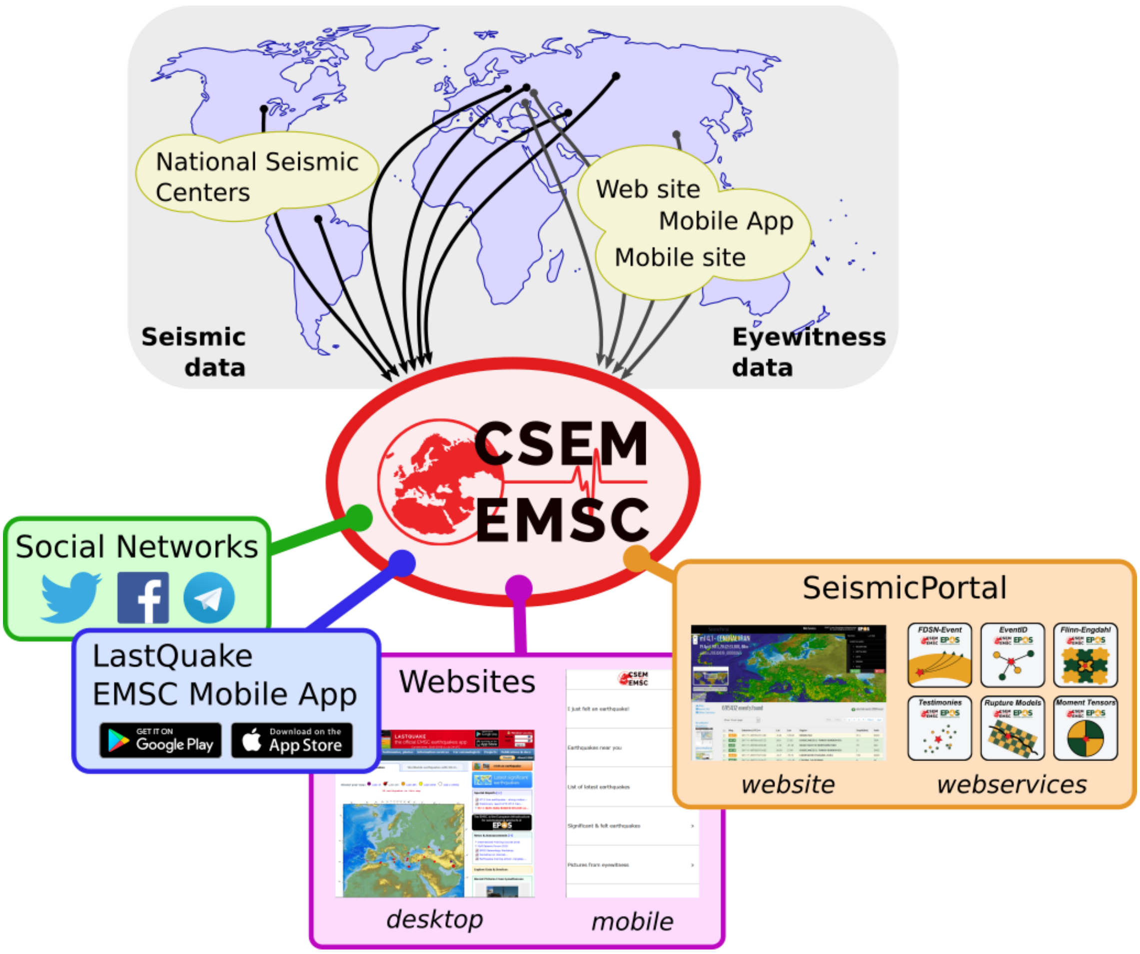

Figure 1 : Overview of the EMSC and its main services for the general public and for seismologists (www.seismicportal.com)

II Status and performance of the Real Time Services

Each year, we assess the status and the performance of the EMSC real time services using the following metrics:

- Status and performance of the email Earthquake Notification Service
- Seismological data received and number of earthquakes published
- In-situ data provided by the eyewitnesses (felt reports, comments, pictures)
- Who uses EMSC real time services and how?

II.1 Earthquake Notification Service (ENS)

II.1.1 Presentation

The EMSC operates an email Earthquake Notification Service (ENS), thanks to the technical and operational support of the **LDG** (Bruyères-le-Châtel, France), and of the **IGN** (Madrid, Spain). The ENS is a free public service[1] which consists of quickly disseminating (within 10-20 minutes after earthquake occurrence) an email notification to its users for potentially damaging earthquakes (i.e. M5+ in Europe; M6+ for continental Asia; M7+ worldwide). The earthquake location and dissemination is performed by a seismologist on call. On average, 100-150 messages are disseminated each year via the ENS.

In the framework of the ENS, the seismologist on call is also in charge of relocating, when necessary, the earthquakes published on the EMSC website during the week-end. This task allows the seismologist on call to remain aware of the recent seismicity and to quickly detect any technical problems.

II.1.2 Role of the LDG

The Laboratoire de Détection de de Géophysique (LDG) is the EMSC's host institute. The LDG is part of the Commissariat à l'Energie Atomique (CEA) and is located in Bruyères-le-Châtel, France.

The LDG covers EMSC's overheads (premises, phone lines, …) as well as the computer infrastructure. All servers and computer are the property of the CEA. The CEA provides facilities to the EMSC to insure that it remains operational 24/7 thanks to people on call: seismologists, IT's, technicians. A dedicated vehicle, a laptop and a cell phone are at the disposal of the seismologist on call so that he/she can easily and securely connect to the EMSC from his/her home and therefore quickly disseminate messagesto the ENS users.

