ISC-GEM: Global Instrumental Earthquake Catalogue (1900-2009)
II. Earthquake Magnitudes

S53A-2472

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1) Objectives

As one of the global components of the Global Earthquake Model Foundation (GEM, www.globalquakemodel.org), we produced a New Reference Global Instrumental Seismic Catalogue (1900-2009) to be used by GEM for the characterization of the spatial distribution of seismicity, the magnitude-frequency relation and the maximum magnitude. This poster describes procedures of calculating magnitude values in the ISC-GEM catalogue.
We
•collected and digitized arrival and amplitude data from various data sources for the period 1900-1970;
•relocated instrumentally recorded moderate to large earthquakes spanning 110 years of seismicity (see poster S53A-2473);
•calculated body and surface wave magnitudes from original amplitude-period observations;
•provided direct/proxy Mw estimates based on either direct seismic moment M_0 measurements, or newly derived non-linear empirical Ms-Mw or mb-Mw relations;
•estimated uncertainties for each estimated parameter.

2) Data used for re-computation of Ms and mb

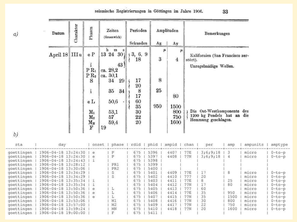
Event selection
•1900-1917: Ms ≥ 7.5 and some smaller shallow events in stable continental areas;
•1918-1959: Ms ≥ 6.25;
•1960-2009: Ms ≥ 5.5

Amplitude data
•Manually added ~148,000 valid surface and body-wave amplitude-period pairs to the ISC database:
- 1904-1970: Original paper-based station bulletins from the ISC archive (~100,000 surface wave and ~10,000 vertical component body-wave amplitude-period pairs); [amplitude-period data is missing in the ISS and no *OCR* technique would work efficiently with seismological bulletins];
- 1971-1977: KIR, UPP and former Soviet Union stations (~38,000 additional surface wave amplitudes).

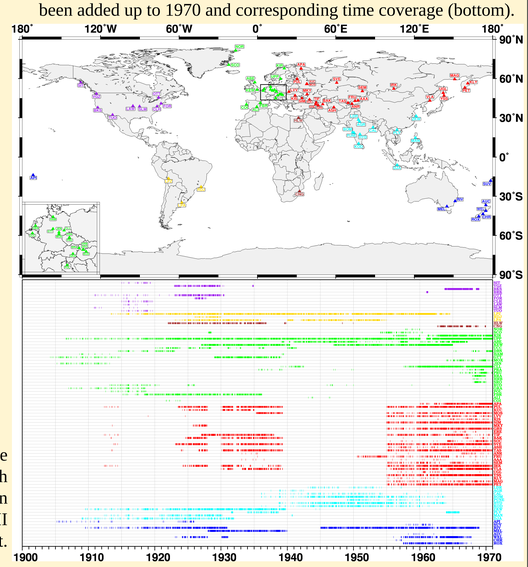
•Digitally available
- 1964-2009: ISC bulletin (2,500,000 amplitudes from the ISC database).

The amplitude-period data manually added to the ISC database, especially in the period up to 1970 provide us an unprecedented dataset to re-compute magnitudes homogenous to the large extent possible.

a) example of station parametric data from Göttingen (Germany) relevant to the 1906 San Francisco earthquake and *b)* the same data once entered in the ISC database. The surface wave amplitude-period data is ready to be processed and allow magnitude re-computation.



Location of stations (top) for which amplitude-period data has been added up to 1970 and corresponding time coverage (bottom).

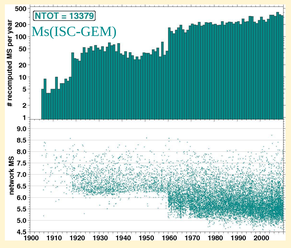


Each vertical segment represents the earthquake origin time for which station parametric data has been added. The effect of WWI and WWII are clearly seen on the timeline plot.

3) Re-computation of Ms and mb

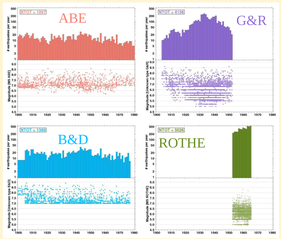
For the ISC-GEM catalogue we proceeded to re-compute Ms and mb using:
1. new hypocentral locations (see poster S53A-2473);
2. previously unavailable amplitude-period data digitized during this project;
3. a more reliable algorithm for magnitude computation based on 20% alpha-trimmed median network magnitude from several stations (Bondár and Storchak, 2011).

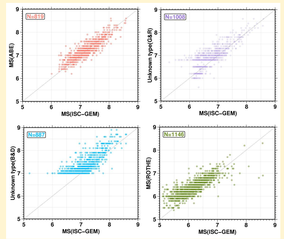
Annual number and re-computed Ms/mb time distribution of earthquakes in the ISC-GEM catalogue.



3.1) Comparisons of Ms with early instrumental period global catalogues

Comparisons of the ISC-GEM re-computed Ms with magnitude from the ABE (Abe, 1981; Abe and Noguchi, 1983), G&R (Gutenberg and Richter, 1954), B&D (Båth and Duda, 1979) and ROTHE (Rothé, 1969) global catalogues. Those catalogues are often quoted for earthquakes that occurred up to 1980 (magnitude time distribution shown below). Only Ms from the ABE catalogue provides a good fit with the re-computed Ms.



