Final Technical Report

Earthquake Hazards Program Assistance Awards

September 23, 2015

USGS Award Number: G14AC00149

Title of award: Extension of the ISC-GEM Global Instrumental Earthquake Catalogue (Year 1)

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Abstract

During the project year we extended the ISC-GEM Global Instrumental Earthquake Catalogue with approximately 4,000 reliably known earthquakes above moment magnitude 5.5 that occurred during the 1950-1959 period as well as recently, in 2010-2011. As a result, the magnitude cut-off threshold now applies for much longer period 1950-2011. To achieve this goal, a large volume of parametric seismic data was digitised from paper-based historical observatory bulletins and catalogues available at the ISC and other institutions.

The main and supplementary parts of the catalogue are available form the website of the International Seismological Centre (**www.isc.ac.uk/iscgem**) and commonly used in assessment of seismic hazard and risk worldwide.

The data for the historical part of the ISC-GEM catalogue (prior to late 1970s) will also contribute towards the current USGS effort to compile the ComCat that is designed to bring the parametric earthquake data of all US state-funded networks together.

Procedures used to build the catalogue have been published in the special volume of the Physics of the Earth and Planetary Interior.

Report body:

Status of the original ISC-GEM catalogue at the start of the project

As far as the earthquakes of 1950s are concerned, the original ISC-GEM catalogue reflected the cut-off magnitude of 6¼. Table 1 gives an overview of relevant earthquake numbers.

Table 1. Number of earthquakes in the original ISC-GEM catalogue in the 1950s (both the main and the supplementary catalogues) with cut-off magnitude of 6¼

Year	Number of earthquakes in the main catalogue	Number of earthquakes in the supplementary catalogue
1950	48	21
1951	40	17
1952	36	10
1953	50	12
1954	45	19
1955	55	11
1956	38	6
1957	80	12
1958	36	8
1959	48	16
TOTAL	**476**	**132**

Earthquakes listed in the supplementary catalogue have either poorly constrained location or (more often) no reliable magnitude estimate.

Collection of arrival time data

We collected arrival time data for those earthquakes with potential magnitude likely to be in excess of 5.5. The main source of arrival times of seismic phases needed for relocation is the International Seismological Summaries (ISS). The ISS lists in a tabulated form the arrival times of body-waves from large earthquakes recorded by seismic stations worldwide. We processed already available scanned pages of the ISS using optical character recognition (OCR) procedures in order to obtain the arrival times in digital form. The OCR outputs were then interactively checked and edited to correct errors/typos, data consistency checked. Table 2 and Figure 1 show the annual numbers and geographical distribution of concerned stations during 1950-1959 period.

Table 2. *Summary of the phase data collected from the ISS; these figures exclude those large earthquakes already included in the original ISC-GEM catalogue.*

Year	Number of stations in the ISS	Number of ISS phases
1950	310	57,883
1951	384	68,506
1952	420	102,604
1953	409	64,361
1954	462	81,872
1955	463	78,623
1956	483	73,218
1957	556	114,324
1958	577	121,392
1959	583	119,552