II.1.3 Role of the IGN

The **Instituto Geografico Nacional** (IGN), in Madrid, Spain, operates a back-up of the Earthquake Notification Service (ENS) when the EMSC is not able to operate it for maintenance reasons for example. When the EMSC website is offline, the real time seismicity is available on IGN website:

http://www.01.ign.es/ign/resources/sismologia/www/csem/csem.htm

It's important to notice that due to an hardware update, this backup system provided by the IGN is no longer operational. However, with our effort to update the data collection core system (see IV.3), it's now one of our main objectives and plan to install this system at IGN as soon as possible.

[1] http://www.emsc-csem.org/service/register.php

II.1.4 ENS USERS

The number of users registered to the Earthquake Notification Service is rather stable since 2013, with a total of 12,020 users on 01/01/2019 (Table 1). With the soar in smartphones devices and the release of numerous smartphone applications for earthquakes information, classical email-based services have become less interesting to the general public.

The database of ENS users is regularly cleaned and the email addresses that are not valid anymore are removed from the database.

II.1.5 ENS PERFORMANCE

We present here the evolution, over the last few years, of the response time performance of the ENS. Only Euro-Med earthquakes are considered because this is the region on which the ENS is focused. For each earthquake that has been processed via the ENS, we consider separately:

- **The Preliminary information time**

The preliminary information is the very first source parameters published on the EMSC website for a given earthquake (generally an automatic location).

The time delay between earthquake occurrence and publication of the preliminary information has continually decreased since 2006 to 2017 with a median value of 4.0 minutes. In 2018 this value increased to 5.5 minutes for Euro-Med earthquakes (Table 1 and Figure 3).

- **The Alert triggering time**

The Alert triggering time is the time elapsed between the earthquake occurrence and the time when the seismologist on call is automatically called, when the magnitude of an earthquake exceeds the local threshold[2] (Figure 2). The regular decrease of the Alert triggering time since 2004 is mainly due to the improvements in the performance of the individual seismological agencies in detecting and locating earthquakes more rapidly.

In 2018, the median Alert triggering time was 3.2 minutes (Table 1 and Figure 3).

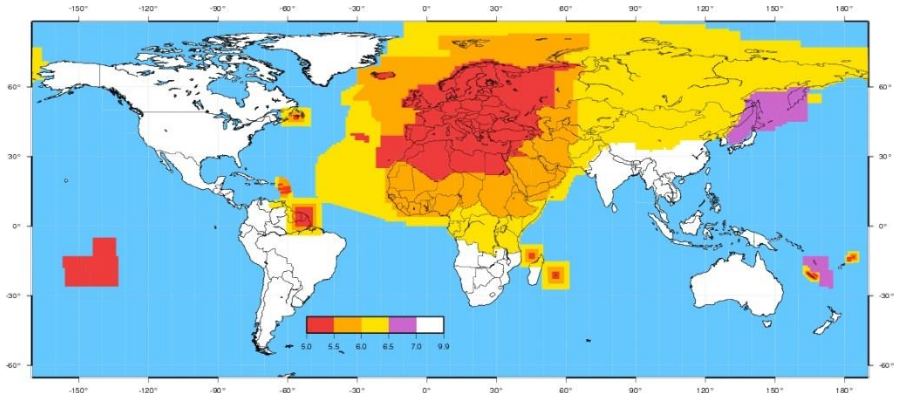

Figure 2: Map of magnitude thresholds for the alert triggering

[2] http://www.emsc-csem.org/Images/threshold.jpg

- **The Alert dissemination time**

The Alert dissemination time is the time elapsed between the earthquake occurrence and the time when the seismologist on call disseminates the alert message to the ENS users. After slightly increasing in 2016 due to the arrival of 3 new seismologists in the on-call team, who needed some training, the alert dissemination time decrease in 2017 to 15.4 min and stayed stable in 2018 (Table 1 and Figure 3).

Earthquake Notification Service												
Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	
Number of users	6,570	7,541	8,644	9,667	10,862	11,461	11,628	11,888	11,881	11862	12020	+1.3%
Number of disseminated earthquake notifications	157	135	122	137	152	156	208	119	131	151	170	+12.6%
Median preliminary information publication time for Euro-Med earthquakes	9.9	9.5	9.1	7.6	7	7	6	4.2	4.3	4	5.5	+37.5%
Median Alert triggerring time for Euro-Med earthquakes	7	7	7.5	7	7	6	6	3.5	3.7	2.6	3.2	+23.1%
Median Alert dissemination time for Euro-Med earthquakes	22	20	18	18	17	16	16	14.5	18.1	15.4	15.4	+0.0%

Table 1: Change in the response time performance of the Earthquake Notification Service over the last 10 years for Euro-Med earthquakes

