The Guide to Sustainable Networks: Configuring Networks and Processing Procedures to Optimise Seismic Event Parameterisation

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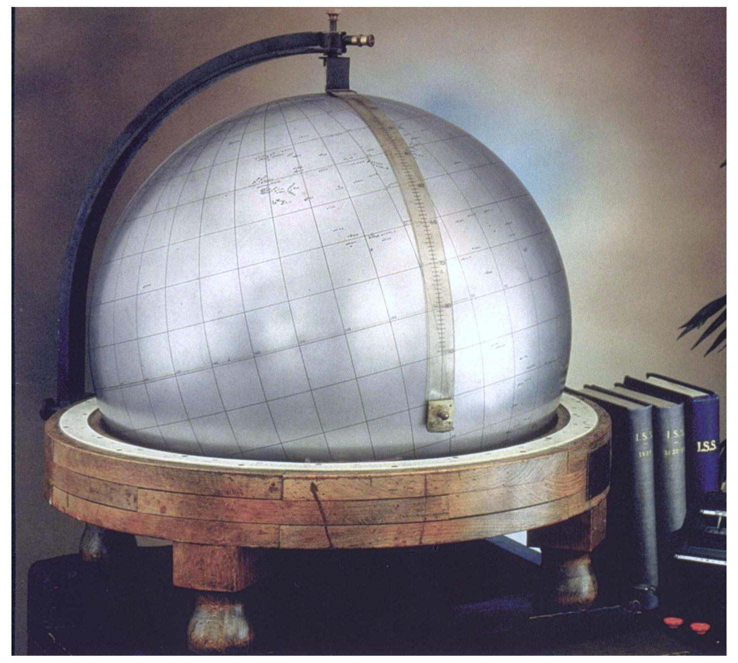


Introduction

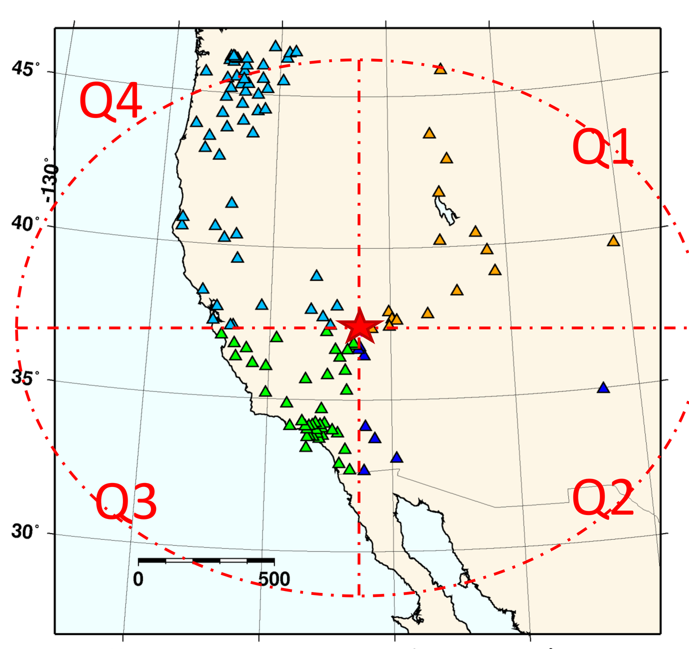
Building a sustainable seismographic network requires well-informed cooperation between commercial companies and the government or other agencies that will be responsible for funding and operating them. A guide that would inform about the advantages and challenges of building, operating and managing appropriate seismic networks is being planned by the International Development Seismology (IDS) Committee. The International Seismological Centre (ISC) is willing to take part in this project by bringing its expertise in managing, using and archiving the parametric data obtained from approximately 120 networks worldwide.

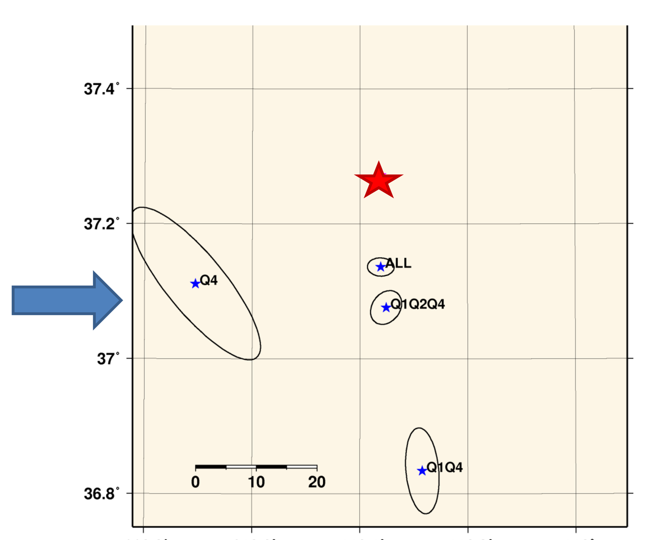
We plan to discuss the importance of a network's appropriate geometrical configuration, the value of three-component stations, the advantages of measuring the arrival times of useful seismic phases and taking appropriate amplitude measurements.

