

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



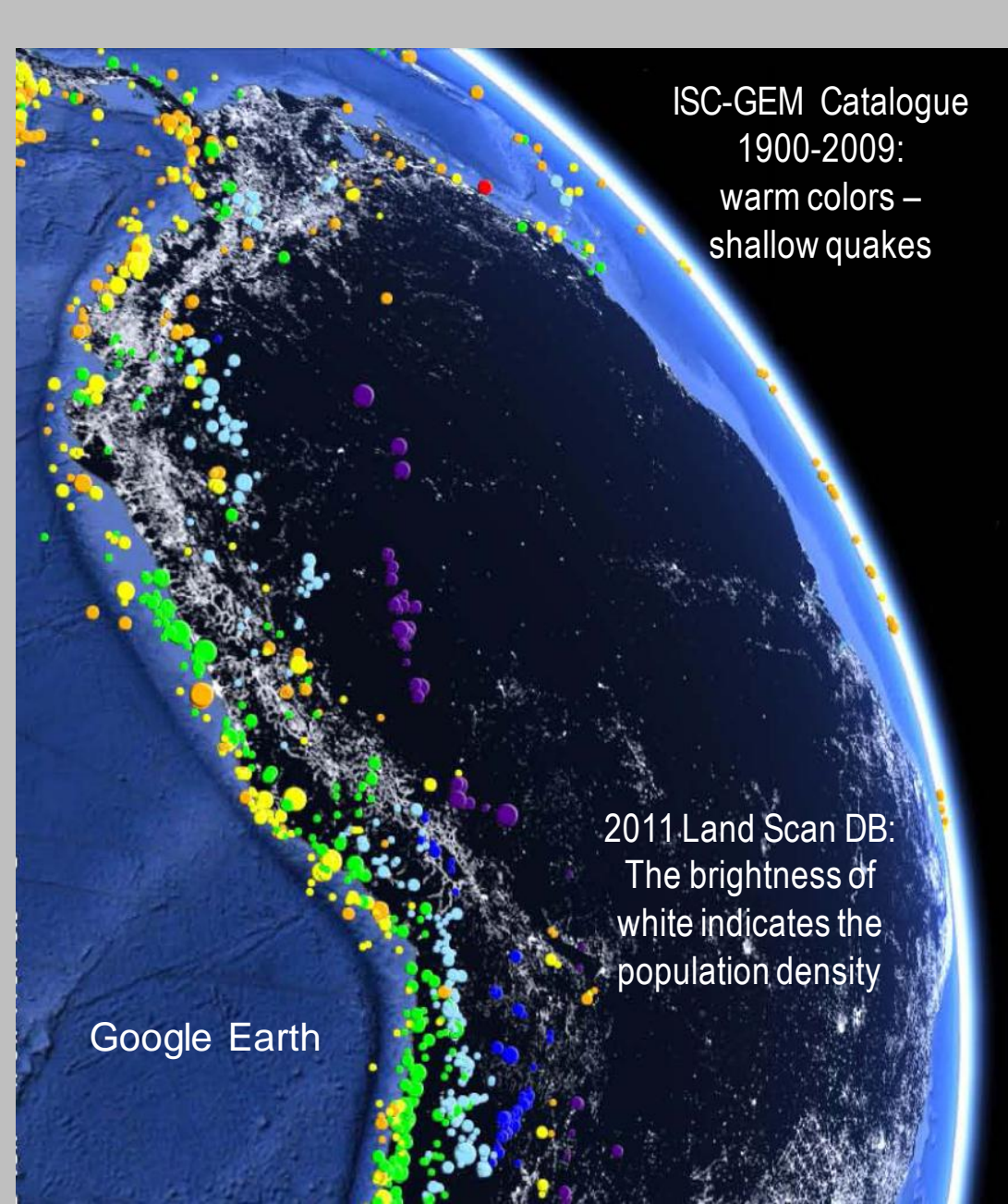
Dmitry A. Storchak, Domenico Di Giacomo, István Bondár and James Harris  
*International Seismological Centre (ISC)*

# Motivation

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

is our special effort to adapt our bulletin data to serve requirements of specific group of our users that assess and model seismic hazard and risk:

- ❑ accurate knowledge of the spatial distribution of seismicity and the magnitude-frequency relation;
- ❑ homogeneous locations and magnitudes;
- ❑ estimates of uncertainty;
- ❑ spanning the entire 100+ years period of instrumental seismic recordings.

