

REVIEW

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Rebuild of the Bulletin of the International Seismological Centre (ISC), part 1: 1964–1979

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Abstract

The data from the Bulletin of the International Seismological Centre (ISC) have always been and still remain in demand for a wide range of studies in Geosciences. The unique features of the Bulletin include long-term coverage (1904-present), the most comprehensive set of included seismic data from the majority of permanent seismic networks at any given time in the history of instrumental recording (currently ~ 150) and homogeneity of the data and their representation. In order to preserve this homogeneity, the ISC has followed its own standard seismic event processing procedures that have not substantially changed until the early 2000s. Several considerable and necessary advancements in the ISC data collection and seismic event location procedures have created a need to rebuild the data for preceding years in line with the new procedures. Thus was set up a project to rebuild the ISC Bulletin for the period from the beginning of the ISC data till the end of data year 2010. The project is known as the Rebuild of the ISC Bulletin. From data month of January 2011, the ISC data have already been processed with the fully tested and established new procedures and do not require an alteration. It was inconceivable even to think about such a project for many tens of years, but great advances in computer power and increased support by the ISC Member-Institutions and Sponsors have given us a chance to perform this project. Having obtained a lot of experience on the way, we believe that within a few years the entire period of the ISC data will be reprocessed and extended for the entire period of instrumental seismological recordings from 1904 till present. The purpose of this article is to describe the work on reprocessing the ISC Bulletin data under the Rebuild project. We also announce the release of the rebuilt ISC Bulletin for the period 1964–1979 with all seismic events reprocessed and relocated in line with the modern ISC procedures, ~ 68,000 new events, 255 new stations, ~ 815,000 new seismic phases, more robust and reliable *mb* and *M_s* magnitude evaluations and the addition of ~ 2700 new *M_s* magnitudes.

Keywords: ISC, Earthquake, Bulletin, Rebuild, Global, Relocation, Magnitude, Homogeneity, Long-term

Introduction

Since 1964, the ISC has been charged with producing and distributing the most comprehensive Bulletin of the Earth's seismicity and other seismic events. This work superseded the publication of the International Seismological Summaries (ISS 1918–1963) and other historical periodical publications such as the so-called *Shide Circulars*, produced with financial assistance from the

British Association for the Advancement of Science (BAAS 1900–1912, 1913–1917).

The ISC fulfils its mission by collecting local, regional and global seismic bulletins from almost all permanent seismic networks and observatories existing at any point in time around the world (Willemann and Storchak 2001), currently almost 150. For moderate to large earthquakes, the ISC computes its own seismic event locations and magnitudes based on the hypocentre solutions and individual station measurements. Data on smaller earthquakes are republished as reported by local agencies,

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unless data from several sources were given to the ISC and provided a basis for better location.

Over the decades, the ISC Bulletin has served to a wide range of scientific research studies. Today, hundreds of research articles that acknowledge the use of ISC data are published every year. A selection of them can be found at the end of each annual ISC Director's Report available at <http://www.isc.ac.uk/docs/dirreport/>.

The value of the ISC Bulletin is dependent on a certain degree of conservatism in adhering to uniform procedures over a long period of time (Adams et al. 1982). Nevertheless, updates and changes sooner or later become inevitable (Fig. 1).

Today, the ISC is using the *ak135* velocity model (Kennett et al. 1995) where *Jeffreys-Bullen* travel-time tables (Jeffreys and Bullen 1935, 1940) were previously used for decades until the end of data year 2005. A new seismic event location program (locator) based on different approaches and techniques was initially introduced into the ISC operations with the beginning of data year 2009 (Bondár and Storchak 2011). The locator was altered and fine-tuned during the processing of data years 2009 and 2010.

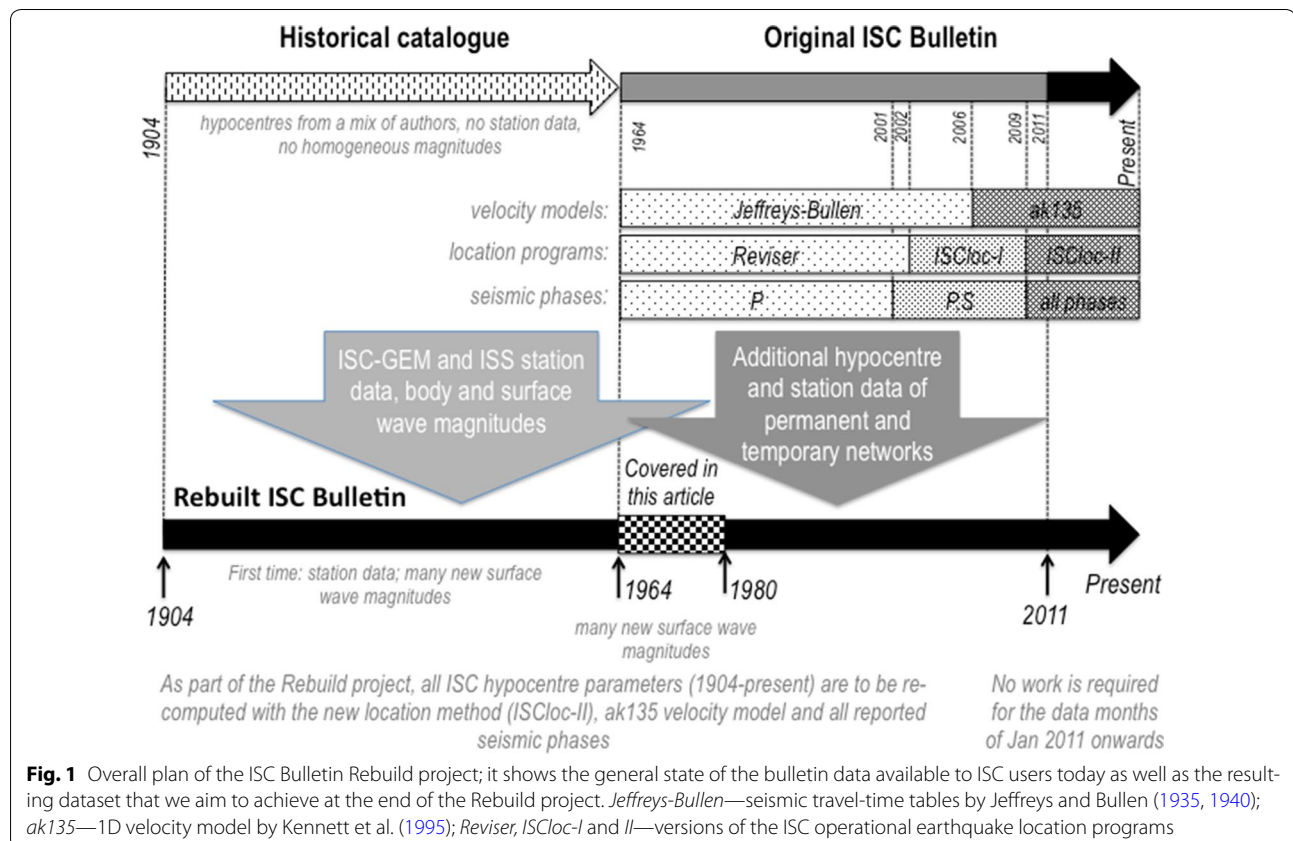
Throughout the ISC history different sets of seismic phases were used: P to start with and then also S from

data month of January 2001 (Storchak et al. 2000). The list of recognised seismic phase names has changed with each edition of the manual of seismological observatory practice (Willmore and Karnik 1971; Willmore 1979; Bormann 2002, 2012). From data year 2009, the ISC used in location all standard seismic phases (Storchak et al. 2003, 2011) for which the arrival times can be calculated.