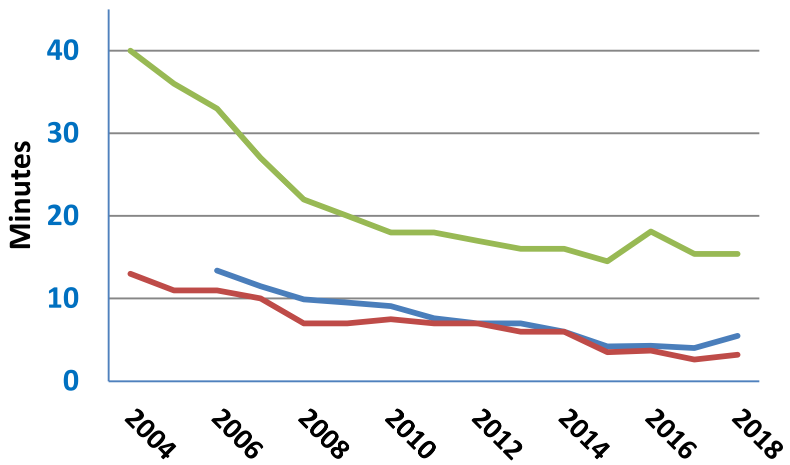

Figure 3: Earthquake Notification Service: improvement of the median values of the alert triggering time (in red), the preliminary information publication time (in blue) and the dissemination time (in green) since 2004 for Euro-Med earthquakes.

- **Location and magnitude accuracy**

Until 2013, we used to assess each year the location and magnitude accuracy of the information published or disseminated in the framework of the ENS. To perform this, we used to consider the location provided by the Euro-Med Bulletin (EMB; Godey et al.; 2007) as a reference location. However, the EMSC 2014 General Assembly, held during the ESC 2014 in Istanbul, decided to stop the production of the EMB which prevented us from assessing these performance anymore. Nevertheless, we showed in the report on 2013 real time activities that these performance had been rather stable in recent years, with a median accuracy of the disseminated locations of 10-12km and a median magnitude accuracy of 0.1 for Euro-Med earthquakes.

The reasons why the EMB production stopped and the final status of the EMB are presented in the report on Euro-Med Bulletin activities in 2015 (Godey et al. 2015).

II.2 SEISMOLOGICAL DATA

II.2.1 DATA CONTRIBUTORS

In 2018, a total of 96 seismological agencies provided real time data to the EMSC. This count can be compared to the 86 contributors of 2017 and this change shows our efforts to have our contributor list as up-to-date as possible. We have 6 new contributors:

- INSN: Irish National Seismic Network
- BRGM: Bureau de Recherches Géologiques et Minières, France
- UASD: Universidad Autonoma de Santo Domingo
- KIS: Kyrgystan
- CNRM: Morocco
- VEN: Venezuela

And we have also 4 contributors that are reactivated:

- MLT: Malte
- NSC: Nepal
- PIVS: Philippines
- UPSL: University of Patras Seismological Laboratory

II.2.2 DATA COLLECTED

The amount of data contributions has regularly increased since 2004 (Figure 4). In 2018, the 96 agencies contributed to the EMSC:

- Source parameters and phase pickings (see VII.1):
    - 151,276 origins (Figure 4) or 4,660,688 arrival times from 7,260 seismic worldwide stations (Figure 4; Figure 5; Table 2)
- Moment tensors solutions (see VII.2):
    - 3,703 moment tensor solutions[3] (Table 2)

[3] List of moment tensors received: http://www.emsc-csem.org/Earthquake/tensors.php

Data received																
Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	
Nb of origins received	13,992	18,030	31,537	35,644	43,151	50,789	60,628	78,756	81,828	84,060	92,421	89,954	103,495	122,702	151,276	+23.3%
Arrival times received	447,552	671,225	731,878	1,032,159	1,244,879	1,532,786	1,670,703	2,084,588	2,304,648	2,262,900	2,440,773	2,329,705	2,650,725	3,077,100	4,660,688	+51.5%
Nb of contributing Euro-Med stations	1,100	1,249	1,359	1,624	1,672	1,782	1,896	1,996	2,100	2,236	2,415	2,459	2,431	2,603	2,653	+1.9%
Moment Tensors solutions received	1,013	1,139	1,105	1,175	1,328	1,285	1,303	2,488	2,886	3,024	3,972	3,557	3,438	3,868	3,703	-4.3%
Earthquakes with Moment Tensor solutions	182	640	622	699	725	703	701	1,037	1,198	1,230	2,052	1,910	1,612	1,348	1,299	-3.6%
Data published																
Nb of worldwide earthquakes	*NA*	9,814	11,109	14,342	15,386	16,582	17,540	24,237	32,944	36,181	42,530	39,471	49,731	52,459	75,776	+44.4%
Nb of Euro-Med earthquakes	*NA*	6,228	6950	8,993	9,819	11,018	12,189	18,049	24,771	24,908	22,168	18,674	18,800	23,278	14,533	-37.6%
Proportion of Euro-Med [2]earthquakes	*NA*	63.5%	62.6%	62.7%	63.8%	66.4%	69.5%	74.5%	75.2%	68.8%	52.1%	47.3%	37.8%	44.4%	19.2%	-56.8%

Table 2: Trends in the amount of data received and the number of earthquakes published in EMSC real time catalogue since 2004. NA=Not applicable