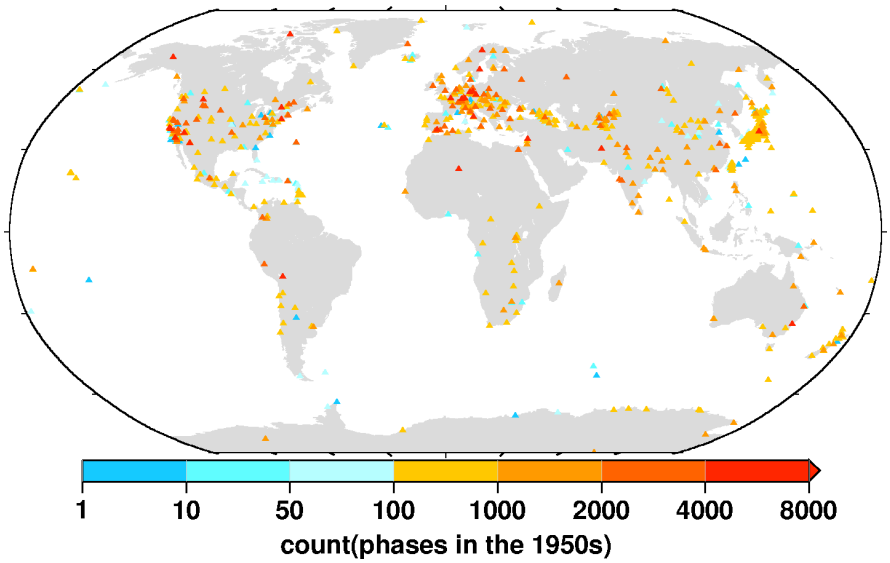

Fig. 1: Geographical distribution of seismic stations listed in the ISS during the 1950s color-coded by the overall number of reported phases.

Collection of amplitude/period data

As the ISS does not list the necessary amplitude and period information to re-compute M_S and *mb/mB*, the amplitude-period data search was performed based on the original station or network bulletins. Table 3 summarizes the amplitude-period data collected from individual station bulletins covering the 1950s.

Table 3. Summary of the amplitude-period data collected from station/network bulletins.

Year	Number of amplitudes-periods (stations)
1950	8504 (37)
1951	8641 (38)
1952	12252 (76)
1953	9421 (78)
1954	9471 (103)
1955	8365 (155)
1956	7791 (137)
1957	12928 (150)
1958	12728 (156)
1959	13356 (167)

Figure 2 shows the spatial distribution of the stations contributing to magnitude computation color-coded for number of *readings* (in the ISC jargon a *reading* groups all the parametric data from a single station associated to a specific earthquake and reported by the same agency) for the 1950s.

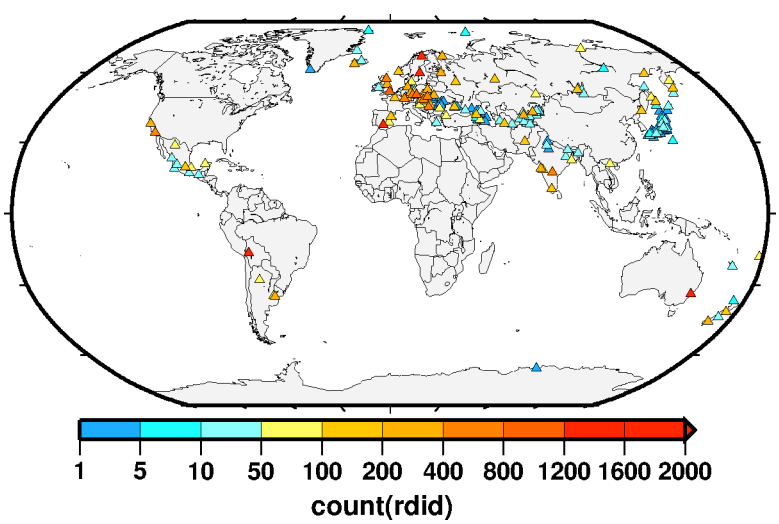

Fig. 2: Map of the stations contributing to magnitude re-computation for 1950s. The stations are color-coded according to the number of reported readings.

Relocation and magnitude determination

We used the two-tier location approach described in Bondár *et al.* (2014) to re-compute locations of earthquakes in the 1950s and during the 2010-2011 period.

We followed the procedures described in Di Giacomo *et al.* (2014b) to obtain magnitude estimates for these events. Due to the lack of reliable short-period measurements in this period, we accepted only 12 *mb* values for the entire decade. We accepted 2,216 M_S values after checking the station magnitude distribution for each re-computed M_S and cross-checked our results with other magnitude information, if available, investigating large differences.

Table 4 gives the annual numbers of processed events in 1950s. In addition, we processed 1,176 events in the period 2010-2011.

Table 4. Numbers of ISS earthquakes processed during the 1950s.

Year	**Number of earthquakes processed**
1950	438
1951	469
1952	560
1953	352
1954	316
1955	299
1956	311
1957	355
1958	530
1959	526
Totals	4156

The preliminary results of work on this project are summarised on Figure 3 that shows cumulative annual number of earthquakes of different magnitudes through the entire 110 year period in the ISC-GEM Catalogue.

