



# Strategies for the ISC development

## 2012-2015

### Introduction

The original document with a similar title covered the period of 2008-2011. That document received the approval of both the ISC Executive Committee and the Governing Council at their meetings in Cape Town in January 2009 and served as a mid-term development plan. While many items from that plan have been successfully implemented, some remain to be addressed.

Among the achievements are:

1. Introduction of the new earthquake location and magnitude determination algorithm;
2. Substantial improvement of the ISS/ISC Bulletin in its historical part (GEM);
3. Preparation of the Printed ISC Bulletin Summary;
4. Compilation of the preliminary on-line ISC Bulletin within days of event occurrence;
5. Providing selected data from the ISC Bulletin in specific formats to different user groups via the ISC web search tools;
6. Creating and running the ISC database and website mirrors and backup at the IRIS DMC in Seattle and at the ERI in Tokyo.

Development topics from the original plan that are still in progress include:

1. New International Seismic Network and Station Registry (ISNSR);
2. Interactive ISC Bulletin Analysis System (IBAS);
3. Rebuild of the entire ISC Bulletin (1964-2009);
4. Automatic waveform measurements to enhance the ISC Bulletin.

This document is setting the strategies for the next four years between 2012 and 2015 by summarising the items in progress and adding new relevant directives. It is offered for discussion at the ISC Executive Committee during its meeting in Thatcham on June 17-18, 2012. It will then be distributed to the ISC Governing Council in preparation for their meeting in July 2013 in Gothenburg, Sweden.

It is our intention to update this document every two years.

The current financial situation at the ISC is stable. As the result of successful work on additional projects over the past four years, appropriate funds have been accumulated at the ISC to pay for further development without a need to increase membership fees beyond inflation. The general world economic outlook in the middle of year 2012 is still not bright. Governmental and research funding agencies are concentrating on funding the core projects, prioritising their spending and saving on services that are not in high demand. It is especially important in this situation to continue

development of the Centre to ensure that the ISC services and products remain an important requirement for geophysical research.

## Summary

During 2012-2015, the ISC development shall be focused on the following major tasks. These tasks include both the improvement of existing operational procedures as well as creating new ISC products and services:

1. Perfecting and enlarging the acquisition of **preliminary and revised** bulletin data from seismic monitoring agencies worldwide;
2. **Rebuilding** the original ISC **Bulletin** (1964-2009);
3. Extending the ISC Bulletin to the **early instrumental period**: 1900 onwards;
4. Developing the **Interactive ISC Bulletin Analysis System** (IBAS);
5. Setting up the International Seismic **Network** and **Station Registry** (ISNSR), jointly with NEIC;
6. Developing and putting into operation a new advanced **database schema** and bulletin format;
7. Advancing the ISC **web services**;
8. Establishing **automatic** procedures to build a consistent set of specific **waveform measurements** to improve the accuracy of the ISC Bulletin;
9. Advancing the **ISC location** procedures;
10. Improving the **GT** dataset, jointly with the IASPEI and CTBTO;
11. Improving the automatic procedures to take **shear wave splitting** measurements from waveforms;
12. Setting up an interactive **Bibliography** of scientific articles related to specific ISC Bulletin events.

These tasks are described below in greater detail.

### 1. Perfecting and enlarging the acquisition of preliminary and revised bulletin data from seismic monitoring agencies worldwide

The ISC database remains one of the most comprehensive collections of reviewed parametric data. Yet this collection requires improvement in many areas.

- The completeness of the ISC data collection varies dramatically around the globe.
  - The ISC shall continue its efforts to improve collection from both new and established networks in Africa, South America and South East Asia;
  - Institutions operating ocean-bottom networks shall be invited to produce and contribute bulletin data to the ISC.
  - Further attention shall be given to networks with artificially restricted bulletin data reporting.
- The ISC shall encourage data contributors to provide uncertainties for all types of submitted information.
- Reporting of information conforming to IASPEI standards shall be encouraged.
- The ISC shall consider collecting additional types of parametric data. Examples include: finite source rupture models, information on the quality of onset time picking, event type etc. The ISC will need to take part in a collaborative worldwide effort to define how this information should be determined and reported.

- A large number of agencies worldwide have moved towards issuing preliminary seismic event solutions based on automatic picking of first arrivals followed by a seismologist's review. Currently the ISC collects these preliminary data from only 26 out of 130 agencies that contribute the revised bulletins to the ISC. These data form the basis for the ISC Preliminary Bulletin that is available from the website soon after earthquakes occur. The ISC shall encourage all of its reporting agencies to start sending the preliminary bulletin data prior to their revised analysis.