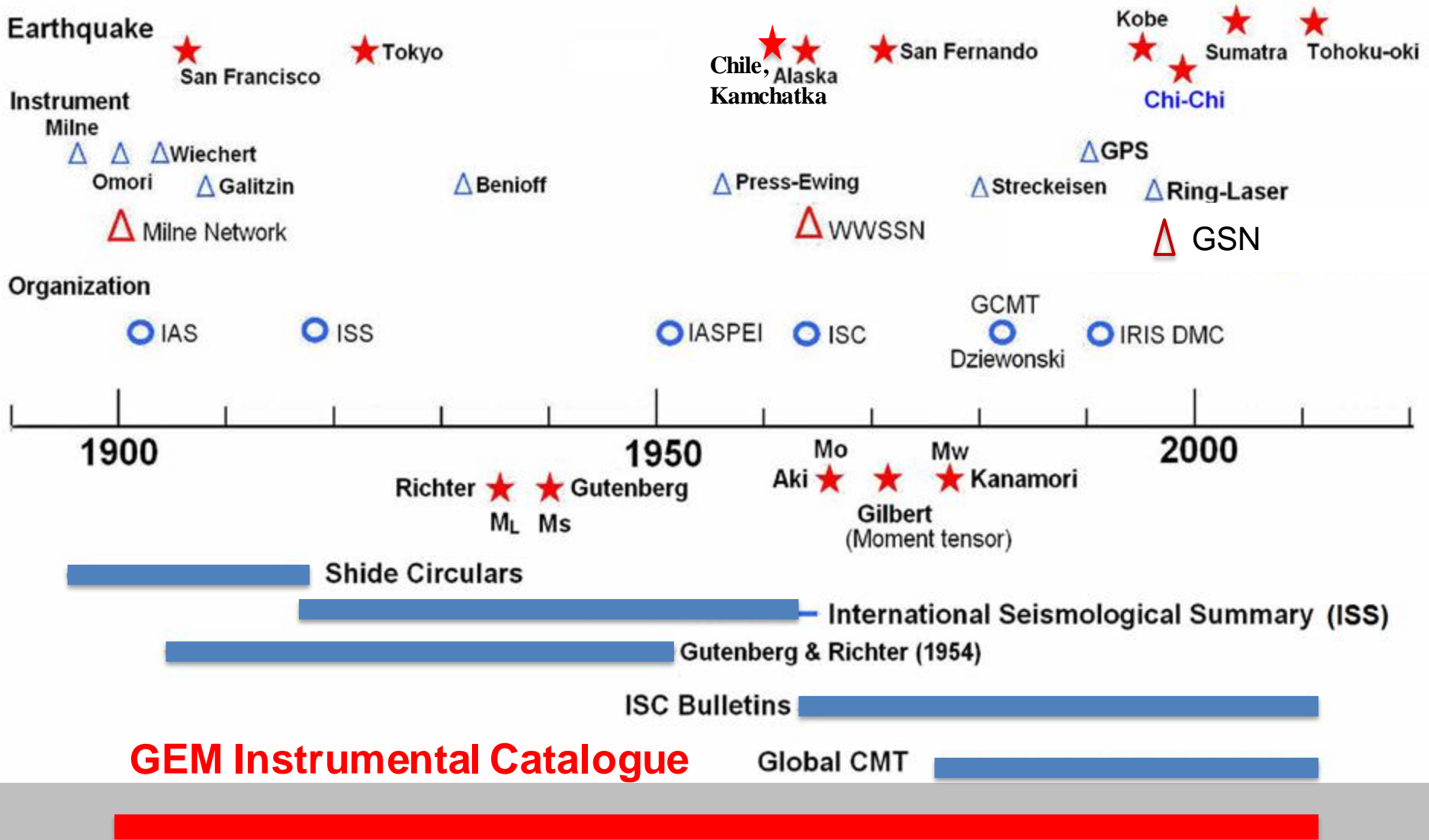


ISC-GEM Catalogue  
1900-2009:  
warm colors –  
shallow quakes

2011 Land Scan DB:  
The brightness of  
white indicates the  
population density

Google Earth

# ISC-GEM Catalogue and Seismology Timeline



# ISC-GEM Catalogue is Unique



- ✓ **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 the original amplitude measurements;

This Catalogue is **unique** because it contains **homogeneous** locations and magnitude estimates with the estimates of uncertainty for the entire 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:  $M_S \geq 6\frac{1}{4}$
- ✓ 1960-2009:  $M_S \geq 5.5$

# 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 Jaime 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 available electronically	ISC Bulletin		
Surface Wave amplitudes & periods	Not available electronically		ISC Bulletin	
$M_0$ & $M_W$	Not available 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;



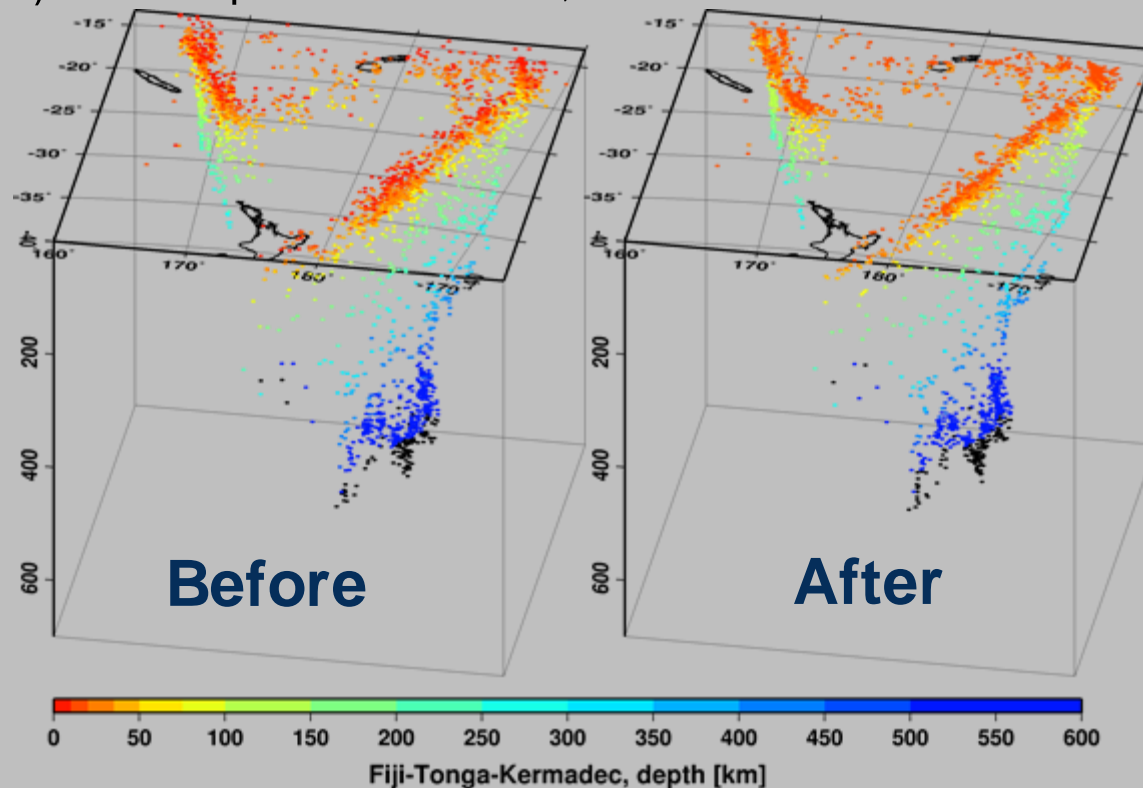
- Arrival times, body and surface wave amplitudes and periods entered from the **historical paper based bulletins** of high quality stations from the **ISC warehouse collection** with gaps filled from collections at **USGS/Berkeley** (1900-1971), **GS RAS** and **IS NASK**;

# Two-stage Relocation Procedure

## Stage 1:

Earthquake depths are determined using the **EHB** technique ([Engdahl, van der Hilst & Buland, 1998](#)):

- comprehensive analysis of near-event surface reflections off the earth surface inland and ocean bottom or water surface in the oceans;
- Station patch corrections;



