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

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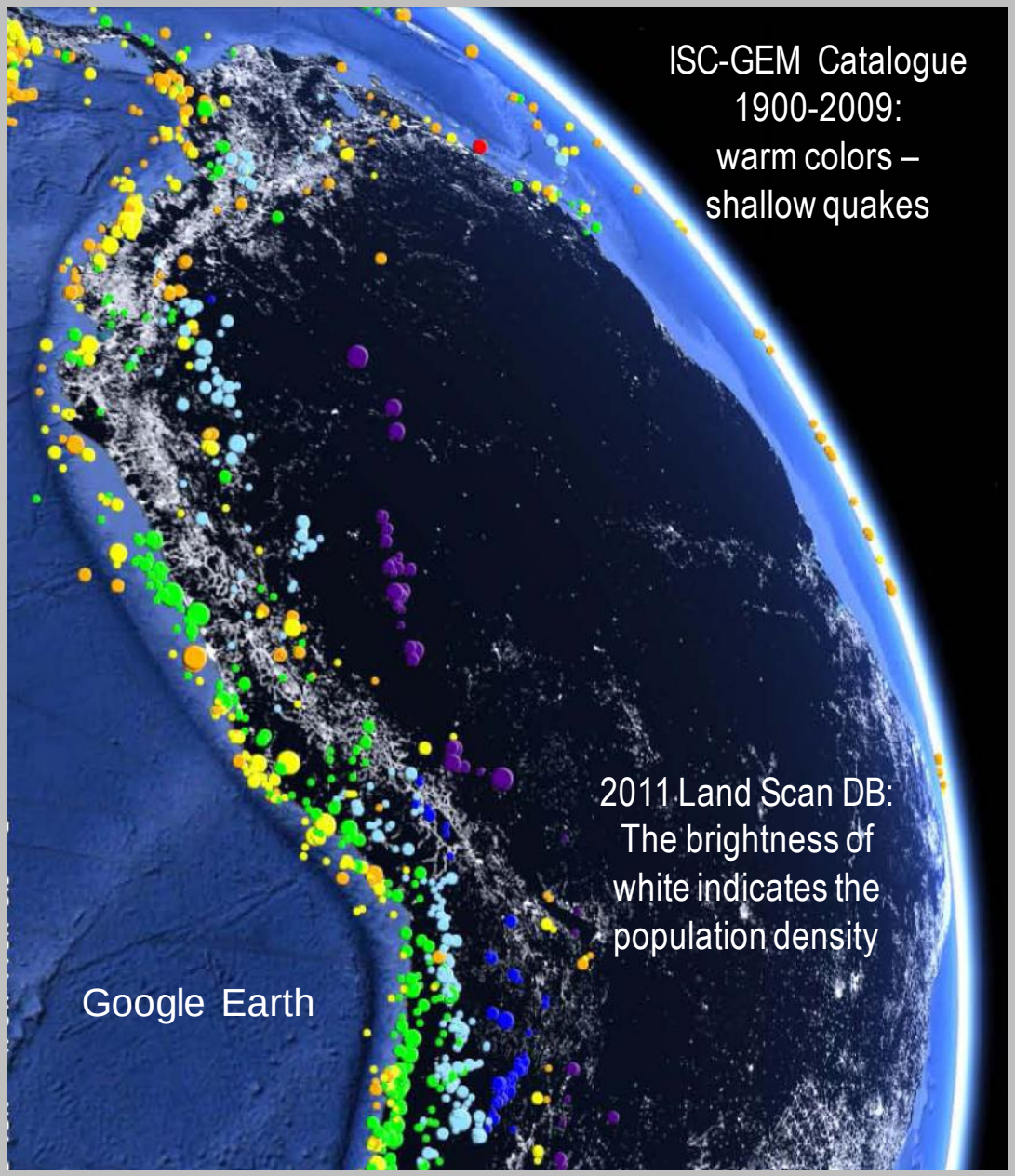
International Seismological Centre

working together to assess risk

GEM

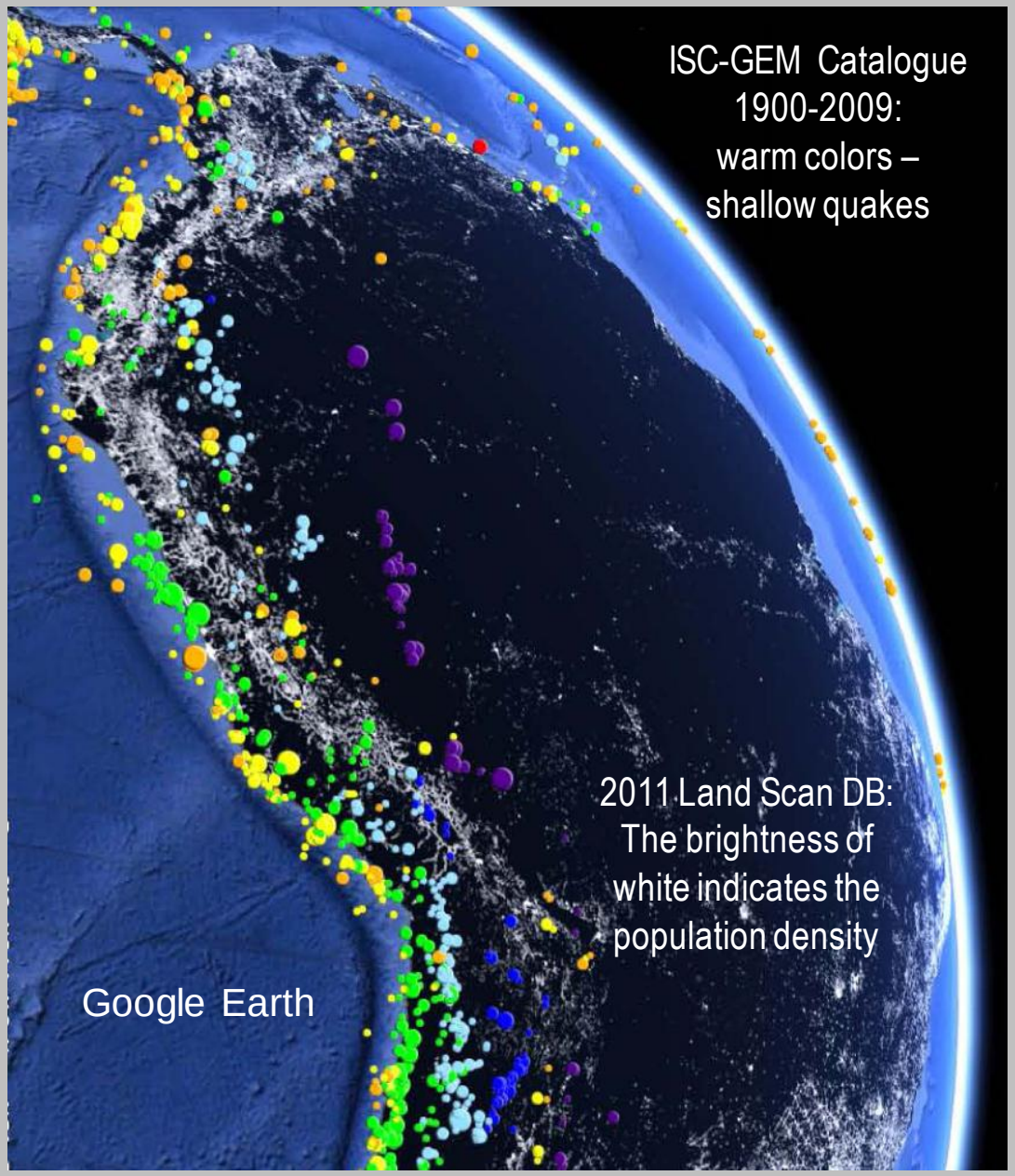
GLOBAL EARTHQUAKE MODEL

Introduction



The ISC-GEM Global Instrumental Reference Earthquake Catalogue (1900-2009) is the first GEM Global Component to complete its mission.

