ISC Contribution to Global and Regional Seismic Hazard Assessment and Civil Engineering

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Abstract

The ISC collects earthquake bulletins from seismic networks worldwide and prepares the ISC Bulletin – the most complete long-term global summary of seismicity. Recently, the ISC has been working on products closely linked to the ISC Bulletin yet designed for specific communities, such as those assessing seismic hazard for scientific, insurance and civil engineering purposes.

The first product prepared for this user-group is the ISC-GEM Global Instrumental Earthquake Catalogue (1900-2012). The main features include improved homogeneity, accuracy and uncertainty estimates of the earthquake parameters over ~110-year period. We are currently extending the catalogue by including recent earthquakes and earthquakes in the early instrumental period below the original cut-off magnitude 6¼.

The second product relevant to this user-group is the ISC Event Bibliography that allows an interactive search for references to ~18,000 scientific articles published in the last ~100 years and related to ~15,000 earthquakes occurred in the last ~110 years.

Keywords: global, homogeneous, earthquake, catalogue, bibliography

1. INTRODUCTION

The main mission of the International Seismological Centre (ISC) is to collect earthquake bulletin data from permanent and temporary seismic networks worldwide and prepare the ISC Bulletin – the most complete and long-term summary of the world seismicity. In recent years, the ISC has also been working on several data products and services such as the CTBTO Link, Ground Truth database, EHB bulletin, Seismological Contacts and others that are closely linked to the ISC Bulletin yet designed for specific research communities.

Two new data products were prepared for users working in the area of seismic hazard and risk for scientific, insurance, re-insurance and civil engineering purposes. The first product is the ISC-GEM Global Instrumental Earthquake Catalogue (1900-2012). The second product is the ISC Event Bibliography (1906-2016). This article is designed to increase user awareness with respect to these two relatively new ISC datasets and offer advice on appropriate interpretation of involved data.

2. ISC-GEM CATALOGUE

The ISC-GEM Global Instrumental Earthquake Catalogue was built by the International Seismological Centre (ISC) and the team of international experts. The original work, covering the 1900-2009 period, was funded by the ISC and the Global Earthquake Model (GEM) Foundation. As far as the GEM is concerned, the ISC-GEM catalogue is one of the five GEM global databases, methodologies and tools for use in global seismic hazard area. The ISC maintains the ISC-GEM catalogue as one of its major products that is a special selection and extension of the ISC Bulletin for use in global and regional seismic hazard analysis.

During the first 27 months of work that started in 2010, the team of international experts collected and digitized necessary parametric observatory data, reviewed a multitude of scientific publications, developed appropriate processing procedures, re-computed earthquake locations and magnitudes and produced a publically available catalogue of major earthquake parameters.

We worked towards the following cut-off magnitudes when selecting the earthquakes to be included into the ISC-GEM catalogue (Storchak *et al.*, 2015):

- 1900-1917: $M_S \geq 7.5$ worldwide plus a selection of smaller shallow events in stable continental areas;
- 1918-1959: $M_S \geq 6¼$;
- 1960-2009: $M_S \geq 5.5$.

2.1 DATA AND METHODS USED

The full name of the ISC-GEM catalogue implies that unlike the historical GEM catalogue (Albini *et al*., 2013), the ISC-GEM catalogue, with rare exceptions, is based on the instrumentally recorded data that include arrival times, amplitudes and periods of body and surface waves. In the early instrumental period (before 1964) these data were collected (Di Giacomo *et al*., 2015a) from historical, mostly paper-based seismic bulletins of individual seismic observatories, networks as well as global earthquake summaries such as the BAAS, ISA, ISS and others. From 1964 onwards, these data were predominantly sourced from digitally available sources such as the ISC Bulletin.

In addition, we used reliable seismic moment and moment magnitude determinations as computed by Harvard CMT (Dziewonski *et al*., 1981) and GCMT (Ekström *et al*., 2012) projects. We also collected scalar seismic moments and moment magnitudes for individual earthquakes, mostly before 1976, from a multitude of scientific studies that used the original analogue waveform records (Lee & Engdahl, 2015).

The major parameters of earthquake hypocentres and their uncertainties were re-computed based on the collected arrival times of all seismic waves (Storchak *et al*., 2011) reported by seismic stations and networks worldwide. The hypocentre determination procedure (Bondár *et al*., 2015) involves a combined use of the EHB (Engdahl *et al*., 1998) and new ISC location procedures (Bondár and Storchak, 2011) based on the *ak135* velocity model (Kennett *et al*., 1995).