We also aim to discuss the importance of the data exchange on a regional scale and also internationally by bringing examples of successful data use when several networks' data are processed together. We will explain why registration of stations in the International Seismographic Station Registry is vital. We will show that in addition to serving local purposes, data of local seismic stations can contribute towards global long-term goals of improving our knowledge of the Earth's inner structure, monitoring compliance with Comprehensive Test Ban Treaty as well as providing further information for regional and global seismic hazard assessment studies.

Geometrical station configuration

It is well-known that in the ideal case the best location results can be achieved with the network that is equally distributed in azimuthal space and preferably has at least one station above the hypocentre.





The figure above illustrates a case of locating an event where the position is known within 1 kilometre by alternative means. Although this event was recorded by a rather extensive network of stations, we deliberately exclude stations in various combinations of quadrants to show the effect on event location with a standard location algorithm. In particular, the largest mis-location occurs when only stations of Q4 (light blue) or stations of Q1 and Q4 (light blue and yellow) are taken into account. Using stations within Q1, Q2 and Q4 makes the location closer to the reference, where using all four: Q1-4 achieves the best fit out of all.

It is well-known that in the ideal case the best location results can be achieved with a network that is equally distributed in azimuthal space and preferably has at least one station above the hypocentre. Nevertheless, in reality, there is always a good number of other considerations that one has to take into account when performing seismic station siting:

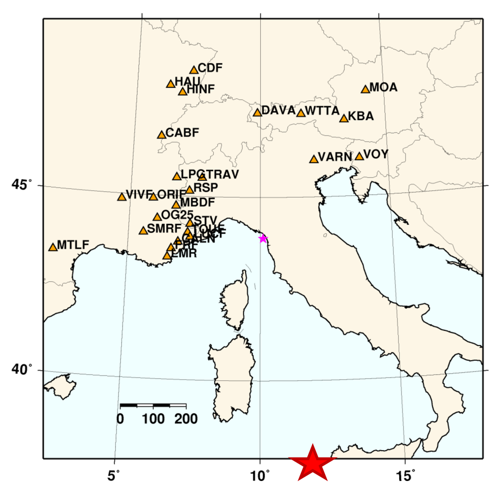
- *Political and administrative borders*
- *Coastlines*
- *Landscape*
- *Severity of climate*
- *Presence of bedrock on the surface*
- *Absence of highways, industrial plants and other sources of noise*
- *Equipment safety in remote/populated areas*
- *Availability of electric power*
- *Costs of service in remote areas*

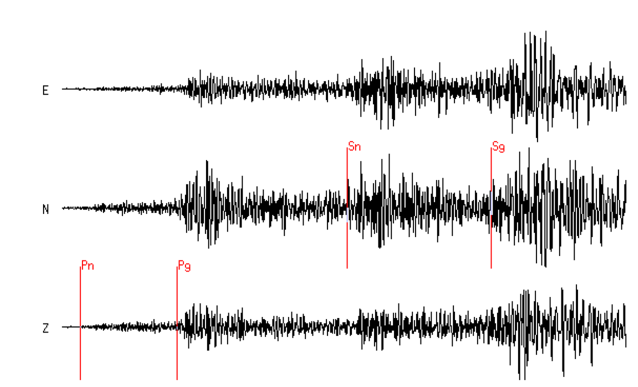
These constraints put severe constraints on station installation that often makes the final positioning of any seismic station in a network far from ideal. Nevertheless, aiming at surrounding potential seismic sources generally improves the location.

