# ISC-GEM: Global Instrumental Earthquake Catalogue (1900-2009)
# I. Location and Seismicity Patterns

**S53A-2473**


**István Bondár[1], Bob Engdahl[2], Antonio Villaseñor[3] and Dmitry Storchak[1]**

[1]International Seismological Centre, istvan@isc.ac.uk
[2]University of Colorado at Boulder, Bob.Engdahl@colorado.edu
[3]Institute of Earth Sciences Jaume Almera, antonio@ictja.csic.es


## Objectives

One of the global components of the Global Earthquake Model Foundation (GEM) effort is to compile a Reference 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.

- Collect and digitize arrival and amplitude data from various data sources for the period 1900-1970;
- Relocate instrumentally recorded moderate to large earthquakes spanning 110 years of seismicity;
- Calculate body and surface wave magnitudes from original amplitude-period observations;
- Provide direct/indirect Mw estimates based on either seismic moment measurements, or empirical Ms-Mw or mb-Mw relations;
- Provide uncertainties for each estimated parameter.

## Data used for relocation

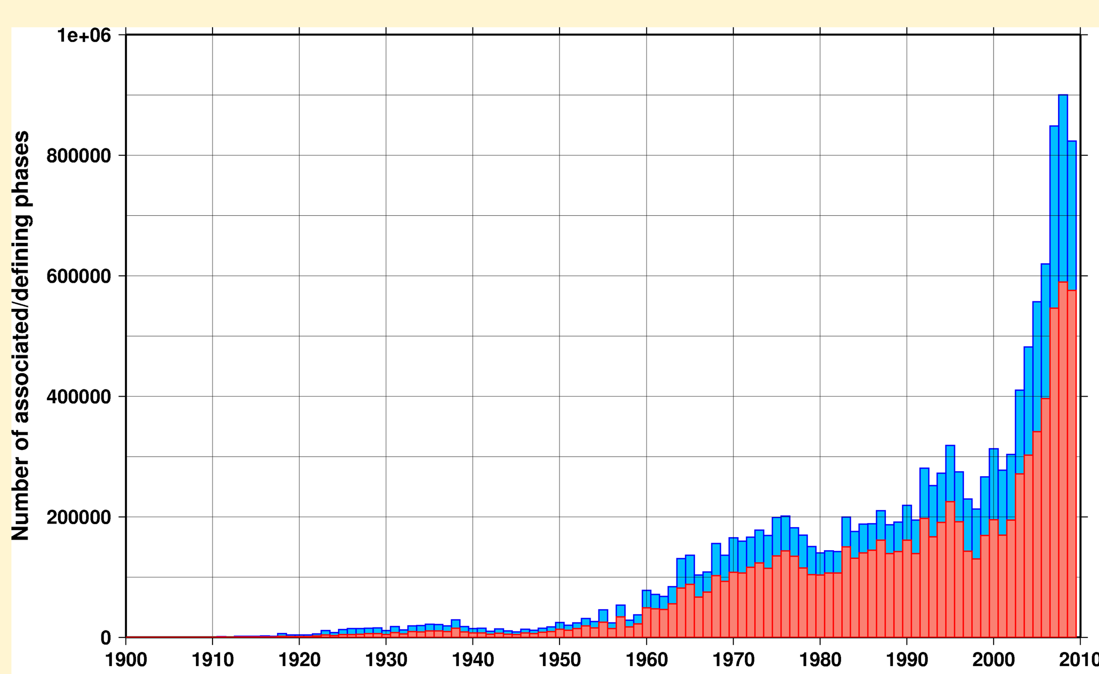
### Event selection

- 1900-1917: Ms ≥ 7.5 and some smaller shallow events in stable continental areas;
- 1918-1959: Ms ≥ 6.25;
- 1960-2009: Ms ≥ 5.5

