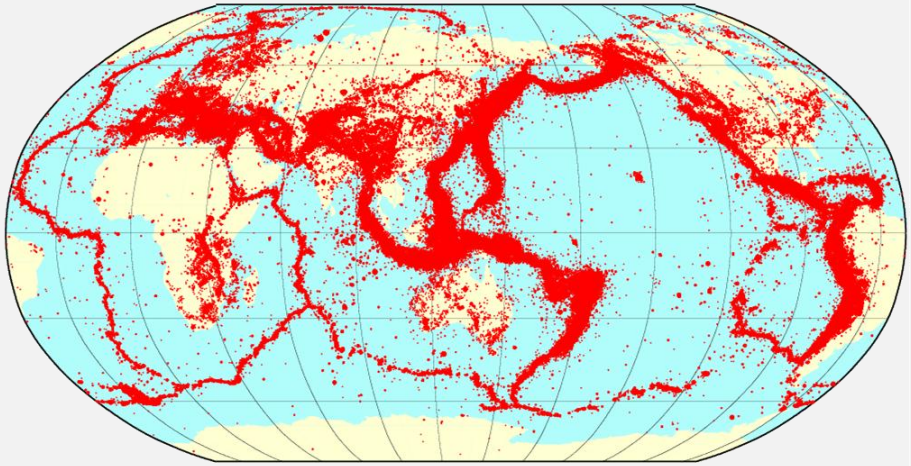
# Global Instrumental Earthquake Catalogue (1900-2009)


Dmitry A. Storchak (ISC),
on behalf of the
International Team of experts

International Seismological Centre

GEM
GLOBAL EARTHQUAKE MODEL

# Purpose of the project



To compile the Reference Global Instrumental Earthquake Catalogue (1900-2009)
to be used by GEM for
characterization of the spatial distribution of seismicity, the magnitude frequency relation and the maximum magnitude.

# Overall Project Deliverables (May 2012):

- 110 years of relocated earthquake hypocenters;
- recomputed $M_S$ (or other) magnitude values for relocated events;
- $M_W$ values (with uncertainty) based on seismic moment where possible (mainly 1976-2009) and proxy values in other cases using appropriate empirical relationships;
- Database of above information with references to original sources, including scanned historical bulletin pages.

# 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*)
- ✓ Antonio Villaseñor (IES Jaume Almera, *Spain*)
- ✓ István Bondár (ISC, *UK*)
- ✓ Peter Bormann (GFZ, emeritus, *Germany*)
- ✓ Willie Lee (USGS, emeritus, *US*)
- ✓ 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**.

# Task 1: Earthquake Relocation

**Approach:**

1. Earthquake depth to be determined as in the **Centennial Catalogue** (*Engdahl, van der Hilst and Buland, 1998*),
2. followed by epicentre relocation done at the ISC using the **new ISC Earthquake Locator** (Bondár, Storchak, 2011)

**Bulletin Data Sources:**

1. Abe and Noguchi (1900-1903)
2. Gutenberg Notepads (1904-1917)
3. BAAS (1913-1917)
4. ISS Bulletins (1918-1963)
5. ISC Bulletins (1964-2009)
6. a number of quality station (e.g. Uppsala) and network (e.g. JMA) bulletins as part of Task 3.

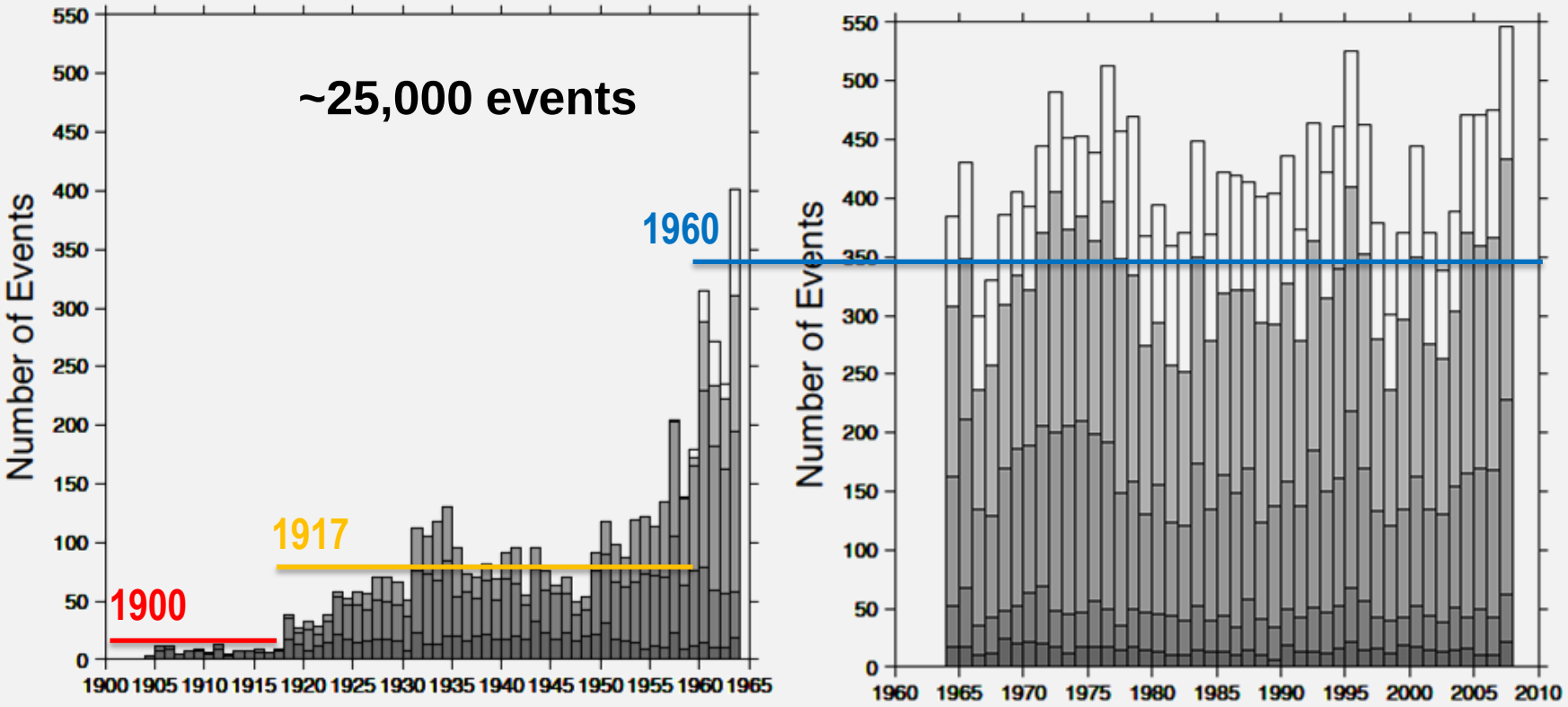
- ✓ 1900-1917: $M_S \geq 7.5$ worldwide + smaller shallow events in stable continental areas
- ✓ 1918-1959: $M_S \geq 6.25$
- ✓ 1960-2009: $M_S \geq 5.5$

Engdahl, ISC

# T1: Selected earthquakes (1st iteration)

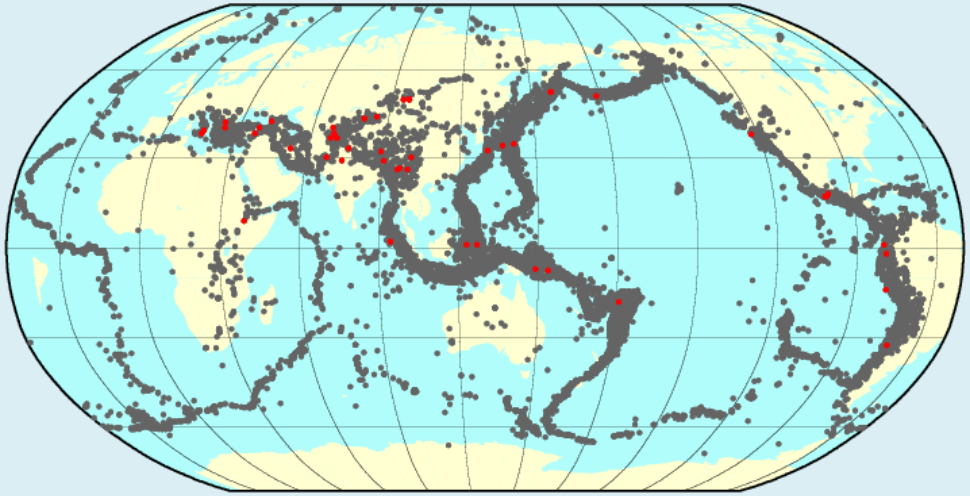
Mostly based on the ISS, etc

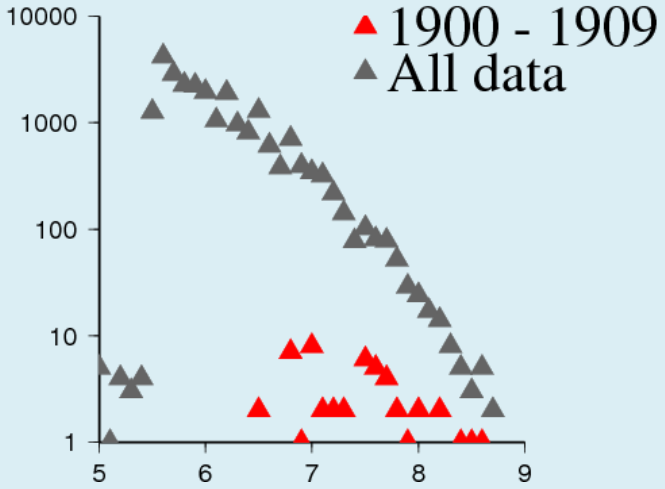
based on the ISC




Bars (lightest to darkest) indicate the number of events with Mw ≥ 5.5, **5.7**, 6.0, **6.5**, **7.0**