## Stage 2:

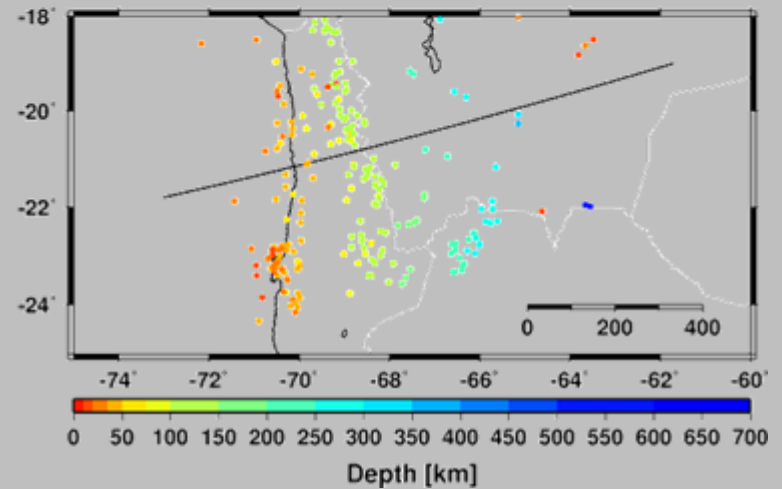
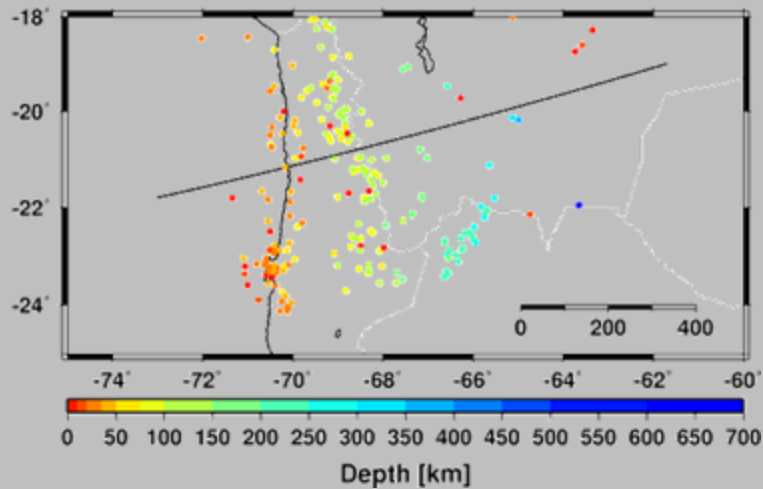
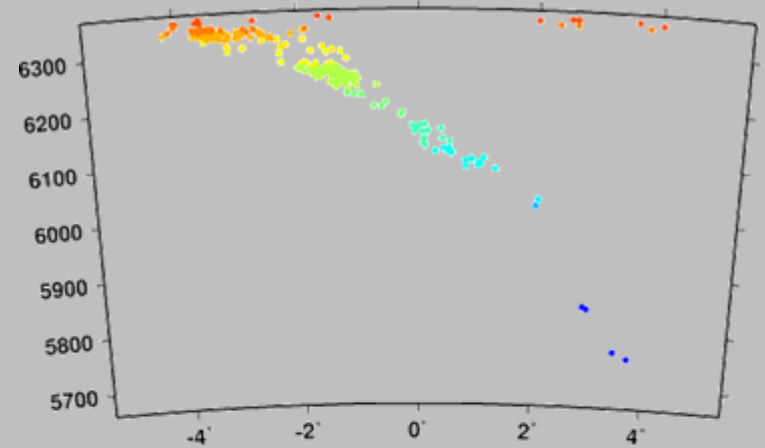
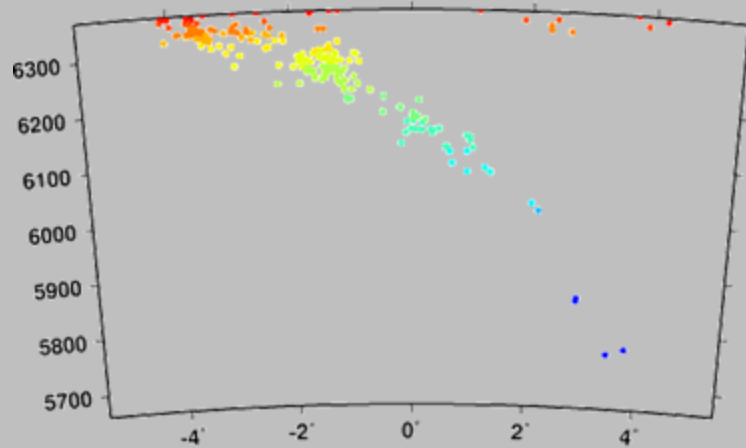
New **ISC location** algorithm ([Bondár & Storchak, 2011](#)) is used with earthquake depths fixed to those from EHB analysis:

- independent depth confirmation using depth phase stacking;
- 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 - Arica, 226 events