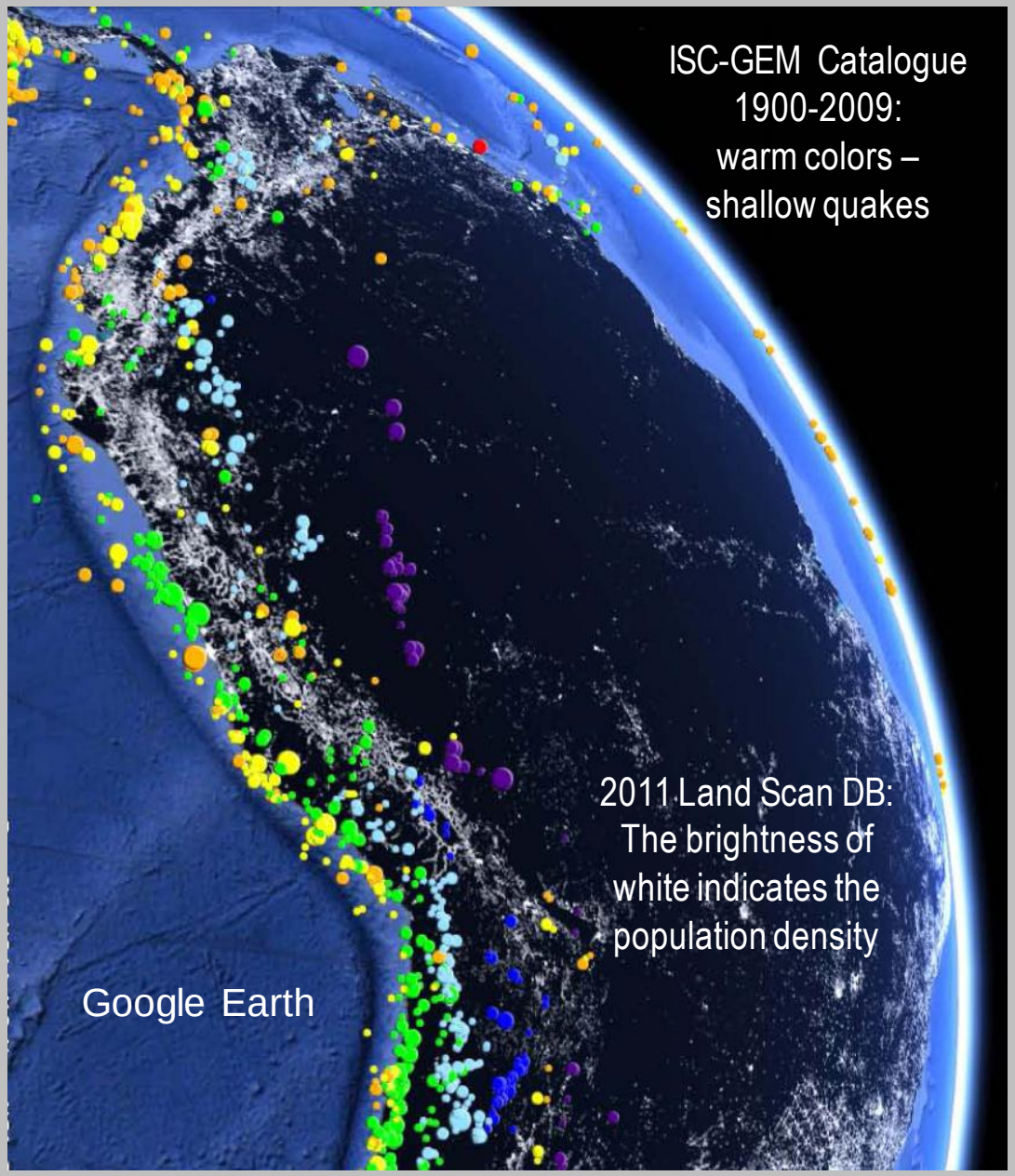
Without the support of GEM this task would have been impossible to accomplish any time soon.



Motivation

The ISC-GEM Global Instrumental Reference Earthquake Catalogue (1900-2009) is a special effort to adapt and substantially extend currently existing bulletin data to serve requirements of specific group of users that assess and model seismic hazard and risk:

- ✓ accurate knowledge of the spatial distribution of seismicity and the magnitude-frequency relation;
- ✓ Homogeneous, comparable locations and magnitudes;
- ✓ with estimates of uncertainty;
- ✓ spanning the entire 100+ years period of instrumental recordings.



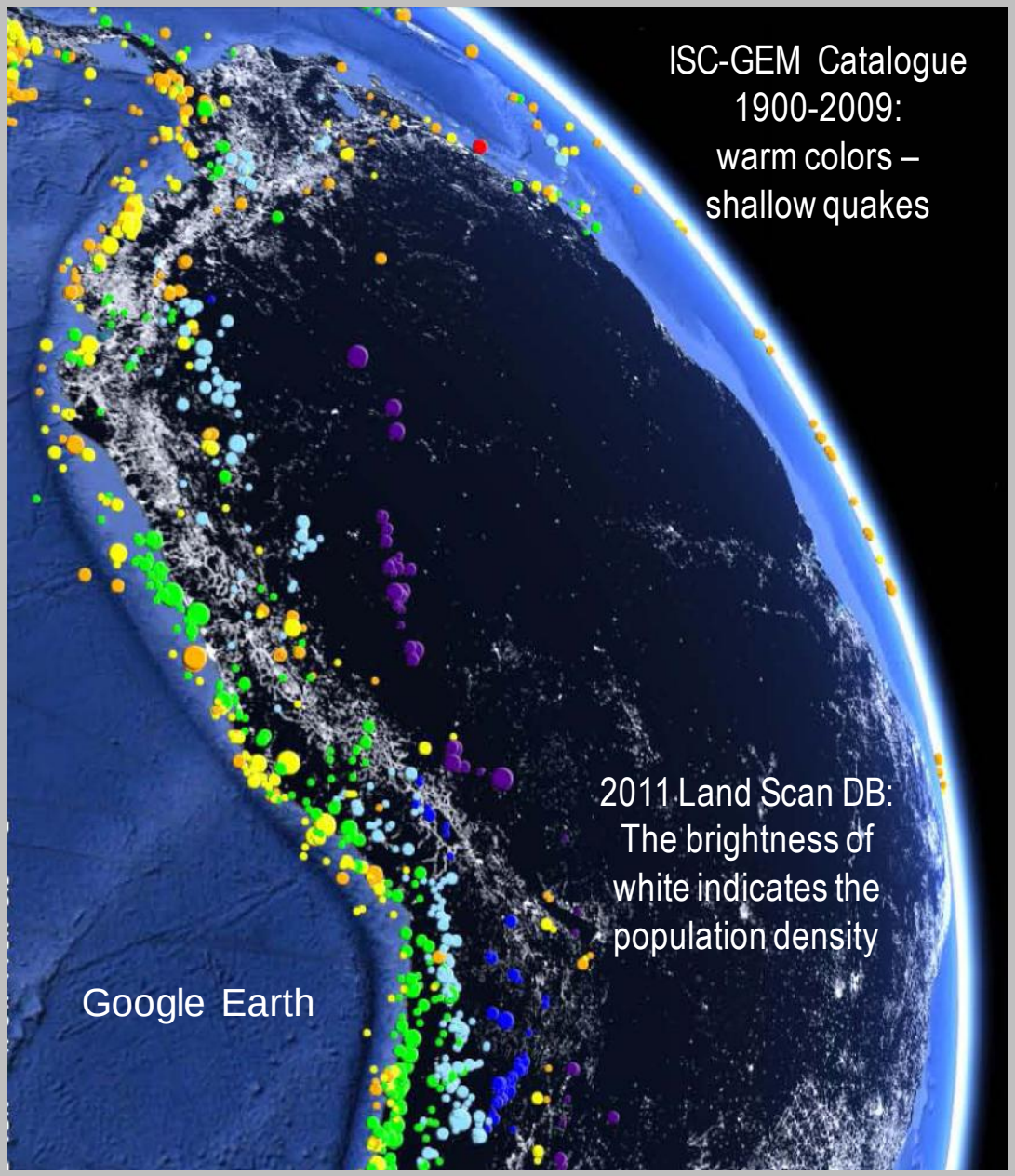
Unique

The ISC-GEM Catalogue is unique because it contains:

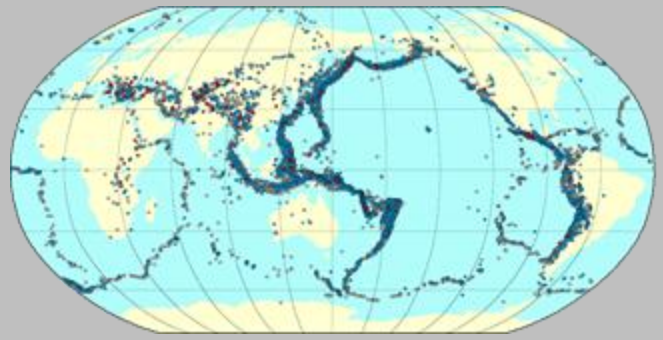
- ✓ **homogeneous** hypocentre locations and M_W estimates
- ✓ with the estimates of uncertainty
- ✓ for the period 1900-2009,
- ✓ prepared using **uniform technique**.

Cut-off magnitudes:

- ✓ 1900-1917: $M_S \geq 7.5$ worldwide + smaller shallow events in stable continental areas
- ✓ 1918-1959: $M_S \geq 6¼$
- ✓ 1960-2009: $M_S \geq 5.5$