In line with the original requirement, all earthquake magnitudes in the ISC-GEM catalogue are expressed in M_W scale. Where possible we used the direct determinations. Otherwise, mostly before 1976, we used M_W proxy values based on the re-computed values of M_S or m_b magnitudes and our own non-linear regression relations developed during this project (Di Giacomo *et al*., 2015b).

2.2 FORMAT

The first public version of the ISC-GEM catalogue was released in 2013 (Storchak et al., 2013). The catalogue is distributed from the dedicated suite of webpages at the ISC website: http://www.isc.ac.uk/iscgem/ that includes a log of updates with a description of changes for each released version, general overview, citing instructions, acknowledgements and contact pages.

The distribution package consists of the main and supplementary catalogues along with the visualization kmz-file to be used with Google Earth package. The catalogues are given in a comma-separated format with the following parameters for each earthquake:

- Date of occurrence and origin time;
- Latitude and longitude of the epicenter;
- Error ellipse parameters: length of major and minor semi-axis and strike angle;
- Quality of epicenter determination (A through D, where A is the highest);
- Hypocentre depth with uncertainty and quality of determination (A-D);
- Moment magnitude with uncertainty and quality (A-D);
- Magnitude source: direct determination (d) or proxy (p) recalculation from other magnitude types;
- Scalar moment and six components of the moment tensor (if available), author (either GCMT or Bibliographical search);
- Unique earthquake identification number.

The main catalogue contains earthquakes with reasonable parameter confidence (all epicentre, depth and magnitude quality flags are within A to C). The supplementary catalogue lists those earthquakes for which one of the parameters has quality flag D. Usually, this is the magnitude quality that is poor. Users are advised to use both catalogues in their studies. Poor quality of an earthquake parameter determination is often a consequence of a sparse recording network; it does not compromise the fact of such earthquake occurrence.

2.3 MAJOR ADVANTAGES OF THE ISC-GEM CATALOGUE

For those studying global and regional seismic hazard, the ISC-GEM catalogue has substantial advantages over the other global comparable sources:

- The ISC-GEM catalogue covers the entire ~110-year period of instrumentally recorded seismicity;
- The hypocentres are computed with the same advanced location technique and seismic wave velocity model;
- The magnitudes are expressed in M_W scale appropriate for large earthquakes;
- All parameters are accompanied with estimates of uncertainty and quality of determination that allow for more accurate estimation of hazard uncertainties;
- The ISC-GEM catalogue, as a catalogue of large earthquakes, plays an important magnitude calibration role when regional catalogues of seismicity with smaller magnitude cut-offs are compiled by researchers;
- The ISC-GEM catalogue is not frozen in time; it is constantly updated and extended with newly recovered historical or newly recorded recent data.

2.4 EXTENSION OF THE ISC-GEM CATALOGUE

Having studied the historical summaries of earthquakes in the early instrumental period during the original stage of the ISC-GEM project, we learned that there are further possibilities to enrich the content of the ISC-GEM catalogue beyond the original requirements of the GEM Foundation.

Our plan is to continue updating the ISC-GEM catalogue for years beyond 2009 as well as to incrementally include into the catalogue all known earthquakes in the magnitude range 5.5-6¼ that occurred during the period 1918-1959 as well as earthquakes in the magnitude range 6¼-7.5 that occurred during 1904-1917. The work for the 1st part of the 20th Century is based on the existing global earthquake summaries such as the ISS and complemented with recorded seismic wave amplitude and period data from individual historical observatory bulletins to facilitate the magnitude computation. Finding and digitizing the original amplitude data requires a very large manual effort.

With the support of the sponsors and the ISC Member-Institutions, the ISC embarked on the four-year project at the end of 2013 to include additional earthquakes in the 1st half of the 20th Century to approximately the same magnitude cut-off level as was used for the 2nd half.

As a result of the two-year effort on the Extension project, 8,559 known earthquakes that occurred during the 1935-1959 period with magnitude in the range 5.5-6¼ had been re-assessed and added to the ISC-GEM catalogue; 1,590 earthquakes with magnitude greater or equal to 5.5 that occurred during 2010-2012 period have also been added (Fig. 1). As of January 2016, the Version 3 of the catalogue is available for download. Based on the download logs held at the ISC, on average, the ISC-GEM catalogue is downloaded ten times a day by professionals in the field. Approximately two percent of the total number of downloads are made by researchers in Australia.