Latitude and longitude standard error estimates were computed before the data month of October 2002 and full error ellipses after. The procedures that determine what events need to be relocated by the ISC have changed in 1999, 2005 and 2006. Also, computation of ISC magnitudes was regularised and improved with the introduction of the new locator (shown as ISCloc II in Fig. 1) (Bondár and Storchak 2011).

The most comprehensive list of changes to ISC procedures can be found in the Addendums 1–3 of the most recent printed Bulletins of the ISC (International Seismological Centre, 2011) and the printed Summaries of the ISC Bulletin (International Seismological Centre, 2017).

Thus, in order to homogenise the ISC Bulletin, the data period from 1964 till the end of 2010 has to be subjected to event relocation and subsequent analyst review. This article describes the procedure used to achieve this goal for the data period 1964–1979. The same procedure is



now used for data years 1980–2010. To provide a timely access to new data, the results of this project will be published and made available in 10-year portions as soon as the corresponding part of the analysis is completed.

Procedure

The ISC Bulletin consists of seismic events, mostly earthquakes, for which it lists a number of hypocentre and magnitude estimates reported by various agencies, ISC's own hypocentre solution and magnitudes (if available) and a set of arrival times and amplitude/period readings reported at individual stations. For each event, one of the hypocentres is considered as primary (prime) and all arrival time residuals are computed with respect to this hypocentre. In the absolute majority of cases, if an ISC hypocentre is published, then it is considered prime.

General cleaning

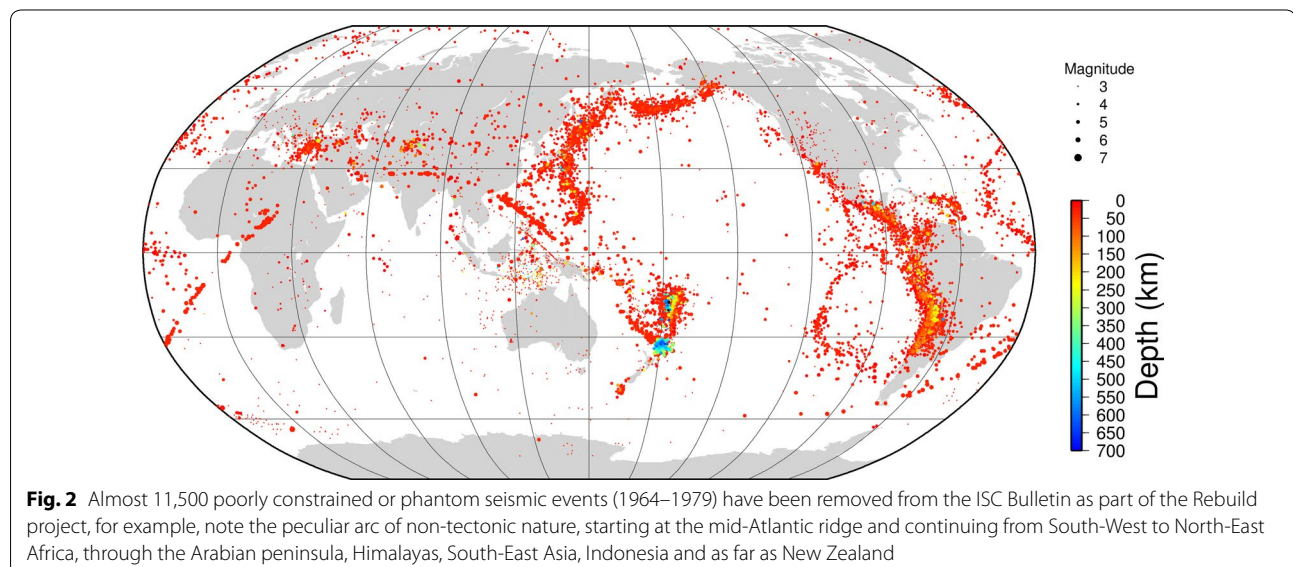
As part of the standard operations, the ISC received hypocentre solutions from several hundreds of agencies along with associated seismic station data. Some of these hypocentre solutions were not very well constrained by data, whilst associated station readings were much more useful for constraining the ISC hypocentres along with other data reported for the same events by other agencies. Having searched through the 1964–1979 period, we have taken the decision to remove events with just one reported hypocentre solution that was based on less than three stations. We also removed those solutions that were well outside of the agency's area of control where their network of seismic stations can be considered to have a reasonable geometrical configuration. Figure 2 shows a map of all removed seismic events. We

removed ~ 7900 events where the hypocentre solution of Montana Large Aperture Seismic Array (LAO) (Matkins 1973) was the only solution available with insufficient number of additional station readings available. The work of this array was useful for the purpose for which it was created (nuclear test monitoring), yet the general hypocentre accuracy was insufficient for general scientific research or seismic hazard assessment purposes. We also removed ~ 800 hypocentres originally reported by the New Zealand seismic network, ~ 300 hypocentres of Hagfors observatory, ~ 100 solutions of Bulawayo observatory and a small number of hypocentres from ~ 50 other agencies.

Correcting seismic phase names

Over many decades, the ISC has collected more than 202 million reports of arrival times of seismic waves at individual seismic stations. The majority of these reports carried a local operator's phase identification (name) that, where possible, was translated by the ISC programs into a standard phase name. Due to limitations of the Jeffreys–Bullen tables and location software used at the time, many operator identifications could not be automatically translated and ISC analysts could not see travel-time residuals to be able to correct phase name translations efficiently.

At the start of the Rebuild project, we reviewed the entire list of existing operator phase identifications and reduced this list from 6276 distinct names down to 2021 names. Many of the phases have become compliant with the IASPEI Standard Seismic Phase List (Storchak et al. 2003, 2011). Nevertheless, several hundreds of distinct phase names (small percentage in terms of the corresponding total number of phase reports) are still not



compliant because they cannot be safely reinterpreted. Typical deficiencies that were corrected included obsolete notations, upper and lower cases mixed up, missing characters, parts of other information such as the emergent/impulsive character of the onset attached to phase names as well as mere artefacts of parsing poorly tabulated or formatted original files.

This work has allowed the ISC locator program to re-identify and use the arrival times of many more phases reported by local agencies during almost 50 years.

Correcting typical time stamp errors

Once a very common expression, a “*minute error*”, has now almost completely disappeared from the vocabulary of seismologists as the conversion of seismographs from analogue to digital recording has been accomplished around the world. As a result, the newest generation of ISC Bulletin users are mostly unaware of this feature. Nevertheless, the original ISC Bulletin still contains a large number of seismic arrival times with unusually large travel-time residuals in the vicinity of ± 60 s, usually indicating an error in the onset time measurement manually taken by analysts from the analogue seismograms.

Similarly called “*hour-errors*” and “*day-errors*” were usually a result of local bulletin producers failing to update the hours/days values in a case where the arrival time at a particular station was falling into the next hour/day as compared to the event origin. At times, some later secondary seismic phases from the same seismic event arrive at the same station on a different day as compared to the earlier phases. A common tendency of the past to keep the bulletin pages as concise as possible for economical reasons often led to individual station readings or even whole pages of local seismic bulletins not containing a full year-month-day-hour-minute-second stamp, which contributed to the problem.

