The ISC-GEM Global Instrumental Earthquake Catalogue (1900-2009)

Poster #28

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1) Objectives

As one of the global components of the Global Earthquake Model Foundation (GEM, http://www.globalquakemodel.org/), we produced the 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 earthquake relocation and 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;
- recalculated short-period body- and surface-wave magnitudes from original amplitude-period observations;
- provided for each earthquake in the catalogue a direct/proxy Mw determination based on either direct computation of seismic moment M_0, or on newly derived non-linear empirical Ms-Mw or mb-Mw relations;
- provided uncertainties for each estimated parameter.

The earthquakes in the catalogue were selected based on three cut-off magnitudes:
- 1900-1917: Ms ≥ 7.5 and some smaller shallow events in stable continental areas;
- 1918-1959: Ms ≥ 6.25;
- 1960-2009: Ms ≥ 5.5.

2) Data used for relocation and recomputation of Ms and mb

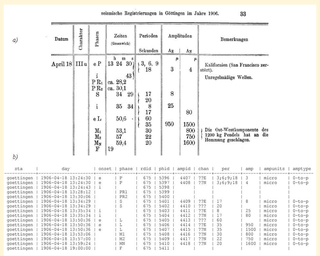
Arrival data

- Manually added ~1,000,000 arrivals to the ISC database:
  - 1904-1970: Original station bulletins from the ISC archive (~270,000 picks);
  - 1904-1917: Gutenberg notepads and ISA bulletin (~1,900 picks);
  - 1913-1917: BAAS, predecessor of ISS (~3,800 picks);
  - 1918-1959: ISS bulletin, predecessor of ISC (400,000 picks).
- Digitally available:
  - 1918-1942: Shannon tapes, partially digitized ISS bulletin (~220,000 picks);
  - 1923-1970: JMA early instrumental bulletin (~270,000 picks);
  - 1960-2009: ISS and ISC bulletin (~330,000 + ~11,000,000 picks from the ISC database).

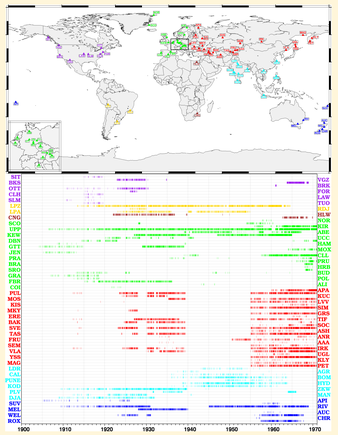
Amplitude data

- Manually added ~110,000 surface and body-wave amplitude-period pairs to the ISC database:
  - 1904-1970: Original paper-based station bulletins from the ISC archive; amplitude-period data is not included in the ISS and no *OCR* technique would work efficiently with station seismological bulletins;
- Digitally available
  - 1964-2009: ISC bulletin (2,500,000 amplitudes from the ISC database).

Hence, the amplitude-period data provided us an unprecedented dataset to re-compute magnitudes homogenous to the largest extent possible. Below is shown an excerpt of station bulletin and a map with the timeline of a stations where amplitude and arrival data were manually added.



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

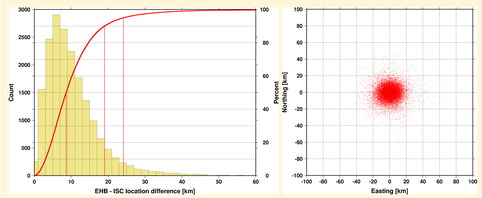


Each vertical segment represents the earthquake origin time for which station parametric data was added. The effect of WWI and WWII are clearly seen on the timeline plot.

3) Location methodology and relocation results

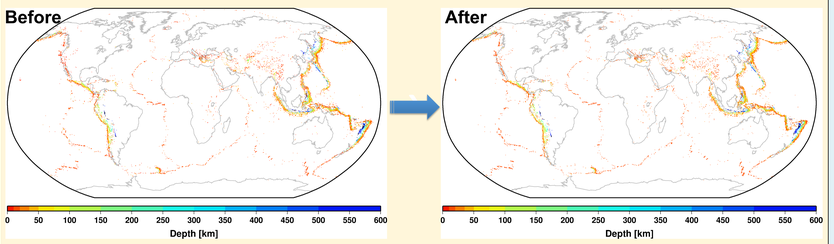
All events are located using a two-tier procedure that provides the necessary quality assurance to produce highly accurate earthquake locations for the ISC-GEM catalogue.