# T1: Distribution in time, space and size





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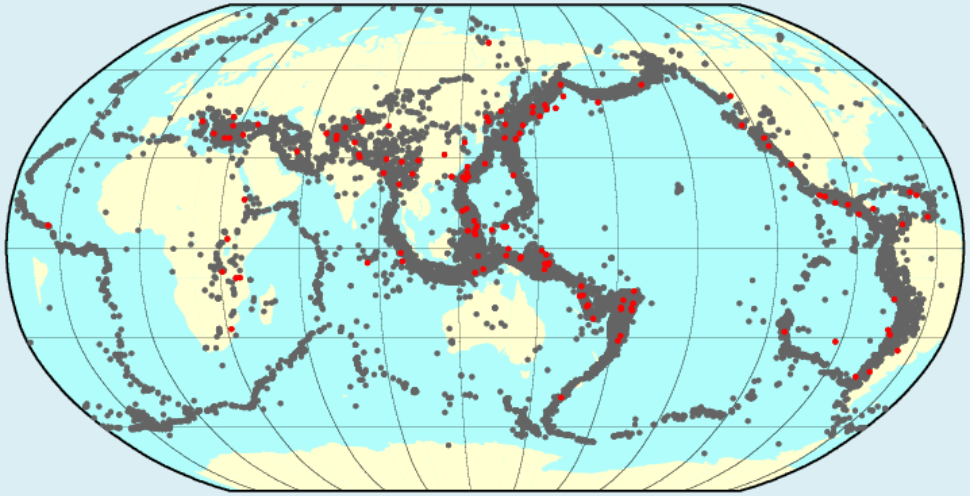

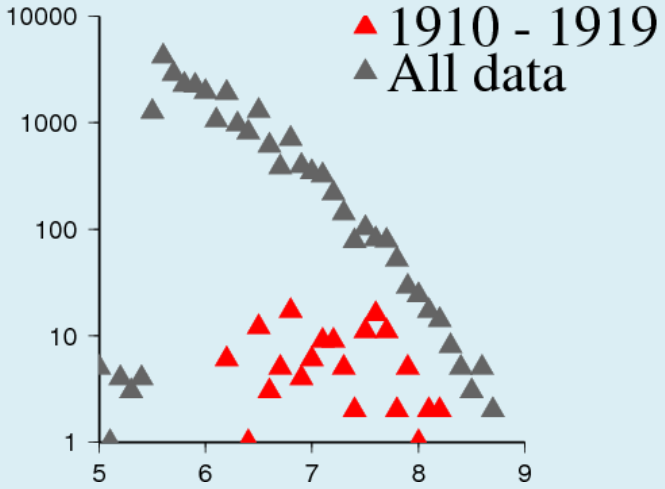

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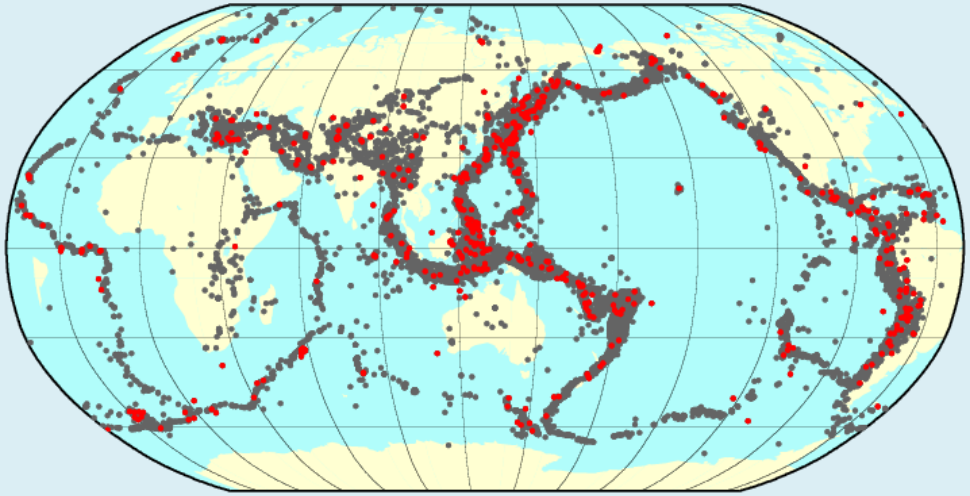

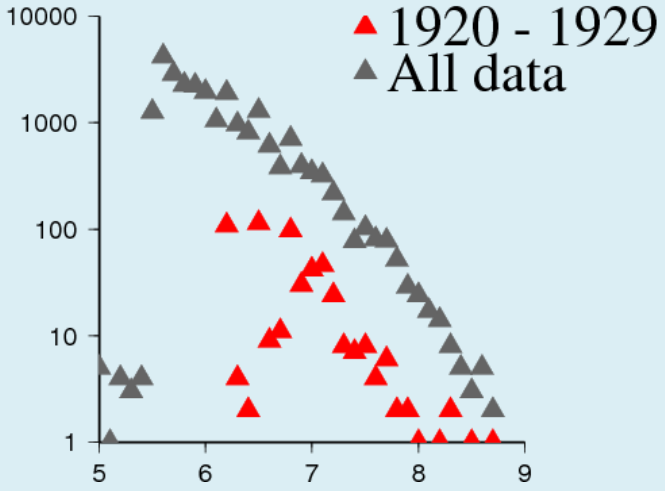

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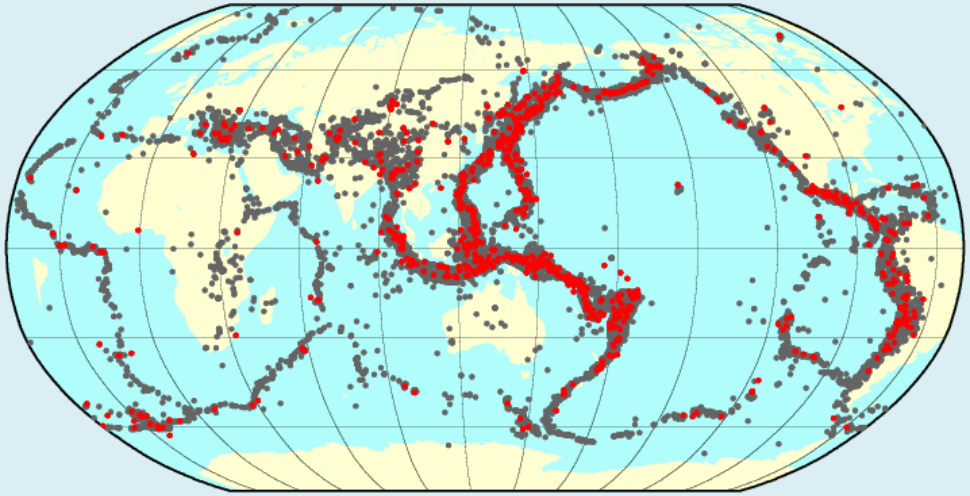

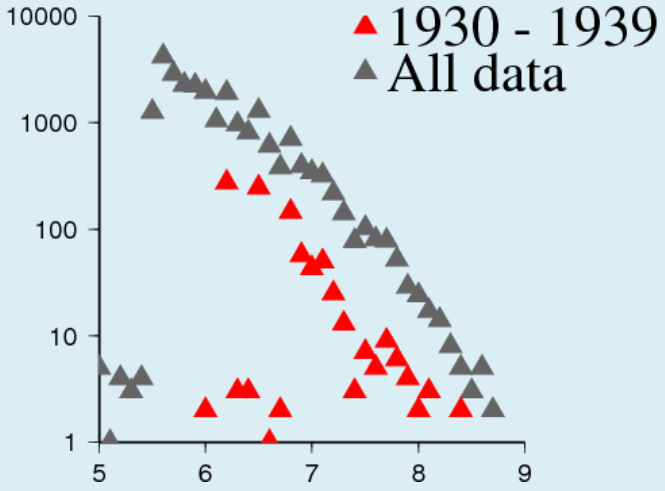

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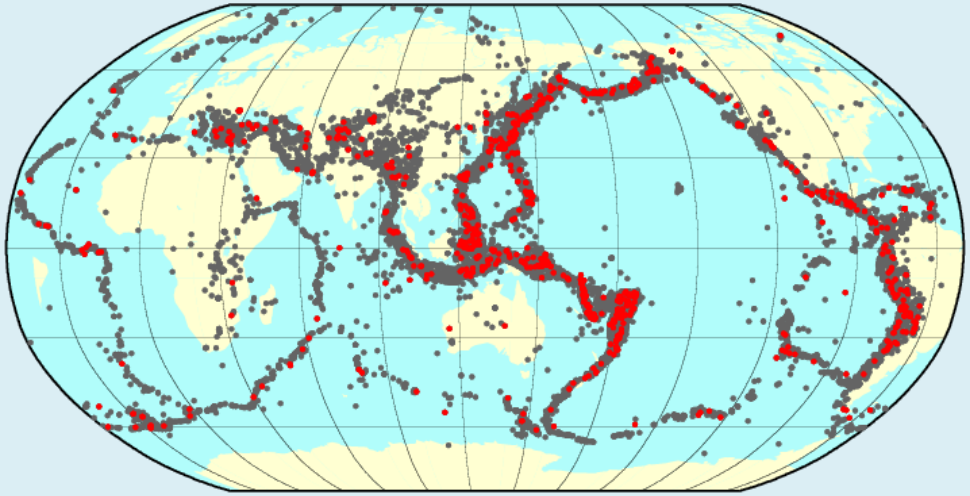