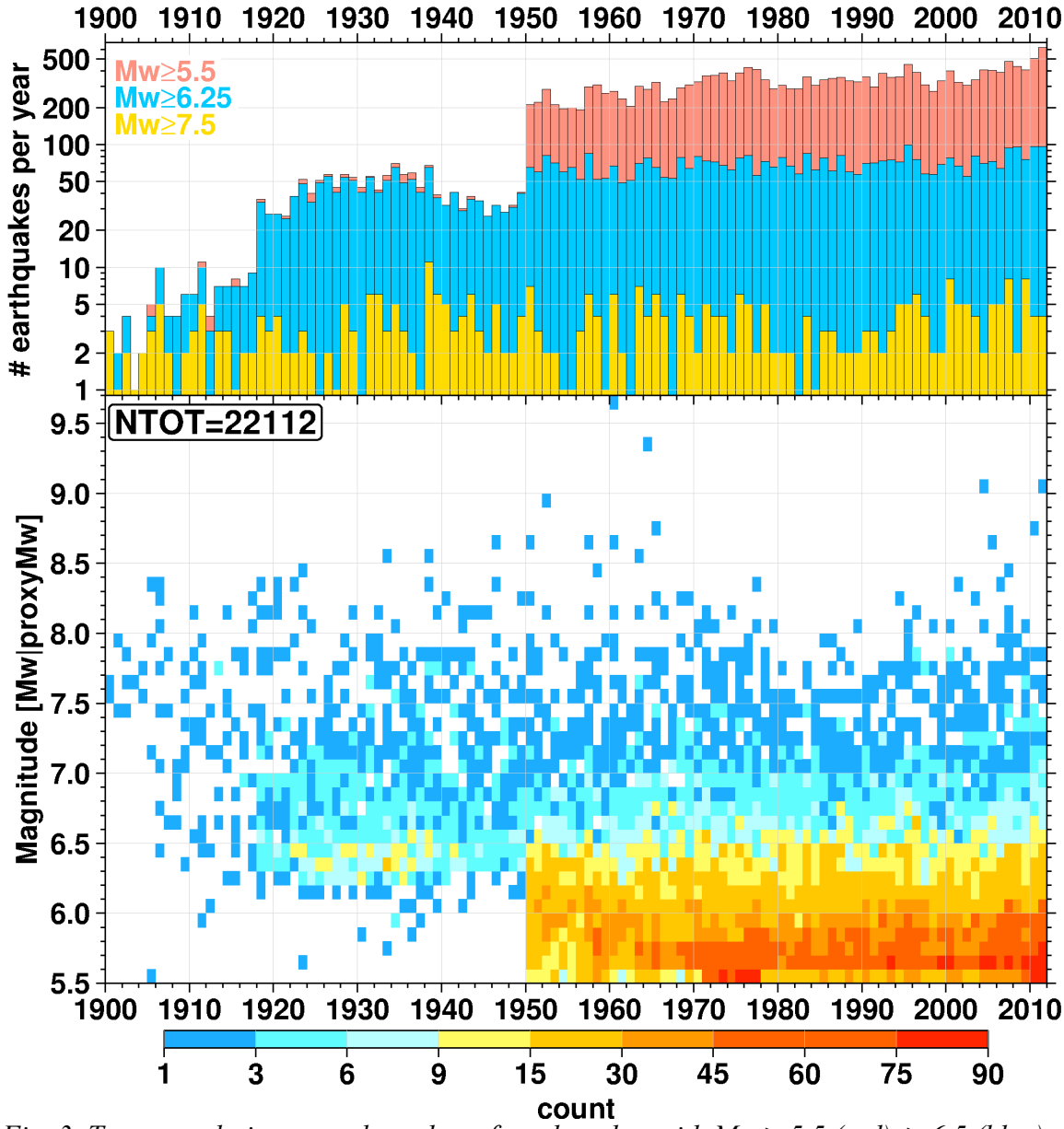

Fig. 3. Top: cumulative annual number of earthquakes with Mw ≥ 5.5 (red), ≥ 6.5 (blue) and ≥ 7.5 (yellow); bottom: time-magnitude distribution color-coded in cells of 0.1 Mw units for each year of the ISC-GEM main catalogue