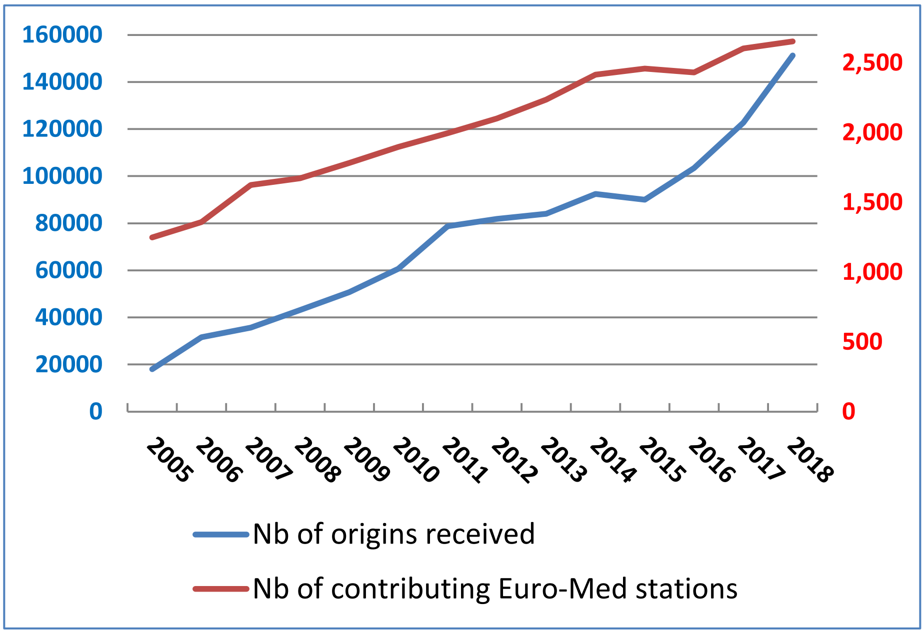

Figure 4: Growth in the number of origins received by the EMSC from the data contributors (in blue) and the number of Euro-Med stations that provided phase pickings (in red) in real time since 2004

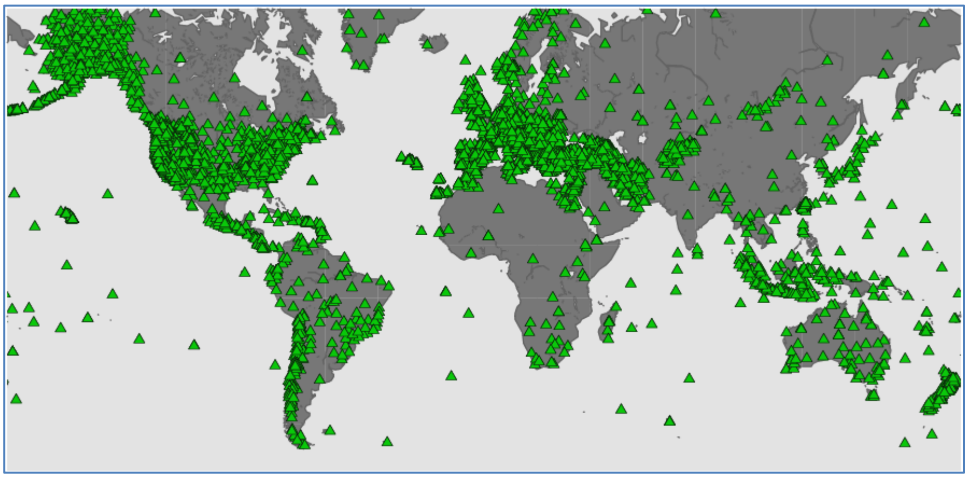

Figure 5 : Maps of the 7,260 contributing stations for 2018 referenced in the station book of ISC.

II.3 Real time catalogue

II.3.1 Number of earthquakes published

The number of worldwide earthquakes published each year by the EMSC in its real time catalogue has kept on increasing since 2004 and reached 75776 earthquakes in 2018 (Table 2, Figure 6 and Figure 7). The huge increase of seismic events (+44%) in 2018 is mostly due to a seismic crisis in Hawaii where we received a lot a small events (<M3).

The curve of daily distribution of earthquakes collected by EMSC is composed of different periods:

- In 2017, the number of earthquakes increased by 23.8 % compared to 2016 and this trend is probably linked to 3 main earthquake sequences: in Italy in January 2017, in Western Turkey in February 2017 and in Macedonia in July 2017.
- The regular increase observed between 2005 and 2012 is mostly due to the additional seismological stations available in real time (red curve on Figure 4) and the improvement of the detection capacities of the different seismological agencies which provide real time earthquake data to the EMSC. Concerning the Euro-Med earthquakes, their number did not increase since 2012. In this case, the year-to-year changes are mostly governed by the natural changes in the seismic activity.

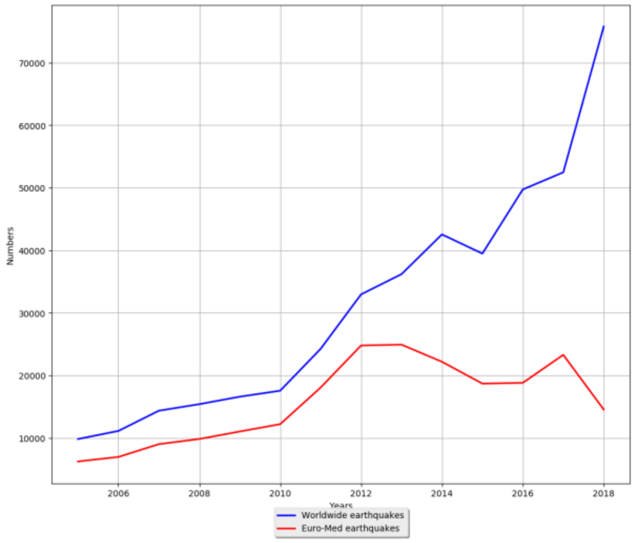

Figure 6: Change in the number of worldwide (in blue) and Euro-Med (in red) earthquakes published in EMSC real time catalogue per year since 2005