## **2. Rebuilding the original ISC Bulletin (1964-2009)**

The project of rebuilding the original ISC Bulletin (1964-2009) began in 2010, prompted by the introduction of the *ak135* velocity model (in data year 2006, to replace the JB model) and then the new location algorithm (in data year 2009) into the ISC operation. In addition to relocation and magnitude recomputation of all events, this project includes essential quality control and rectification of errors and inconsistencies, especially in the early ISC years, as well as the introduction of a good number of currently missing datasets from both permanent and temporary networks.

In addition to providing a consistent set of ISC locations, based on the same location technique and velocity model, this project will provide a set of consistent and homogeneous uncertainties of both location and magnitude estimates throughout the entire period.

## **3. Extending ISC Bulletin to the early instrumental period: 1900 onwards**

Preparation of the GEM Global Reference Instrumental Earthquake Catalogue (1900-2009) is a major step forward towards providing better services to researchers involved in studies of seismic hazard and risk as well as seismic engineers and scientists involved in earthquake prediction. The following steps appear necessary to build upon this effort:

- When included in the ISC Bulletin, this tremendously important dataset will effectively increase the time span of the ISC Bulletin to more than a century compared to the original 47 years, providing consistent homogeneous magnitude estimates and locations of large earthquakes worldwide over a 110 year period.
- The cut-off magnitudes for earthquakes in the early instrumental areas are comparatively high as they were set based on the available funding and the deadline given by the GEM Foundation. These cut-off magnitudes should be lowered, especially in 1900-1917, with many more parametrical data extracted from the paper-based sources such as the BAAS, ISS, Gutenberg Notepads and individual historical station bulletins. Historical bulletin collections at the British Geological Survey, Hamburg University, SISMOS project at INGV should also be searched for useful paper-based and digitally scanned documents.
- Additional effort in recovery of surface and body wave amplitudes and periods from historical observatory bulletins in the 1970s shall complement the original ISC data collection done at the challenging time when the first  $M_S$  computation procedures were introduced at the ISC.
- The ISC Bulletin would benefit from the standard review of all earthquakes prior to 1964 by the ISC analysts.
- Continuation of the scientific literature search, started during GEM project, shall make many more determinations of  $M_o$  and  $M_w$  accessible for large earthquakes of the 20th century.

#### **4. Developing the Interactive ISC Bulletin Analysis System (IBAS)**

The ISC Bulletin Review is the most fundamental yet highly resource-consuming task that the ISC performs. Although the ISC analysts adjust only ~5% of the data, it is their analysis that makes the ISC Bulletin a trustworthy source of worldwide earthquake bulletin data. With constant improvement of existing seismic networks and the installation of new ones, the amount of seismic arrival data has grown dramatically over the recent ten years. This continuing increase threatens the viability of existing bulletin analysis currently performed using paper-based listings equipped with bar codes.

In order to be able to cope with this hike in data volume without the need to employ a progressively large number of analysts, the ISC needs to develop a new Interactive Bulletin Analysis System (IBAS) that will feature:

- screen-based analysis that uses a graphical representation of bulletin information as opposed to the current use of plain script listings of all available information;
- instant database update;
- pre- and post-analysis quality control (QC), marking items requiring an analyst's attention;
- high level review of those events that passed the QC;
- full review of remaining events with analysis of automatically marked outliers as opposed to the review of the entire set of station reports;
- separate review of significant earthquake sequences;
- two pass system with a first review by individual analysts followed by additional review by senior analysts.

A future version of IBAS shall feature an occasional access to waveforms, temporarily stored at the ISC.

#### **5. Setting up the International Seismic Station and Network Registry (ISNSR), jointly with NEIC**

The International Seismic Network and Station Registry (ISNSR) will act as a successor to the original International Seismographic Station Registry (IR) that has been jointly maintained by the ISC and NEIC for many decades. The design of ISNSR was developed under the IASPEI Commission on Seismological Observation and Interpretation (CoSOI), discussed by the FDSN and approved by the IASPEI during its Scientific Assembly in Cape Town, 2009.

The new coding standards will necessitate a significant revision in the role and operation of the international station registry. The ISC and the NEIC, in close co-operation, will continue to act as the central authority for collecting, organizing, and distributing basic seismic station information (e.g., coordinates, owners, operator(s), etc. This will include tools supporting the simultaneous use of parametric and waveform data (e.g., providing the correspondence between the new coding standard and FDSN nomenclature).