Retrospective correction of these mistakes in the ISC Bulletin is not a trivial task. Firstly, the travel-time residuals in question are not offset by 60 s exactly. Instead, they are usually masked by inaccuracies in event epicentre and depth determination as well as by the deficiencies of the standard velocity model in its application to a particular region. Secondly, some large travel-time residuals of ~ 60 s could, in fact, indicate a seismic phase miss-interpretation when, for example, a near-source surface reflection (*pP* or *sP*) is erroneously interpreted as the direct *P* arrival or when a *PKPab* arrival is miss-interpreted as either the *PKPbc* or *PKPdf*. Thus, we corrected the arrival times only in those cases where the likelihood of a misjudgement on our part was small. To help this, we also used travel-time residual statistics for individual stations to correct only those stations for which a minute error was a common occurrence.

Overall, we corrected $\sim 30,000$ min-errors, ~ 1000 h-errors and 138 day-errors in the arrival times of the total of 1334 distinct seismic stations. The vast majority of corrected travel times have been subsequently used for corresponding hypocentre relocation. Another benefit of this correction is that those users of the ISC Bulletin that are uninformed in specifics of the analogue recordings, will no longer be at risk of misinterpreting these erroneous travel times for a natural phenomena.

Adding previously unavailable bulletin data

During the Rebuild project, we made an attempt to revisit the continuity of various elements of the bulletin as far as contributions from different agencies are concerned. Thus, we looked through the gaps in each individual agency’s hypocentres and each individual station’s reports. We approached relevant agencies and stations with requests for missing data. As a result, we have received a number of different seismic bulletin datasets that fall into the following categories:

Historical data from agencies that started reporting to the ISC from a certain point in time and were not encouraged to report their data retrospectively from the start date of their operations.

Data from permanent networks not delivered in time for the original ISC analysis due to internal delays and difficulties.

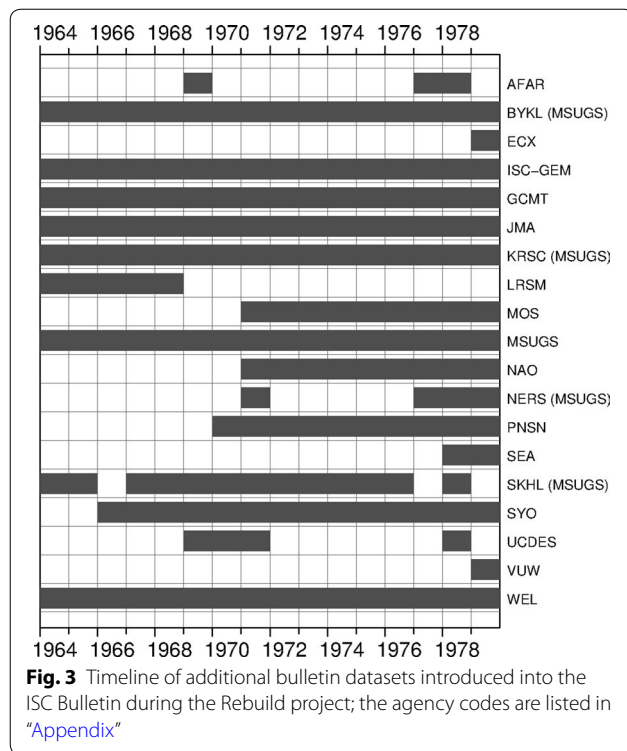
Data from permanent networks not given in time due to political and administrative disputes or adverse changes in data distribution policy.

Data from temporary deployments set up to record aftershocks of large earthquakes.

Data from temporary deployments that were part of individual scientific research projects.

Figure 3 summarises all additional datasets that we received for inclusion into the rebuilt ISC Bulletin up to data year 1979 from various agencies and corresponding time periods that they cover.

New hypocentre solutions (for previously unreported seismic events) from these datasets can be seen in Fig. 4. The majority of these earthquakes are concentrated in East Siberia, Kamchatka, Sakhalin, Alaska, Mexico, New Zealand plus some in the Euro-Mediterranean region. This figure though does not show other valuable contributions of individual stations reported for already known earthquakes, such as the contribution of missing bulletin years from the Japanese station Syowa Base (SYO) in Antarctica. Many of those bulletins could not have been included in the original ISC Bulletin because, quite often in the past, the seismograph recordings were brought to



Japan from Antarctica, assembled and processed after the normal ISC data collection deadlines.

Figure 5 shows the existing and 255 additional stations which were never part of the original ISC Bulletin and were added during the Rebuild project. Notably, the two new stations in Africa are Abeche (ABC) in Chad and Bangui (BCAO) in Central African Republic.

In total, the rebuilt Bulletin has gained 814,695 new seismic phases (10% increase of the original number of

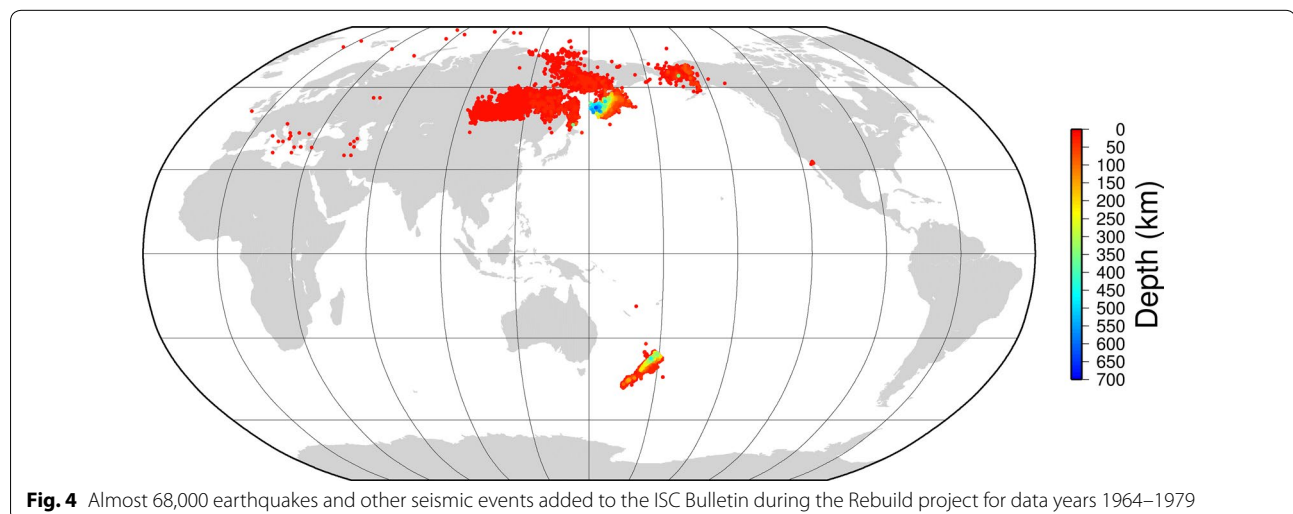
8,414,278) for data years 1964–1979, of which 115,485 came from newly registered stations shown in Fig. 5. Figure 6 shows the uneven character of these data's distribution over the years, which is mostly to do with the turbulent process of setting up new seismic networks and their reporting procedures in the late 1960s.

Selection of events for ISC relocation and analyst review

Due to specifics of the ISC operations, the meaning of the analyst review (or manual review) differs from that commonly accepted among seismologists.