### Phase arrival time data

- Manually added ~675,000 arrival picks 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 (~230,000 picks)
  - 1923-1970: JMA historical bulletin (~270,000 picks)
  - 1960-2009: ISS and ISC bulletin (330,000 + 11,000,000 picks from the ISC database)

| | 1904 | 1913 | 1918 | 1923 | 1942 | 1960 | 1964 | 1970 | 2009 |
|---|---|---|---|---|---|---|---|---|---|
| Station bulletins | 270,000 | | | | | | | | |
| Gutenberg/ISA | 1,900 | | | | | | | | |
| BAAS | | 3,800 | | | | | | | |
| ISS | | | 400,000 | | | | | | |
| Shannon tapes | | | 230,000 | | | | | | |
| JMA | | | | 270,000 | | | | | |
| ISS | | | | | | 330,000 | | | |
| ISC | | | | | | | 11,000,000 | | |

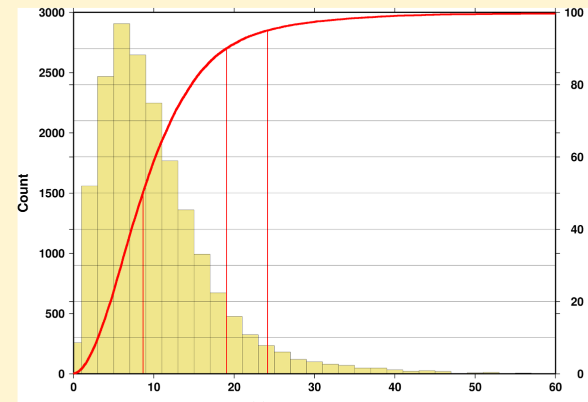


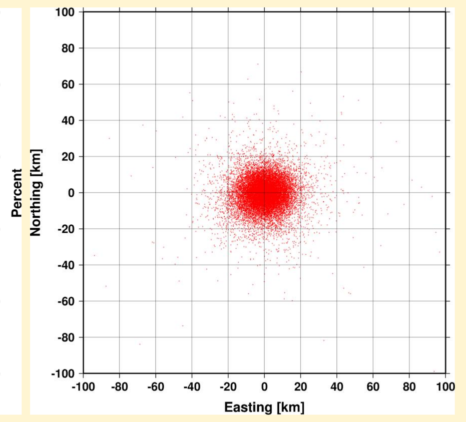

The number of associated phases (blue) and the number of defining phases (those that used in the location; red) increase exponentially with time in the ISC-GEM bulletin.

## Location methodology

All events are located using a two-tier procedure that provides the necessary quality assurance to produce highly accurate event 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