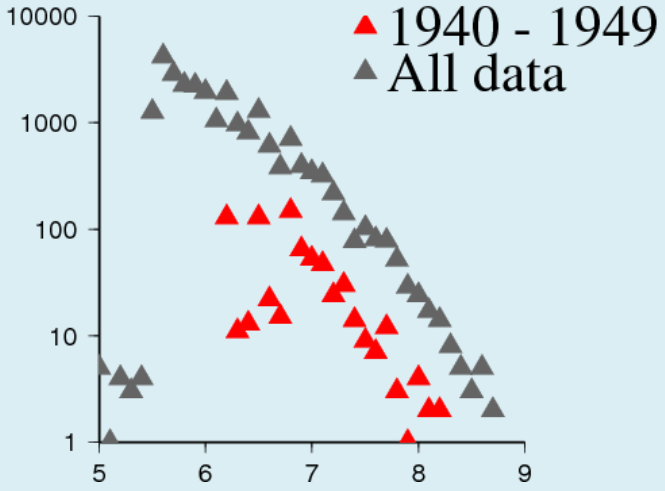

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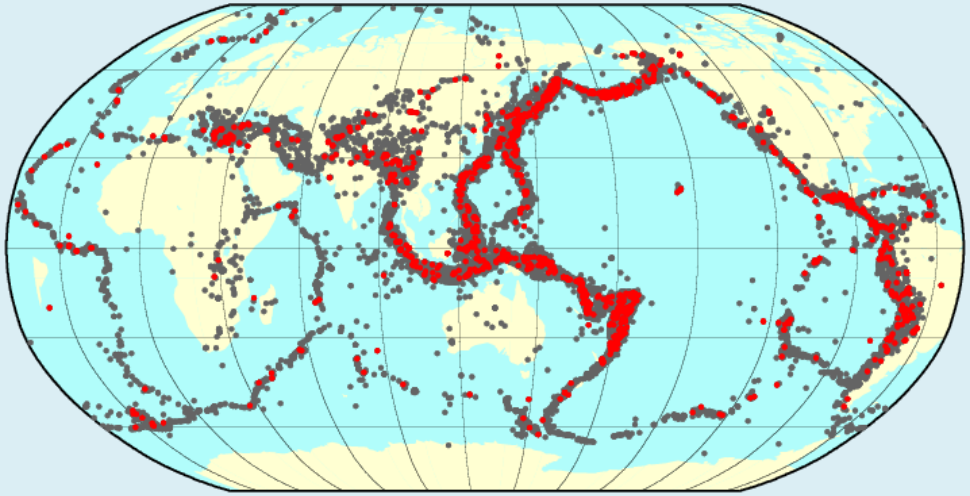

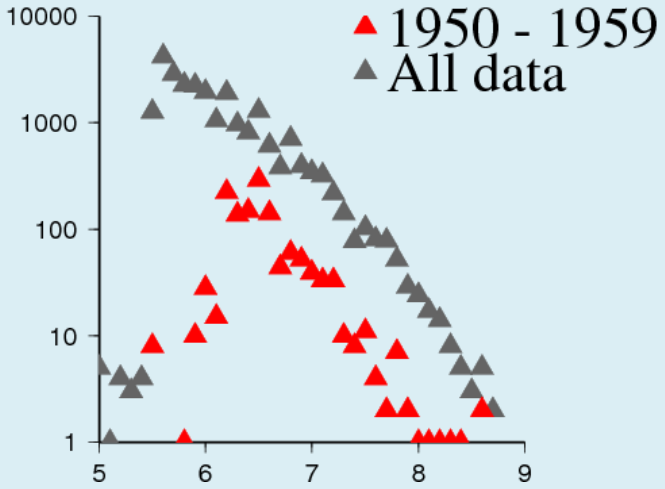

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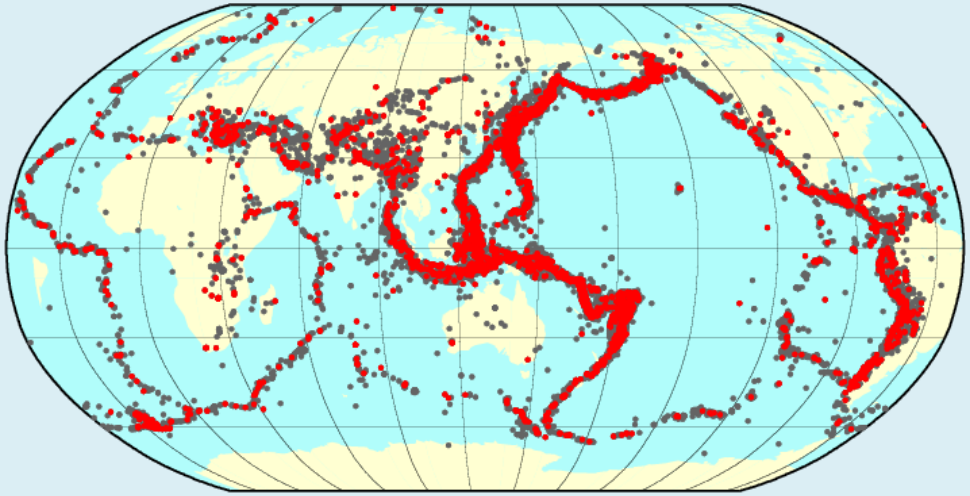

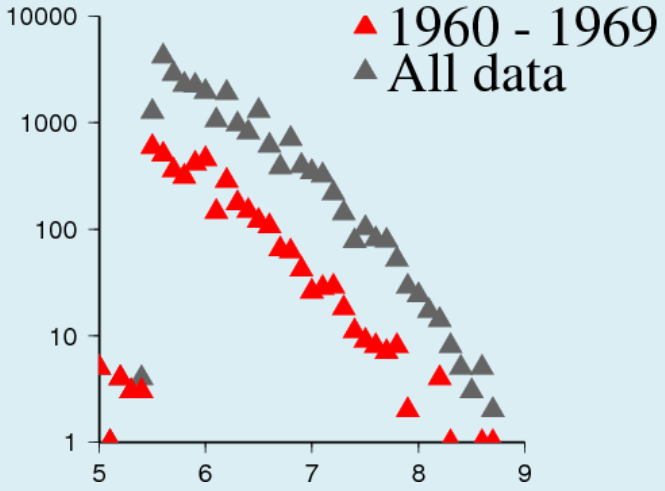

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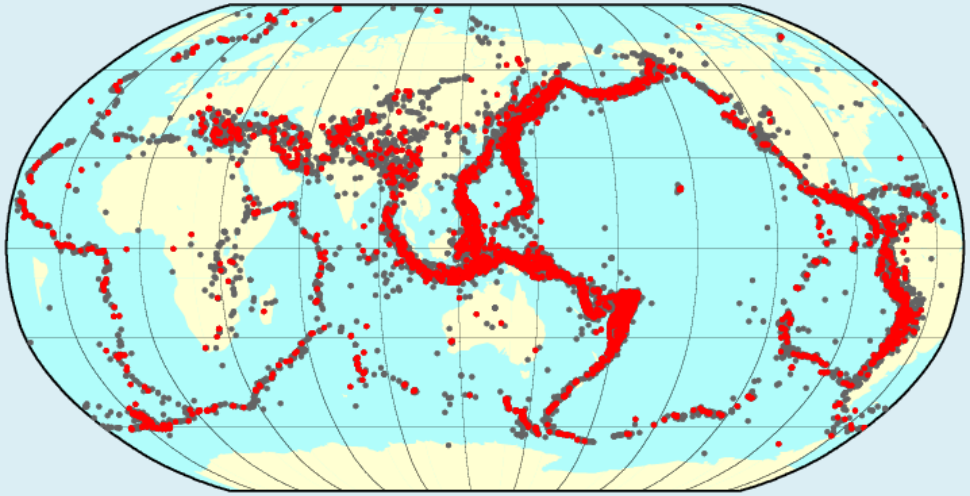