1. **EHB location algorithm** (Engdahl, van der Hilst and Buland, 1998)
   - Improved hypocentre w.r.t. starting solution
   - Special focus on depth determination
2. **ISC location algorithm** (Bondár and Storchak, 2011)
   - Depth kept fixed to that from the EHB analysis
   - Independent depth estimate from depth-phase stacking (Murphy and Barker, 2006)
   - Reduces location bias by accounting for correlated travel-time prediction errors

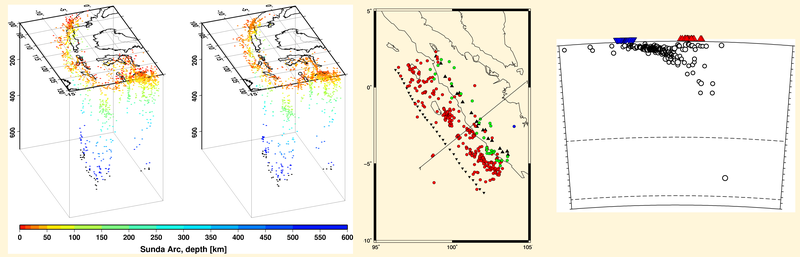


The distribution of the distances between the hypocentres obtained by the EHB and ISC methodologies show remarkable consistency. The median distance between the EHB and ISC solutions is 9 km, and 90% of the locations are within 20 km of each other. The deviations between EHB and ISC locations show no bias.

We expect the largest location improvements in the first half of the 20th century. The preferred locations before the ISC-GEM project constituted a mixture of locations from the Abe (Abe, 1981, 1984; Abe and Noguchi, 1983), the Centennial (Engdahl and Villaseñor, 2002), the ISS (Villaseñor and Engdahl, 2005; 2007) and the ISC catalogues. Below we compare these locations (before) to the ISC-GEM locations (after).

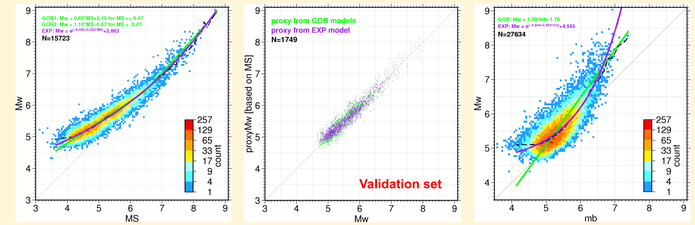


Map view and cross section (true scale) of ISC-GEM earthquakes in the Sumatra area. Volcanoes and trench points are plotted as red and blue triangles, respectively. Note the well-defined interplate slab dip in the cross section.



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

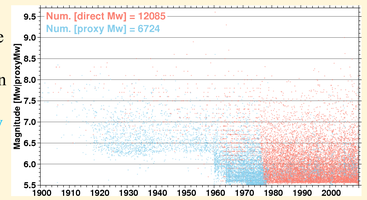
We used the comprehensive and homogeneous dataset of our re-computed Ms and mb in order to derive new conversion relationships for proxy Mw estimation. We used Mw in the GCMT (http://www/globalcmt.org/, see Dziewonski *et al.*, 1981; Ekström *et al.*, 2012) catalogue. The datasets were split into a training set (90% of the data, used to derive the models) and a validation set (10% randomly selected) 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 are preferred to GOR ones since they follow much better the median values for separated bins and provide more reliable uncertainty estimates.



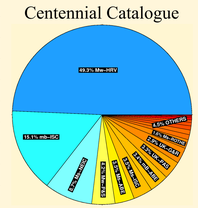
5) Final magnitude composition and completeness assessment

The proxy Mw obtained from the newly derived conversion relationships complement direct Mw values. For the relocated earthquakes, we adopted the Mw(GCMT) whenever available. In addition, after examining ~1,100 papers covering the period up to 1979, we included 971 reliable direct Mw values from the literature. When direct Mw is not available, then the catalogue lists the proxy Mw based on Ms or mb if Ms is not available. As a result, there are four Mw sources in the ISC-GEM catalogue. The final magnitude composition represents an improvement in magnitude homogeneity compared to previous catalogues, e.g., the Centennial Catalogue .

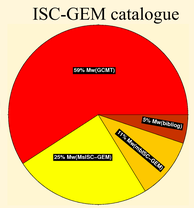
Magnitude time distribution of direct Mw/proxy Mw



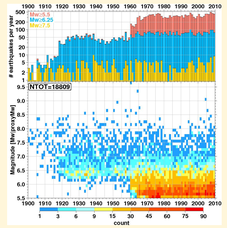
Centennial Catalogue

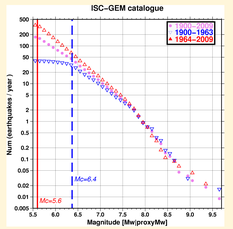


ISC-GEM catalogue



Colour-coded magnitude-time distribution and annual number of earthquakes for the three cut-off magnitudes (5.5, 6.25, 7.5).





Frequency-magnitude distributions for different time periods: entire catalogue (1900-2009), early instrumental (1900-1963) and modern (1964-2009). Mc is estimated as 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.

6) Summary

- The ISC-GEM main catalogue consists of 18,809 events with ~13 million associated phases
  - All events (except for 10 events between 1900-1903) are relocated and Ms and mb magnitudes are calculated from original amplitude-period measurements;
  - Each event is characterized by a direct or proxy value of Mw. The latter is obtained with newly derived non-linear conversion relationships between Ms-Mw and mb-Mw.
- The ISC-GEM Appendix consists of ~ 900 events with ~260,000 associated phases
  - Events with less reliable hypocenters
  - Events for which no Mw or proxy Mw can be accurately calculated due to lack of data.

Publicly available from February, 2013 at the ISC website, http://www.isc.ac.uk/iscgem/

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