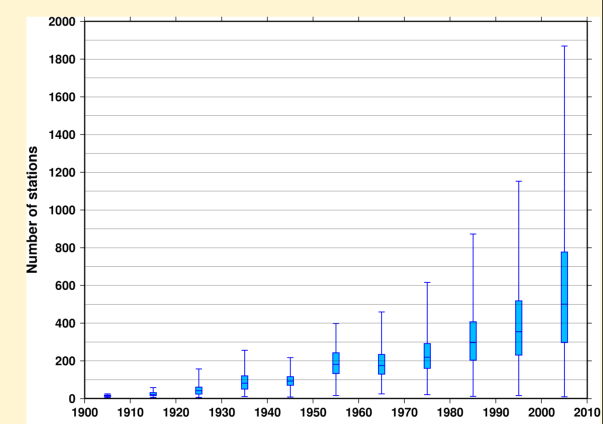



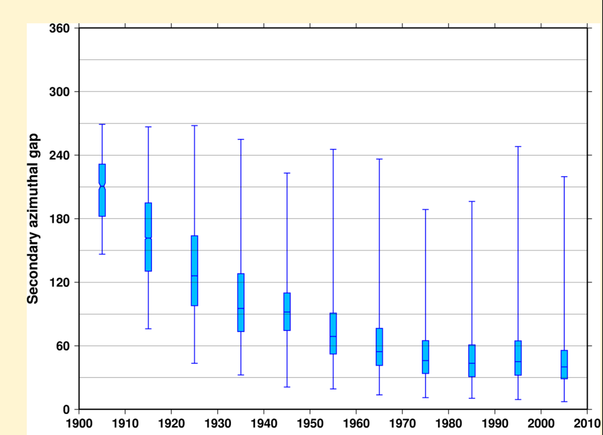

The distribution of the distances between the hypocenters obtained by the EHB and ISC methodologies show remarkable consistency. The median distance between the EHB and ISC solutions is 9 km, and 90% of the locations are within 20 km of each other. The deviations between EHB and ISC locations show no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

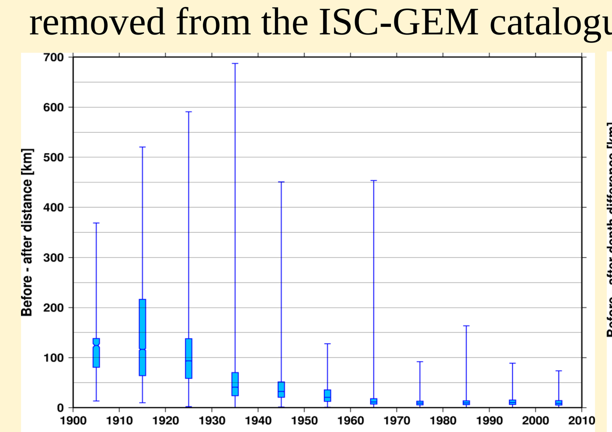
Unsurprisingly, the median number of stations used in the location increases in each decade. Note that although no substantial amount of new phase data were acquired for the modern period (1964-2009), the number of phases used in the location has still increased by 3 million, owing to the fact that both the EHB and ISC locators use most phases with a valid *ak135* (Kennett, Engdahl and Buland, 1995) travel-time prediction to locate an event.

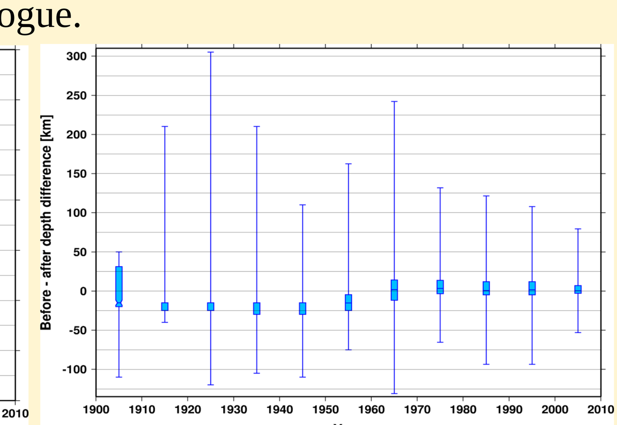
The secondary azimuthal gap (the largest azimuthal gap when one station is removed from the network) decreases with time, and the median secondary azimuthal gap levels off at about 90° after 1970.

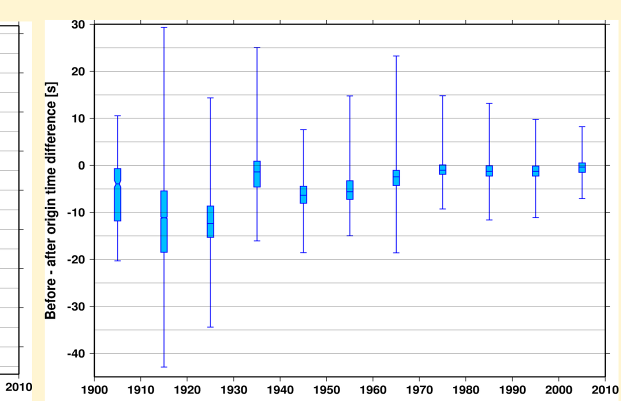
Thus, we expect the largest location improvements in the first half of the 20th century. The preferred locations before the ISC-GEM project constituted a mixture of locations from the Abe (Abe, 1981, 1984; Abe and Noguchi, 1983), the Centennial (Engdahl and Villaseñor, 2002), the ISS (Villaseñor and Engdahl, 2005; 2007) and the ISC catalogues. Below we compare these locations (before) to the ISC-GEM locations (after). The median location difference in the first three decades is about 100 km but it gradually decreases to about 10 km in the modern period. The apparent bias in the depth and origin time differences in the first six decades is due to the fact that in the historical period many event depths were fixed to the surface; owing to better depth estimates, this artifact is removed from the ISC-GEM catalogue.