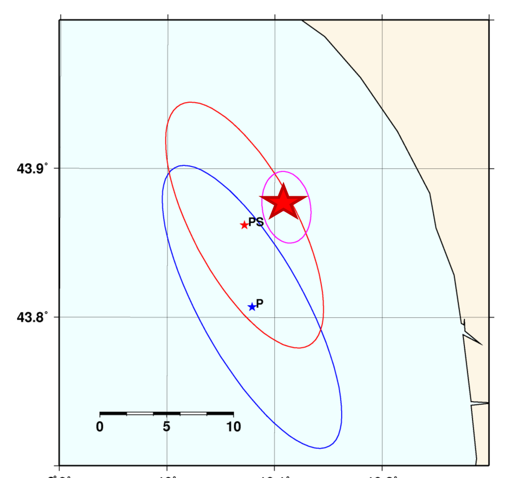
Aiming at waveform review / analysis

When planning a new network it is important for the costs of manual review/processing to be taken into account. It is too tempting to resort to applying automatic waveform analysis packages. Without manual review, the results often prove disappointing. The example below illustrates an importance of picking later seismic arrivals in addition to first arrivals. The automatic seismic phase pickers excelled at picking first onsets, yet secondary onsets are harder to pick reliably. In the case of a network with poor network configuration (for a valid reason), it is important for secondary phases to be picked correctly and used in the location. Simultaneous use of seismic waves with different apparent velocities simultaneously constrains the hypocentre better.

The hypocentre of the event below (red star) is known well thanks to the wealth of local and regional seismic networks in Southern Europe. We deliberately ignored all close stations as well as stations to the south of the hypocentre in order to simulate a rather common case of a network poorly configured with respect to an event.

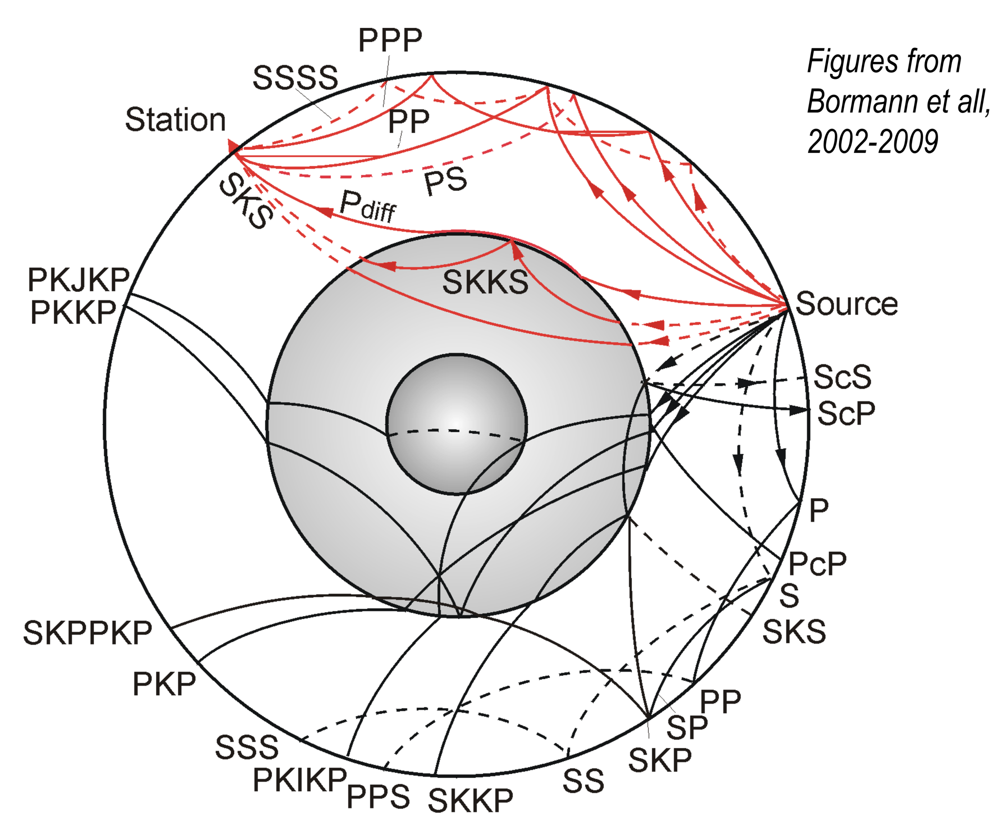




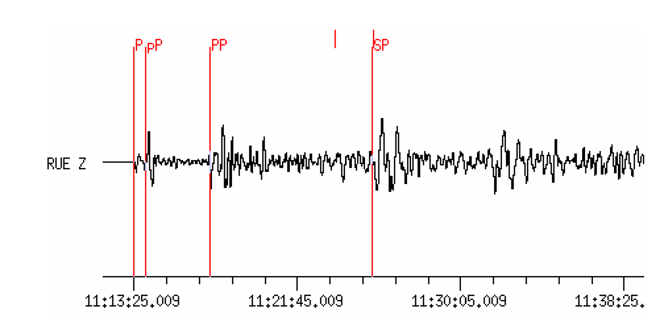


An automatic location that uses just the first P-type seismic arrivals would be further away from the reference as oppose to location that uses results of manual seismic phase pickings of both P- and S-type arrivals.