After - Arica, 226 events

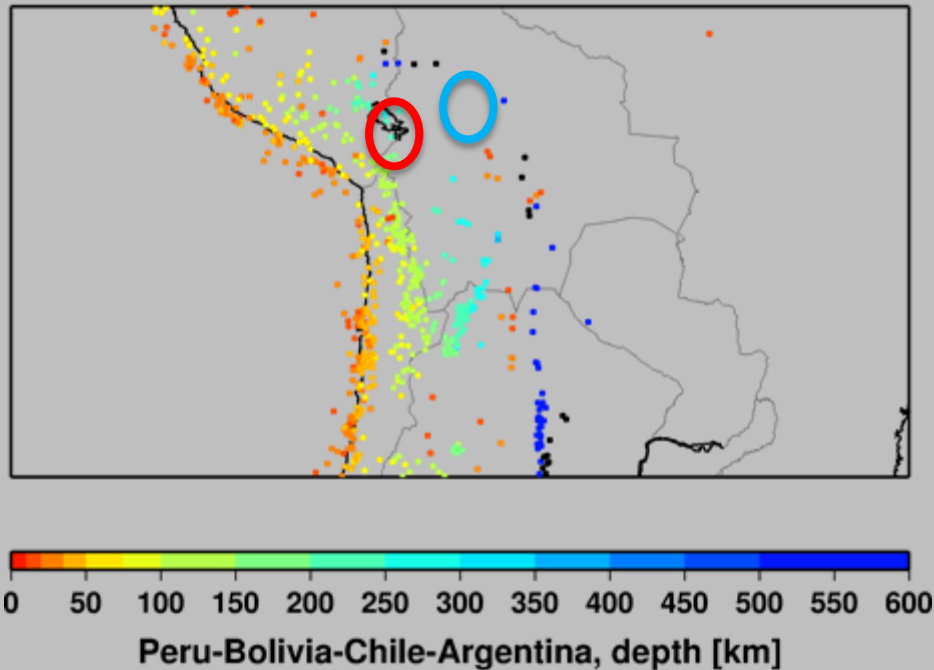


**Before**

**After**



# Examples of Relocation: Bolivia



**ISC-GEM** versus **Centennial**

*2 Sep 1923, Bolivia, mB 6.8*

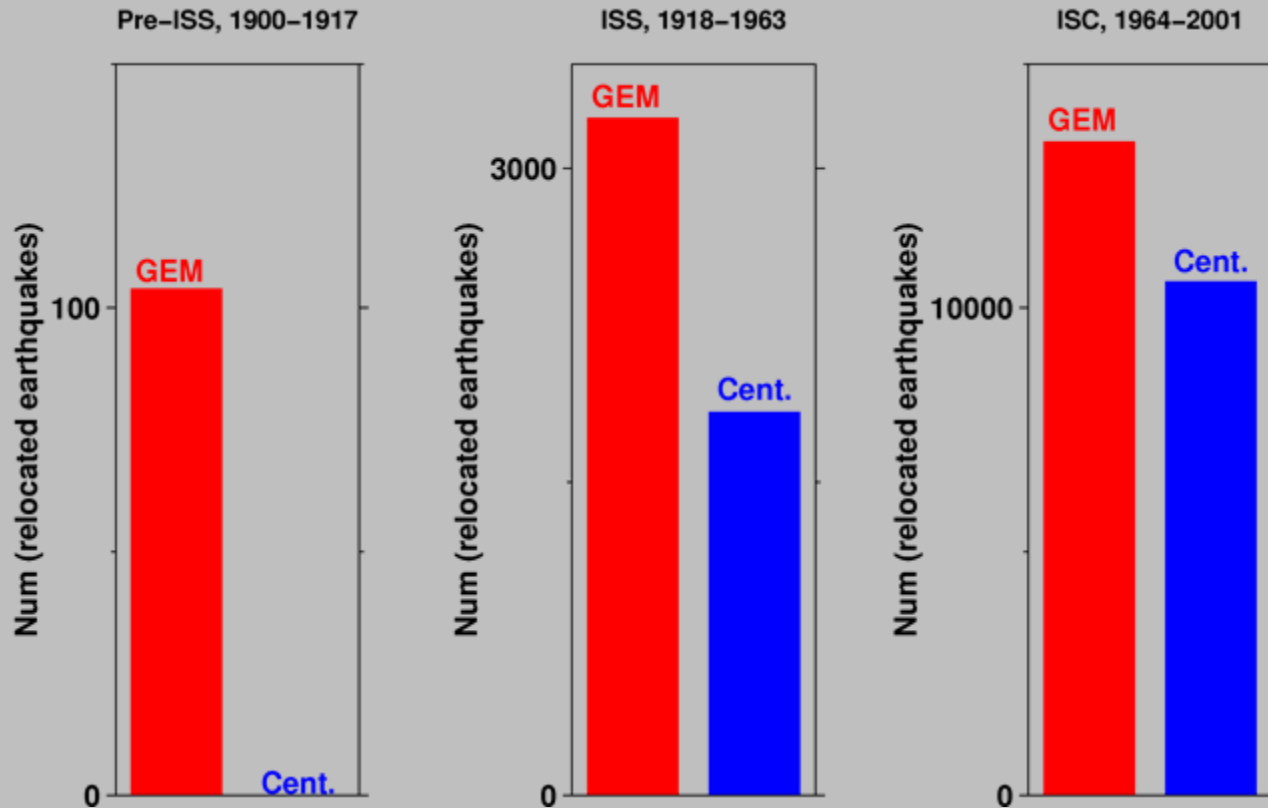
- ❑ ~400 km correction in location,
- ❑ 155km depth in ISC-GEM where the depth was fixed to be shallow in the Centennial Catalogue

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

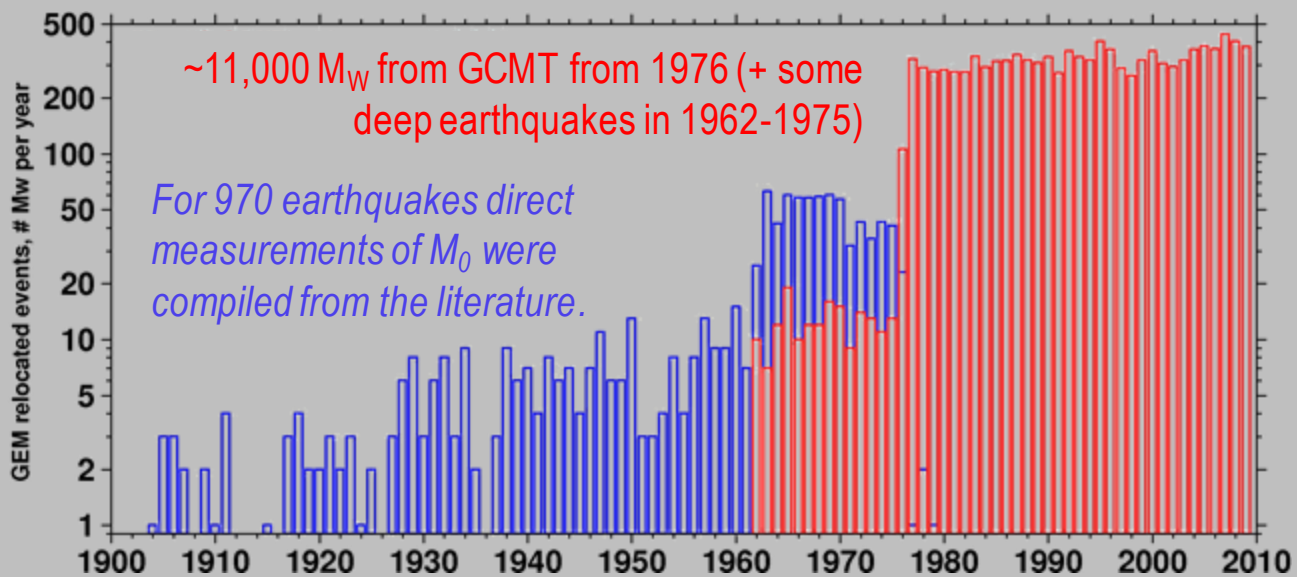
In **ISC-GEM** Catalogue, all events, except 1900-1903, were **relocated** based on the newly entered and already available **arrival time data**