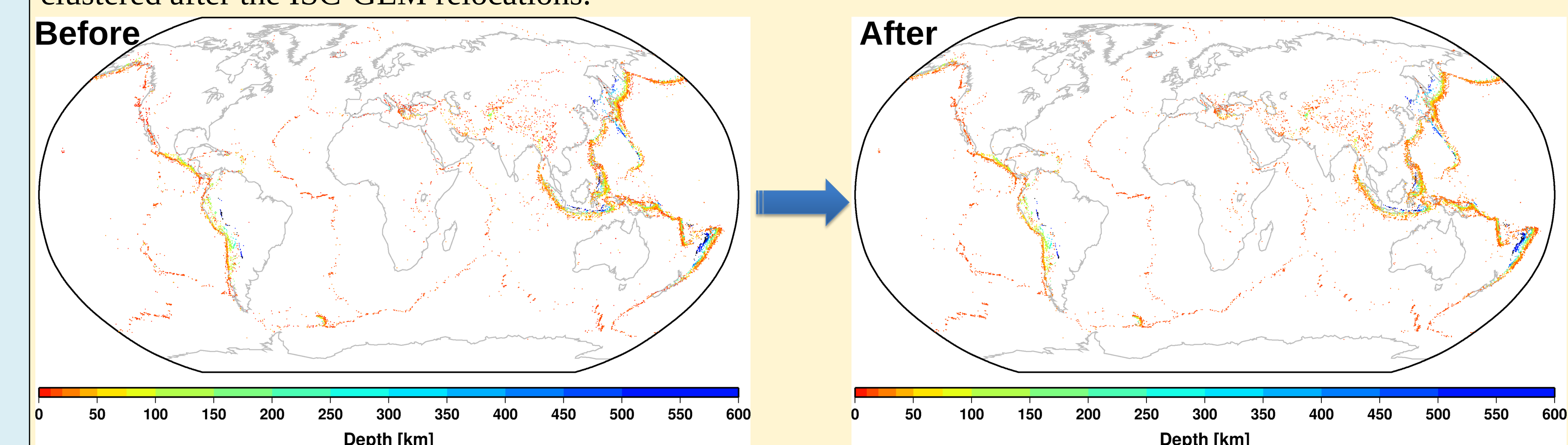




## References

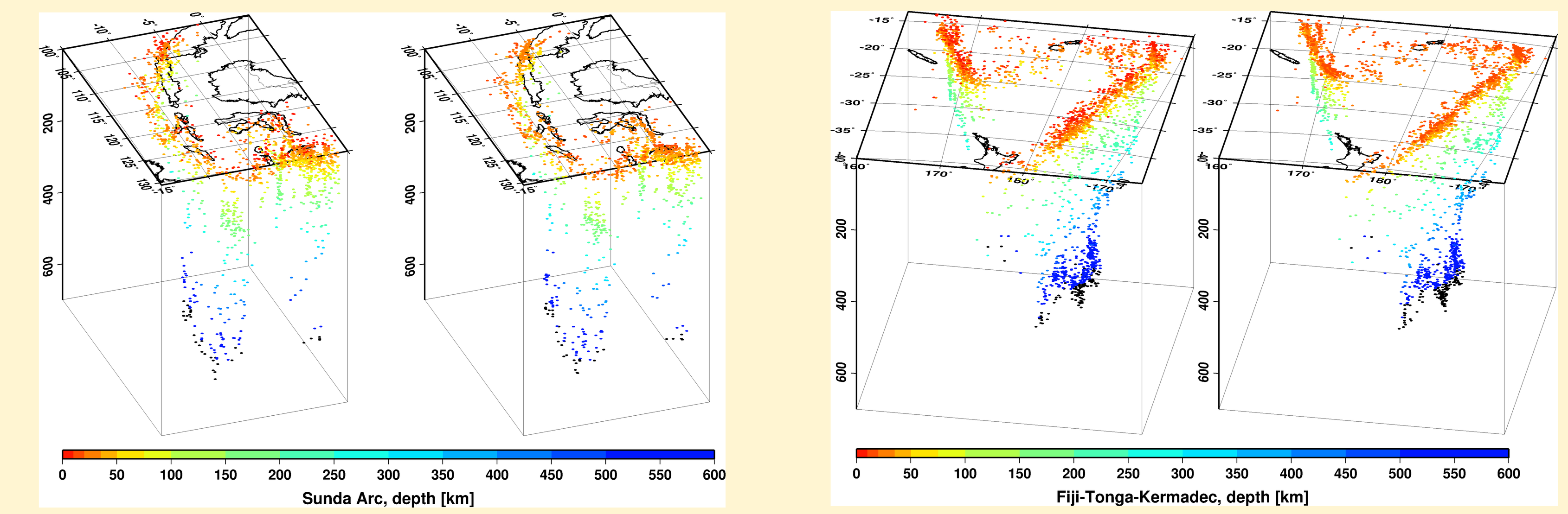

Abe, K., 1981, Magnitudes of large shallow earthquakes from 1904 to 1980, Phys. Earth Planet. Int., 27, 72-92.
Abe, K. and S. Noguchi, 1983, Revision of magnitudes of large shallow earthquakes 1897 – 1912, *Phys. Earth Planet. Int.*, **33**, 1-11.
Abe, K., 1984, Complements to "Magnitudes of large shallow earthquakes from 1904 to 1983", *Phys. Earth Planet. Int.*, **34**, 17-23.
Bondár, I., and D. Storchak, Improved location procedures at the International Seismological Centre, 2011, *Geophys. J. Int.*, **186**, 1220-1244.
Engdahl, E.R., R. van der Hilst, and R. Buland, 1998. Global teleseismic earthquake relocation with improved travel times and procedures for depth determination, *Bull. Seism. Soc. Am.*, **88,** 722-743.
Engdahl, E.R., and A. Villaseñor, Global Seismicity: 1900–1999, in W.H.K. Lee, H. Kanamori, P.C. Jennings, and C. Kisslinger (editors), *International Handbook of Earthquake and Engineering Seismology*, Part A, Chapter 41, 665–690, *Academic Press*, 2002.
Kennett, B.L.N., E.R. Engdahl, and R. Buland, 1995. Constraints on seismic velocities in the Earth from traveltimes, *Geophys. J. Int.*, **122**, 108-124.
Murphy, J.R. and B.W. Barker, 2006. Improved focal-depth determination through automated identification of the seismic depth phases pP and sP, *Bull. Seism. Soc. Am.*, **96,** 1213-1229.
Villaseñor, A. and E.R. Engdahl, 2005. A digital hypocenter catalog for the International Seismological Summary, *Seism. Res. Let.*, **76,** 554-559.
Villaseñor, A. and E.R. Engdahl, 2007. Systematic relocation of early instrumental seismicity: Earthquakes in the International Seismological Summary for 1960-1963, *Bull. Seism. Soc. Am.*, **97,** 1820-1832.