Further to that, the analysis of more distant event generally benefits from picking secondary teleseismic phases, especially the depth sensitive ones such as pP, sP, PcP etc. In the absence of nearby network (which is often the case), the event depth and origin time are the least constrained parameters. It is only by picking and correctly identifying these depth sensitive phases that the seismic event depth can be well constrained.



Figures from Bormann et all, 2002-2009



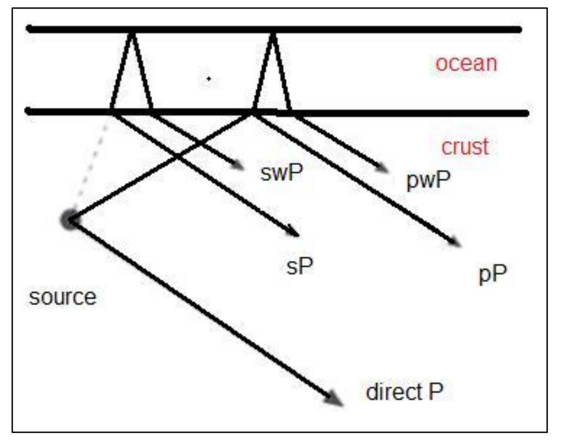
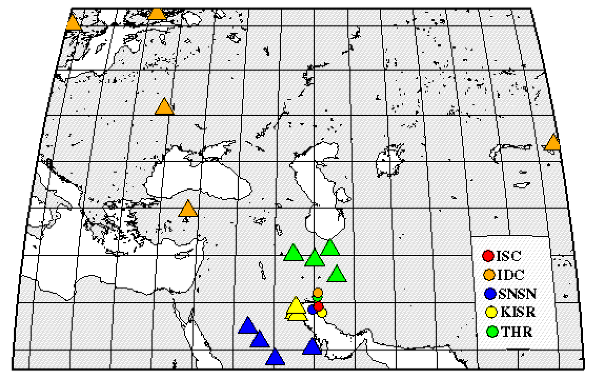


***Figure**. In the absence of very close seismic stations it helps to constrain the depth of seismic events using differential times of arrival of direct P wave and waves reflected from free crust or ocean surfaces.*

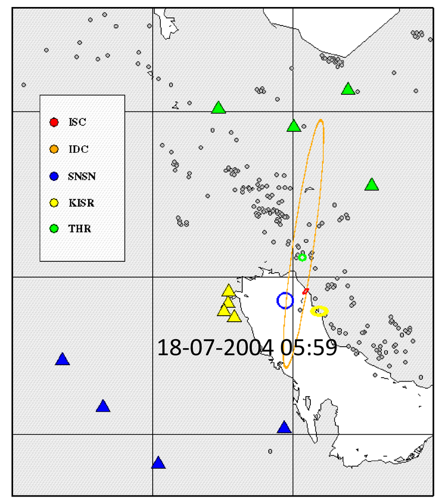
This poster is merely a first attempt to work on a particular chapter of the Manual. Since the work is in progress, none of this material is considered as final or definitive. In fact, during the work on this poster we realised that there will be a few more issues that will need to be addressed.
Cooperation with authors of other chapters would be useful to avoid duplication of material or lack of coverage of important topics.

Exchanging data with neighbouring networks

Due to many reasons explained above, national and regional seismic networks would often benefit from station data sharing between them. An example below relates to the Persian / Arabic Gulf area where several networks of Saudi Arabia, Kuwait, Iran, Oman, UAE, Yemen operate independently with infrequent communication.

