D. Storchak, D. Di Giacomo, I. Bondár, on behalf of the International Team of experts

GEM: June 2012, Taipei
GEM Instrumental Earthquake Catalogue

- 110 years of ~20,000 re-located earthquake hypocentres & uncertainties, using original arrival time data;
- $M_W$ with uncertainties, based on seismic moment, where possible;
- proxy $M_W$ in other cases, using empirical relationships with $M_S(20)$, $M_S(BB)$, $mb$ and $mB$, that were re-computed using original amplitude measurements;
- $M_S$ (or other) magnitudes, many of which were not available before.

The Catalogue is to be used by GEM for characterization of spatial distribution of seismicity, magnitude frequency relation and maximum magnitude.

Cut-off magnitudes:
- 1900-1917: $M_S \geq 7.5$ worldwide + smaller shallow events in stable continental areas
- 1918-1959: $M_S \geq 6\frac{1}{4}$
- 1960-2009: $M_S \geq 5.5$

This Catalogue will be unique because it will contain homogeneous locations and magnitude estimates with the estimates of uncertainty for the entire period 1900-2009 done using the same techniques to the extent possible.

GEM: June 2012, Taipei
International Team of experts

To work on the project, the ISC put together the Team of International experts in the field:

✓ Bob Engdahl (Colorado Uni, US)
✓ Dmitry Storchak (ISC, UK)
✓ Domenico Di Giacomo (ISC, UK)
✓ István Bondár (ISC, UK)
✓ Willie Lee (USGS, emeritus, US)
✓ Antonio Villaseñor (IES Jaume Almera, Spain)
✓ Peter Bormann (GFZ, emeritus, Germany)
✓ Graziano Ferrari (INGV/SISMOS, Italy)
✓ Peter Suhadolc and observers on behalf of the IASPEI: Roger Musson (BGS, UK), Johannes Schweitzer (NORSAR, Norway), Goran Ekstrom (Columbia Uni, US), Nobuo Hamada (JMA, Japan)

The team is assisted by further eight IT, Data Entry and Admin staff at the ISC.

The Project is managed by Dmitry Storchak with scientific input from Willie Lee.
Paper-based and **Electronic** data availability prior to the start of the Project

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**Paper-based sources of bulletin data:**
- Abe and Noguchi (1900-1903)
- Gutenberg Notepads (1904-1917)
- BAAS Bulletins (1913-1917)
- ISS Bulletins (1918-1963)
- Mo/Mw, scientific literature (1900-1975)
- Quality station bulletins (1904-1970)

**Electronic sources of data:**
- ISC Bulletins (1964-2009)
- GCMT Catalogue (1976-2009)
Grand scale data entry from historical bulletins.

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There is a long way between a box in a warehouse and a row in a database.
Data entry from historical bulletins

We used historical bulletins of quality seismic stations around the world to obtain previously electronically unavailable amplitudes and periods of body and surface waves to contribute towards reliable and homogeneous magnitude estimates.

The timeline of individual stations clearly shows the effect of the WWI and WWII.
Scientific literature search (1900-1979)

- As many as **1,092** scientific articles have been processed in order to obtain quality estimates of *Mo*.
- *Mo* values were converted to *Mw* for **2,000** large historical earthquakes.

JPE: J. Phys. Earth
JGR: J. Geophys. Res.
PEPI: Phys. Earth & Planet. Interior
TECT: Tectonophysics
Thesis: Ph.D. Thesis
Others: Other publication sources
In Centennial Catalogue, magnitudes have been compiled from different authors and scales. In GEM Catalogue, magnitudes have been recomputed from original amplitudes and periods and then, where necessary, converted to Mw.