Investigations undertaken:

- Digitizing hypocentres and arrival times from the International Seismological Summaries
- Digitizing relevant arrival times and amplitudes and periods of body and surface waves from individual historical seismic observatory bulletins
- Loading into the database, associating per physical event
- Re-computation of locations and magnitudes
- Checking and validation

Accomplishments:

- The ISC-GEM Global Instrumental Earthquake Catalogue was extended with ~4,000 reliably known earthquakes above magnitude 5.5 during 1950-1959 and 2010-2011 periods.
- As a result, the cut-off magnitude threshold of 5.5 now applies for a longer period of time from 1950 till 2011.
- Large volume of parametric seismic data was digitized from paper-based historical documents available at the ISC and several other institutions.
- Locations and magnitudes of added earthquakes have been recomputed based on instrumental data and advanced techniques used for production of the original catalogue.
- The ISC-GEM catalogue remains the longest and most homogeneous global source of instrumentally based earthquake parameters.
- The ISC-GEM Catalogue and underlying parametric seismogram measurements are likely to serve as a basis for the USGS ComCat catalog.
- During the year we also received station bulletins provided by colleagues from Edinburgh (UK), Eskdalemuir (UK), Obninsk (Russia), Prague (Czech Republic), Strassbourg (France) and Apatity (Russia). Those station bulletins helped us to fill some significant gaps in the ISCs original collection and allowed us to add new amplitude-period data for earthquakes listed in previous versions of the ISC-GEM Catalogue. With the data newly available, we obtained fresh magnitudes for about 200 earthquakes that were previously listed in the Supplementary Catalogue (Version 1.05) and added 237 new earthquakes between 1960 and 1963. Finally, we revised the hypocentre locations of 458 earthquakes in the catalogue, predominantly in remote areas, with 75% of depth changes within 20km and the rest within 60km.

- **Problems encountered**: No critical problems were encountered during this period of time.
- **Publications and/or presentations to date**:

The following publications are attached to this report in pdf. These publications are subject to copyrights maintained by Elsevier publishing house.

Storchak, D.A., D. Di Giacomo, E.R. Engdahl, J. Harris, I. Bondár, W.H.K. Lee, P. Bormann and A. Villaseñor, 2015. The ISC-GEM Global Instrumental Earthquake Catalogue (1900-2009): Introduction, *Phys. Earth Planet. Int.,* 239, 48-63, doi: 10.1016/j.pepi.2014.06.009.

Di Giacomo, D., J. Harris, A. Villaseñor , D.A. Storchak, E.R. Engdahl, W.H.K. Lee and the Data Entry Team, 2015. ISC-GEM: Global Instrumental Earthquake Catalogue (1900-2009), I. Data collection from early instrumental seismological bulletins, *Phys. Earth Planet. Int.,* 239, 14-24, doi: 10.1016/j.pepi.2014.06.003.

Bondár, I., E.R. Engdahl, A. Villaseñor , J. Harris and D.A. Storchak, 2015. ISC-GEM: Global Instrumental Earthquake Catalogue (1900-2009): II. Location and seismicity patterns, *Phys. Earth Planet. Int.,* 239, 2-13, doi: 10.1016/j.pepi.2014.06.002.

Di Giacomo, D., I. Bondár, D.A. Storchak, E.R. Engdahl, P. Bormann and J. Harris, 2015. ISC-GEM: Global Instrumental Earthquake Catalogue (1900-2009): III. Re-computed MS and mb, proxy MW, final magnitude composition and completeness assessment, *Phys. Earth Planet. Int.,* 239, 33-47, doi: 10.1016/j.pepi.2014.06.005.

Lee, W.H.K. and E.R. Engdahl, 2015. Bibliographical search for reliable seismic moments of large earthquakes during 1900-1979 to compute MW in the ISC-GEM Global Instrumental Reference Earthquake Catalogue (1900-2009), *Phys. Earth Planet. Int.,* 239, 25-32, doi: 10.1016/j.pepi.2014.06.004.

Date: September 23, 2015

/D.A. Storchak/