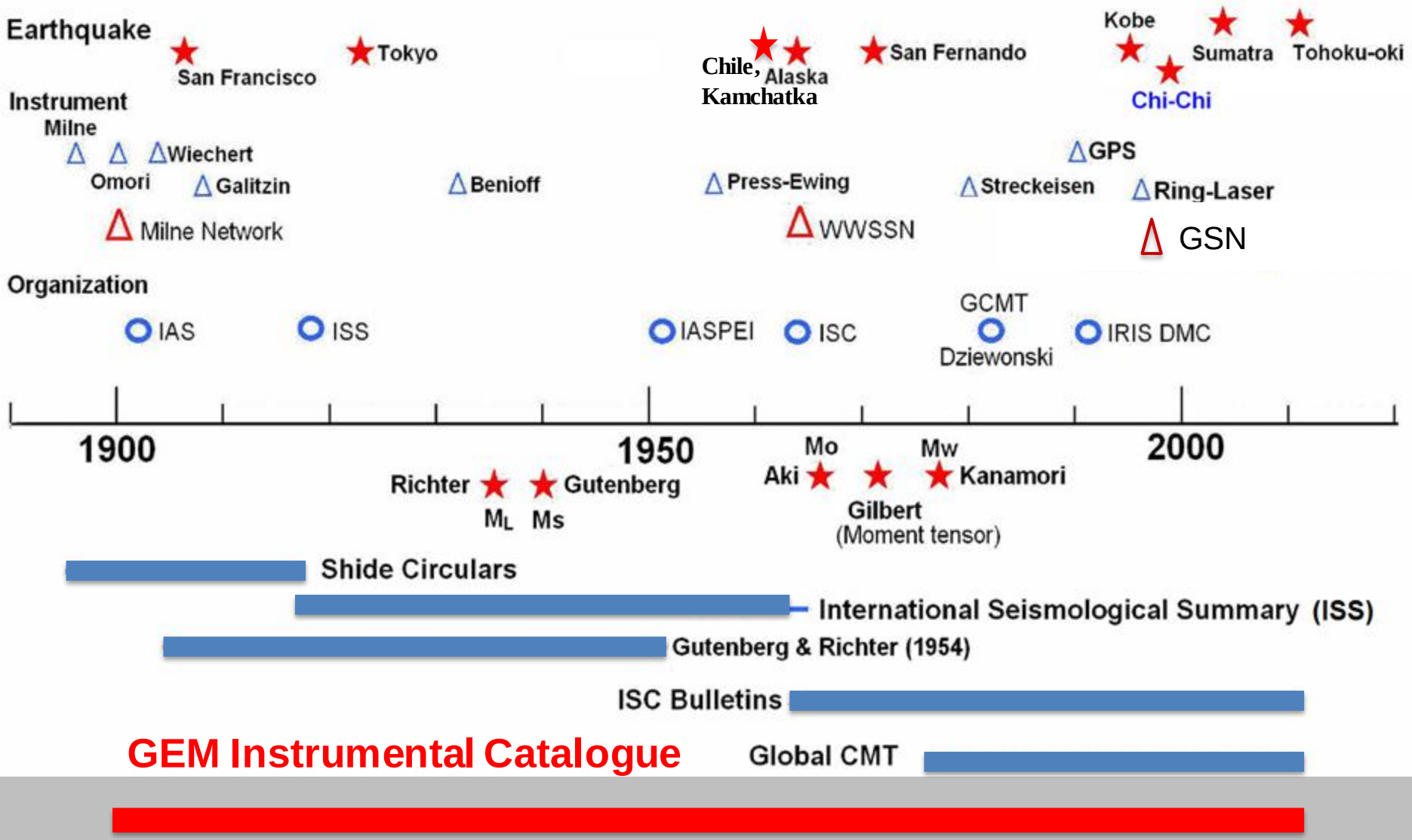


Re-computed, not compiled



- ✓ **110** years of **~20,000** re-located earthquake hypocentres & uncertainties, using the original seismic wave arrival time measurements;
- ✓ 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 the original amplitude measurements;

ISC-GEM Catalogue and Seismology Timeline



Adapted from Willie Lee

The Team

- **The ISC formed the Team of international experts in the field**:

Bob Engdahl (Colorado University, *US*)

Dmitry Storchak (ISC, *UK*)

Domenico Di Giacomo (ISC, *UK*)

István Bondár (ISC, *UK*)

Antonio Villaseñor (IES Jaume Almera, *Spain*)

Peter Bormann (GFZ, emeritus, *Germany*)

Willie Lee (USGS, emeritus, *US*)

Graziano Ferrari (INGV/SISMOS, *Italy*)

- **Observers on behalf of the IASPEI**:

Göran Ekström (Columbia Uni, *US*),

Roger Musson (BGS, *UK*),

Johannes Schweitzer (NORSAR, *Norway*),

Nobuo Hamada (JMA, *Japan*)

- assisted by further **8 IT, data entry and admin staff** at the ISC;
- the project managed by **Dmitry Storchak** with scientific input from Willie Lee.

Prior Electronic Data Availability

Parametric Data	1900-1959	1960-1970	1971-1977	1978-2009
Body wave arrival times	Not	ISC Bulletin		
Surface & body wave amplitudes & periods	available			ISC Bulletin
M_0 & M_W	electronically			GCMT, ISC

- Abe's catalogue (1900-1903);
- Gutenberg Notepads (Abe's adaptation) (1904-1917);
- BAAS Bulletin (1913-1917);
- ISS Bulletin (1918-1963);
- JMA historical bulletin;
- M_0 and M_W from selected reviewed scientific literature;

- Arrival times, body and surface wave amplitudes and periods entered from the **historical paper based bulletins** of high quality stations from the **ISC warehouse collection** with gaps filled from collections at **USGS/Berkeley** (1900-1971), **GS RAS** and **IS NASK**;

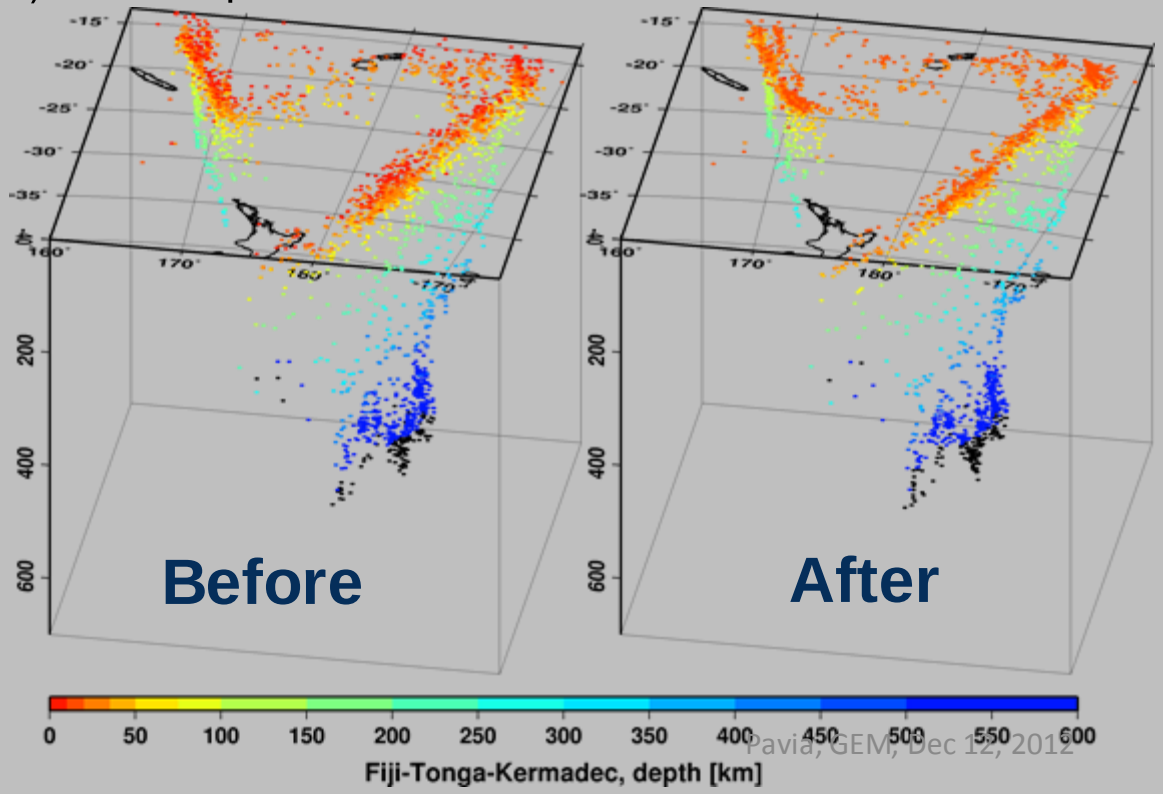
Two-stage Relocation Procedure

Stage 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;



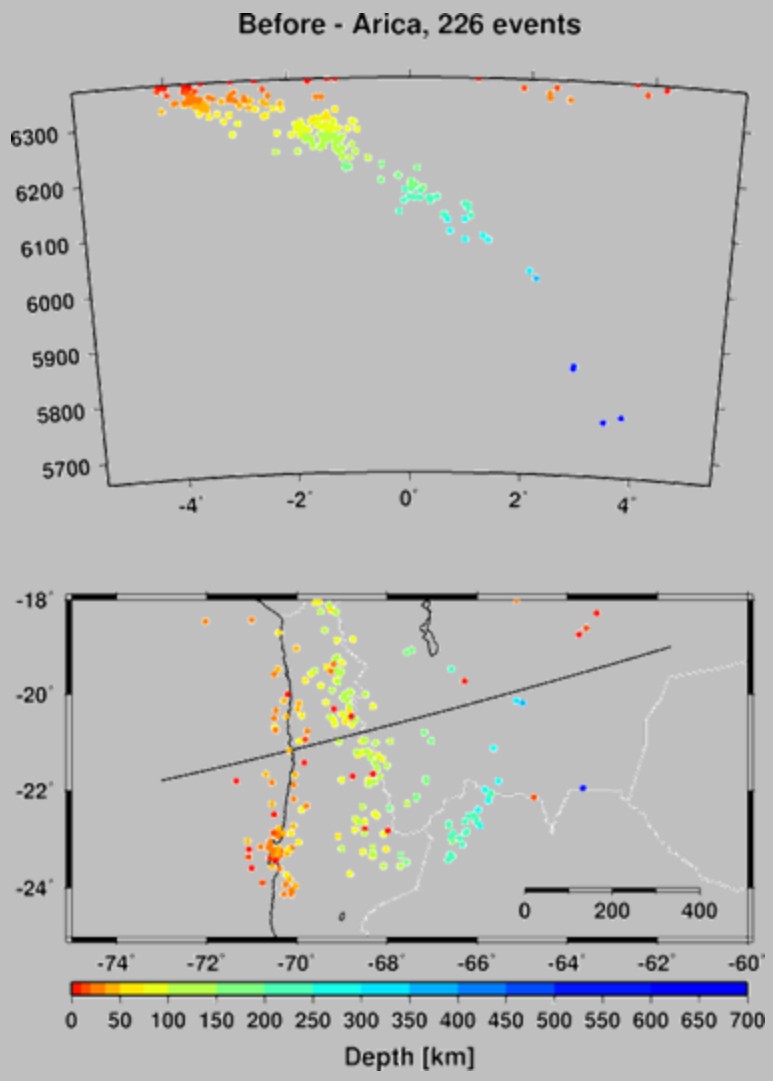
Stage 2:

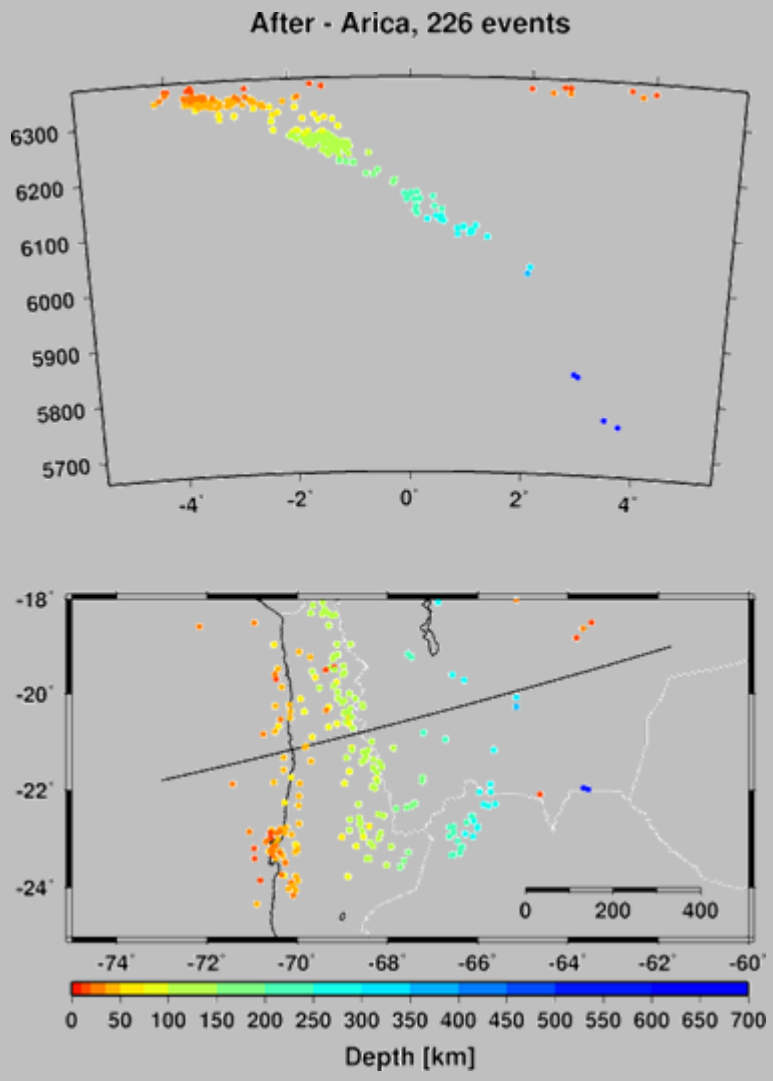
New **ISC location** algorithm *(Bondár & Storchak, 2011)* *is* used with earthquake depths fixed to those from EHB analysis:

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)

Examples of Relocation, Northern Chile

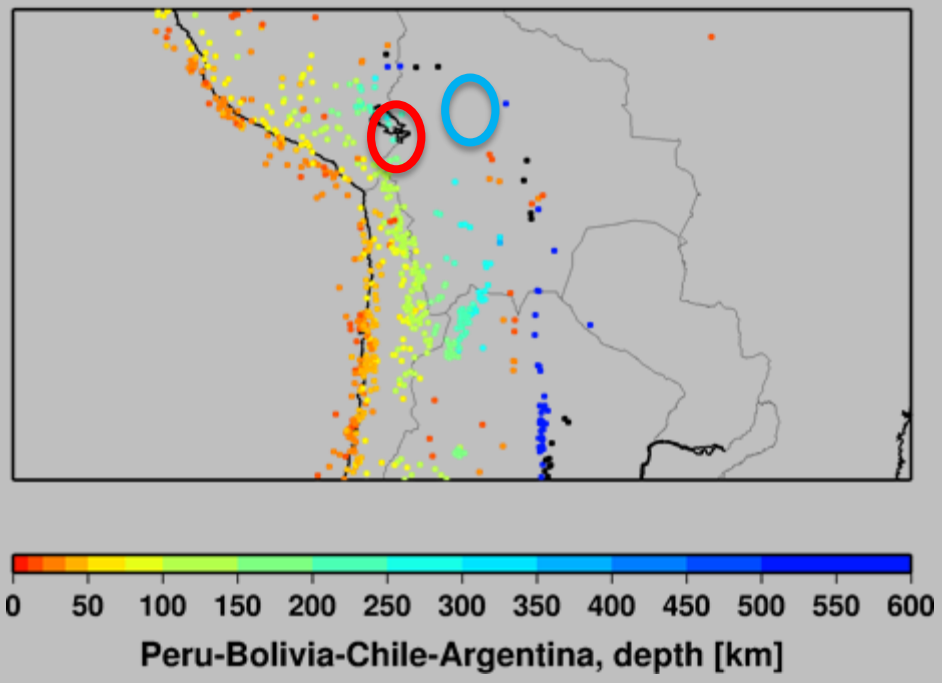




Before

After

Examples of Relocation: Bolivia



ISC-GEM versus **Centennial**

*Sep 2, 1923, **Bolivia**, mB 6.8*

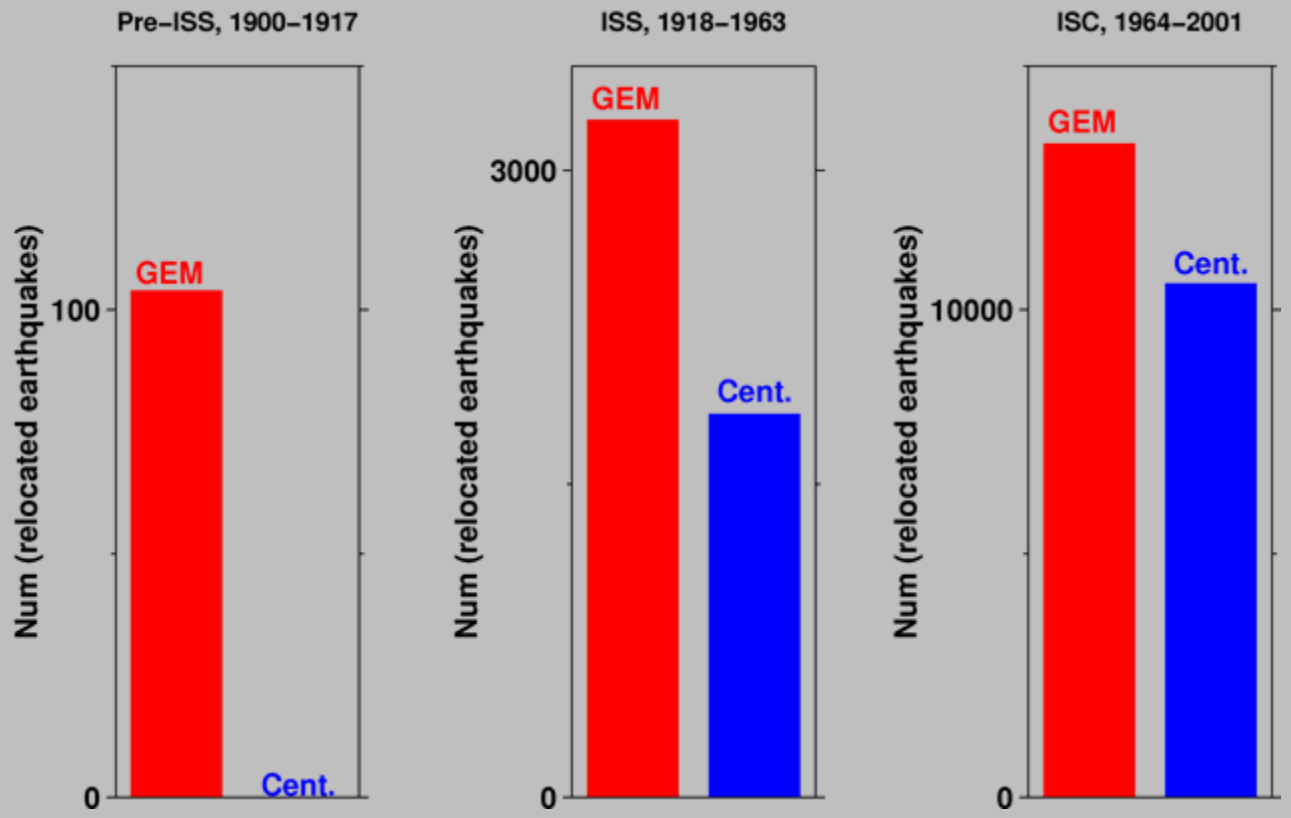
- ~400 km correction in location,
- 155km depth in ISC-GEM where the depth was fixed to be shallow in the Centennial Catalogue

The ISC-GEM location is based on 55 stations with 162 degrees of secondary azimuthal gap.