The ISC analysts step into the Bulletin production at a comparatively late stage, yet their efforts make a large impact on the Bulletin's quality. The analysts review appropriate automatic grouping of data reported by different agencies and formation of individual physical events. They merge and split automatically formed events, review correct association of comments, fault planes solutions, reported network magnitudes and station arrival time and amplitude data. They move station readings from one event to the other and make judgments on the correctness of phase identification. The ISC analysts also review the quality of the ISC hypocentres and network magnitudes. To this day, the ISC analysts have not been able to see the waveforms of seismic events routinely, partly because there are approximately 7000 stations that report to the ISC these days and partly because a large fraction of these waveforms are not openly available. Thus, at the ISC, we are reusing the eyes and skills of local seismic analysts worldwide.

Prior to the data year 1999, the ISC analysts reviewed every seismic event in the ISC Bulletin. At that time, the ISC was routinely trying to compute an ISC solution for every event. On rare occasions, mostly at the time of very



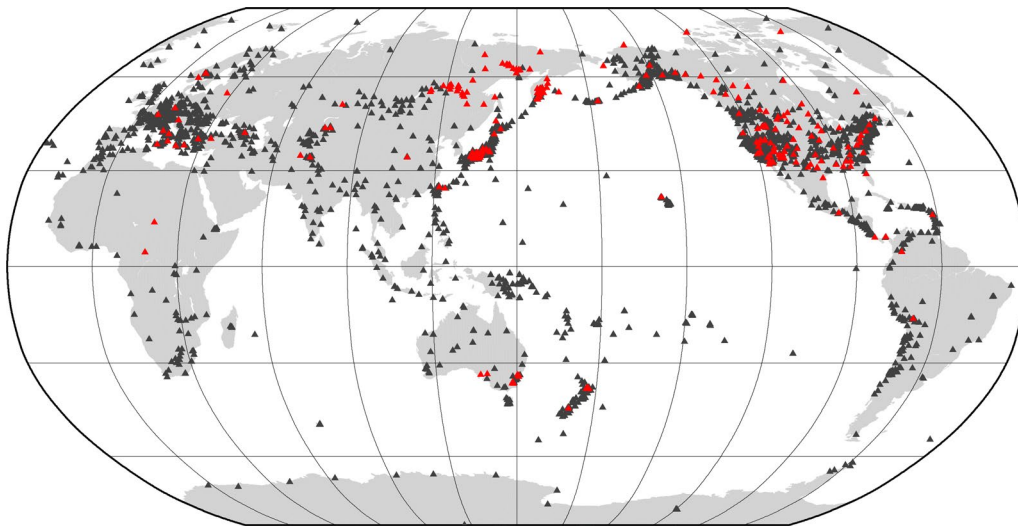


Fig. 5 Seismic stations (1964–1979) that contributed arrival time data to the original ISC Bulletin (in black) and stations that are new to the rebuilt ISC Bulletin (in red)

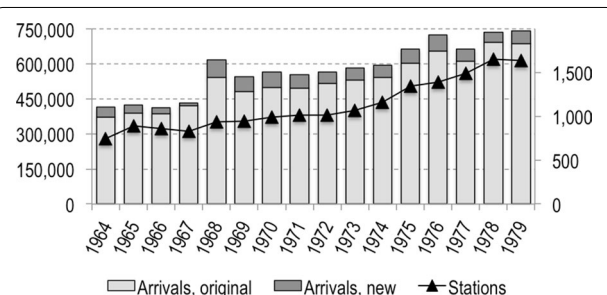


Fig. 6 The annual number of seismic station arrival times: original and those added to the ISC Bulletin (dark grey) during the first part of the Rebuild project (1964–1979); the total number of stations in the rebuilt bulletin is added for reference

large earthquake sequences, some data for small earthquakes below magnitude 3.5 (or even 4.0) have not been entered into working files from some individual agency reports (notably JMA) in order to reduce the workload on ISC analysts.

From the beginning of data year 1999, concurrently with the set up of the first database, the ISC has started following a set of so-called “*thresholding*” criteria that are designed to determine which events require manual analyst review and which events warrant an ISC solution (ISC 2017). This was done for two reasons. Firstly, to reduce the continuing increase of the workload on the ISC analysts. Secondly, to make sure that the ISC solutions are produced only in those cases where the ISC is in possession of a more superior combined set of station reports, as compared to any one local agency, and is therefore in a position to produce a better, well-constrained solution. This decision is currently based on

event magnitude (if reported), maximum recorded distance and the knowledge of which agencies have contributed each individual station reading. Unfortunately, for data years before 1999, the latter information is mostly unavailable today. It can be partly recovered, though with a high level of uncertainty, based on the known positions of seismic stations within the borders of one country or another. The political borders have of course changed dramatically since 1964, especially in Eurasia, which complicates our task further.

Whether before or after the data year 1999, one rule remained valid. If an ISC hypocentre was produced, then it has always been reviewed by at least two ISC analysts.

During the Rebuild project, we have reconsidered every event in the ISC Bulletin and marked those events that required an ISC relocation. We took into consideration only those events with four or more associated station reports that either had an ISC hypocentre produced originally or had new additional station data associated to them during the Rebuild. We then relocated all events with the largest recorded distance (Δ) of more than 20° and also the events with the largest Δ between 10 and 20° where the number of station countries was greater than one. For the remaining events, the best available local agency hypocentre has been selected as prime with all station arrival time residuals recomputed based on that hypocentre.

In this process, we discarded a large number of previously reported ISC hypocentres in favour of the hypocentres reported by local agencies; the latter were promoted to prime hypocentres. The best example for this group of events would be many small earthquakes around Japan

reported by JMA, for which no other essential information had been reported by any other agency.

As previously explained, relocation of selected events has been made using the new standard earthquake locator (Bondár and Storchak 2011), ak135 velocity model (Kennett et al. 1995) and the uniform set of seismic phases (Storchak et al. 2003). Location error ellipse parameters have been computed for all ISC hypocentres. Where the data have not provided control over the event depth, the ISC depth estimates have been fixed to those most commonly observed among well-recorded events in each 1×1 degree cell or, if unavailable, to standard 10 or 35 km default depths set for each Flinn–Engdahl geographical region (Flinn et al. 1974; Young et al. 1996; Bolton et al. 2006).

As part of the relocation process, all ISC magnitudes, both m_b and M_S , have been recomputed based on existing and newly added amplitude and period station data whilst taking into account the updated event-station distances. These magnitudes were computed as medians among individual station contributions. The standard median absolute deviation (SMAD) was computed based on the alpha-trimmed set of available station magnitudes for each event (ISC 2017).

Many original ISC magnitudes were dropped where there were less than three eligible by distance station amplitude and period pairs available. Some of the surface wave magnitudes were lost/gained due to event depth recomputed to be deeper/shallower than 60 km (IASPEI 2005).

Review

Standard Bulletin review required different number of person-years in different periods of time. This number

however was never smaller than 1–2 persons even during 1964–1979 period (Robin Adams, personal communication, 2017). It would require the ISC to employ 10–15 analysts to review all events in line with the standard practice within two calendar years. We were in a position to use an equivalent of 3.5 persons during these 2 years. Thus, we had to work out a different review strategy that would still guarantee a high quality end product.

Bearing in mind that in the past every original ISC hypocentre has been reviewed by ISC analysts, we have decided to review only those new ISC solutions that showed a large departure (50 km and more) from the original hypocentre or large change of origin time (“WITH ISSUES” category shown in Fig. 7). The tolerance of 50 km may appear too large at first, yet we need to remember that the original ISC locations were based on P, Pn and Pg arrivals, leaving S, Sn, Sg, PcP, PKP arrival times largely ignored. It is thus expected that usage of additional phases by the new locator generally improves the location. Further to this argument, it was proved during the new ISC locator testing stage (Bondár and Storchak 2011) that the new locator does not introduce additional bias when its locations are tested against the locations in the IASPEI Reference Event List (GT).