The location of seismic instrumentation shall be designated by the four fields: *Agency.Deployment.Station.Location*. Agencies, deployments, stations, locations, and channels shall be defined in discrete time periods called epochs. Agency codes shall be centrally assigned (i.e., guaranteed to be globally unique by the International Registry). Deployment codes and station codes shall be created by agencies as needed and recorded by the ISC for tracking purposes. A system of

aliases will link the ISNSR codes with both the FDSN two character network codes as well as the original IR codes.

The ISC and NEIC will work together to implement the ISNSR by:

- Developing the underlying database structures to support the new coding, epochs, and aliases;
- Revising operation code to enable it to recognise and use the ISNSR codes;
- Interacting with seismic monitoring institutions around the world to set up appropriate agency and deployment codes that are consistent with appropriate institutional names;
- Revising web forms to register agencies and report deployments, stations, locations, channels, epochs and aliases;
- Populating the new database with the currently registered stations;
- Populating the new database with channels currently documented in *dataless* SEED volumes;
- Working with the seismological agencies and the FDSN to create aliases to existing FDSN network codes;
- Updating the database from the web form input;
- Making the contents of the new database accessible by means of an interactive web interface and a software accessible network service;
- Developing strategies of correct attribution of parameter data reported by agencies in the existing bulletin formats;
- Working with appropriate bodies to add *Agency.Deployment.Station.Location.Channel* information to existing bulletin formats.

## **6. Developing and putting into operation a new advanced database schema and bulletin format**

The ISC database schema was first put in operation to collect data for the year 1999. The schema took advantage of previous design work at the SAIC in the US with significant changes introduced to enable it to hold the complexity of the ISC Bulletin data. Almost 15 years of its operation and significant changes in both data contents and volumes dictate an essential upgrade of the original schema.

In addition, the standard bulletin data exchange formats, such as ISF1.0 and QuakeML, require an update to hold comprehensive bulletin information available at the ISC; this includes the new ISNSR codes, comprehensive amplitude and station magnitude information etc.

## **7. Advancing the ISC web services**

The new ISC website has been put in operation in early 2012. This development, among other benefits, has given users additional ways to search through the ISC Bulletin and the database and retrieve data in the variety of formats convenient for a particular task.

At the same time, under a special contract, the ISC has developed an alternative web-based application, the CTBTO Link. Under this project conventional ISC data are presented in the form convenient to the nuclear explosion monitoring community. The application is only available to the personnel of the CTBTO Provisional Secretariat and all National Data Centres for CTBTO. Thanks to a special funding, this product is superior to the standard services given by the ISC to its general users. It is built around the needs of monitoring community with the ISC data packaged around the IDC REB bulletin and the IMS network.

Some of its features, such as the graphical selection tools based on Google Maps, have already been transferred to the standard ISC website. With a reasonable delay to allow for continuous funding from CTBTO, the ISC shall continue re-using developments at CTBTO Link website to improve its services to all researchers. The following topics shall be explored in the first instance:

- statistics of seismicity for specific regions;
- station specific history of recordings;
- statistics of individual agency reporting;
- snippets of waveforms for specific events.

## **8. Establishing automatic procedures to build a consistent set of specific waveform measurements to improve the accuracy of the ISC Bulletin**

The availability of continuous on-line seismic waveforms is improving day by day. It becomes apparent that to address specific well known problems the ISC could use this enormous source of data to make consistent automatic sets of measurements for use in operations in addition to reported data. Such problems include:

- absence of reliable depth constraints and magnitude estimates for a large fraction of bulletin events;
- persistent incoherence of amplitude measurement techniques used by various networks;
- frequent inconsistency of the onset time of surface reflections reported by different networks.

The ISC shall investigate the possibility of:

- amplitude measurements in line with new recommendations of IASPEI/COSOI working group in order to build a consistent set of automatic ISC magnitudes in addition to those built using the reported amplitude data;
- measuring signal-to-noise ratio for reported seismic arrivals for use as a measure of confidence in earthquake location and consequent bulletin analysis;
- using surface reflections at a number of stations to assist depth determination of those seismic events where close station readings are unavailable;
- picking first arrivals at unreported stations that show high likelihood of detection for a combination of event position and magnitude.

These procedures, new to the ISC, shall be built using the experience gained by leading research groups worldwide.

Manual waveform measurements independently made by analysts at different institutions and collected by the ISC will for a long time remain a powerful benchmark for quality assessment of newly compiled sets of automatic readings. Yet it is important to start breaking stereotypes linked to the ISC and gradually try using specific waveform measurements where appropriate to improve the accuracy of the ISC Bulletin.