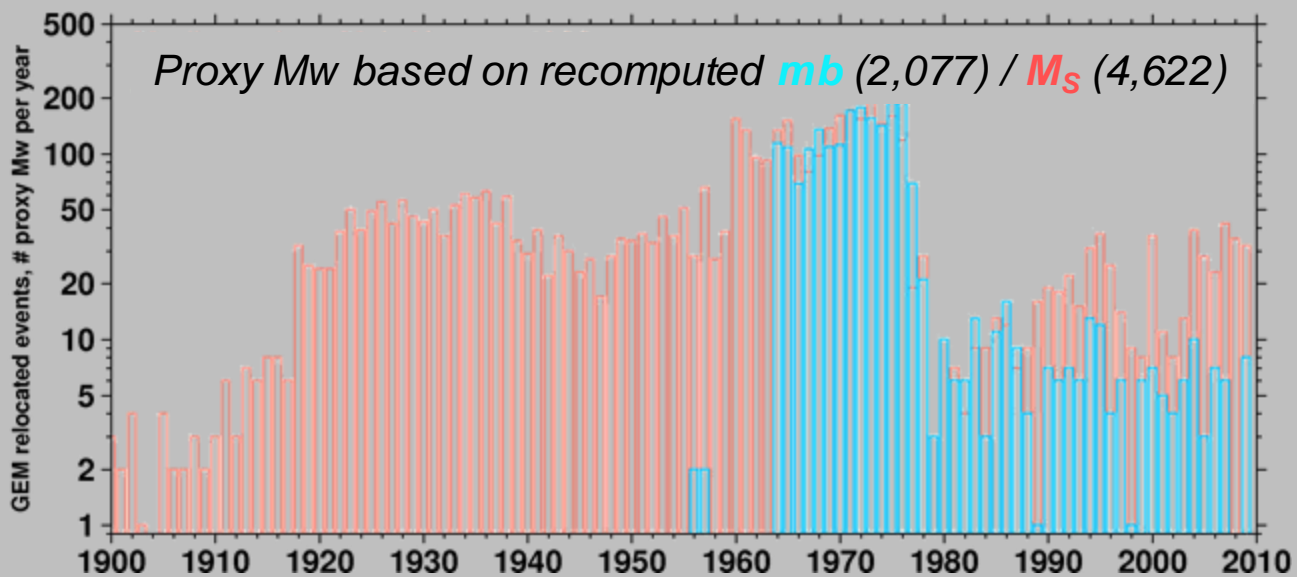
Both formal uncertainty and quality of both location and depth are given in the **ISC-GEM** Catalogue

# Magnitude composition of the ISC-GEM catalogue

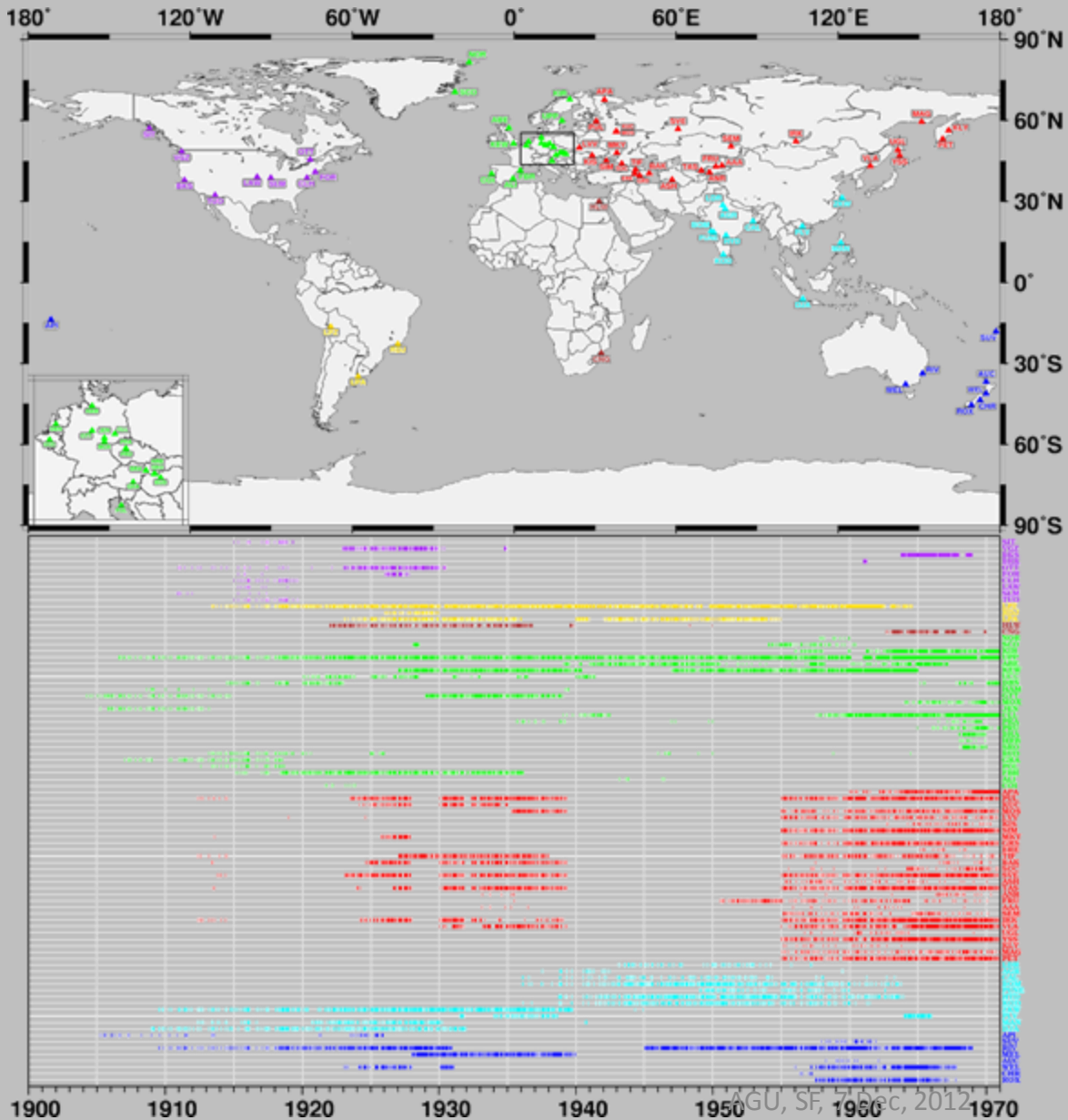
Direct  $M_W$  (per year)



Proxy  $M_W$  (per year)