We also decided to review the events with a large depth difference between the original and rebuilt depth, making allowance for depth being fixed to a default grid depth in a much larger number of cases than was the case in the past. These events would also fall into the “WITH ISSUES” category. Where the *EHB* locations (Engdahl et al. 1998) were available, they were used as a reference too.

In addition, we set up tolerance criteria on the median travel-time residual within a certain group of seismic

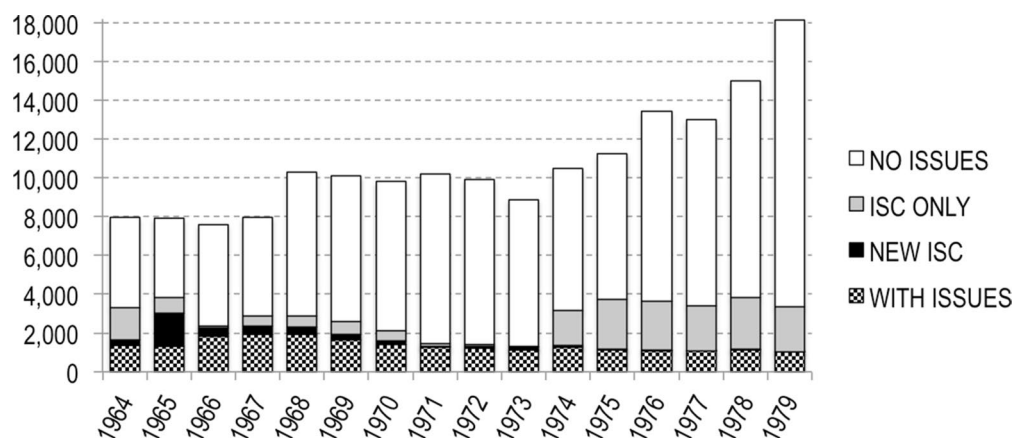


Fig. 7 Distribution of the annual number of seismic events that fall into different review categories; the ISC analysts reviewed all events “WITH ISSUES”, all ISC hypocentres for events that did not have an ISC hypocentre before (“NEW ISC”) and all events where an ISC hypocentre is the only hypocentre available (“ISC ONLY”)

phases (P, Pn, Pg, S, Sn, Sg) and distances, trying to imitate general criteria used by ISC analysts in day-to-day analysis. Events with station arrival times not meeting those criteria were also added to the “WITH ISSUES” category.

For obvious reason, we reviewed all “NEW ISC” solutions where there was no ISC hypocentre available in the original ISC Bulletin.

We also reviewed all events that have only ISC hypocentre solutions and no other agency solutions. These events were and still are built by the ISC analysts at the end of their monthly analysis based on individual stations readings not associated with any already known event (“ISC ONLY”).

Figure 7 shows the distribution of these groups of events and also those with “NO ISSUES” during the 1964–1979 period.

It appears that the fraction of events reviewed under the first part of the Rebuild project varied from 40 to 50% of the total at the beginning of the period to

approximately 20–25% at the end. Due to high variability of data, it is too difficult to project what analyst resources would be required for review of the more recent bulletin periods.

Overall, nearly a quarter of the total 172,071 seismic events were reviewed during the Rebuild project.

Discussion of the results

Figure 8 shows a general improvement in characterisation of seismicity as a result of the Rebuild project. No longer can we see the artificial arc of hypocentres crossing Africa in South-West to North-East direction. Even on these large-scale maps we see that the rebuilt epicentres generally exhibit more focused and clustered structures, for example, in the Fiji–Tonga–Kermadec area, the mid-Atlantic ridge and the Galapagos area. Examples of potential improvement in seismicity of individual regions have already been shown by Bondár and Storchak (2011).

Figure 9 shows a cumulative distribution of epicentre and depth differences between the original and the

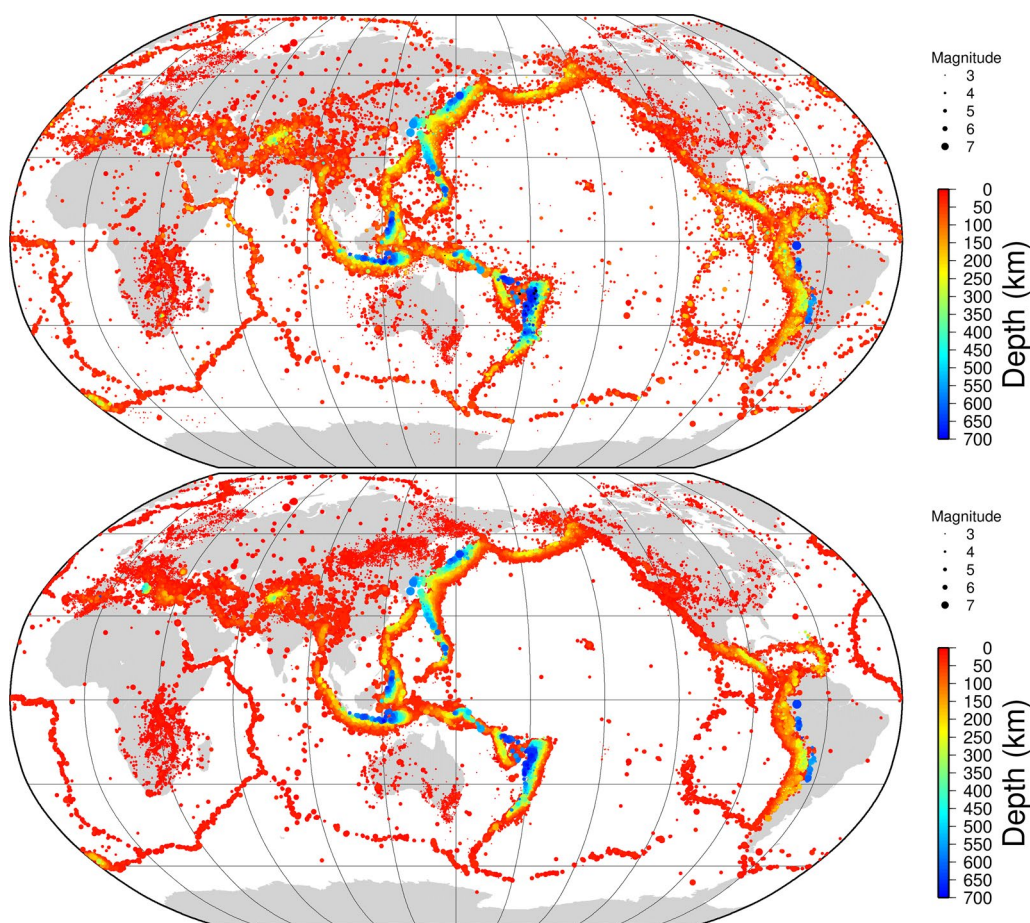


Fig. 8 Global distribution of earthquakes and other seismic events in the ISC Bulletin during 1964–1979 period before (top) and after the Rebuild project (bottom)