## ISC-GEM Catalogue

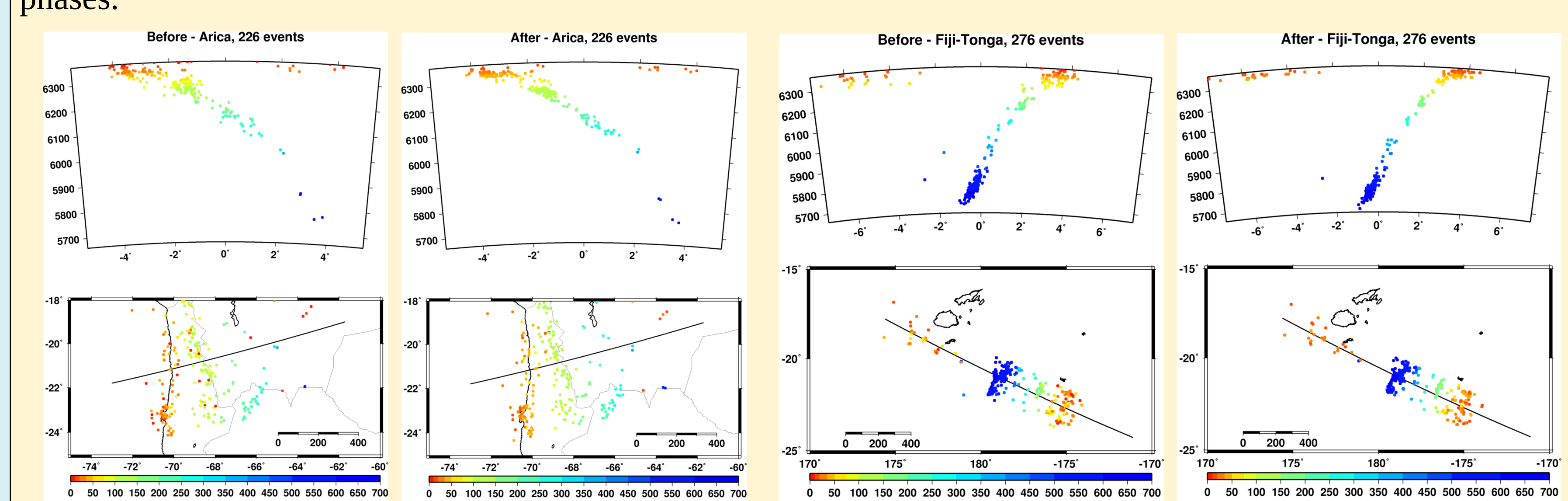
Global map of preferred solutions (a mixture of hypocenters from the ISC, ISS, Centennial catalogues) before the ISC-GEM relocations (left), and the relocated ISC-GEM hypocenters (right). The event locations are better clustered after the ISC-GEM relocations.




Three-dimensional seismicity maps for Indonesia and the Fiji-Tonga-Kermadec Islands regions before (left) and after (right) the ISC-GEM relocations. Owing to the ISC-GEM location procedures and to the substantial increase in the volume of observational data used in the relocations, the ISC-GEM catalogue offers an improved view of the seismicity of the Earth with significantly better depth estimates and considerably reduced scatter in location estimates.




Map view and cross-sections before and after the ISC-GEM relocations in the Arica, Peru and the Fiji-Tonga regions. The subducting slabs are better resolved in the ISC-GEM catalogue. Note that the apparent deep outlier in the Tonga cross section is an event from 1986 with well-determined depth confirmed by long-period depth phases.




## Summary

- The ISC-GEM main catalogue consists of 18,871 events with ~13 million associated phases
  - All events (except for 10 events between1900-1903) are relocated
  - Ms and mb magnitudes are calculated from original amplitude-period measurements
  - Each event is characterized by a direct/indirect estimate of 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 January 15, 2013 at the ISC website, www.isc.ac.uk, or at the ISC mirror at the IRIS website, http://isc-mirror.iris.washington.edu.