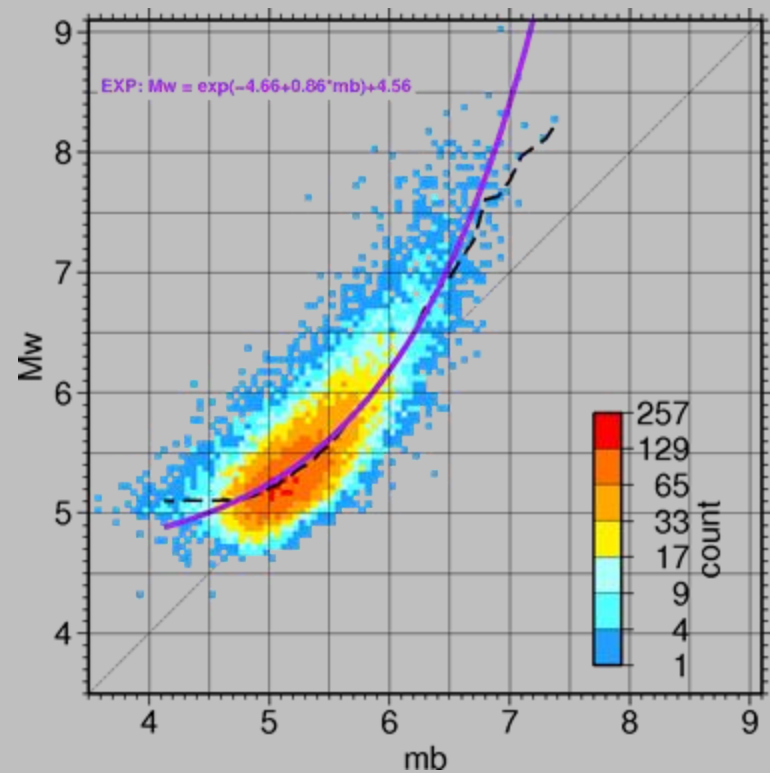
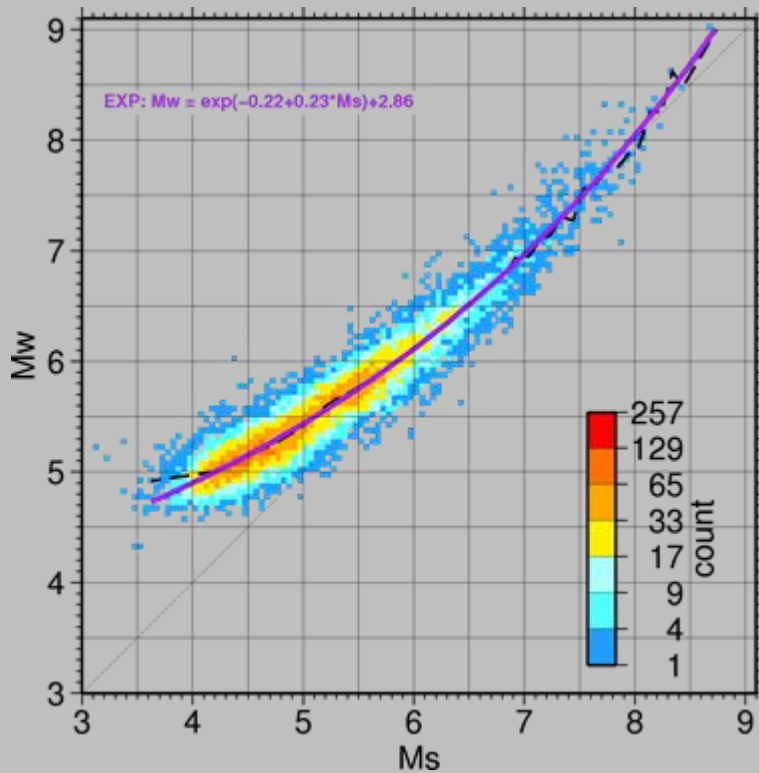


# Amplitudes from Quality Station Bulletins



- ~300,000 previously unavailable amplitudes have been entered into the ISC database for the 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  $mb$ , many of them didn't exist prior to the project start.**

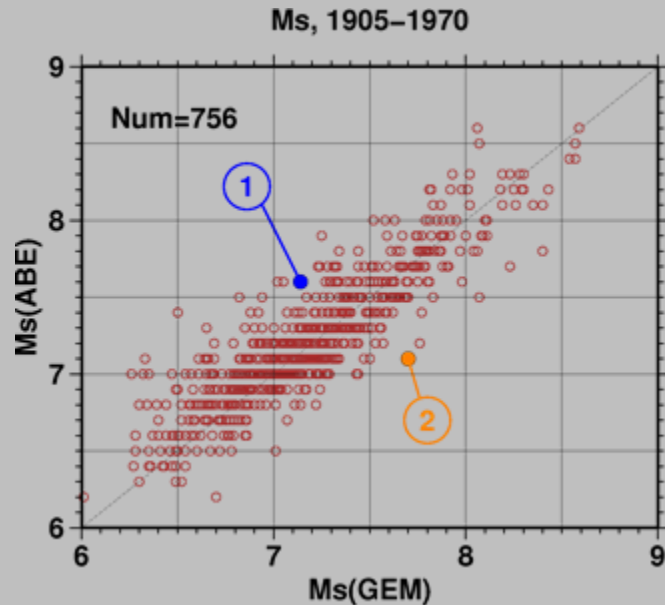
# $M_W/M_S$ and $M_W/m_b$ Regressions



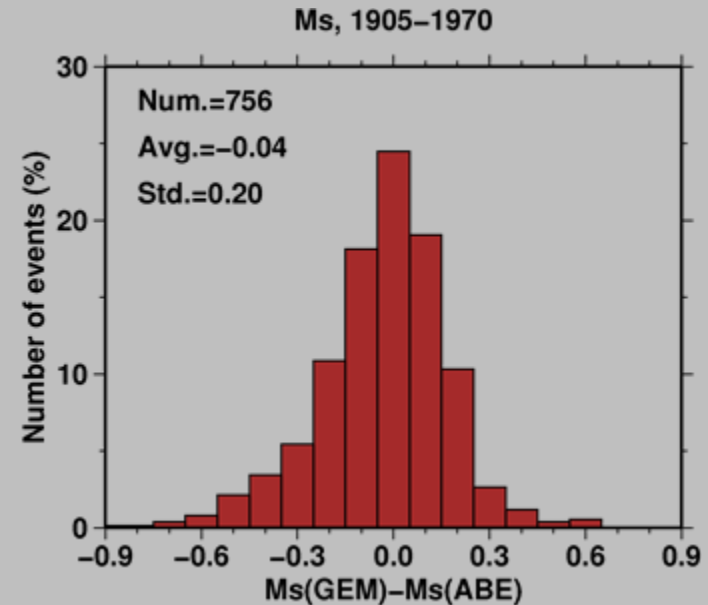
Based on the large set of recent earthquakes with GCMT  $M_w$  and the ISC-GEM  $M_S/m_b$  available, we built and validated  $M_W/M_S$  and  $M_W/m_b$  regression curves in exponential form.

We then used these regressions to obtain  $M_w$  for those events in ISC-GEM Catalogue where no direct determination of  $M_W$  is available.