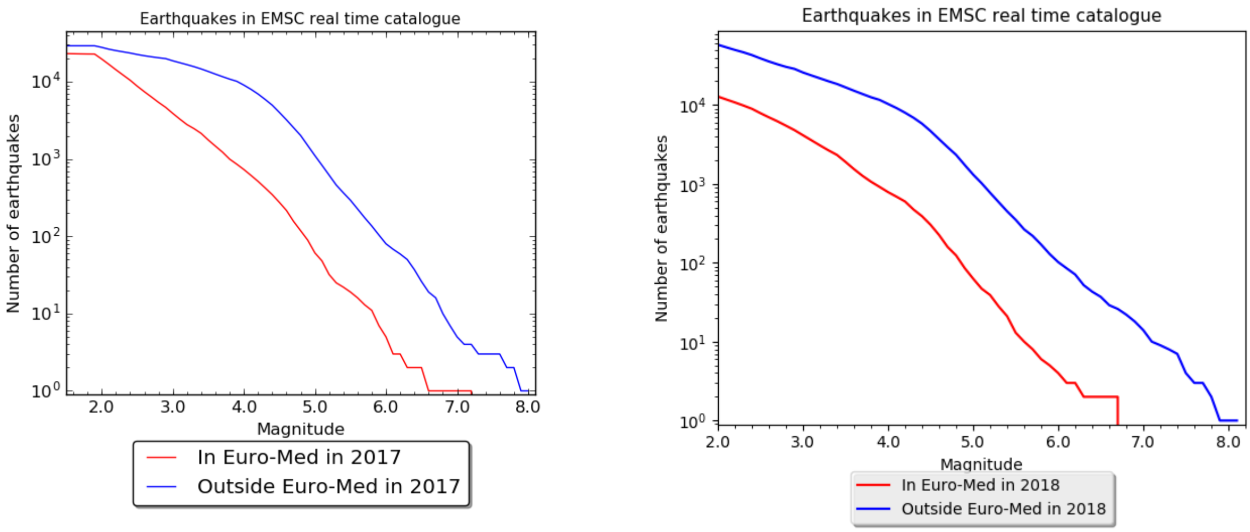

Figure 7: Comparisons of Gutenberg-Richter magnitude distribution of the earthquakes published in EMSC real time catalogue in 2017 (left) and in 2018 (right)

II.3.2 TYPES OF LOCATIONS

Among the tens of thousands of earthquakes in the EMSC real time catalogue, we distinguish four types of locations (Table 3):

- 1. Reported locations: earthquakes reported by only one contributor/agency which is the local agency but for which its location is not authoritative (Bossu et al.; 2011). The EMSC does not relocate them.
- 2. Authoritative locations: earthquakes for which at least one of the locations provided by the contributing agencies is authoritative (Bossu et al.; 2011). The EMSC does not relocate them.
- 3. Data Selected Locations (DSL): locations computed by the EMSC where no authoritative location is available but where a Ground Truth (GT) location (Engdahl et al.; 2001 and Bondar et al.; 2004) can be obtained by merging the data of the different agencies. DSL are accurate locations by definition.
- 4. EMSC locations: locations computed by the EMSC using all the pickings provided by the data contributors.

Table 3 clearly shows that the vast majority of the locations published in EMSC real time catalogue are not computed by the EMSC. In 2018, 87.3% of the worldwide seismic events (70.0% of the Euro-Med ones) diffused by the EMSC use a location directly provided by individual seismological agencies.

Type of locations	Worldwide	Euro-Med only	Computed by the EMSC
Reported locations	58.8%	49.9%	No
Authoritative locations	28.5%	20.1%	No
Data Selected Locations	0.1%	0.3%	Yes
Locations computed using all available stations	12.5%	29.8%	Yes
Locations not computed by the EMSC	*87.3%*	*70.0%*	-

Table 3: Distribution of the different types of locations published in EMSC real time catalogue in 2018

II.4 DATA COLLECTED FROM EYEWITNESSES

This section is dedicated to the information collected from the earthquake eyewitnesses in terms of felt reports, comments and pictures.

The EMSC collects eyewitnesses felt reports for several reasons:

- It provides a way to collect felt reports in countries where no online questionnaire is available.
- It supplies redundancy to macroseismic questionnaires provided by the local institutes.
- It is a way to collect and process felt reports over frontiers and in a homogenous way.

The EMSC collects felt reports:

- Either via the classic online questionnaire available on the EMSC desktop website[4] (i.e. for desktop)
- Or via the thumbnails describing each level of shaking (Figure 8) and made available on the mobile website[5] and LastQuake application.

In this report, the word "felt report" stands for both types.

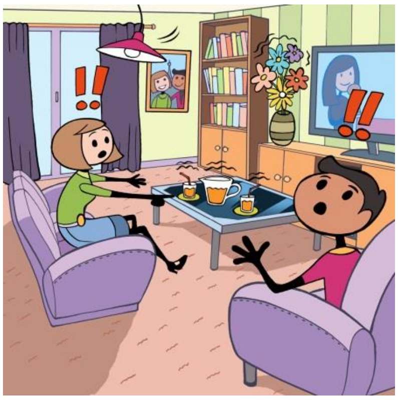

Figure 8: Example of thumbnails proposed to eyewitnesses to share their experience, corresponding to an intensity of 3.