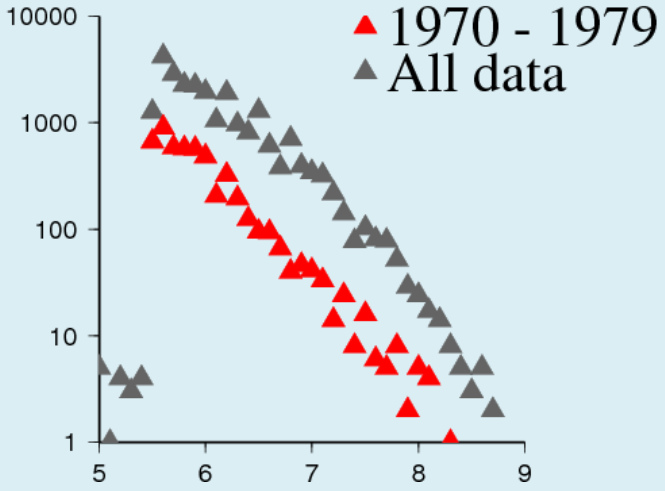

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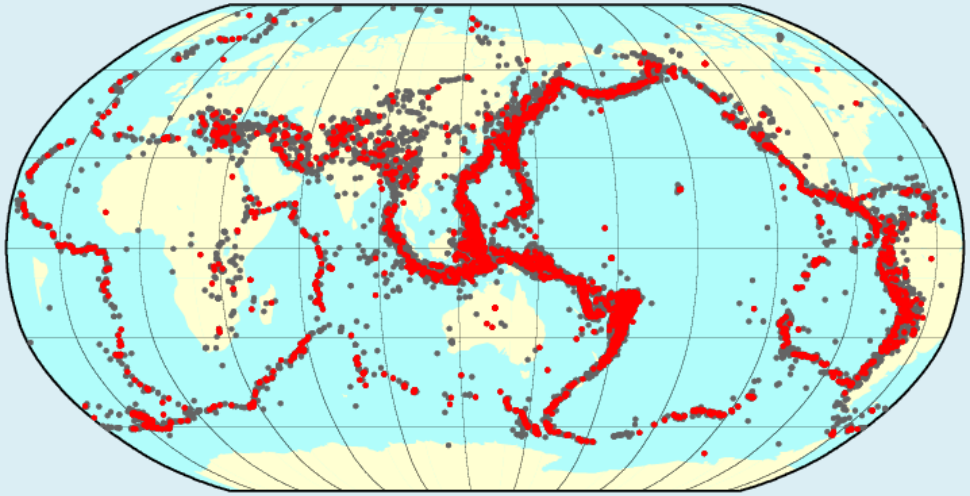

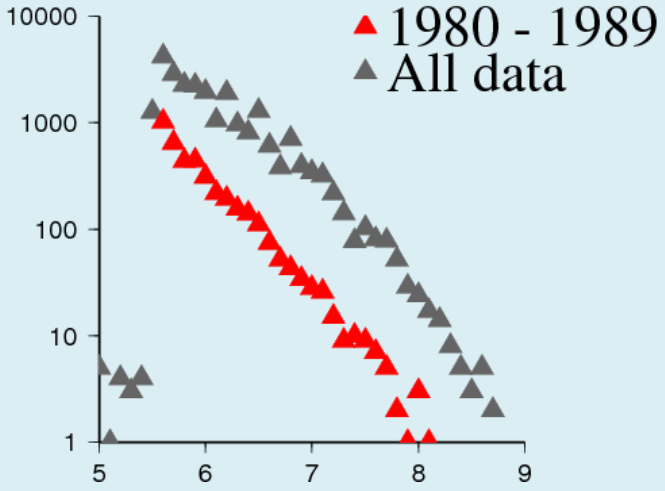

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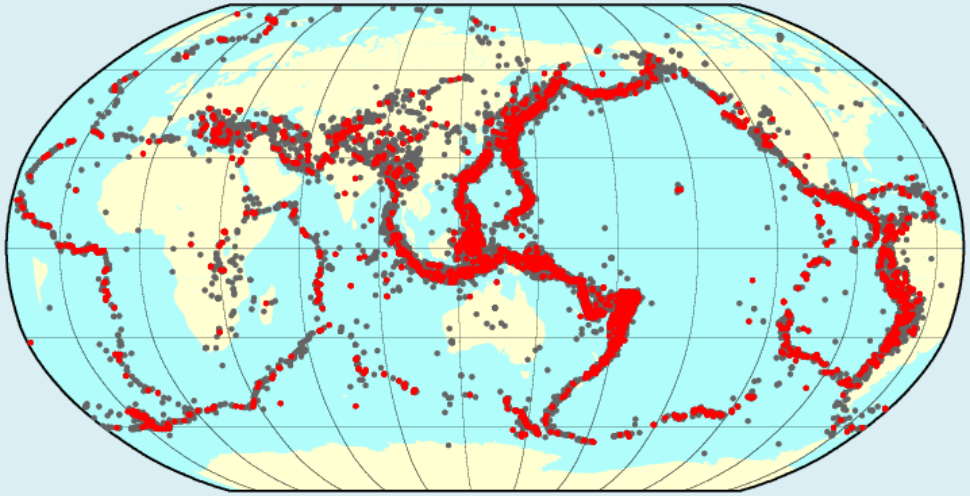

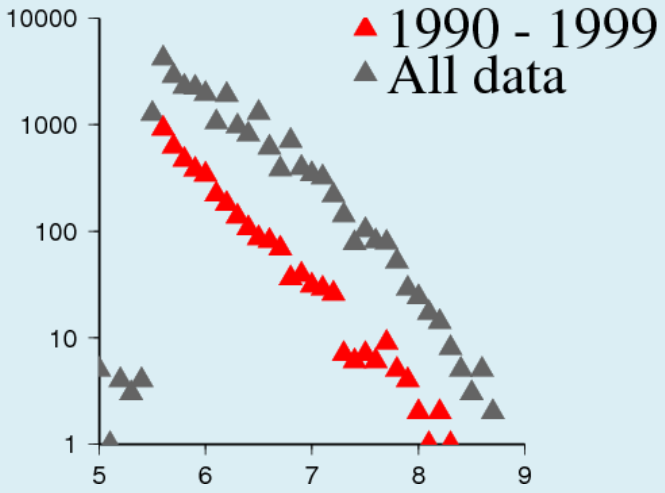

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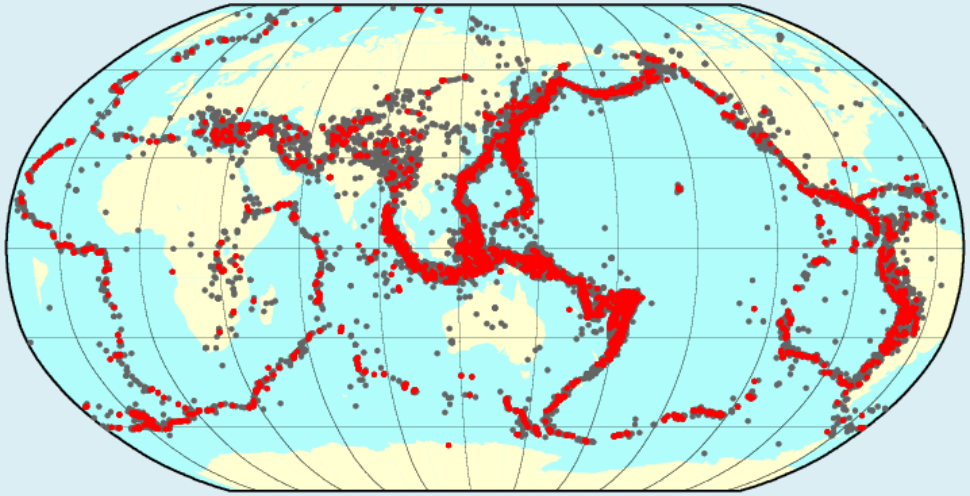
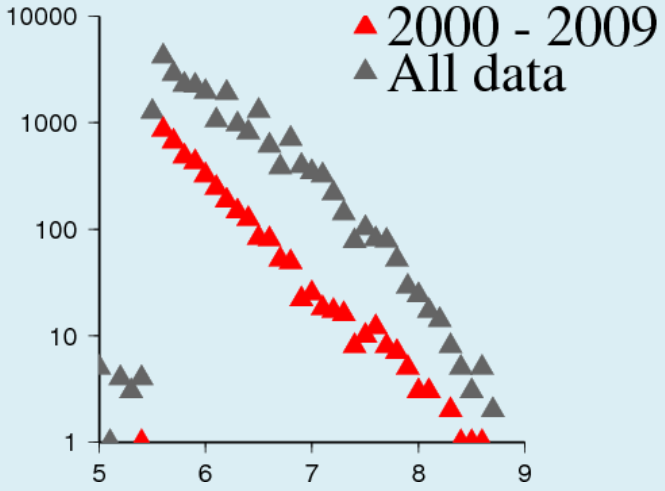




# T1: Review of station positions

We conducted a rigorous review of position/elevation parameters of those seismic stations that reported to the ISS/ISC.

This review included station lists at the ISC, NEIC and LLNL.

Most inconsistencies have been resolved and new revised lists of station parameters and alternate station codes have been created.

A new feature of the station list is the addition of time periods over which the station parameters are valid.