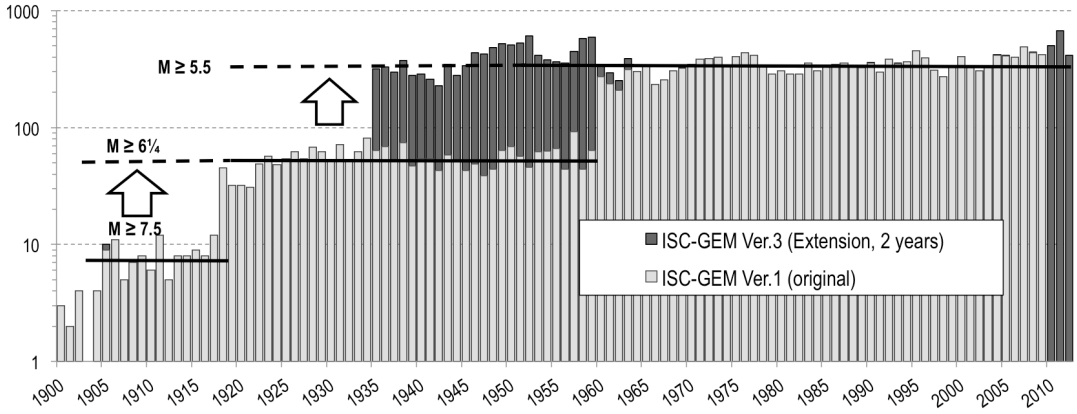

Figure 1. The annual numbers of earthquakes in the original ISC-GEM catalogue (Version 1, 2013, light grey) have changed (dark grey) after two years of work on the Extension project (Version 3, 2016) when earthquakes with magnitudes of 5.5 and above were re-assessed and added to the catalogue.

An example of how the ISC-GEM catalogue was extended in South-East Asia and Australia is shown on Fig. 2. Many earthquakes in the South–East Asia and a few in Australia in the magnitude range 5.5-6¼ have been added for years 1935-1959. The remaining visible lack of small earthquakes during 1940-1960 is perhaps a consequence of the limited number of seismic observatories operated in this part of the world during that period, which is more critical for earthquakes in magnitude range 5.5-6.0 as compared to larger earthquakes reliably quantified by stations at teleseismic distances alone.