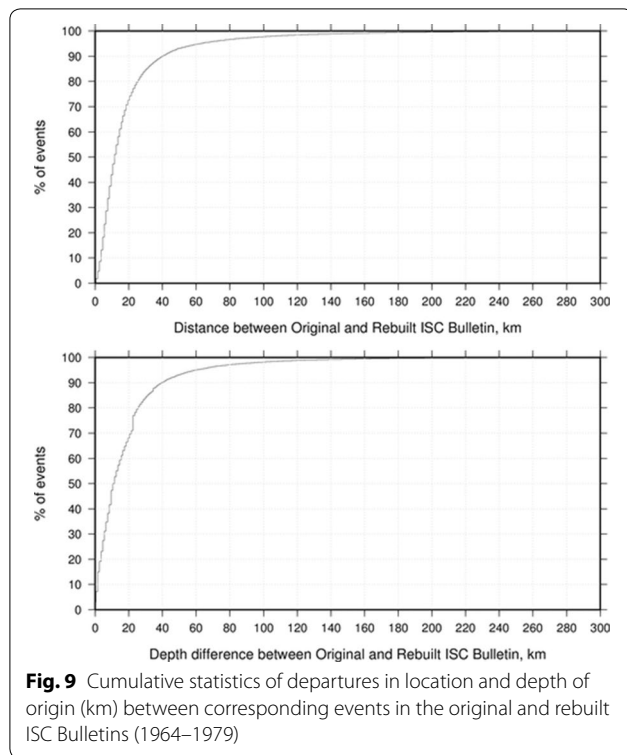


Fig. 9 Cumulative statistics of departures in location and depth of origin (km) between corresponding events in the original and rebuilt ISC Bulletins (1964–1979)

rebuilt ISC solutions, where both are available. For 98% of all seismic events, the departure in location or depth is less than 100 km. For 90% it is less than 40 km and for 70% it is less than 20 km. The figure does not show 460 seismic events ($\sim 0.4\%$ of the total) with location difference in excess of 300 km and, in its extreme case, up to 3740 km (see an example below).

Only 205 events ($\sim 0.2\%$) have a depth difference in excess of 300 km with a maximum of 634 km. These extreme cases can usually be attributed to large subduction zones where different default depths have been selected in the original and the rebuilt ISC Bulletins. The current system of default depths is much more consistent for the rebuilt bulletin as it is based on general statistics of well-located events in each geographical area/cell. Notably, a vertical step at a depth difference of just over 20 km can be attributed to a large number of cases where the default depth has been switched from the typical Jeffreys–Bullen table based default of 33 km to a more appropriate default depth of 10 km, especially at the mid-oceanic ridges.

An example of large discrepancy in location, in fact one of the most extreme and curious cases, is shown in Fig. 10.

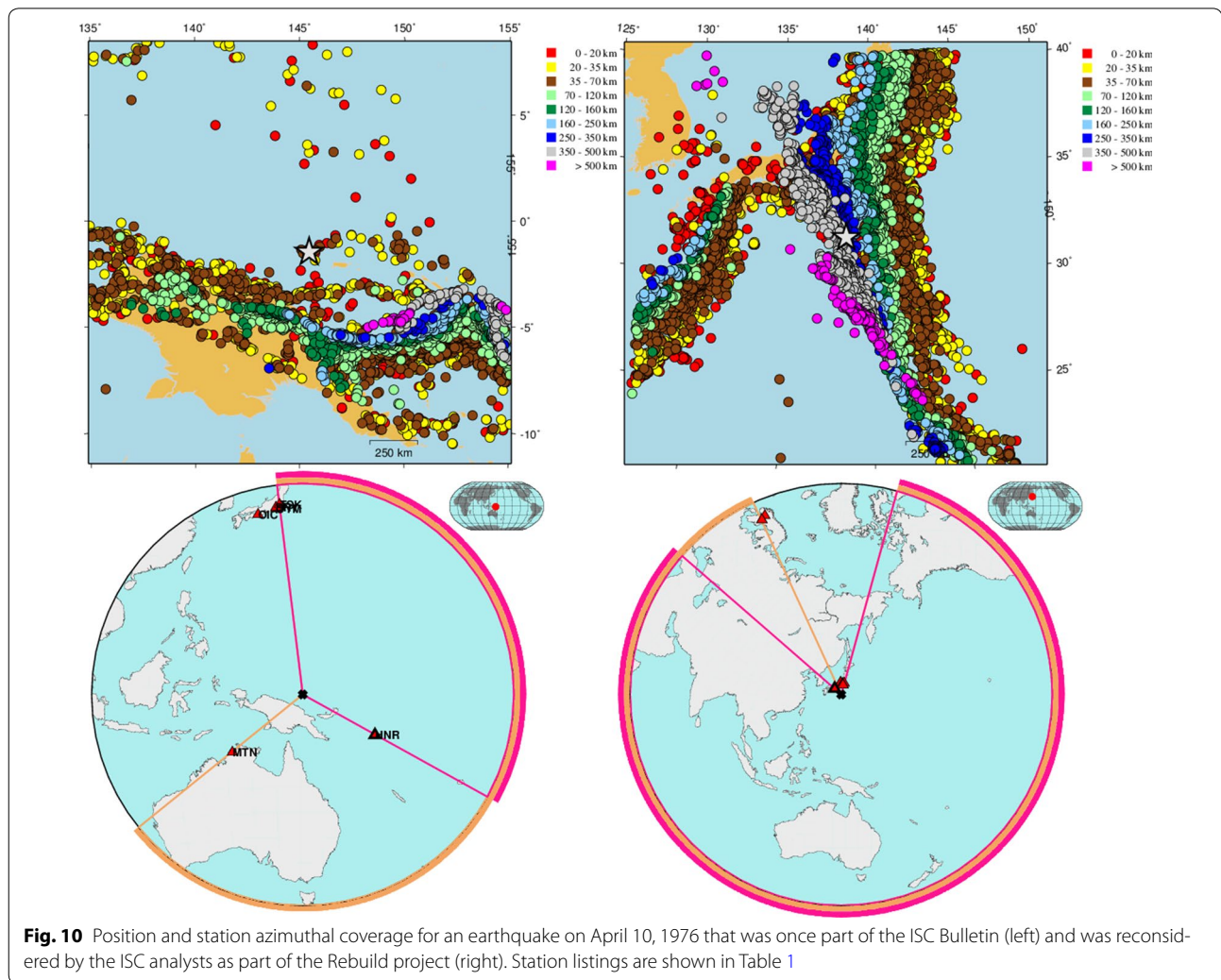
This bulletin event was originally built by those ISC analysts who worked at the end of 1970s. The event was based on the un-associated arrival times reported at the HNR station in Solomon Islands, MTN station in Northern Territory of Australia and four stations in Japan. The travel-time residual for S-arrival at MTN was probably not shown to analysts as part of a standard listing. This is why they might have not paid attention to the S–P time of only 53 s, reported at this station. Usually, such difference indicates a delta of less than 5° , and, therefore, it was indicative of a dubious association of the station reading to the event that was 18 degrees away. More to the case, it is highly uncommon for a Japanese station, with exception to Matsushiro (MAT), to report teleseismic events because JMA concentrates all their efforts on rather intense local seismicity and usually ignores earthquakes outside their area of responsibility.

Whilst reviewing all “ISC ONLY” events during the Rebuild project, the ISC analysts were able to rebuild this event by using the four existing stations in Japan and two others available in the ISC database, also in Japan, with P and S arrivals (DDR and MAT) as well as the arrival times at the Swedish station APP and Norwegian NAO. It is actually very common for Scandinavian stations to detect and report relatively small events in Japan. The ISC analysts have fixed the depth to 400 km, which is appropriate for this area. This rebuilt event is perhaps less well constrained (station azimuthal coverage is only 64° with a couple of S&P pairs helping to tighten the solution) but it shows more accurately where the real earthquake occurred and that the original ISC location was in fact a phantom event based on a spurious association of unrelated seismic phases.