ISC-GEM Location: comparison with Centennial

In early years of **Centennial** Catalogue locations of many events were merely **adopted** from reliable sources

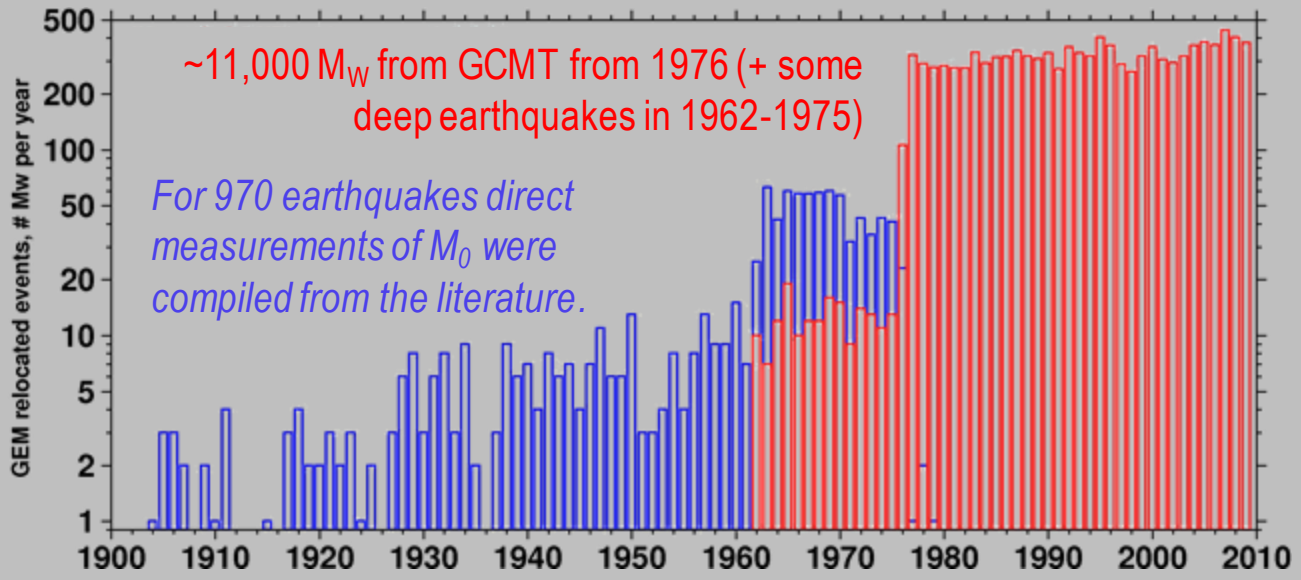
In **ISC-GEM** Catalogue, all events, except 1900-1903, were **relocated** based on the newly entered and already available **arrival time data**



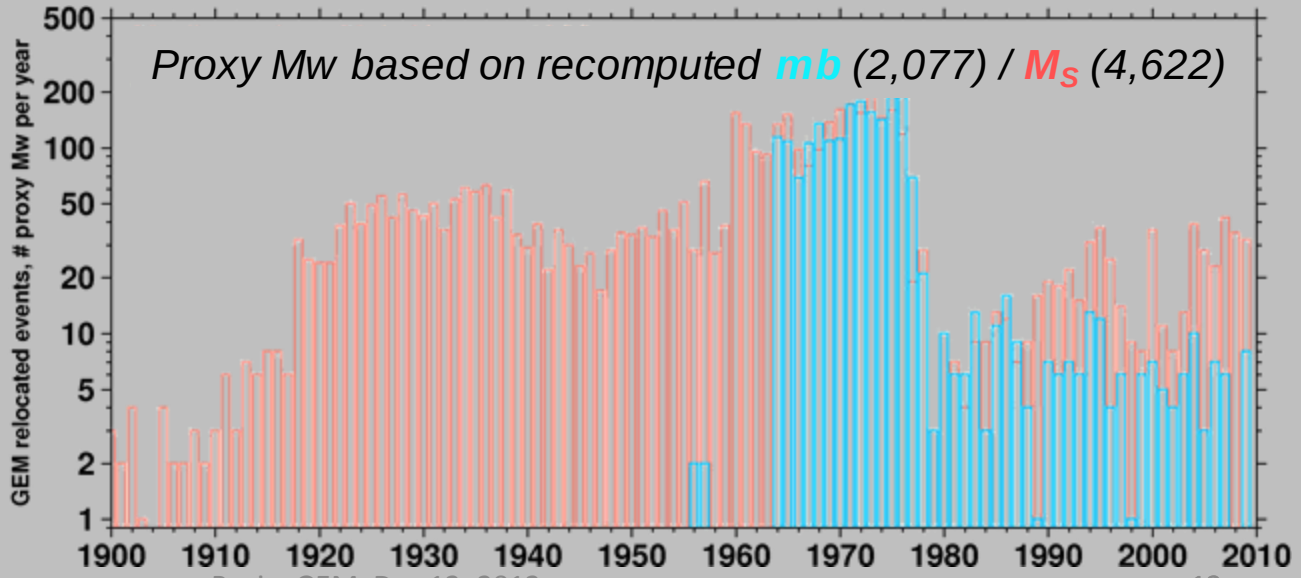
Both formal uncertainty and quality of location and depth are given in the **ISC-GEM** Catalogue

Magnitude composition of the ISC-GEM catalogue

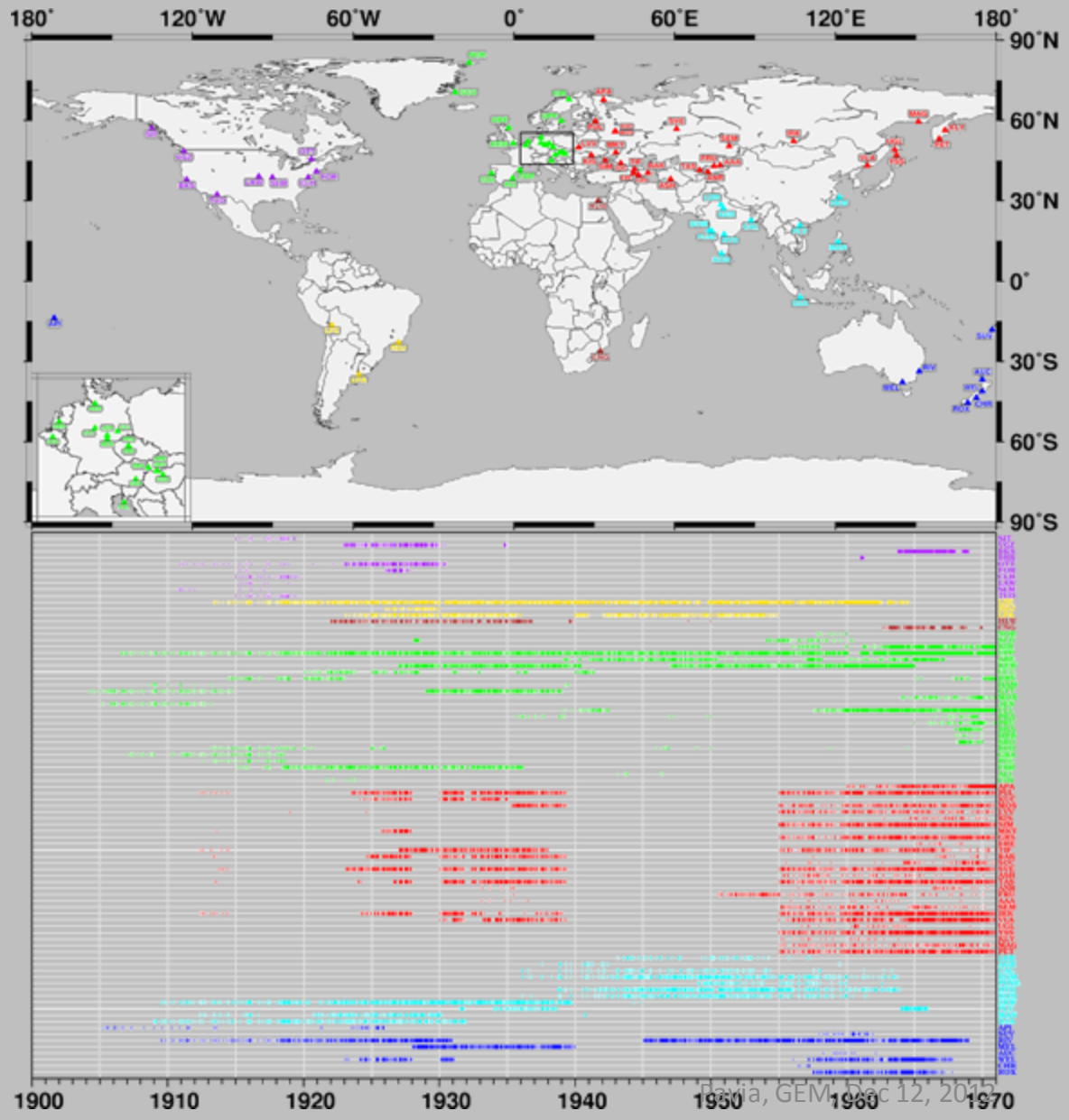
Direct M_W (per year)