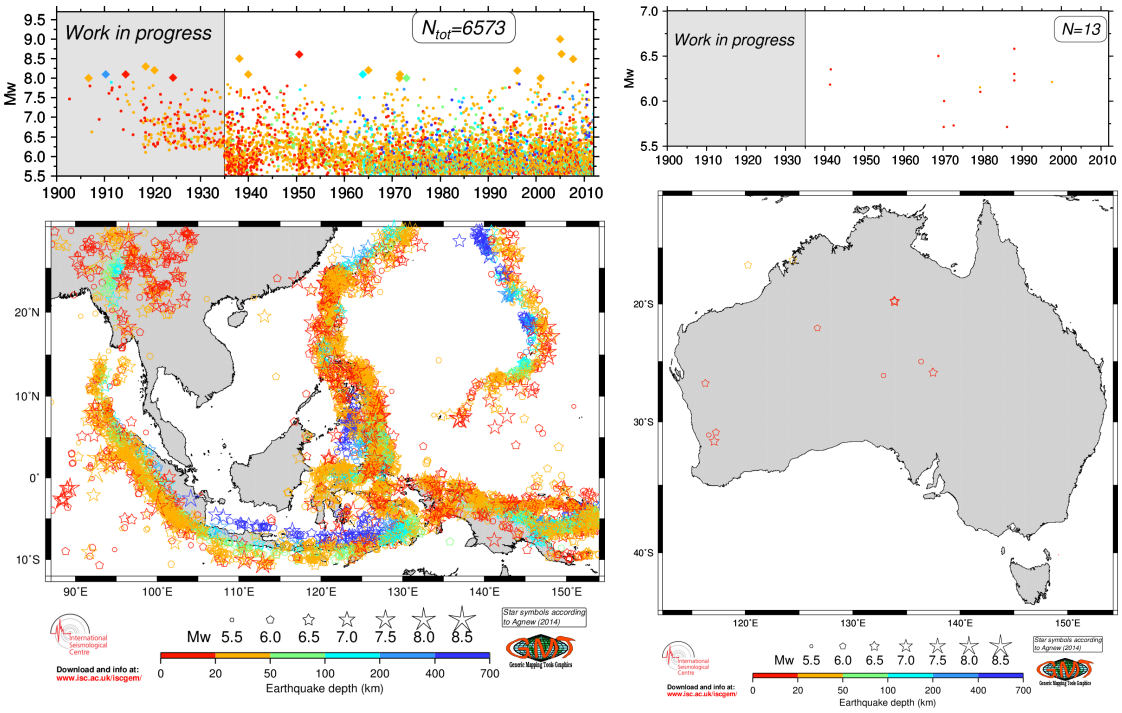

Figure 2. ***Top***: timeline of the ISC-GEM magnitude distribution of 6,573 earthquakes in South-East Asia (left) and 13 earthquakes in Australia (right); in the first two years of the Extension project many earthquakes with M_W 5.5 and above were added to unify the magnitude cut-off thresholds during the 1935-2012 period; the time period

1900-1935, shaded in grey, indicates where further work needs to be done to lower the magnitude cut-off thresholds. ***Bottom***: the maps of the earthquakes in South-East Asia (left) and Australia (right); the colours indicate depths of earthquakes; the variable star symbols indicate earthquake size as per Agnew (2014); in Australia, ten earthquakes with magnitude above M_W 6.0 are included in the ISC-GEM catalogue during the period 1941-1997.

Overall, the annual number of known earthquakes in the historical volumes of ISS (contains no magnitude estimates) indicates a good chance to further improve the ISC-GEM catalogue during the first 35 years of the 20th Century in the next two years of the Extension project.

3. THE ISC EVENT BIBLIOGRAPHY

The second ISC product that can be of interest to those studying seismic hazard is the ISC Event Bibliography (Di Giacomo *et al.,* 2014) that links specific seismic events (both natural and anthropogenic) and dedicated scientific publications that describe them. It is a web-based interactive service run from the ISC website that allows users to run search for references to scientific articles by selecting the area and parameters of both earthquakes and publications.

On a global scale, the ISC Event Bibliography joins ~18,000 scientific articles published in the last ~100 years to ~15,000 earthquakes occurred in the last ~110 years. Figure 3 shows corresponding numbers for South-East Asia.