# Examples: 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

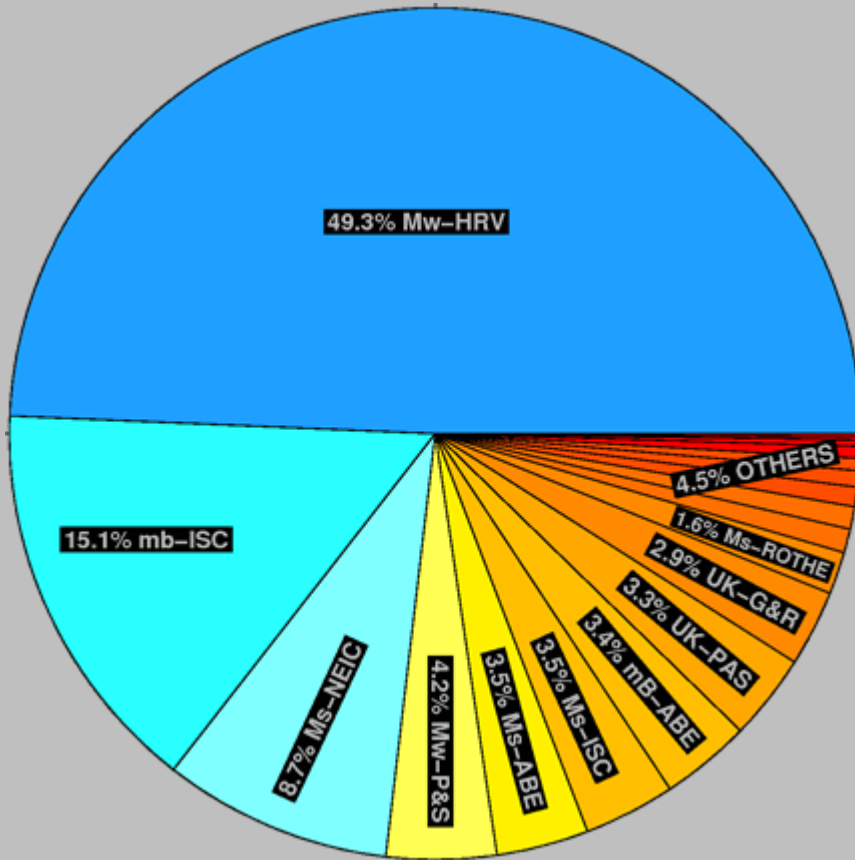


2) GEM location → OT: 1969–07–18 05:24:48  
 LAT: 38.33 LON:119.57 DEPTH: 10.0 km  
 Northeastern China (~320 km from Beijing)  
 Ms(ABE)=7.1 NSTA=?  
 Ms(GEM)=7.70±0.02 NSTA=10