Proxy M_W (per year)

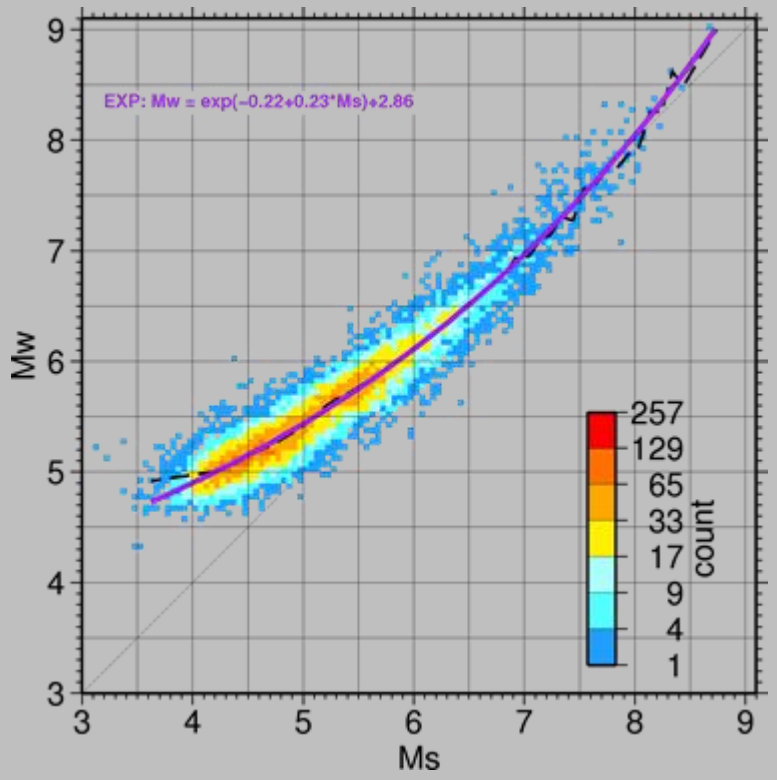


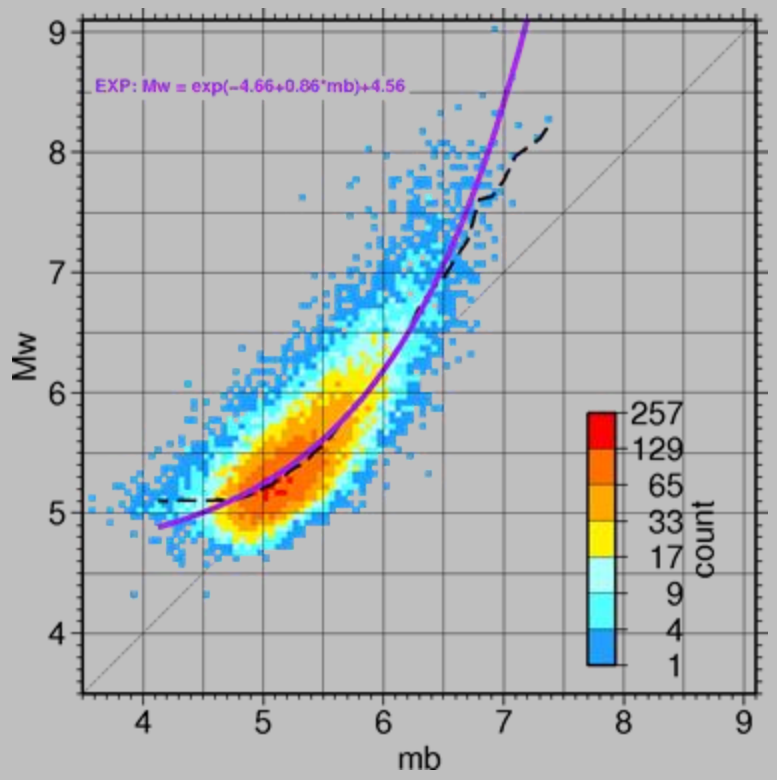
Amplitudes from Quality Station Bulletins



- ~300,000 previously unavailable amplitudes have been entered into the ISC database for th e years prior to 1970;
- records of UPP (Sweden), RIV (Australia), and LPZ (Bolivia) nearly continuous;
- gaps for other stations, especially during WW I & II;
- large input from former Russian Empire and USSR stations with systematic credible surface wave amplitudes and periods.
- **These data have been used to compute M_S and m_b, many of them didn't exist prior to the project start.**

M_W / M_S and M_W / m_b Regressions

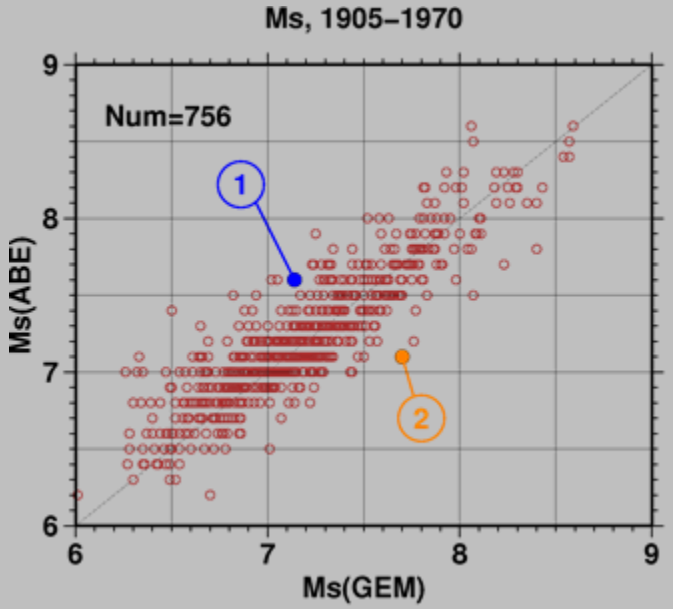


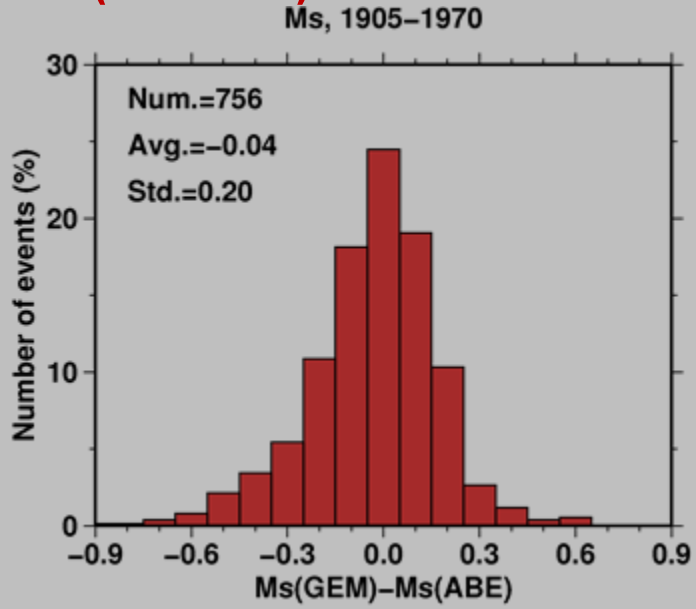


- Based on the large set of recent earthquakes with GCMT Mw and the ISC-GEM MS/mb available, we built and validated M_W/M_S and M_W/mb regression curves in exponential form.
- We then used these regressions to obtain Mw for those events in ISC-GEM Catalogue where no direct determination of M_W is available.

Examples: 1912, 230km from Istanbul,

M7.6 → 7.14±0.21 (nsta:12)