Uncertainties and quality of magnitude determinations is given in GEM Catalogue.
Preliminary frequency magnitude relation

Good match is found between $M_S$ for common events in GEM and Abe’s Catalogues
Examples of change in earthquake magnitudes

1) GEM location: OT: 1912-08-09 01:29:06
   LAT: 40.75  LON:26.22  DEPTH: 11.0 km
   Turkey (~230 km from Istanbul)
   Ms(ABE)=7.6   NSTA=?
   Ms(GEM)=7.14±0.21   NSTA=12

2) GEM location: OT: 1969-07-18 05:24:48
   LAT: 38.33  LON:119.57  DEPTH: 10.0 km
   Northeastern China (~320 km from Beijing)
   Ms(ABE)=7.1   NSTA=2?
   Ms(GEM)=7.70±0.02   NSTA=10
In early years of **Centennial** Catalogue, locations of many events were merely adopted from reliable sources. In **GEM** Catalogue, all events, except 1900-1903, were relocated based on the newly entered and already available **arrival time data**.

Both formal uncertainty and quality of both location and depth are given in the **GEM** Catalogue.
1. Earthquake depths are determined using the EHB technique (Engdahl, van der Hilst & Buland, 1998):
   a) comprehensive analysis of near-event surface reflections off the earth surface inland and ocean bottom or water surface in the oceans;
   b) Station patch corrections;
2. New ISC location algorithm (Bondár & Storchak, 2011) is used with earthquake depths fixed to those from EHB analysis:
   a) independent depth confirmation using depth phase stacking;
   b) more accurate hypocentre locations due to correlated error structure taken into account (removes bias from uneven geometrical station configuration)

GEM: June 2012, Taipei
Examples of relocation: Pacific North

Centennial Catalogue

GEM Catalogue

GEM: June 2012, Taipei
Examples of relocation: C. America & Caribbean

Centennial Catalogue

GEM Catalogue

GEM: June 2012, Taipei
Example: 02 Sept 1923, Bolivia, mB 6.8

GEM catalogue versus Centennial Catalogue

- ~400 km correction in location,
- 155 km depth in GEM where the event was fixed to be shallow in Centennial Catalogue

GEM location is based on data of 55 stations with 162 degrees of secondary azimuthal gap.
## Current status of the Project

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Planning ahead…

Several excellent global earthquake catalogues have been discontinued which limited their usefulness with the time. GEM Catalogue should not be one of them:

- Gutenberg-Richter 1904-1952
- Abe 1900 - 1980
- Pacheco-Sykes 1900-1989
- GEM: 1900-2009 ??

It would be a serious deficiency, if events such as
- M7.1 Darfield (2010),
- M6.3 Christchurch (2011),
- M9.0 Tohoku (2011)

were not part of the GEM Catalogue.

Neglecting to update the GEM Catalogue would seriously hamper the efforts of testing and refinement of the earthquake forecasting models.
Planning ahead…

Oct 30, 1930 EQ, Central Italy, estimated Mw 6.0. Shaking was felt even at large distances and caused collapse and severe damage in Senigallia, Fano, Montemarciano and Ancona in Marche region.

The L'Aquila EQ, Italy, 6 Apr, 2009, Mw = 6.3 (GCMT), 308 casualties, severe damage.


If similar events occurred in the first half of the 20th century, then due to uncertainties in magnitude determination they may or may not be part of the GEM Catalogue.

Feb 29, 1960 EQ, Agadir, Morocco, Ms5.7, Mw6.0. This once-flourishing port and tourist haven lost about 40% of its population of 35,000 and that property was damaged to the extent of about $70 million. It had been once forgotten that a previous town at this location, named Santa Cruz de Aguer, had been destroyed by an earthquake in 1731.
Summary

✓ We have put together an **excellent international team** of professionals in the field.
✓ We have trained a group of **technical personnel: interested, dedicated and thoughtful**.
✓ The Catalogue of ~20,000 large earthquakes is a **major step forward** as compared to all previously available sources because its hypocentres, magnitudes and uncertainties are computed using the same technique throughout the 1900-2009 period.
✓ We are **on track to finish on time** and produce the Catalogue by mid-2012.
✓ We suggested **further essential work** on the Catalogue and looking forward to continue working with GEM in the coming years.