II.4.1 FELT REPORTS

The number of felt reports collected by EMSC has continued to increase over these past 10 years and reached 120474 in 2018 (Figure 9, Figure 10, Figure 11 and Table 4).

Main observations:

- The number of felt reports collected has increased through all collection channels, the app, mobile website and desktop website; by 23% for LastQuake app and by 40% on the desktop.
- Compared to 2017, the coverage improved in Oceania and in particular in Indonesia (Figure 11) thanks to the Lombok sequence

Although the EMSC collection system is now well established, It's interesting to note that the repartition between the collection channels depends strongly on the region and shows the complementarity of the global collection system (Figure 13).

[4] http://www.emsc-csem.org

[5] http://m.emsc.eu

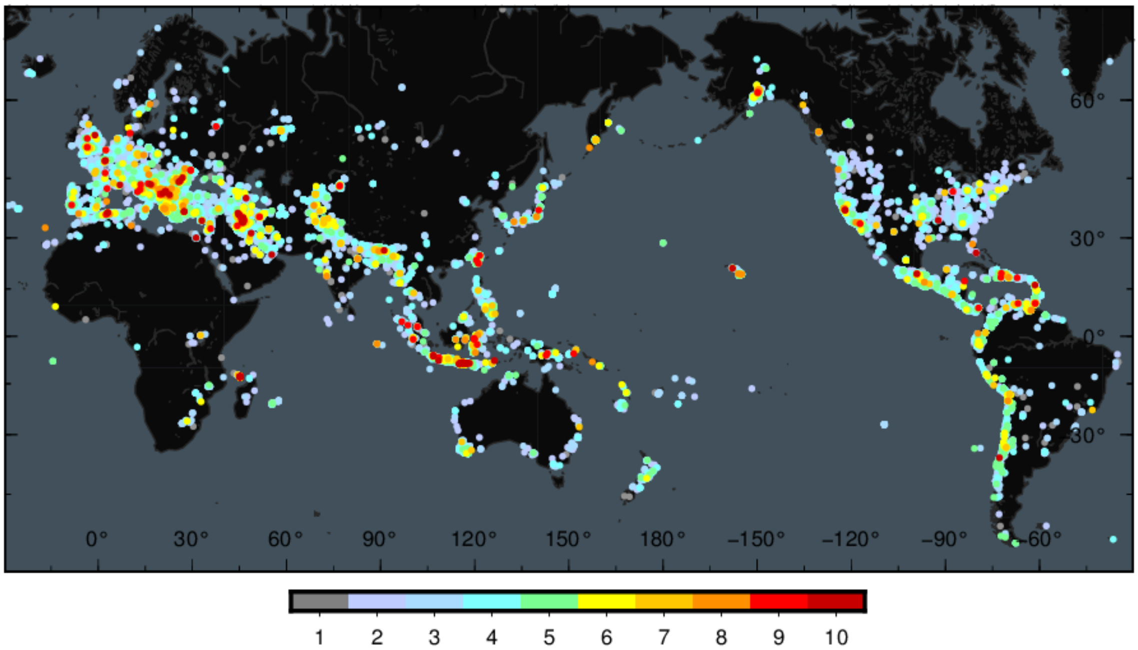

Figure 9: The 119,622 geolocated felt reports collected in 2018. On this map, higher intensity values overlay lower intensity ones.

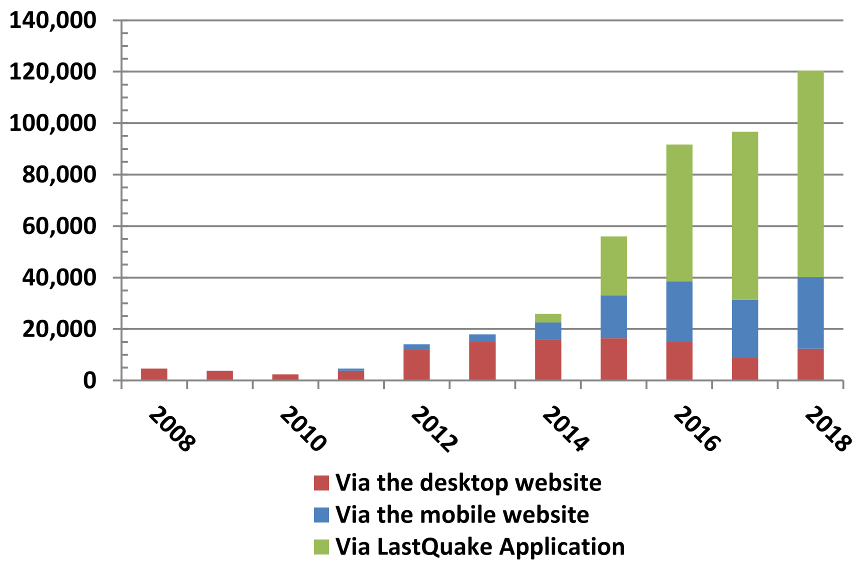

Figure 10: Yearly distribution of felt reports collected every year over the last 10 years.