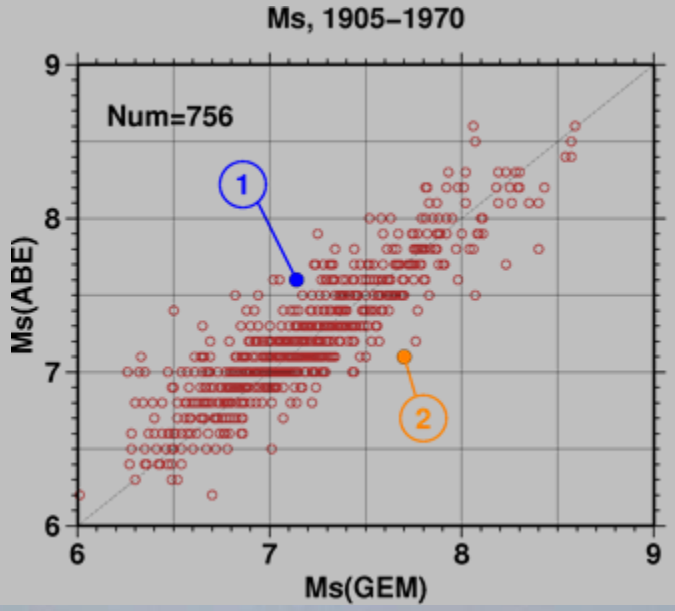


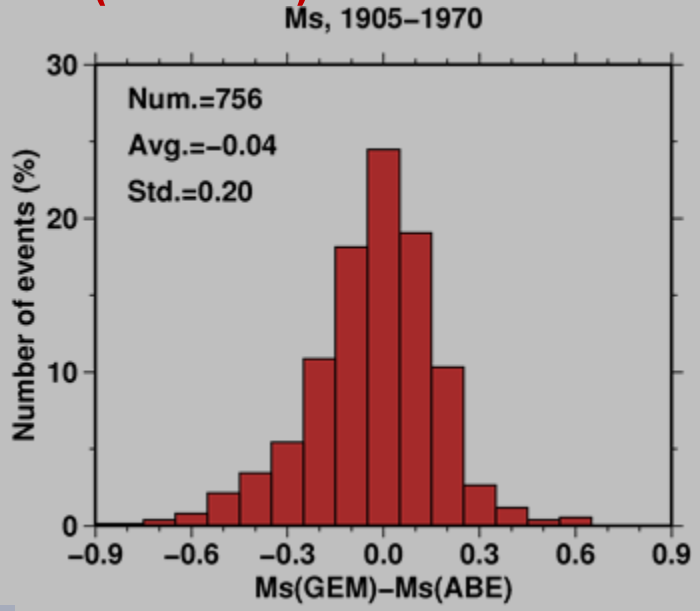


1) GEM location–> OT: 1912–08–09 01:29:06
LAT: 40.75 LON:26.22 DEPTH: 11.0 km
Turkey (~230 km from Istanbul)
Ms(ABE)=7.6 NSTA=?
Ms(GEM)=7.14±0.21 NSTA=12

Examples: 1969, 320km from Beijing,

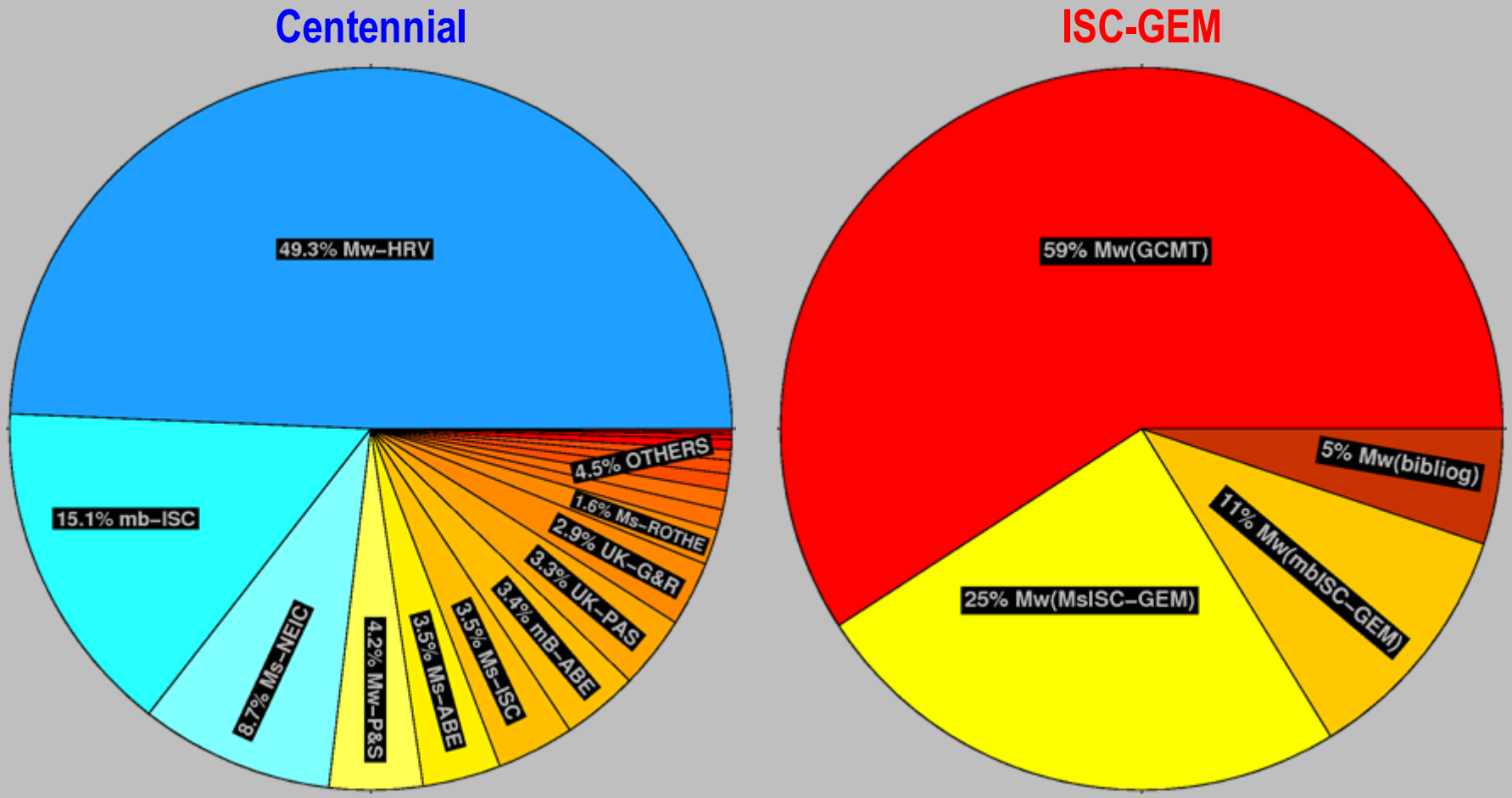
M7.1 → 7.70±0.02 (nsta:10)





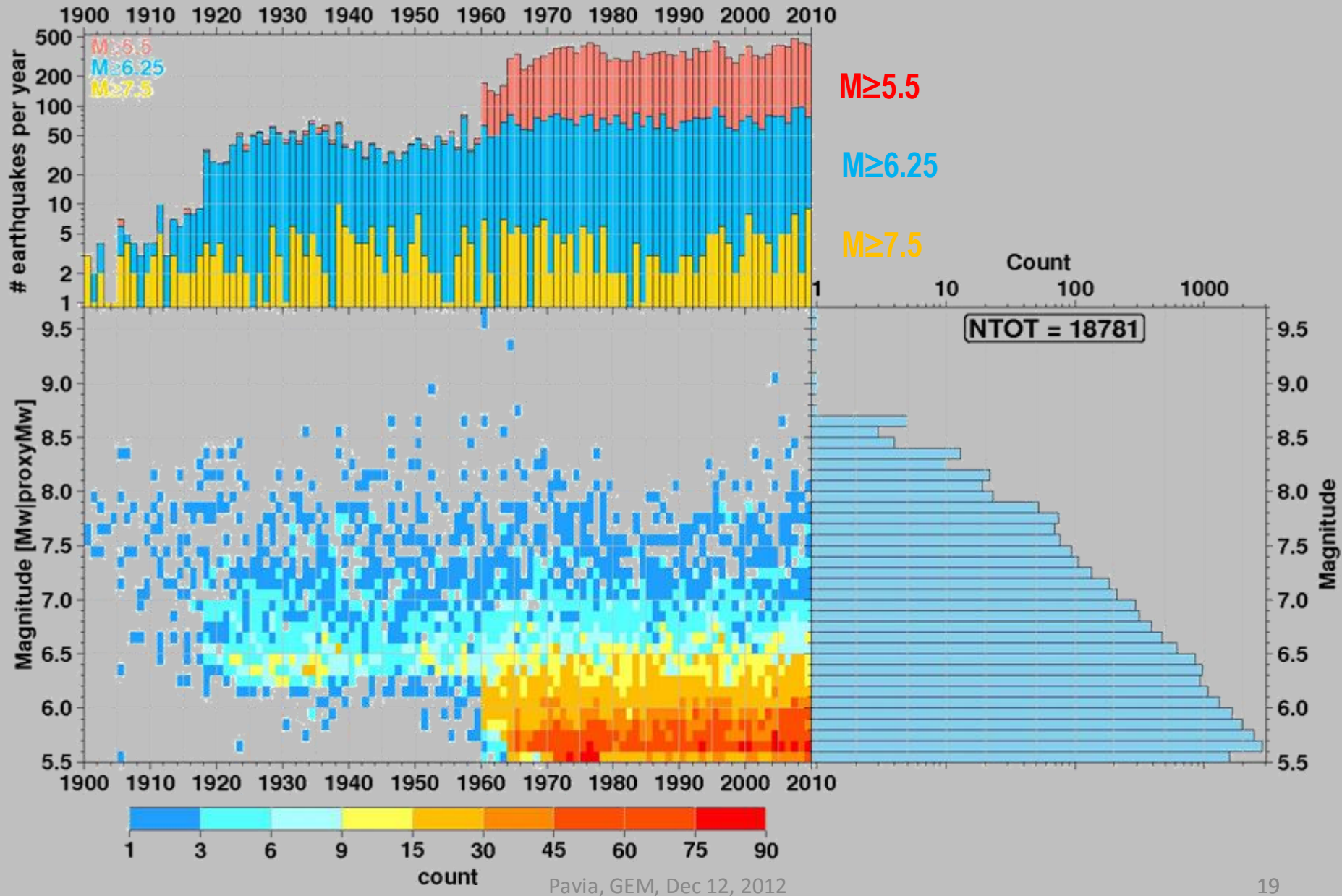
2) GEM location–> OT: 1969–07–18 05:24:48
LAT: 38.33 LON:119.57 DEPTH: 10.0 km
Northeastern China (~320 km from Beijing)
Ms(ABE)=7.1 NSTA=?
Ms(GEM)=7.70±0.02 NSTA=10