Finally, Figs. 11 and 12 demonstrate a dramatic change that took place in the rebuilt Bulletin as far as the ISC mb and M_S magnitudes are concerned.

Many original mb estimates have been deleted in the rebuilt Bulletin because they were based on less than three station readings. Although 4855 events now have no magnitude estimate as a result, on the whole, those estimates left are generally more robust and reliable.

The explanation of the changes in M_S shown in Figs. 11 and 12 is of a different nature. Indeed, a few low value M_S have also been removed due to the lack of the minimum three stations required. More importantly, we found that the ISC had not been computing its own M_S estimates until year 1978, when they finally adopted the IASPEI recommendation of the so-called “Prague formula” (Vaněk et al. 1962). Nevertheless, some fraction of surface wave amplitude readings that are now in the



rebuilt ISC Bulletin were available in the original ISC Bulletin. Apparently, some surface wave readings were routinely collected from a few agencies, but not used for M_S computation. During the Rebuild project, we have used all surface wave amplitudes and periods reported in the original ISC Bulletin plus those transferred from the working database of the ISC-GEM catalogue (Storchak et al. 2013; Di Giacomo et al. 2015). Under this separate project, we collected many surface wave amplitudes from original paper-based bulletins and a few electronic files

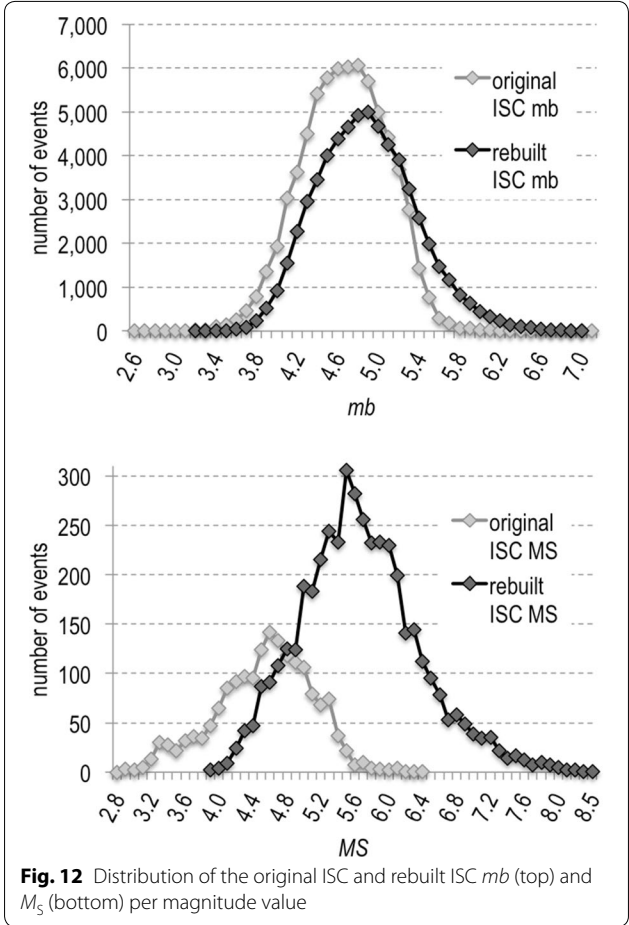
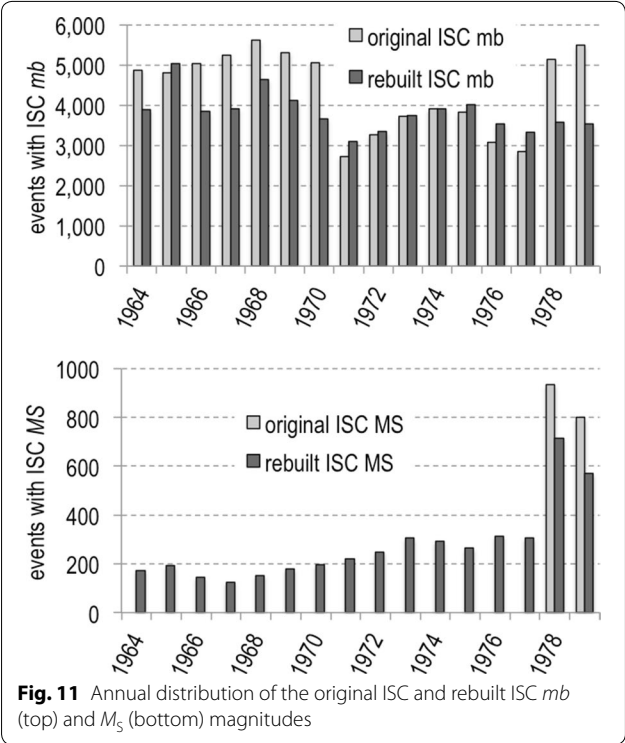
such as the one reported on our request by the Geophysical Survey of the Russian Academy of Sciences (MOS given in Fig. 3 and in “Appendix”).

Conclusions

As part of the ISC Bulletin Rebuild project, we applied the modern ISC procedures to the data period between 1964 and 1979. Considerable amount of previously unavailable data have been added to the Bulletin. We critically reviewed relocated hypocentres and recomputed

Table 1 An example of an event on April 10, 1976 in the original ISC Bulletin (a) that has moved 3740 km as a result of analyst review under the Rebuild project (b)

Original ISC Bulletin:										Rebuilt ISC Bulletin:									
ISC 1976/04/10 19:44:43.06 1.57 S 145.59 E *34km										ISC 1976/04/10 19:50:40.59 31.76 N 138.60 E *400km									
Error ellipse: Major 29 Minor 25 Az 72.9										Error ellipse: Major 40 Minor 23 Az 135.3									
Admiralty Islands: az_cov:233 sec_az_cov:121										Southeast of Honshu: az_cov:64 sec_az_cov:39									
time Code Sta name Delta az. Op ISC ISC										time Code Sta name Delta az. Op ISC ISC									
hr mn sec deg deg ID ID resid										hr mn sec deg deg ID ID resid									
19 48 32.0 HNR Honiara 16.3 119 P P +0.1 T										19 51 48.4 OIC Oishiyama 3.6 311 P Pn -0.7 T									
19 48 53.0 MTN Manton Dam 18.2 231 P P -0.1 T										19 51 50.0 OYM Oyama 3.7 8 P Pn +0.3 T									
19 49 46.0 MTN 2 X.X										19 51 52.9 SRY Shiroyama 3.9 8 P Pn +1.5 T									
19 51 48.4 OIC Oishiyama 36.8 346 P P +0.8 T										19 51 55.6 DDR Dodaira 4.3 7 P Pn +0.5 T									
19 51 50.0 OYM Oyama 37.3 351 P P -1.8 T										19 52 50.3 DDR S S -5.3 T									
19 51 52.9 SRY Shiroyama 37.5 352 P P -0.4 T										19 51 58.4 TSK Tsukuba 4.6 15 P Pn -0.1 T									
19 51 58.4 TSK Tsukuba 37.9 353 P P +1.1 T										19 52 01.5 MAT Matsushiro 4.8 356 P Pn +1.2 T									
										19 53 08.0 MAT S S +2.9 T									
										20 01 53.5 APP Appelbo 77.5 335 P P +0.3 T									
										20 01 58.1 NAO NORSAR 78.4 337 P P +0.2 T									



magnitudes of seismic events as well as the uncertainties of the major epicentre parameters, depth and magnitudes. This work has made the ISC Bulletin data for this period fully consistent with those produced for more recent period (2011–2015) following an introduction of a more appropriate velocity model and earthquake location program.