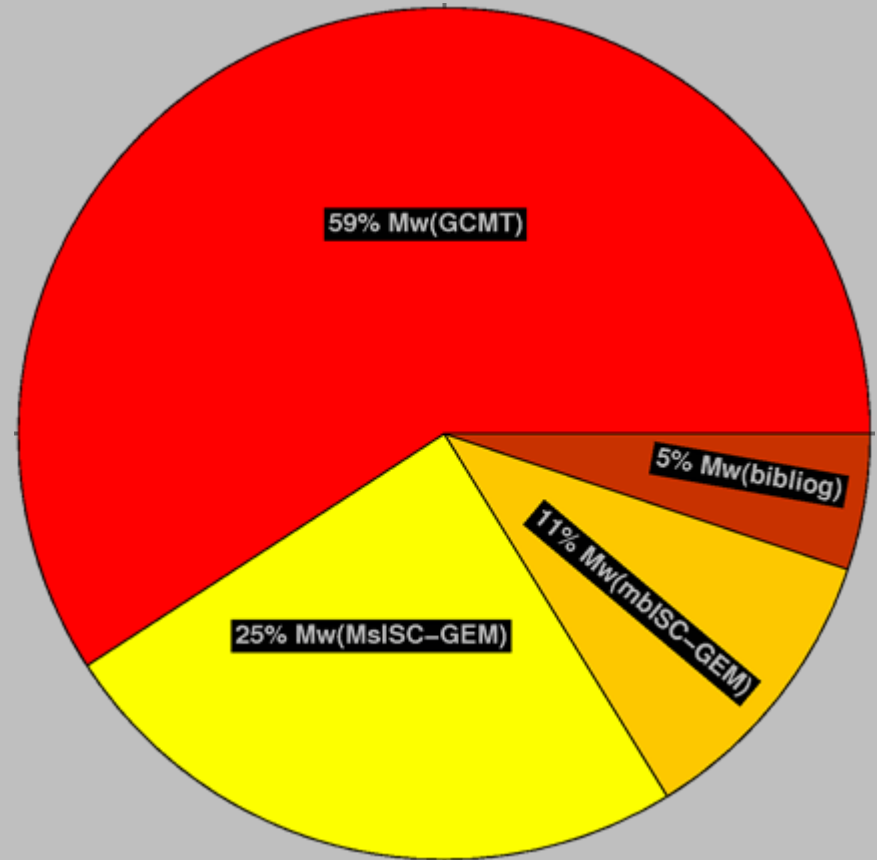


# ISC-GEM Magnitude: comparison with Centennial

Centennial

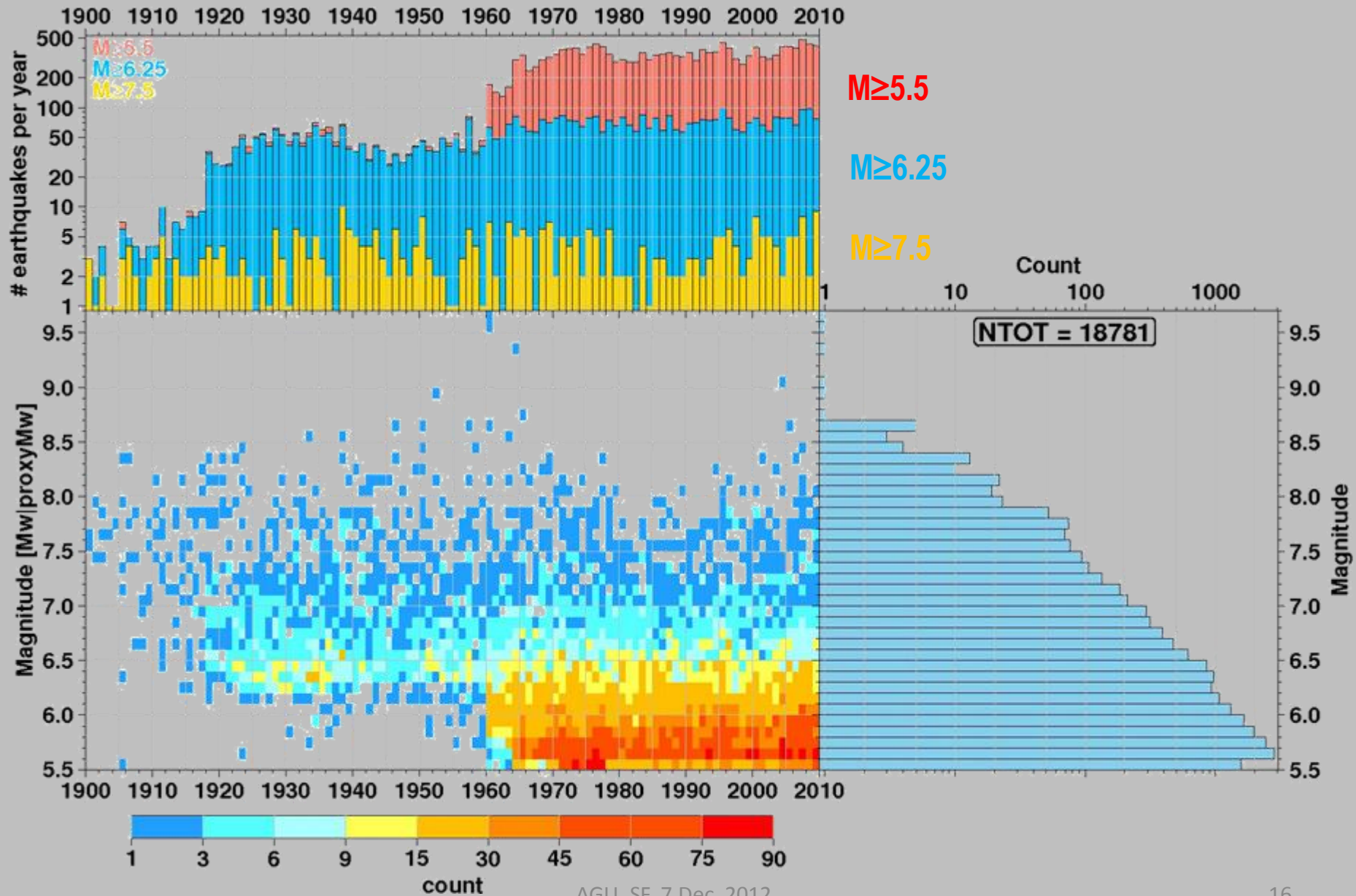


ISC-GEM



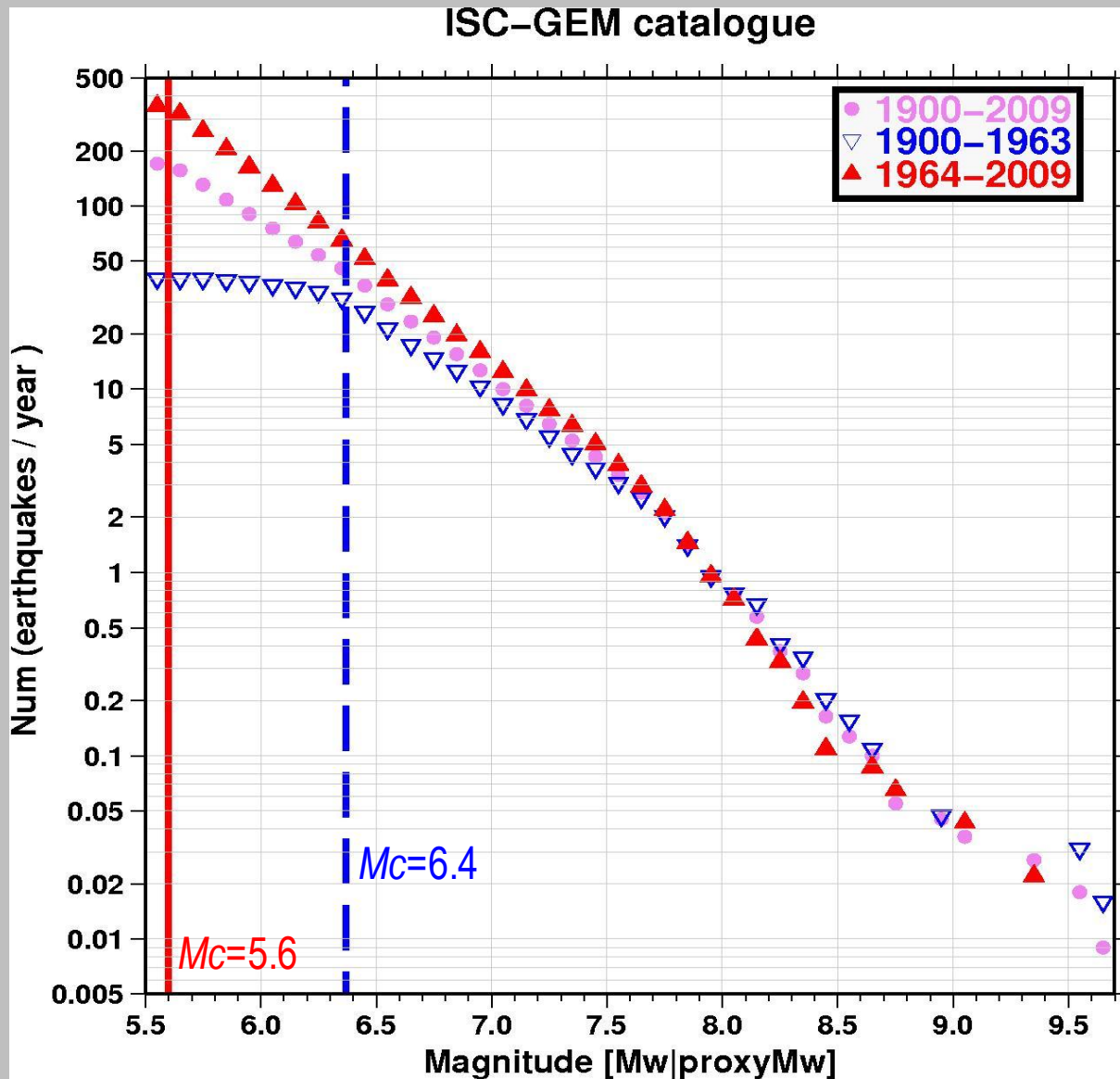
As compared to the Centennial catalogue, the magnitudes in the ISC-GEM Catalogue are much more homogeneous as they come from only four comparable sources.

# 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

# 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 encourage the commercial sector to partially support the Catalogue's further essential development in exchange for access to the existing Catalogue and its further versions.

# Summary

- ❑ We formed an **excellent international team** of professionals in the field and trained a group of **dedicated and thoughtful technical personnel**.
- ❑ The ISC-GEM Catalogue of ~20,000 large earthquakes is a **major step forward** because its hypocentres, magnitudes and their uncertainties were re-computed using the same technique throughout the 1900-2009.
- ❑ Large amount of previously unavailable basic parametric data shall be freely available in digital form.
- ❑ 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** from **commercial companies**.