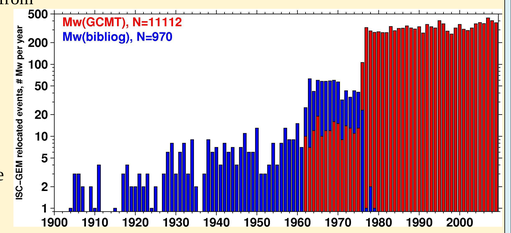


4) Direct Mw from the GCMT catalogue and bibliography search

The GEM Foundation requested that the ISC-GEM catalogue must be characterized by one Mw value for each earthquake. We have used Mw from GCMT (http://www/globalcmt.org/, see Dziewonski et al., 1981; Ekström et al., 2012). The annual distribution in the ISC-GEM catalogue is shown below in red.
In addition, after examining ~1,100 papers covering the period up to 1979, we adopted 970 Mw values available in the literature. We accepted only M_0 values from

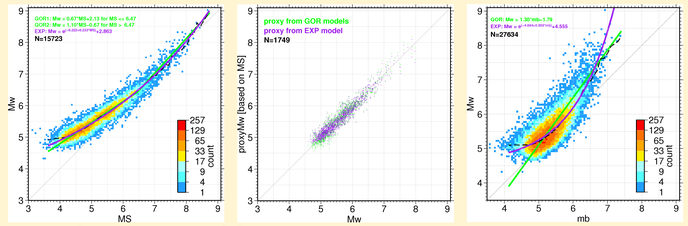
- inversions procedures of digitized *analog* seismograms;
- forward modeling of waveforms;
- *bona fide* measurements of physical parameters;
- direct field surveys (geodetic and/or geologic).

The annual distribution of direct Mw from the literature is shown in blue.



5) Mw proxy estimation via new non-linear regression relationships

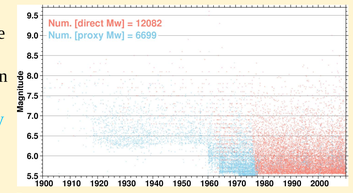
For those earthquakes with no direct measurement of Mw, we used the comprehensive and homogeneous dataset represented by our re-computed Ms and mb in order to derive new conversion relationships and obtain proxy Mw. We added smaller Ms-Mw and mb-Mw data pairs in order to avoid censoring effects around magnitude 5.5. The datasets were then split in training set (90% of the data, used to derive the models) and validation set (10% randomly selected, to validate the models) using an histogram equalization scheme in order to preserve the shape of the Ms-Mw and mb-Mw distributions. The median values for separated bins are plotted as dashed black curves in the figures below. We derived both non-linear exponential (EXP) and linear generalized orthogonal (GOR) relationships. The EXP models were preferred to GOR ones since they follow much better the median values for separated bins and provide more reliable uncertainty estimates.



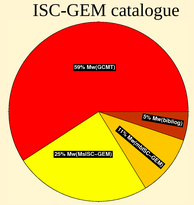
6) Final magnitude composition

The proxy Mw obtained with the newly derived conversion relationships complement the direct Mw values. When no direct Mw is available, we computed proxy Mw from Ms or mb if Ms is not available. As a result, there are 4 Mw sources in the ISC-GEM catalogue and the final magnitude composition represents an improvement in magnitude homogeneity and reliability compared to previous catalogues, e.g., the Centennial Catalogue (Engdahl and Villaseñor, 2002).

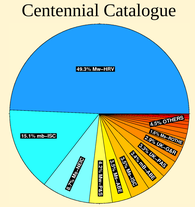
Magnitude time distribution of direct Mw/proxy Mw



ISC-GEM catalogue

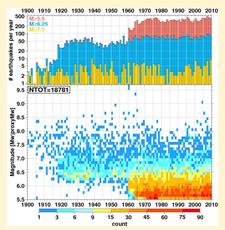


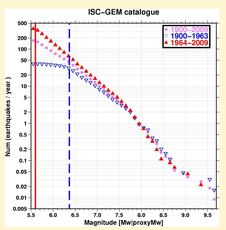
Centennial Catalogue



7) Completeness assessment

The colour-coded magnitude time distribution (bins of 0.1 magnitude units for each year) and the cumulative annual number of earthquakes for the three cut-off magnitudes (5.5, 6.25, 7.5) show the significant increase of events starting from 1964. The frequency-magnitude distribution (FMD) is time dependent over the 110 years covered by the ISC-GEM catalogue.





FMD for different time periods: the entire ISC-GEM catalogue (1900-2009), early instrumental (1900-1963) and modern (1964-2009) periods. Completeness is estimated as Mw 6.4 and 5.6 for the early instrumental and modern period, respectively. Caution must be used in the time window selection for seismicity rate studies.

8) Summary

The ISC-GEM main catalogue consists of 18,871 earthquakes where
•Direct reliable measurement of Mw are used where possible;
•Ms and mb magnitudes are re-computed from original amplitude-period measurements (except for 10 events between 1900-1903);
•Each event is characterized by a direct or proxy value of Mw. The latter is obtained with newly derived non-linear conversion relationships.
Publicly available from January 15, 2013 at the ISC website, www.isc.ac.uk.

References

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