ISC-GEM Magnitude: comparison with Centennial

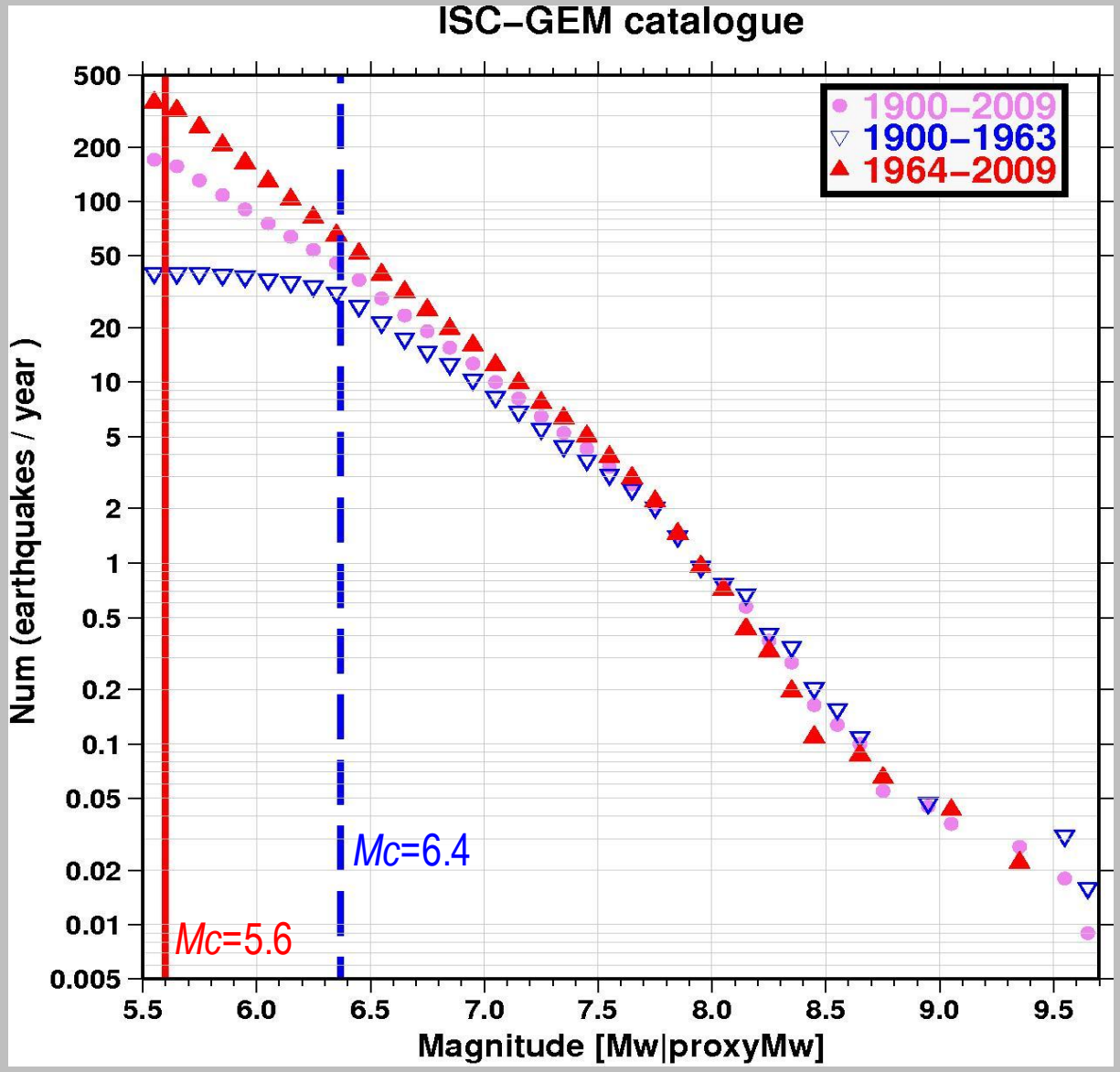


As compared to the Centennial catalogue, the magnitudes in the ISC-GEM Catalogue are much more homogeneous as they come from only four comparable sources.

ISC-GEM Magnitude Timeline

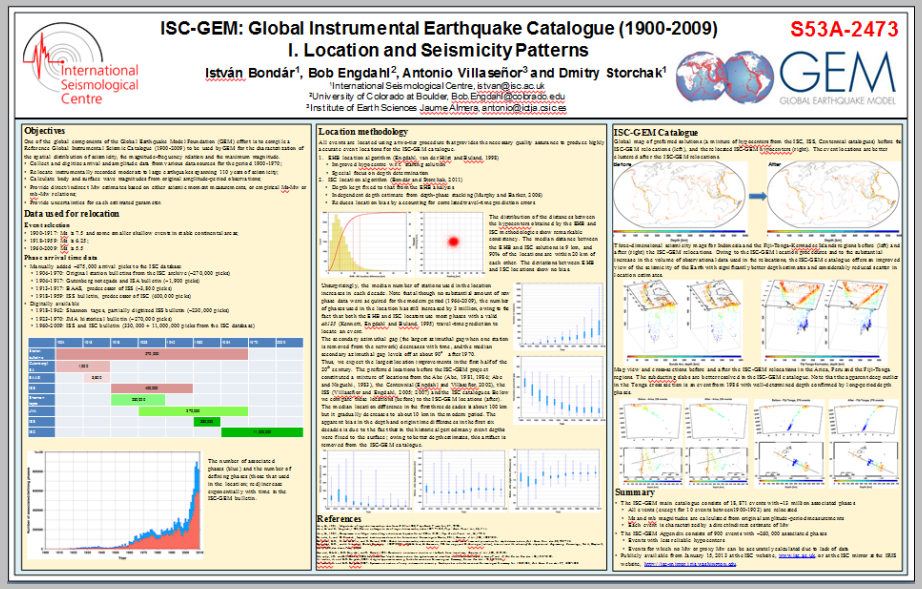


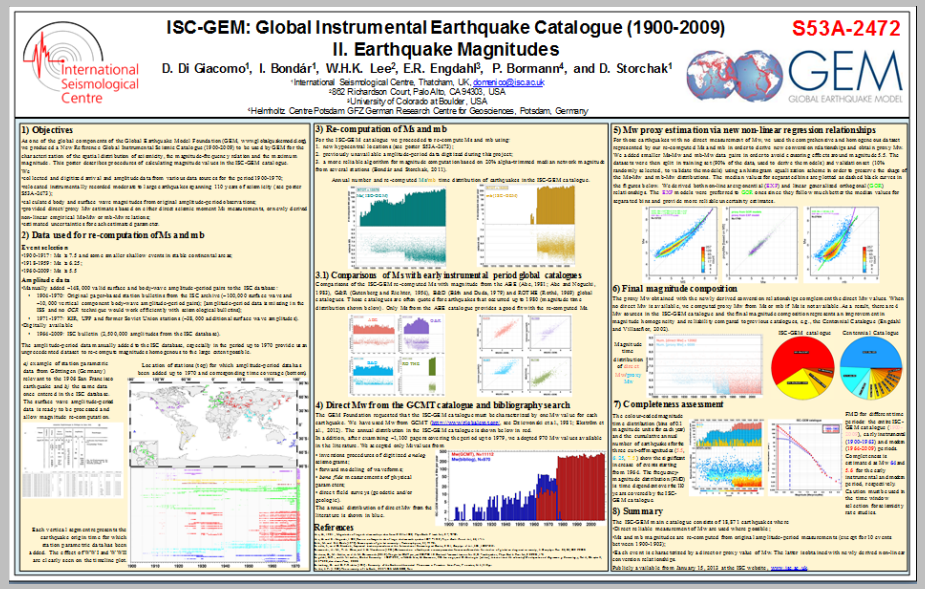
Magnitude Frequency Distribution, ISC-GEM



- Seismicity rates for large (M>7.5-7.6) earthquakes better assessed considering a long time window (violet)
- For moderate earthquakes the modern period (red) is a better basis for magnitude-frequency studies, whereas for strong to major shallow earthquakes the entire ISC-GEM catalogue should be used

Invitation to two ISC-GEM Catalogue posters:





Earthquake location

Earthquake magnitude determination

Availability of the ISC-GEM Catalogue

- Both the ISC and the GEM Foundation have a right to distribute the Catalogue as they see fit, in consultation with each other.
- The GEM public and private sponsors already have access to the Catalogue.
- Non-commercial ISC data users will have access via the ISC website from January 15, 2013.
- There is already a huge interest to the ISC-GEM Catalogue that will be extensively used as a reference in earthquake hazard assessment and modelling worldwide for a long period of time.
- We are currently trying to identify potential sponsors for the next stage of the Catalogue development.

Summary

- The ISC-GEM Catalogue of ~20,000 moderate to large earthquakes is a major step forward because its hypocentres, magnitudes and their uncertainties were re-computed using the same technique throughout the period 1900-2009.
- This task would have been impossible to accomplish without the GEM support.
- We formed an **excellent international team** of professionals in the field and trained a group of **dedicated and thoughtful** technical personnel.
- The Catalogue will be available to GEM Members and all non-commercial users from Jan 15, 2013.
- We suggested **further essential work** and looking for **partial sponsorship:** 20-30K€ a year would make a difference.

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