## **9. Advancing the ISC location procedures**

Starting from the data year 2009 a new location procedure was put into operation that allowed the ISC to remove the bias introduced by uneven distribution of seismic station, compute appropriate uncertainty estimates and benefit from all reported seismic phase for which there exist travel times

predicted by the *ak135* model. As a result the ISC location accuracy matched or surpassed the accuracy achieved by the EHB analysis.

Nevertheless, further progress in location techniques is required for the ISC location results to remain consistent with the ISC mission to serve as the final and definitive source of earthquake information. Hence, the ISC shall:

- explore the feasibility of using 3D velocity models in routine ISC processing:
  - experiment with the *RSTT* travel-time predictions that are fast enough to be used in routine operation;
  - perform location studies with and without *RSTT* predictions in various tectonic provinces;
  - help improving the *RSTT* model and provide feedback to its developers.
- regularly refine the ISC default depth grid based on the new and existing confident depth determinations in each cell;
- use the signal-to-noise measurements to weight the reported seismic arrival times against each other.

## **10. Improving the GT dataset, jointly with the IASPEI and CTBTO**

The ISC shall improve the IASPEI Reference Event List (Ground Truth (GT)) by:

- pro-actively collecting GT events based on:
  - contemporary high-profile seismic events;
  - events that occurred in the middle of temporary seismic deployments;
  - events recorded by networks installed to monitor specific aftershock sequences;
  - events with highly improved station coverage in the Rebuilt ISC Bulletin.
- adding further information such as bibliography and moment tensor solutions to the GT database;
- collecting waveform snippets for GT events.

## **11. Improving the automatic procedures to take shear wave splitting measurements from waveforms**

During 2002-2003, jointly with the University of Leeds, the ISC has undertaken a project to automatically measure the shear wave splitting. A software was developed to retrieve waveform segments at the expected times of SKS and SKKS phases from selected earthquakes. Splitting of teleseismic shear waves reveals the anisotropy which results from alignment of crystals by deformation in the past. Splitting is the delay in arrival of one polarisation after the other. The system automatically measured this delay and its reliability and saved the results in the ISC database. A corresponding webpage exhibited results to interested users.

The ISC shall review and modernise this software, taking into account the advances in the seismic anisotropy made in the last 10 years as well as the progress in the web application software. The splitting measurement software will run automatically. Its performance shall be occasionally reviewed by the ISC seismologists. Archiving and re-distributing these consistently made measurements shall be useful to many researchers, even to those wishing to make ultimate measurements themselves. This is because this archive will save considerable amount of their time that is usually spent looking for potentially useful records. A new web page shall help users formulate queries for particular splitting measurements linked to events in the ISC Bulletin.

This development shall create a new ISC product, the shear wave splitting measurement database that will complement the existing products – the Bulletin, the station registry, the GT and the EHB datasets.

## **12. Setting up an interactive Bibliography of scientific articles related to specific ISC Bulletin events**

In the past, occasional references to scientific articles devoted to specific earthquakes or other seismic events were part of the comment lines in the ISC Bulletin. Yet the work of collecting these references for both recent and new events was not part of the day-to-day operations. Little attempt was made to publicise the existence of such information to users despite a definite advantage of potential geographically referenced system of references over general usage of bibliographical searches for specific earthquake date or name, often differently transliterated from local languages.

The ISC shall step up this work by:

- collecting scientific references to relevant articles and linking those to events in the ISC Bulletin by systematically processing the indexes of past journal issues currently made electronically available by many publishers;
- introducing into the ISC database as many as 1,000 references to quality scientific articles collected during the GEM project that relate to over 2,000 large earthquakes during the period preceding the start of GCMT project in 1976;
- inviting individual researchers to check if their work on specific earthquakes has been reflected in the ISC database;
- designing and putting into operation an interactive web search that allows users to select relevant articles for specific events or events in specific geographical area;
- making arrangements with scientific journal publishers to automate linking relevant new articles to events in the ISC Bulletin.

## **Conclusions**

The ISC Development in 2012-2015 will be concentrating on the essential improvements in the existing operational environment, software and services. In addition, a number of projects will focus on setting up the new ISC products and services.

The above developments shall require further investment into the ISC computer facilities and the Internet connection.

The items listed above do not completely exhaust the scope of the ISC development. There will be a number of new pilot projects, not listed above, where the ISC would be getting a feel in new areas, such as multiple location of event clusters, feasibility of collecting the infrasound recordings, linking the ISC Bulletin with worldwide data on tsunami and exploring a possibility of integrating the data collection efforts with capacity building in developing countries.

The ISC is in a strong position and will work hard to retain its status by providing ever improving services and cautiously venturing into new areas.