# Initial Test of the Location Procedure

In order to test our location procedures we started with one of the late instrumental periods of **1978-1999** because:

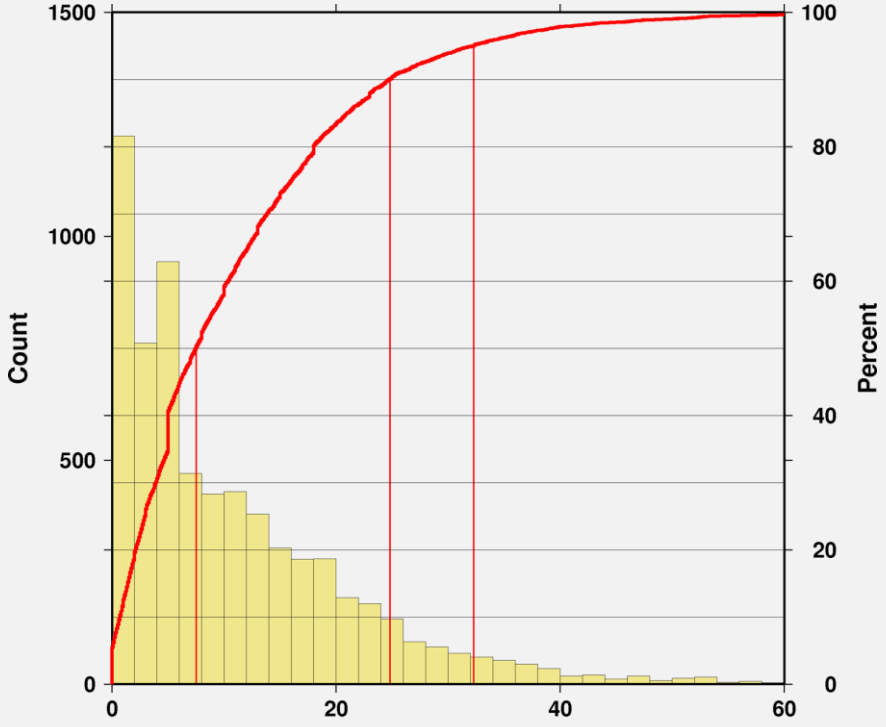
1. all bulletin data (arrival times, amplitudes, periods) are available as part of the ISC Bulletin
2. no additional data arrival time or amplitude data are expected to be gathered as part of Task 3

**Location method**:

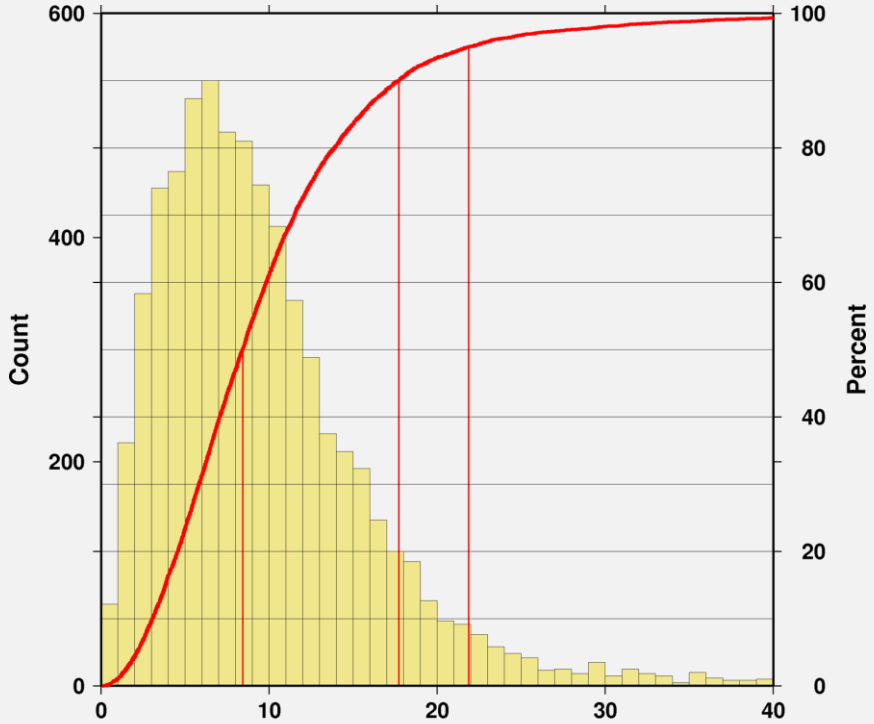
1. Determine event depth using the **EHB** style of processing *(Engdahl, van der Hilst and Buland, 1998)*:
   a) comprehensive analysis of near-event surface reflections off the day-surface inland and ocean bottom or water surface in the oceans;
   b) Station patch corrections;
2. Use the **brand new ISC location** algorithm *(Bondár and Storchak, 2011)* 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 positioning of stations)