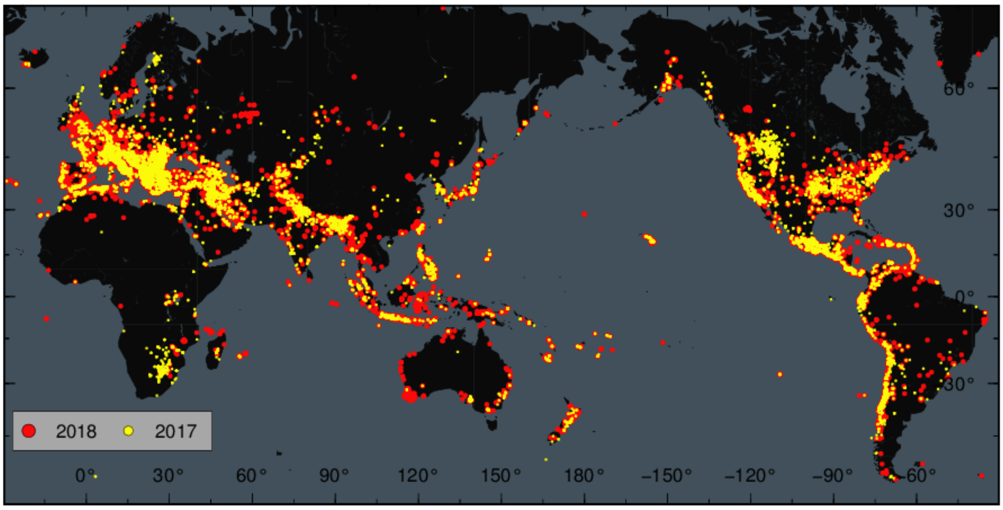

Figure 11: Comparison of the felt reports distribution in 2017 and 2018.

Felt reports collected from eyewitnesses												
Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Via the desktop website	4,581	3,778	2,400	3,831	11,909	14,909	16,056	16,506	15,366	8,782	12,332	+40.4%
Via the mobile website	*NA*	*NA*	*NA*	783	2,235	2,991	6,491	16,581	23,134	22,562	27,818	+23.3%
Via *LastQuake* Application	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	3,314	22,927	53,138	65,293	80,324	+23.0%
TOTAL	**4,581**	**3,778**	**2,400**	**4,614**	**14,144**	**17,900**	**25861**	**56014**	**91638**	**96637**	**120474**	+24.7%
Earthquakes with at least one testimony	686	795	693	841	1410	1526	2041	2705	3737	5152	4319	-16.2%

Table 4: The numbers of felt reports collected from eyewitnesses every year over the last 10 years

The “felt report” number gives a good indicator for evaluating the performances of all components of the collection system, that encompasses the hardware and the software as well as the overall popularity of EMSC. This year, there was no increase in collection speed. However, there were 12 events for which we collected more than 1000 reports and half of these had a magnitude less than M5. Of course these observations depend strongly on the seismic event distribution and so it is difficult to extract global trends. In 2018, the record set in 2016 was beaten twice. In 2016, we collected 4423 reports for an M5.6 event in Oklahoma on 2016/09/03. In 2018, we collected 4480 reports in Romania for a M5.5 on 2018/10/28 and the new “record” is 5407 reports for a M4.4 in the UK on 2018/02/17.

In term of performance, the Figure 12 shows that 60% of the felt reports collected in 2018 came within 15 minutes of earthquake occurrence for thumbnails and 25 minutes for questionnaires. Moreover thumbnails (felt reports from mobile and LastQuake) represent the majority of collected reports (90%). This shows the efficiency of the collection system enabled by the app and the cartoon thumbnails for choosing the felt intensity.

This optimal behavior is possible thanks to the effort made in 2016 to optimize some analysis, to upgrade our web servers and to upgrade our front-end servers (F5-Big-IP load balancers) which manage the traffic peaks generated by sudden visitor arrivals.