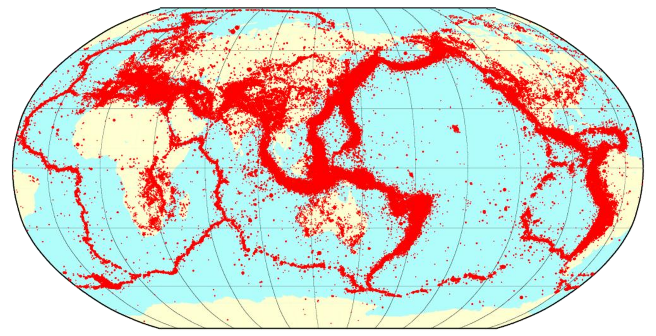


Agency	Discrepancy with ISC, km
THR (IIEES, Iran)	110
KISR (Kuwait)	89
SNSN (Saudi Arabia)	78
IDC (CTBTO)	155



Contributing to international data centres

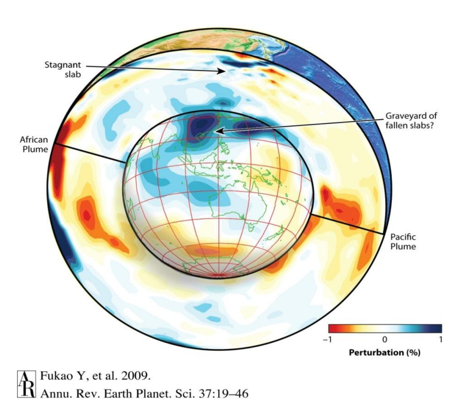
In addition to monitoring local seismicity, analysis of waveforms can greatly contribute to the work of national, regional and international data centres. In particular, the International Seismological Centre (ISC) had a mission of compiling the definitive global summary of seismic events since 60s.



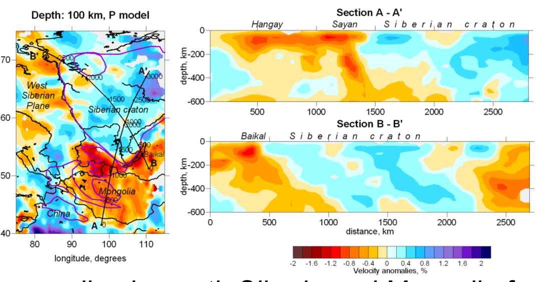
The ISC Bulletin is the longest continuous and uniform set of seismic event hypocentre solutions, moment tensors, magnitudes, felt and damage reports and station arrival information. To produce the Bulletin, the ISC receives parametric bulletin data for natural and non-natural seismic events from over 120 seismic networks worldwide.

***Figure.** ISC Bulletin epicentres for natural, induced and man-made seismic events 1960-2011.*

In turn, the ISC Bulletin remains a basis for a number of exciting research such as illustrated in just two examples below.



Stagnant slab is a subducted slab being trapped in the transition region between the upper and lower mantle. Tomographic images of stagnant slabs were first obtained using the ISC data (Fukao et al, 2009).

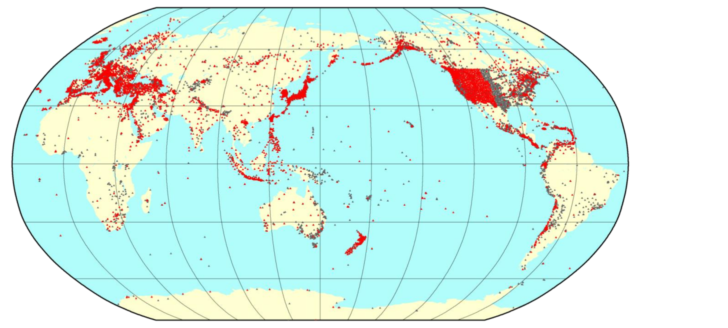


P velocity anomalies beneath Siberia and Mongolia from regional tomographic inversion of the ISC data presented at 100 km depth (left plot) and two vertical sections (Kulakov, 2008).

Registering your network and stations internationally

It is least time consuming yet rather important to register your network and stations in the International Seismographic Station Registry (**IR**) that is jointly run by the ISC and the World Data Center for Seismology, Denver (NEIC). Registration requires station name, position, altitude, depth of the instrument to be recorded and unique station code assigned to each site.

***Figure**. 16,606 stations, open or closed, are currently registered in the IR. 5445 (red) of these reported seismic arrival data to the ISC in 2008.*



References:

Bormann P., K. Klinge and S. Wendt 2002. Data Analysis and Seismogram Interpretation. In: New Manual of Seismological Observatory Practice (NMSOP), 2002-2009, Chapter 11.
Fukao, Y., M. Obayashi, T. Nakakuki and the Deep Slab Project Group, 2009. Stagnant Slab: A Review. Annual Review of Earth and Planetary Sciences, 37, 19-46.
Kulakov I., 2008. Upper mantle structure beneath southern Siberia and Mongolia, from regional seismic tomography, Russian Geology and Geophysics, 49, 3,187-196.