# GEM (new ISC) versus original ISC locations

*Test period:1978-1999,*
*6601 earthquakes*

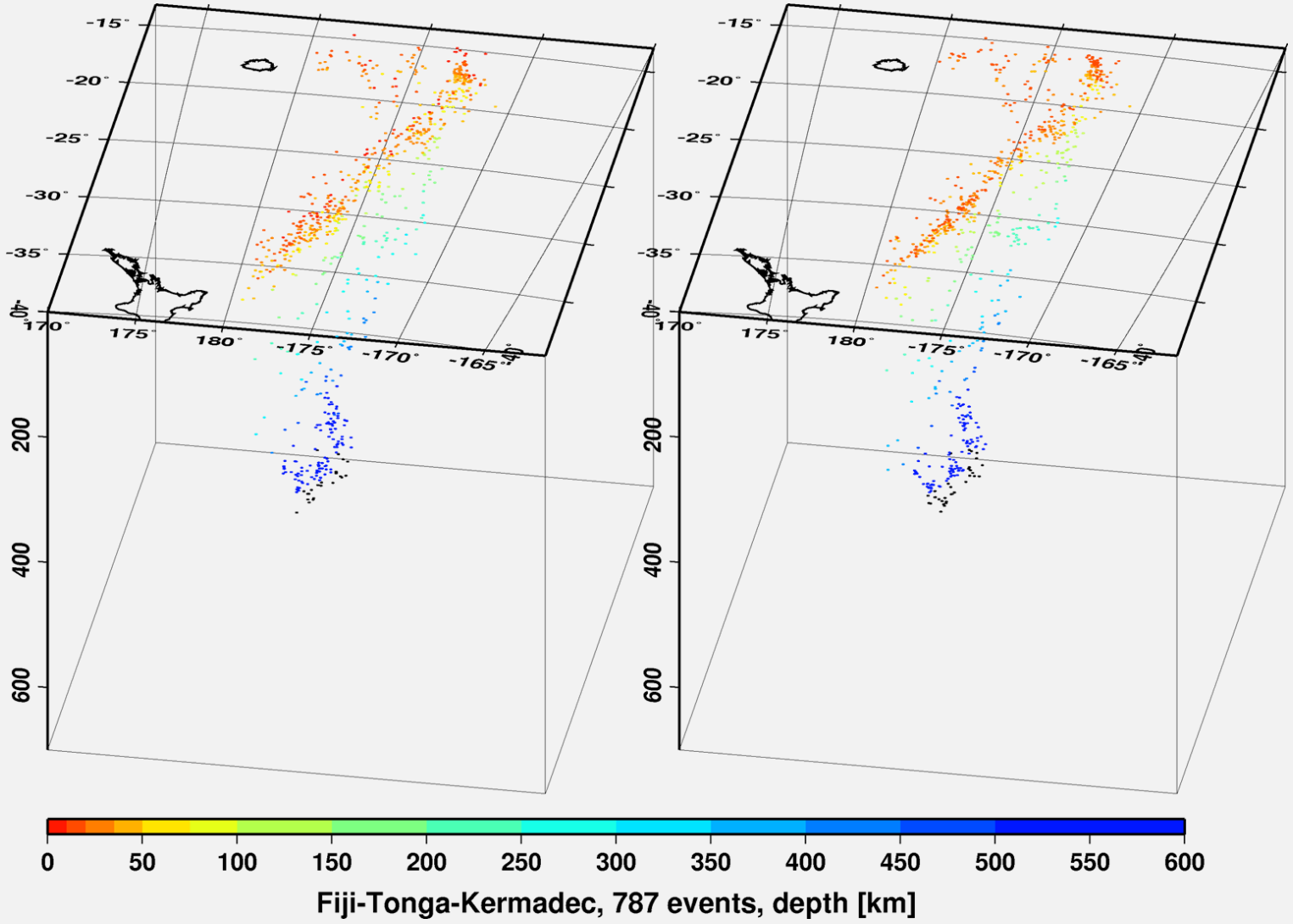



Difference in earthquake depth, km

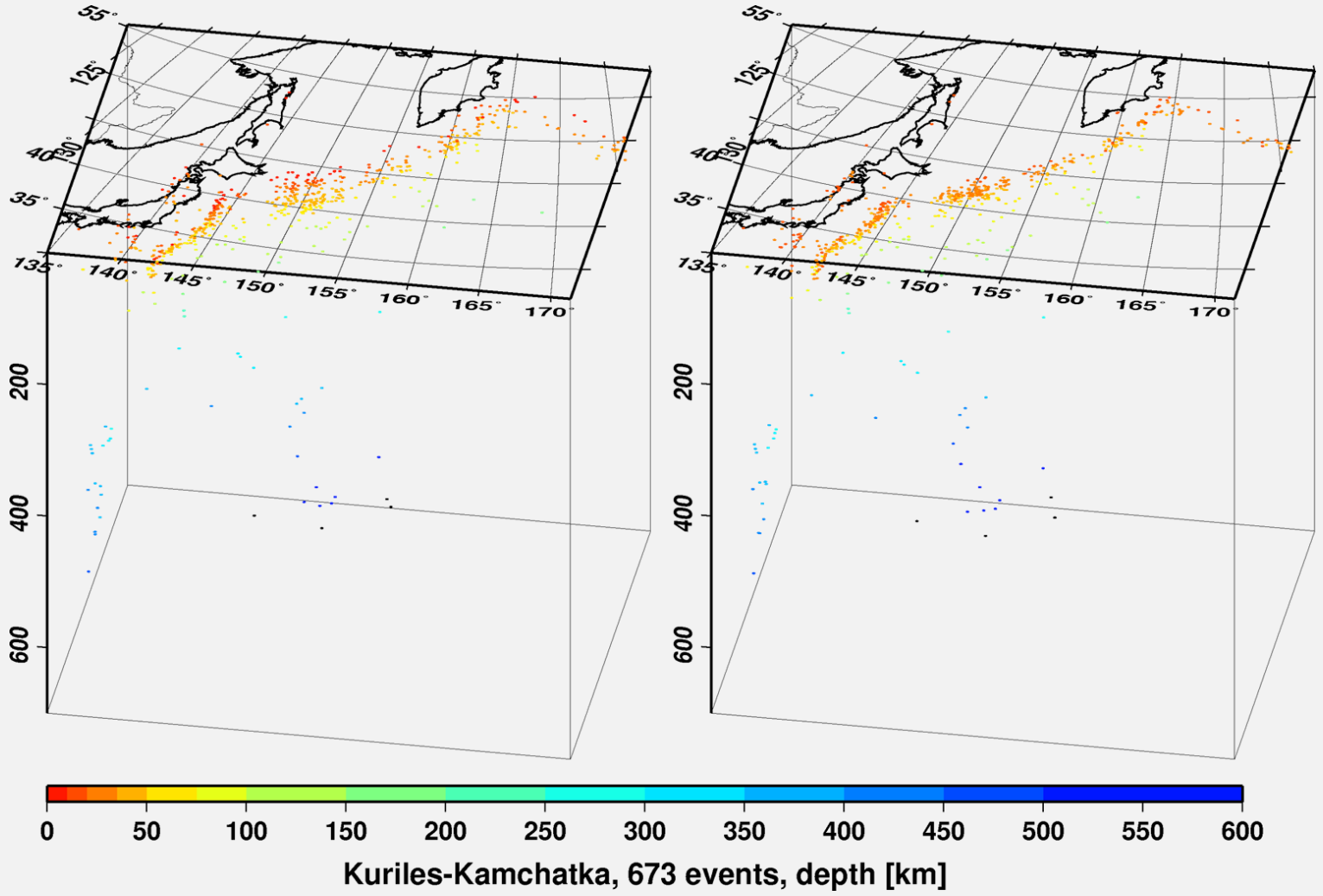



Difference in earthquake location, km

# Fiji-Tonga-Kermadec



# Kuril islands - Kamchatka



# Task 2: $M_S$ Computation

$M_S$ is to be computed based on amplitude & period measurements of surface waves recorded at seismic observatories around the world:

- ❑Already in the ISC database (1971-2009) and those
- ❑Collected from historical station bulletins as part of Task 3.

We shall provide:

- ✓magnitude uncertainties,
- ✓credible magnitudes based on several station measurements,
- ✓using Alfa-trimmed mean in averaging process,
- ✓recovering digitally available data that weren't used before,
- ✓magnitudes consistent with hypocentre solutions from Task 1.

ISC, Bormann

# Task 3: Processing of Historical Seismic Station Bulletins

Huge undertaking, mostly manual work, essential to all Tasks of the Project;

We concentrate on quality sources first and expand as the deadlines permit;

We shall preserve link between the data in the database and the scanned pages of historical bulletins.

## Identified & digitised for 1900-1970:

- ✓ Surface and body wave amplitudes
- ✓ Seismic wave arrival times

## Sources:

- ✓ ISC warehouse
- ✓ Gutenberg Notepads, provided by Prof. Abe
- ✓ Berkley & USGS collection [formerly known as "Willie's garage"]
- ✓ JMA collection, provided by Dr Hamada
- ✓ BGS collection
- ✓ SISMOS/INGV scanned collection
- ✓ Hamburg University collection

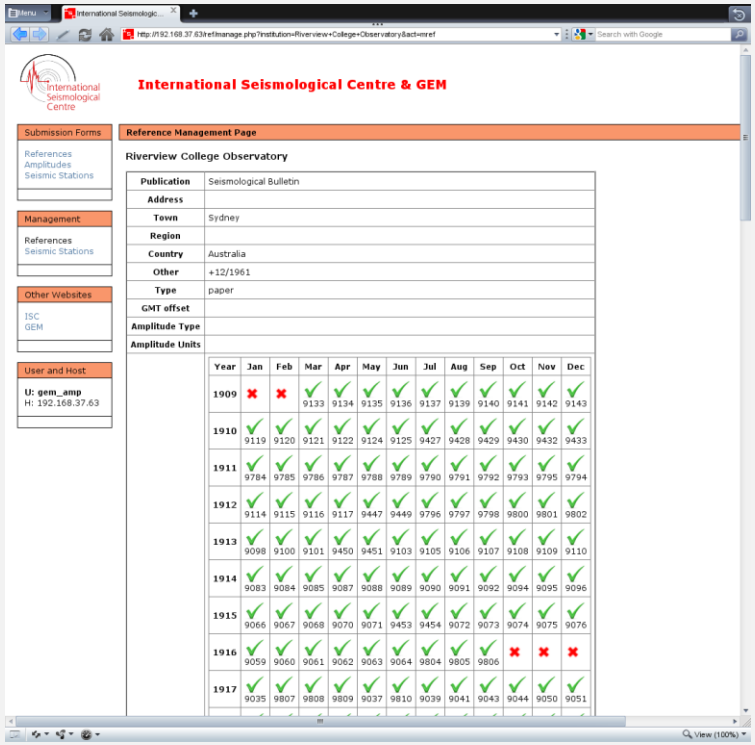
ISC, Villaseñor, Bormann & Lee

# T3: Historical bulletins at the ISC

Over many tens of years printed materials were received, processed and put away to storage in boxes in **chronological order**

To decide what observatory bulletins are most useful for GEM purposes we unpacked and sorted bulletins **per observatory**

# T3: Historical bulletins at the ISC




A browser-based software tool was designed, programmed and tested to assist the Data Entry staff in registering main parameters of each publication.

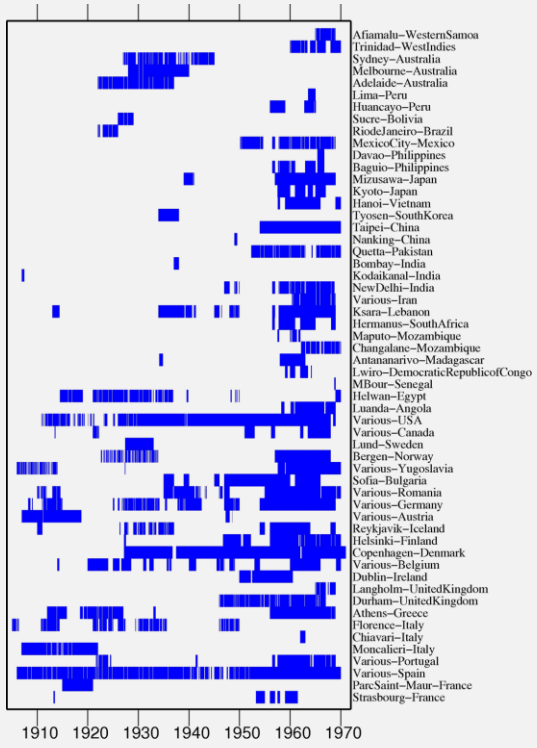
Availability, contents and quality of each publication over a long period of time were carefully reviewed by Seismologist

# T3: Historical bulletins at the ISC

As a result of Seismologist's review, all publications were subdivided into three groups:

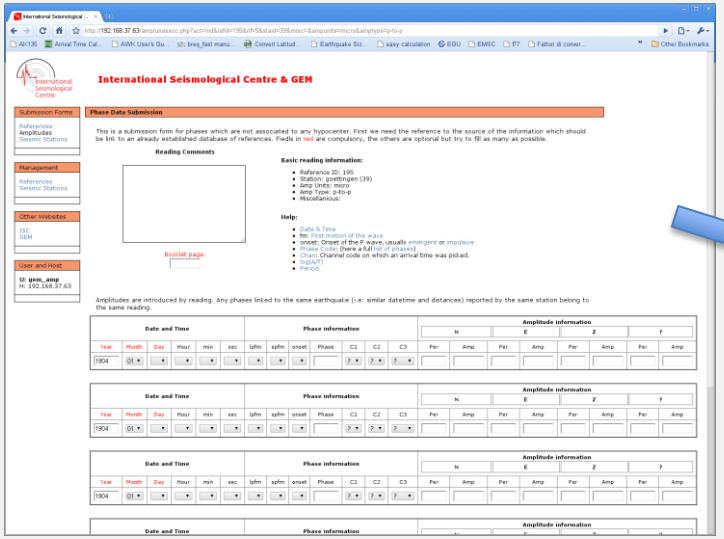
Most Useful – start entering


Useful, if funding permits

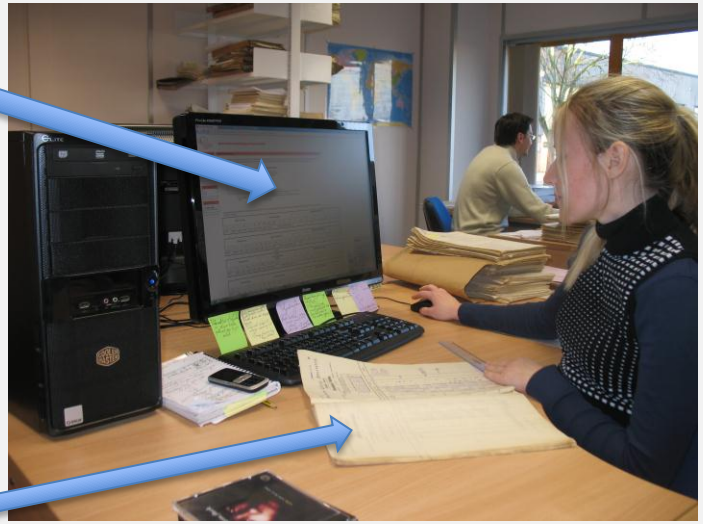


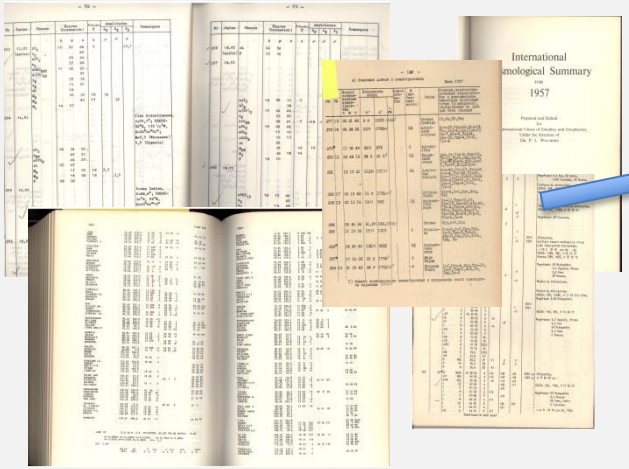

Not Useful – pack away

# T3: Historical bulletins at the ISC



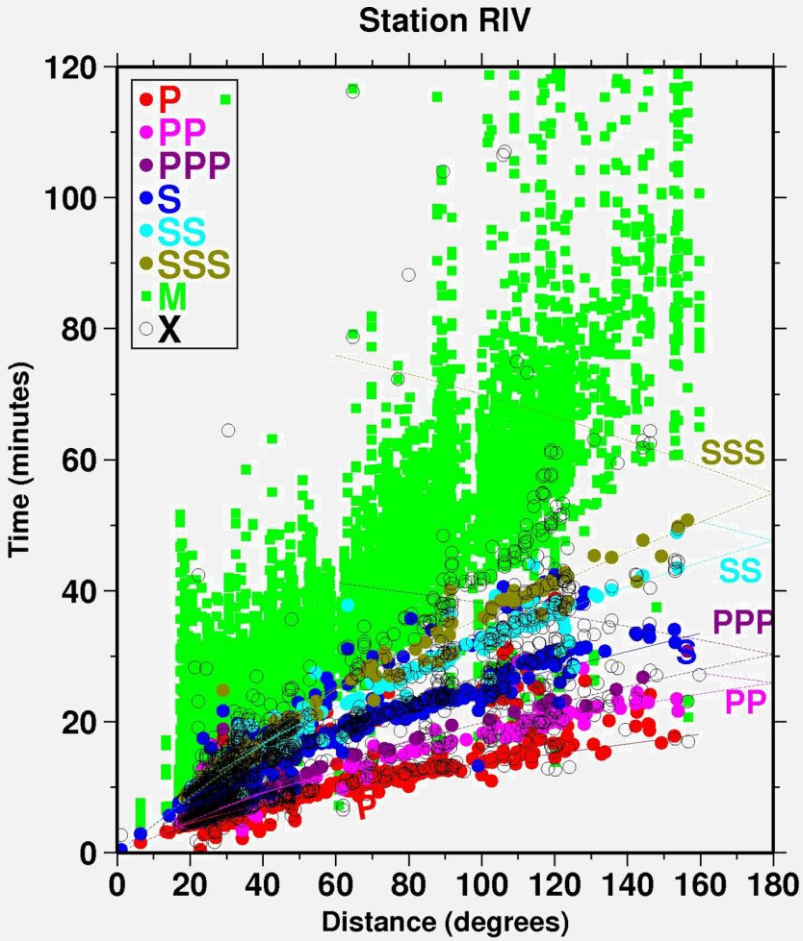

Software applications were developed to organise actual data entry into the database.

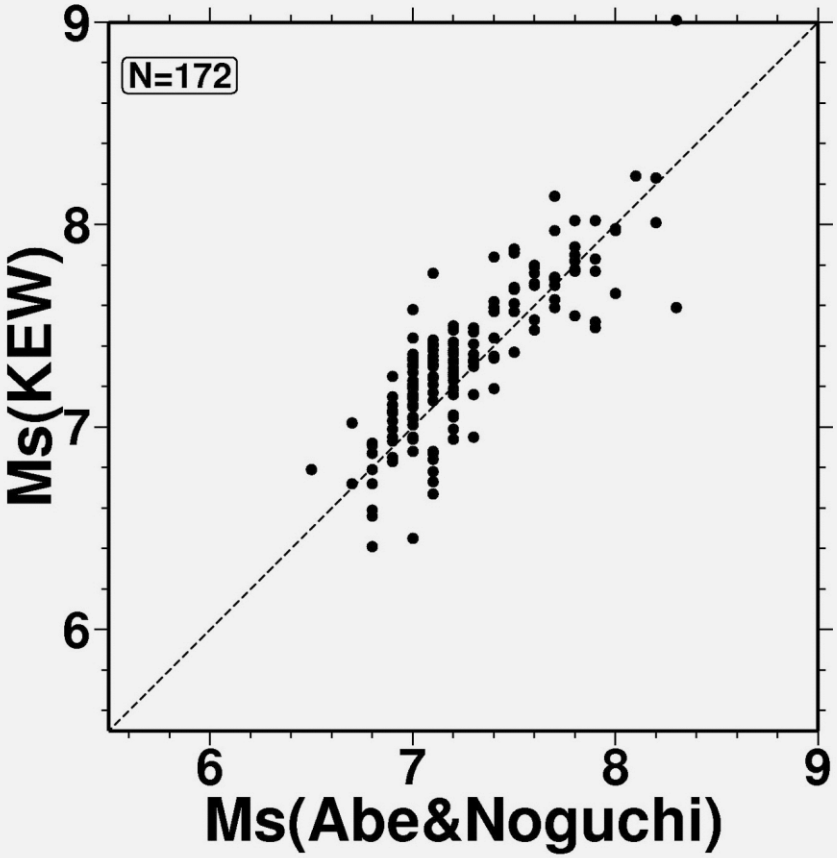





Data entry work started with two clerks working their way through selected publications under the guidance of seismologist. Three additional clerks were hired based on the first progress assessment.

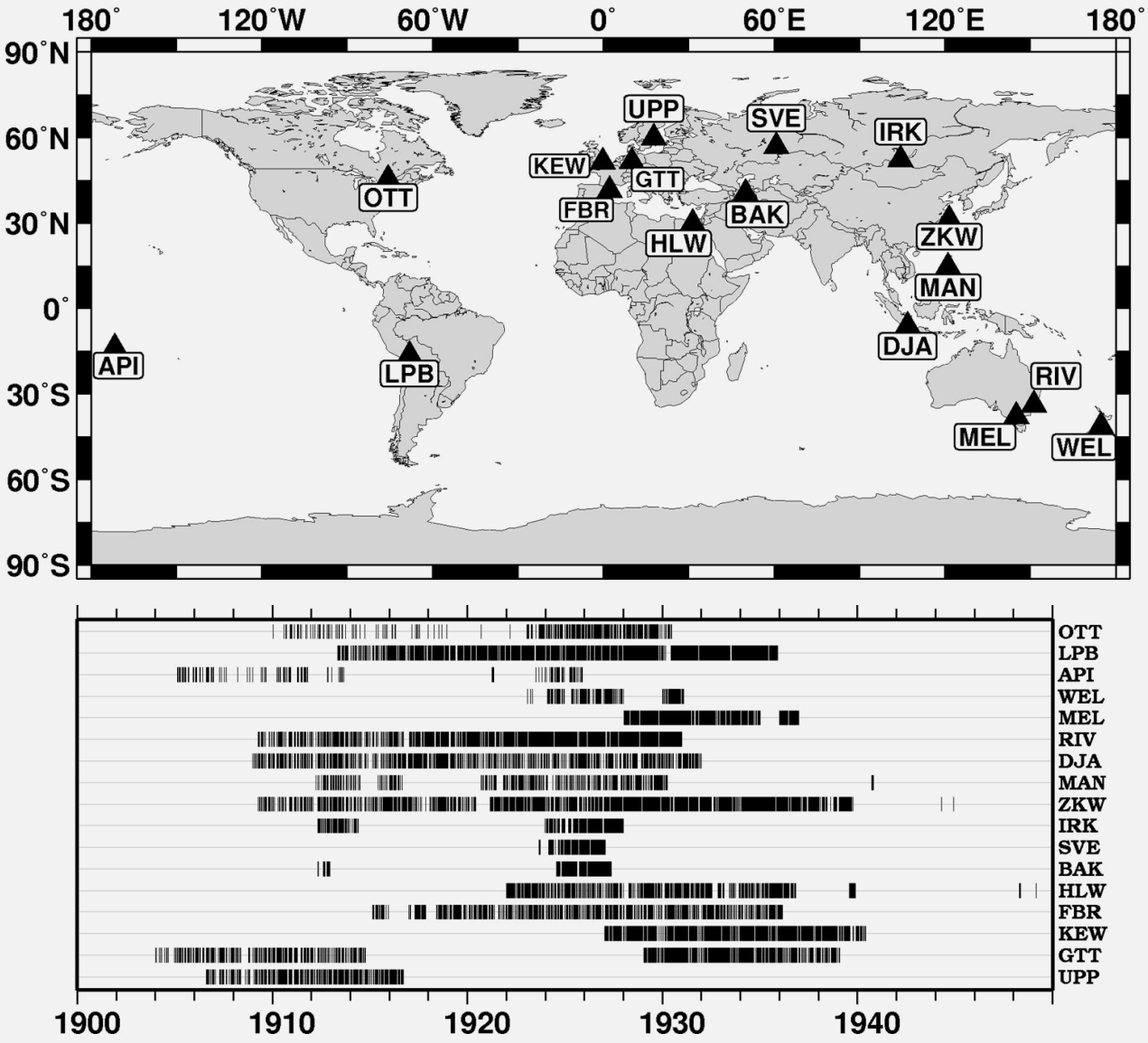
# Data checks




As data are entered into the database, seismologists make routine checks of new data usability by reviewing standard data plots such as travel-time plot for various seismic phases (left) and single station magnitude comparisons with credible sources (right).