The relevant ISC staff members are already working on the data for 1980s and 1990s. Additional bulletin datasets are still being made available to the ISC for inclusion into the ISC Bulletin. We expect the remaining data period (1980–2010) to be rebuilt within the next 2–3 calendar years, with periodical release of newly rebuilt periods of time into the ISC Bulletin available online.

Remarks

By no means do we imply any criticism of the work that was done by generations of ISC Seismologists since 1964. The original ISC Bulletin remains a wealth of knowledge and information collected and created based on the widest possible international collaboration of seismic monitoring experts around the world. Much of the work that is possible for us to do now was impossible to accomplish even 10–15 years ago, before the introduction of powerful computers, sophisticated database software and modern ways of exhibiting the bulletin information graphically and interactively from every possible angle.

We aim to preserve a copy of the original ISC Bulletin and make it available online.

Abbreviations

ak135: seismic velocity model by Kennett et al. (1995); BAAS: British Association for the Advancement of Science; EHB: Engdahl, van der Hilst and Buland catalogue (Engdahl et al. 1998); GS RAS: Geophysical Survey of the Russian Academy of Sciences, Obninsk, Russia; GT: ground truth; GT List: IASPEI Reference Event List, available at <http://www.isc.ac.uk/gtevents>; IASPEI: International Association of Seismology and Physics of the Earth Interior; IRIS DMC: Incorporated Research Institutions for Seismology, Data Management Center, Seattle, United States; ISC: International Seismological Centre, Thatcham, United Kingdom; ISS: International Seismological Summary; JB: Jeffreys-Bulletin travel-time tables (Jeffreys and Bullen 1935, 1940); JMA: Japan Meteorological Agency; LAO: Montana Large Aperture Seismic Array; NIPR: National Institute of Polar Research, Tachikawa, Japan.

Authors' contributions

DAS is the first author. JH and DAS worked out the principles and method of earthquake selection for relocation and took part in the overall bulletin integrity check. JH managed the database for this project. DAS and EIMK worked on identifying, sourcing and parsing additional historical data to the ISC database. DAS worked to obtain the funding for this group that allowed employment of additional analysts at the ISC. LB, KL, BS and RV have all put a lot of time into the review of the rebuilt ISC Bulletin. DAS reviewed the data month of July 1965. LB managed the work of the Rebuild Analysis Group. DDG helped make an overall bulletin check, especially as far as ISC magnitudes are concerned, and took part in many discussions over the course of the project. All authors read and approved the final manuscript.

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We acknowledge the work of approximately 150 agencies in over 100 countries that instal and run permanent seismic networks, process waveform data and report seismic bulletins to the ISC on a regular basis. Many of them have been contributing data to the ISC for many tens of years, some—from the beginning of the 20th century.

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We thank many other colleagues worldwide who provided numerous comparatively small but still useful corrections and additions to the ISC Bulletin (see "Appendix").

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Competing interests

The authors declare that they have no competing interests.

Availability of data

As usual, all ISC data are openly available from the ISC website (<http://isc.ac.uk>), ftp-site, DVD-ROMs and printed materials. In particular, at the time of this article publication, the data of the rebuilt ISC Bulletin will take place of the original ISC Bulletin. Thus, every user search of the 1964–1979 period will return the data of the rebuilt ISC Bulletin.

The snapshot of the original ISC Bulletin will be preserved and provided to interested users in other electronic forms.

Consent for publication

We also declare that none of the content of the manuscript has been published or submitted for any other publication.

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Appendix

Below we present a list of additional seismic bulletin contributions received and included in the ISC Bulletin during the Rebuild project and noted with a set of codes given in Fig. 3.

AFAR—catalogue of earthquakes in the Afar depression (Hofstetter and Beyth 2003), courtesy of Rami Hofstetter, Geophysical Institute of Israel;

BYKL (MSUGS)—historical bulletin of Baykal seismic network, USSR Academy of Sciences, courtesy of Kevin Mackey, Michigan State University, Department of Geological Sciences (Mackey et al. 2010);

ECX—historical bulletin of the Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE), courtesy of Alejandra Nunex, personal communication, 2016;

ISC-GEM—basic seismic measurement data digitised from the original station and network bulletins at the ISC during the ISC-GEM project (Di Giacomo et al. 2015);

GCMT—The Global Centroid-Moment-Tensor (CMT) Project at the Lamont–Doherty Earth Observatory of Columbia University (2006–present); previously at Harvard University (1982–2006) (Ekström et al. 2012; Dziewonski et al. 1981);

JMA—historical catalogue of Japan Meteorological Agency (JMA), courtesy of Nobuo Hamada, personal communication, 2010;

KRSC (MSUGS)—historical bulletin of Kamchatka seismic network, USSR Academy of Sciences, courtesy of Kevin Mackey, Michigan State University, Department of Geological Sciences (Mackey et al. 2010);

LRSM—seismic wave arrival times from the Long Range Seismic Measurements Project (Lilwall and Young 1989), courtesy of John Young, AWE Blacknest, personal communication, 2014;

MOS—historical database of the Geophysical Survey of Russian Academy of Sciences, Obninsk, courtesy of Alexey Malovichko, Vera Babkina and Irina Gabsatarova, personal communication, 2012;

MSUGS—earthquake hypocentre relocations for Eastern Russia made at the Michigan State University, Department of Geological Sciences (Mackey et al. 2010);

NAO—bulletins for early years of NORSAR array, Norway; courtesy of Johannes Schweitzer, personal

communication, 2017; dataset was submitted when the review of the Rebuilt bulletin was complete; thus seismic arrival times have been associated with corresponding events in the ISC Bulletin but not used for ISC hypocenter determination, except the special case described in Fig. 10b and Table 1b.

NERS (MSUGS)—historical bulletin of Magadan seismic network, USSR Academy of Sciences, courtesy of Kevin Mackey, Michigan State University, Department of Geological Sciences (Mackey et al. 2010);

PNSN—focal mechanisms, courtesy of Steve Malone and Tony Qamar, Department of Earth and Space Sciences, University of Washington;

SEA—bulletin with corrected amplitude readings submitted in place of earlier version, courtesy of Peter Burkholder, Ken Creager, Wallis Hutton and Peter Benson (University of Washington, Geophysics Program) and Rick Benson (IRIS DMC);

SKHL (MSUGS)—historical bulletin of Sakhalin seismic network, USSR Academy of Sciences, courtesy of Kevin Mackey, Michigan State University, Department of Geological Sciences (Mackey et al. 2010);

SYO—historical bulletins of Syowa Base in Antarctica, courtesy of Masaki Kanao and Ayuko Ibaraki, National Institute of Polar Research (NIPR), Tachikawa, Japan;

UCDES—focal mechanisms for earthquakes of South Caspian region (Priestley et al. 1994), courtesy of Keith Priestley, University of Cambridge, Department of Earth Sciences, Cambridge, United Kingdom;

VUW—bulletin datasets from two temporary deployments in 1977 in the Bay of Plenty, New Zealand (Richardson 1989a, b);

WEL—update of the bulletin of the New Zealand seismic network, GNS Science, 2014, courtesy of Kevin Fenaughty, personal communication, 2014.

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