Directions for the ISC Development

(2013-2016)

Contents

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 2009 and Melbourne in 2011. It served as a mid-term development plan. While some items from that plan have been successfully implemented, several remain in progress.

Among the achievements are:

1. Introduction of the new earthquake location and magnitude determination algorithm;
2. Compilation of the preliminary on-line ISC Bulletin within days of event occurrence;
3. Providing selected data from the ISC database in specific formats to different user groups via the ISC web search tools;
4. Publication of the Printed ISC Bulletin Summary;
5. Provision of the IASPEI Reference Event (GT) List;
6. Provision of the EHB Bulletin;
7. Creating and running the ISC database and website mirrors and backup at the IRIS DMC in Seattle as well as the database mirrors at the ERI in Tokyo and LLNL in Livermore;
8. Preparation and provision of relevant ISC/ISS data to the Comprehensive Test Ban Treaty Organization (CTBTO) via the dedicated CTBTO Link;
9. Preparation of the ISC-GEM Global Instrumental Earthquake Catalogue (1900-2009);
10. Introduction of the ISC Event Bibliography.

Development topics that still require substantial efforts to be made include:

1. New International Seismic Network and Station Registry;
2. Visual ISC Bulletin Analysis System (VBAS);
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 2013 and 2016 by summarising the items in progress and adding new relevant directions. It is offered for discussion at the ISC Executive Committee during its meeting in Gothenburg on July 20, 2013. It will then be distributed to the ISC Governing Council on July 21, 2013.

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

Major Directions

During 2013-2016, the ISC development shall be focused on the following major directions that include both the improvement of existing operational procedures as well as creating and upgrading new ISC products and services.

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, signal-to-noise ratio, event type etc. The ISC will take part in collaborative worldwide efforts 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 initial review. Currently the ISC collects these preliminary data from 26 agencies (out of 130 agencies that contribute fully reviewed bulletins to the ISC). These preliminary data form the basis for the preliminary ISC Bulletin that is available from the ISC website within a few hours/days after earthquakes occur. The ISC shall encourage all of its reporting agencies to start sending the preliminary bulletin data prior to making their full comprehensive 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 1900 to cover the early instrumental period

Preparation of the ISC-GEM Global Instrumental Earthquake Catalogue (1900-2009) was 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 forecasting. The following steps appear necessary to build upon this effort:

- When partly included in the ISC Bulletin, this tremendously important dataset along with associated station arrival times and amplitudes will effectively double the time span of the ISC Bulletin.
- This inclusion will guarantee more homogeneous and reliable *mb* and M_S magnitude estimates and locations of large earthquakes worldwide over the entire period from 1900 till present.
- 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 1900-1959, with many more parametrical data extracted from the paper-based sources such as the BAAS, ISS, Gutenberg Notepads and individual historical station bulletins available at the ISC. Historical bulletin collections at SISMOS/INGV in Italy, Hamburg University, Geophysical Survey of the Russian Academy of Sciences, British Geological Survey and others should also be explored 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 the GEM project, shall make many more determinations of *Mo* and *Mw* accessible for large earthquakes of the 20th century.

4. Developing the Visual Bulletin Analysis System (VBAS)

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 enhanced 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, jointly with the Oxford e-Science Centre will develop a new Visual Bulletin Analysis System (VBAS) that will feature:

- screen-based analysis that utilises a graphical representation of the bulletin information as opposed to the current use of plain 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 performed by the senior analysts.

Future versions of VBAS shall also feature an occasional access to waveforms, temporarily stored at the ISC.

5. Upgrading the International Seismographic Station Registry (IR) to utilise the ADSL coding standard.

The International Seismographic Station Registry (IR) has been jointly maintained by the ISC and NEIC for many decades. In order to upgrade the IR, a new station coding standard has been 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 location of seismic instrumentation shall be designated by the combination of four fields: *Agency.Deployment.Station.Location* (ADSL). Agencies, deployments, stations, locations, and channels shall be defined in discrete time periods called epochs.

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 aliases between the new coding standard and FDSN nomenclature).

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 upgraded IR codes with both the FDSN two character network codes as well as the original IR codes.

The ISC and NEIC will continue working together to implement the IR by:

- Developing the database structures to support the new coding standard, epochs, and aliases;
- Revising operational code to enable it to recognise and use the new IR codes;
- Interacting with seismic monitoring institutions around the world to set up appropriate agency and deployment codes that are consistent with appropriate institutional names;
- Upgrading the existing 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. Upgrading the ISC database schema and updating commonly used bulletin formats

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 content and volume dictate an essential upgrade of the original database 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 IR codes, comprehensive amplitude and station magnitude information, event type identification, 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 retrieve data in the variety of formats convenient for a particular task.

At the same time, under the CTBTO contract, the ISC has developed an alternative web-based application, the CTBTO Link to the ISC database (The Link). Under this project conventional ISC data are presented in the form convenient to the nuclear test monitoring community. This service is superior to the standard web 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. Although the Link is only available to the personnel of the CTBTO Provisional Technical Secretariat and the National Data Centres (NDC) for CTBTO, nevertheless, many of the ISC Member-Institutions and data reporters that have additional mission of operating the NDC in their home country are also able to use this service.

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 elements shall be explored in the first instance:

- statistics of seismicity for specific regions;
- station specific history of recordings;
- statistics of individual agency reporting;
- previews of station waveforms for specific events in the ISC Bulletin and the GT dataset.

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

The on-line availability of seismic waveforms is improving day by day. Under the CTBTO Link contract the ISC has already developed an extensive in-house experience in selecting and downloading the waveforms for specific seismic events on global scale. The ISC shall use the enormous sources of seismic waveform data to make consistent automatic measurements for use in operations in addition to the parametric data reported by agencies. This will help to address the following problems in the ISC Bulletin:

- absence of reliable depth and magnitude estimates for a considerable fraction of seismic events;
- persistent incoherence of amplitude measurement techniques used by various networks;
- frequent inconsistencies of the onset times of surface reflections reported by different networks.

The ISC shall investigate the possibility of:

- amplitude measurements in line with the CoSOI/IASPEI requirements 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. It is nevertheless 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 the final and definitive 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 well constrained depth determinations in each grid cell;
- use the signal-to-noise measurements to weight the reported seismic arrival times against each other.

10. Extending 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 preview images for GT events.

11. Extending the ISC Event Bibliography of scientific articles related to specific ISC Bulletin events

During 2012 the ISC made a substantial effort of collecting references to scientific articles related to specific seismic events in the ISC Bulletin. Currently, over 14,000 articles published in the last 60 years are linked in the ISC database to approximately 10,000 seismic events, both earthquakes and anthropogenic events, that occurred in the last 110 years. At the beginning of 2013, the ISC introduced an interactive web service that allows ISC users to download these references for events in the area and period of their interest.

The ISC shall continue building up on this work by:

- systematically processing the indexes of past and current journal issues currently made electronically available by many publishers;
- inviting individual researchers to check if their published work related to specific earthquakes has been correctly reflected in the ISC database;
- making arrangements with scientific journal publishers to automate the procedure of linking relevant new research articles to events in the ISC Bulletin.

Conclusions

The ISC Development in 2013-2016 will be concentrating on the essential improvements in the existing operational environment, software and services. In addition, a number of projects will focus on either setting up or advancing 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 combining the data collection efforts with capacity building in developing countries.

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