# Quality Station Bulletins for 1904-1940




In order to get started with the relocation and magnitude re-estimation effort sooner, we initially limited the bulletin data entry work to the period before 1940.

Once finished, the data entry staff will start entering data for the period 1941-1971.

This will allow all members of the Team to simultaneously work on the project in order to finish in line with the deadlines.

# Task 4: $M_W$ Computation and Scientific Evaluation

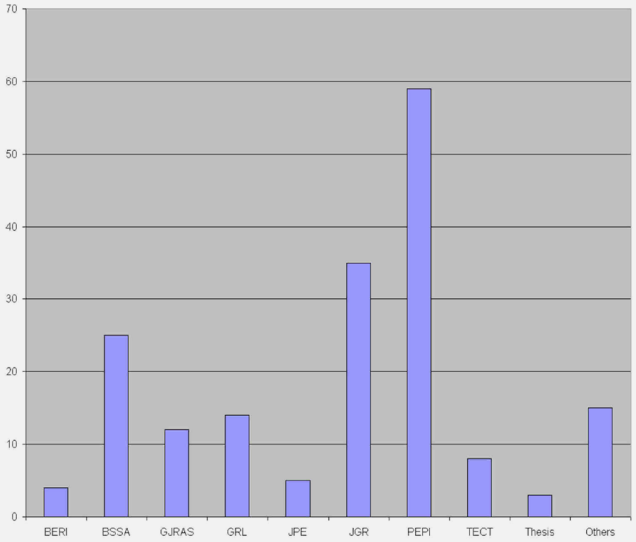
For each seismic event we shall provide
$M_w$ with uncertainty
via $M_o$ or
via $M_S$ or
via other magnitude types
using empirical relationships

We shall evaluate the catalogue's spatial and temporal completeness & thoroughly document all unavoidable temporal and spatial gaps

W. Lee,
P. Bormann,
ISC, IASPEI

# T4: $M_W$ Compilation

Whilst awaiting for surface wave amplitude data being entered in Task 3, we started with compilation of Mo/Mw data published in scientific literature for the largest earthquakes occurred prior to 1976 (start of GCMT project). So far, 182 publications have been processed that cover approximately 400 largest seismic events worldwide.




**BERI: Bull. Earthq. Res. Inst., Tokyo U.**

**BSSA: Bull. Seism. Soc. Am.**

**GJRAS: Geophys. J. Roy. Astron. Soc.**

**GRL: Geophys. Res. Lett.**

**JPE: J. Phys. Earth**

**JGR: J. Geophys. Res.**

**PEPI: Phys. Earth & Planet. Interior**

**TECT: Tectonophysics**

**Thesis: Ph.D. Thesis**

**Others: Other publication sources**

We are working with at least one other GEM Global component, the Active Fault Project, aiming to use the fault rupture data for ~100 more earthquakes to calculate $M_W$.

With the help from Columbia University we are hoping to complement the existing collection of $M_W$ from Global CMT project (1976 onwards) with estimates of $M_W$ uncertainties.

# Task 5: Data Integration, Management & Dissemination

The GEM Database is being put together based on the standard ISC schema; it will include:

- ✓ ISC Bulletin (1964-2009);
- ✓ ISS Bulletin (1918-1963);
- ✓ BAAS Bulletin (1913-1917);
- ✓ Gutenberg Notepads (Abe's adaptation) (1904-1917);
- ✓ Abe's catalogue (1900-1903);
- ✓ Arrival times, 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);
- ✓ JMA historical bulletin;
- ✓ $M_0$ and $M_W$ from scientific literature;
- ✓ GCMT magnitude uncertainties (1976-2009);
- ✓ Mw based on Active Fault Project's data.

# Task 6: Overall Project Management

Start-up **funding** from GEM was received by the ISC at the very end of April 2010 and **distributed** between participants; equipment purchased; work started.

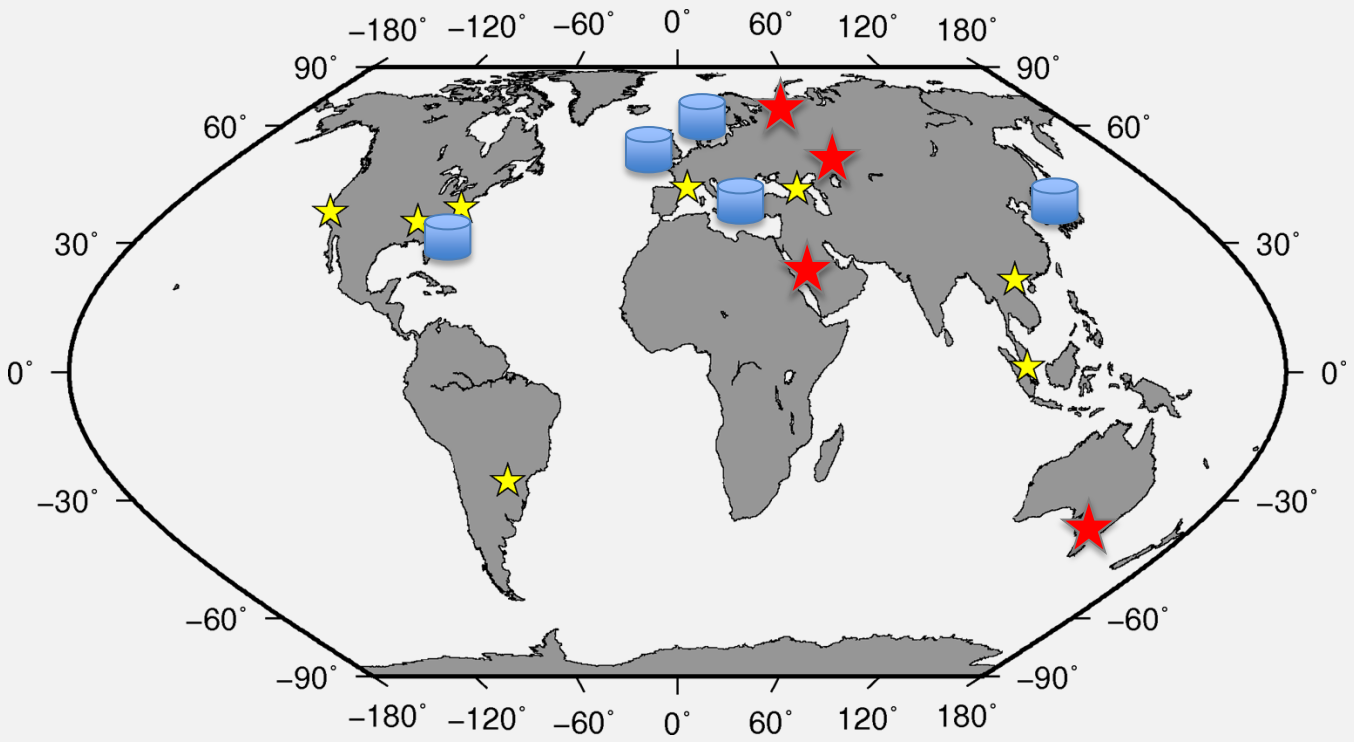
The **Kick-off meeting** of principle workers with the IASPEI observers on board was conducted on May 27-28, 2010 at the ISC with IASPEI observers present or following the meeting on-line.

Two members of the team worked at the ISC for several weeks

- First Annual **Reports** from Task Leaders received.
- The **next coordination meeting** is planned during the IUGG in 4 weeks.

ISC

# Project Outreach




- ✓ Establishing a wide recognition of the final GEM Global Reference Earthquake Catalogue among professionals in the field is one of the main goals of the project.
- ✓ We made a special effort (at no extra cost to the project) to popularise our work during a large number of international scientific gatherings around the world, sometimes in places that GEM hasn't reached yet.
- ✓ The Project developments are also monitored by the IASPEI observers.

# Summary

- ✓ The project has reached the mid-point;
- ✓ Good progress is achieved in all key Tasks;
- ✓ Healthy balance between the costs and value & quality of results is observed;
- ✓ Good communication within the International Team is maintained;
- ✓ Possibilities of collaboration with other GEM Global Hazard Components are explored;
- ✓ GEM Instrumental Catalogue development is widely popularised around the world;
- ✓ **We are on track to finish on time and produce the Catalogue that GEM would be able to consider as one of its flagship products.**


**Plus Willie Lee**







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