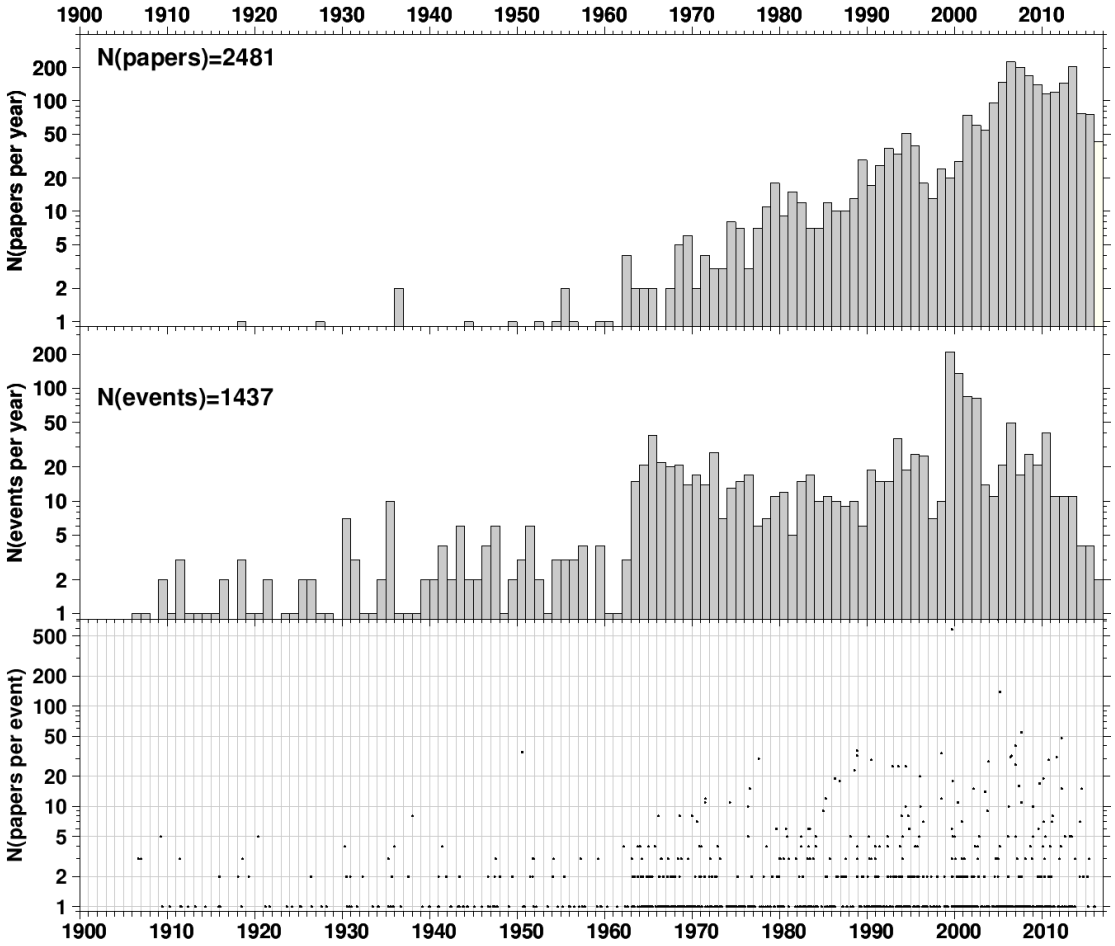

Figure 3. Timeline for the South-East Asia region: the number of scientific publications (top) linked to specific earthquakes (middle) in the ISC Event Bibliography; the bottom panel demonstrates the gradual increase in the number of scientific publications related to the same earthquakes.

Fig. 4 shows a map of earthquakes in South-East Asia with the number of scientific publications recorded in the ISC Event Bibliography. The most well described in the literature earthquakes in this area include the great Sumatra 2004 earthquake and tsunami with 734 articles, followed by the 1999 Chi-Chi earthquake with 580 articles and the 2005 Nias earthquake with 139 articles.

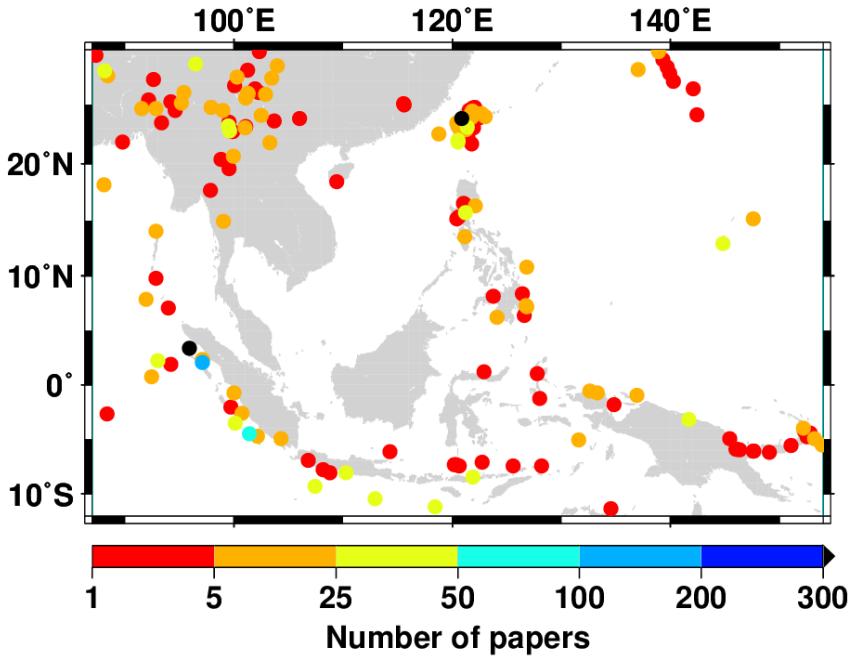

Figure 4. Earthquakes in South-East Asia included into the ISC Event Bibliography; the table below lists five earthquakes with the largest numbers of associated publications.

Event origin time	*N*	*Code*
2004–12–26 00:58:52	734	SUMATRA2004
1999–09–20 17:47:16	580	CHI–CHI1999
2005–03–28 16:09:35	139	NIAS2005
2007–09–12 11:10:26	55	SUMATRA2007
2012–04–11 08:38:37	48	SUMATRA2012

With a few exceptions where a direct permission was given to us by the publishers, we are unable to provide to users an actual copy of the articles due to the associated copyright issues. Nevertheless, a list of references is often a good starting point for users who are interested to clarify certain earthquake parameters and specific effects and damage that they have caused.

3. CONCLUSIONS

The ISC-GEM Global Instrumental Earthquake Catalogue and the ISC Event Bibliography are two valuable and unique ISC datasets that can be used by researchers studying seismic hazard and risk. The ISC continues extending both datasets as far as the past and present earthquakes and publications are concerned.

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