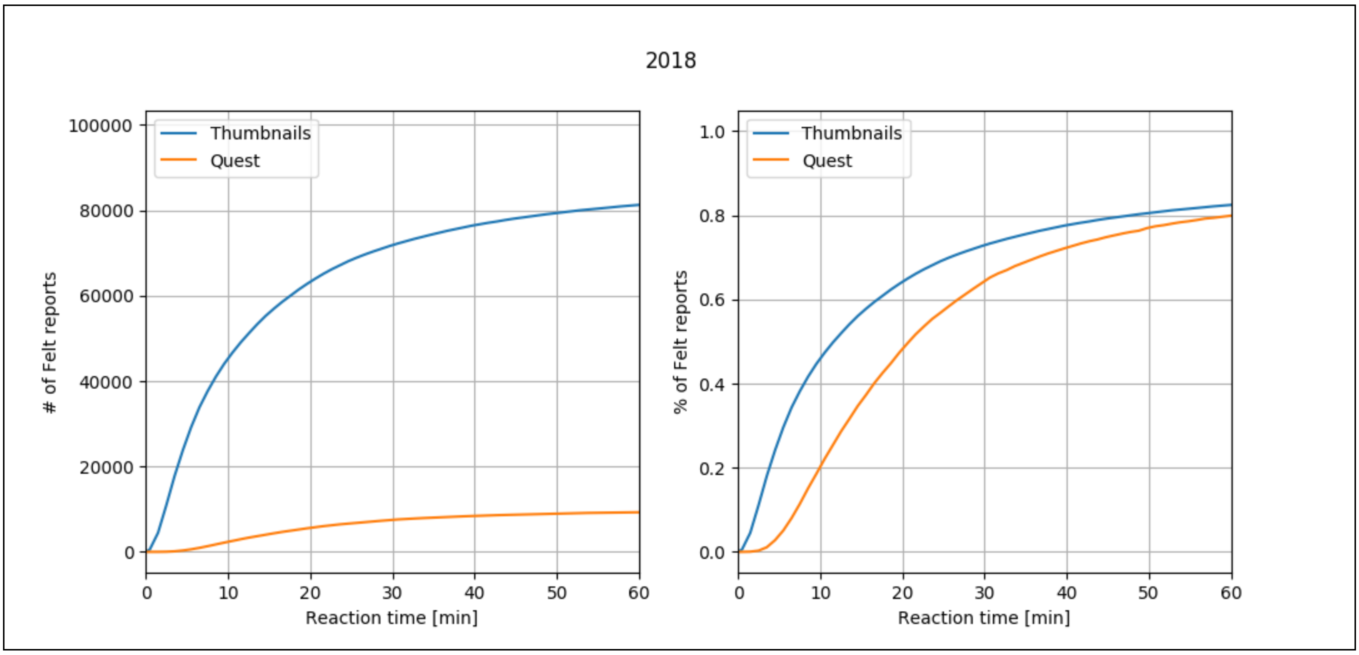

Figure 12: Number (left) and percentage (right) of all felt reports collected in 2018, with respect to time elapsed since earthquake occurrence, by thumbnails-based and online questionnaires.

M4.4 in San Francisco	M6.8 in Greece	M4.4 in England

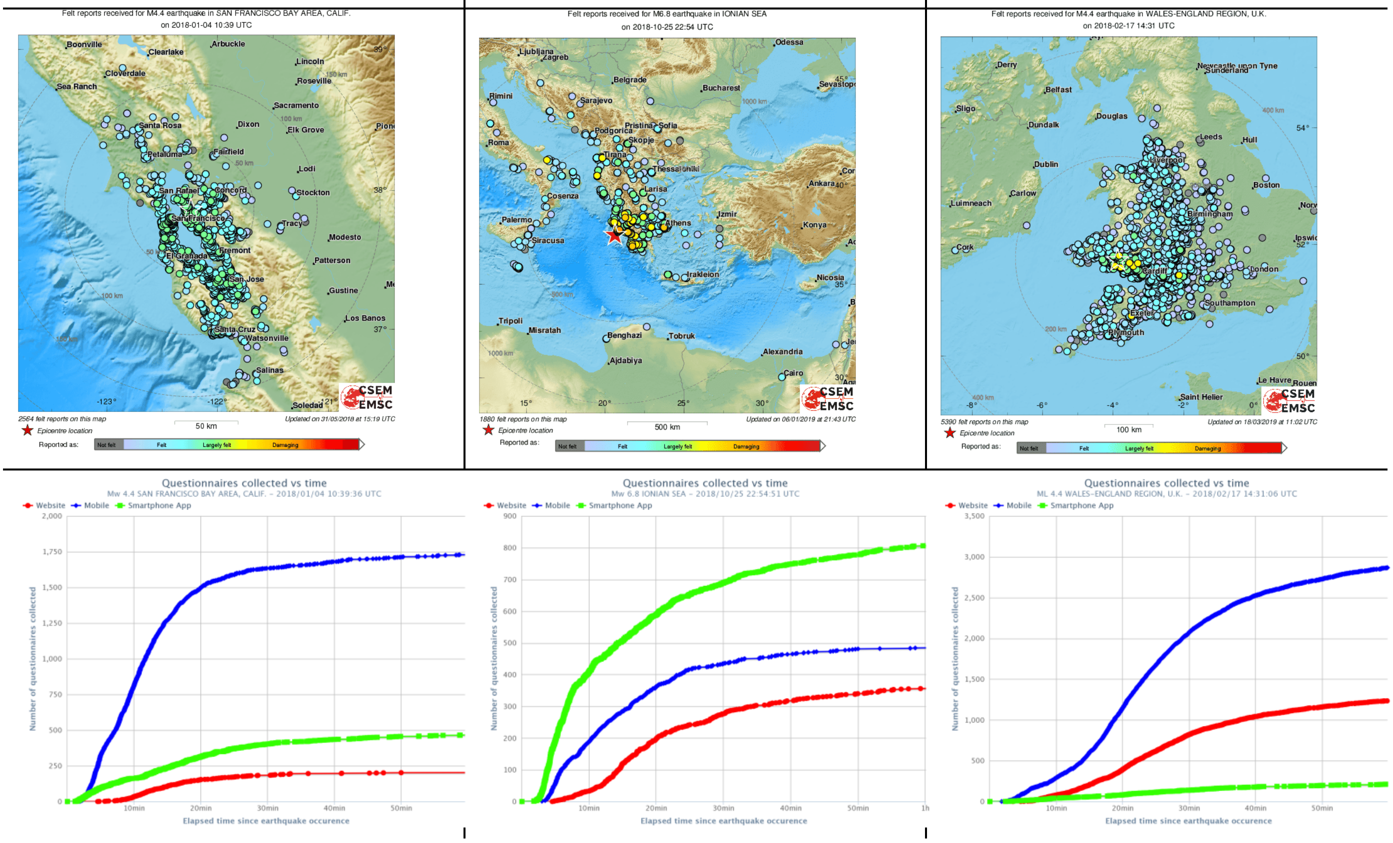

Figure 13: Examples of the three distinct collection mechanisms for three seismic events in 2018.