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The ISC Bulletin as a comprehensive source of earthquake source mechanisms

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Abstract. In this article we summarize the availability of earthquake source mechanisms in the Bulletin of the International Seismological Centre (ISC). The bulletin in its current status contains ∼81,000 seismic events with only one associated mechanism solution, and ∼22,000 events with at least two associated source mechanisms. The main sources of earthquake mechanisms in the ISC Bulletin are reported solutions provided by data contributors, and ISC computed focal mechanisms based on first motion polarities. Given the importance of using pre-determined fault plane solutions in different types of studies, here we focus only on the reported mechanisms and we briefly discuss the methodologies adopted by major data providers to the ISC and investigate the intra-event variability of the source mechanisms. We conclude that the overall agreement among different earthquake focal mechanisms for the same event as reported by different sources can be as high as 90% for the majority of the cases. The earthquake source mechanisms discussed in this work are freely available within the ISC Bulletin websearch at http://doi.org/10.31905/D808B830.

1 Introduction

The International Seismological Centre (ISC, www.isc.ac.uk) currently collects station readings, hypocentre solutions and other earthquake bulletin data from approximately 150 agencies around the world. The ISC Bulletin contains over 7 million seismic events (mostly earthquakes, as well as chemical and nuclear explosions, mine blasts and mining induced events, and other types of seismic events), and approximately 237 million individual seismic station readings of arrival times, amplitudes, periods and first motion polarities (International Seismological Centre, 2018, database last accessed in October 2018).

Considerable effort is put into making sure that the station readings reported by different agencies belong to the correct seismic event. In the first instance, all parametric data sent to the ISC is collected and grouped automatically in unique seismic events. As soon as an event is created it is made openly available via the online ISC Bulletin (www.isc.ac.uk/iscbulletin). Secondly, the ISC analysts manually review (two/three years behind real-time) the collected station readings and hypocentre solutions for seismic events larger than approximately 3.5. If all conditions are met (details at http://www.isc.ac.uk/iscbulletin/review/), the ISC also recomputes location and magnitude (currently only MS and mb) by combining all the available phase arrival times and amplitude measurements, respectively. ISC location and magnitude procedures have recently been improved (Bondár and Storchak, 2011).

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The ISC aims to increase the number of collected bulletins from national data centres or other sources (Willemann and Storchak, 2001) and improve its procedures in earthquake location and magnitude determinations (e.g., Bondár and Storchak, 2011; Di Giacomo and Storchak, 2015; Weston et al., 2018). As a result, the ISC Bulletin has proved to be a very useful resource for seismologists and geoscientists in general, as demonstrated by the vast use of ISC datasets in many research papers, including works on new tomographic models and global tectonics (e.g., Kennett et al., 1995; Rezapour and Pearce, 1998; Bormann et al., 2009; Hayes et al., 2012; Adam and Romanowicz, 2015; Zhan and Kanamori, 2016; Euler and Wysession, 2017; Lay et al., 2017). Recently the ISC has started to compute its own focal mechanisms (freely available in the reviewed bulletin) by using first motion polarities both from reported bulletins and picked automatically from waveform data (Lentas, 2017). In addition, the ISC Bulletin contains a substantial amount of source mechanisms (Fig. 1) calculated using different data and techniques as reported from various agencies working at local/regional and/or global scales, predominantly covering the period from mid 1970s till present.

In this paper, we aim to emphasize the availability of reported (i.e., not computed by the ISC) source mechanisms in the ISC Bulletin and discuss the different features of those solutions, aiming at helping ISC users to decide how best to use the database according to the needs of their research.

2 Source mechanism contributions to the ISC Bulletin

There are currently 64 agencies in the ISC Bulletin which have reported in the past or continue to report source mechanism solutions to the ISC (Fig. 2). By using the term source mechanisms we refer to both moment tensor solutions (and their associated best fitting double couple mechanisms) and pure double couple mechanisms of a point source.

Major contributors of global source mechanisms include the Global Centroid Moment Tensor Project (GCMT, www.globalcmt.org, Dziewonski et al., 1981; Ekström et al., 2012), the US National Earthquake Information Center (NEIC, or NEIS prior to 1984), and for regional earthquakes, the National Research Institute for Earth Science and Disaster Resilience (NIED) in Japan and the Pacific Northwest Seismic Network (PNSN).

Note that prior to data year 2006 the agency code HRVD (Harvard University) was used throughout the ISC Bulletin for GCMT solutions. Here we use a unique agency code for these source mechanisms and replace the HRVD agency code with the GCMT code throughout the ISC Bulletin. This is already done for the time period 1976-1979 covered by the first part of the ISC rebuild project (1964-1979, Storchak et al., 2017). After completion of the ISC rebuild project, all remaining HRVD source mechanism solutions will be available under the GCMT code. Moreover, moment tensor solutions for 76 intermediate depth earthquakes and 104 deep earthquakes from 1962 to 1976 have been added under the GCMT agency code (Chen et al., 2001; Huang et al., 1997).

Since the mid 1990s numerous other agencies, mainly national data centres, started reporting source mechanism solutions to the ISC. This has resulted in a steep increase of available mechanism solutions in the ISC Bulletin (Fig. 1). Nevertheless, the coverage and completeness of seismic events with associated source mechanisms is not uniform and primarily depends on

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the tectonics and the associated seismicity in different regions, the station coverage and the practices of the reporting agencies (Fig. 3).

All the available source mechanisms are included in the ISC Bulletin. However, users particularly interested in focal mechanisms can search using either a dedicated tool at http://www.isc.ac.uk/iscbulletin/search/fmechanisms/ or webservices at http://www.isc.ac.uk/iscbulletin/search/webservices/fmechanisms/. Search parameters include date, area, magnitude, depth and agency code. Search outputs are available either in a comma separated CSV-like format with one line per mechanism solution, or in QuakeML format. Included in the output are the ISC event identifier, scalar moments, moment tensor components, nodal planes, principal axes and the hypocentre/centroid parameters for each mechanism solution, where applicable. The format is explained in detail at http://www.isc.ac.uk/iscbulletin/search/fmechanisms/csvoutput/.

3 Source mechanism variability

Source mechanism solutions can be determined by using two main data types: (i) parametric data such as first motion P-wave polarities and amplitude ratios, and (ii) waveform data modelling. A vast variety of techniques and algorithms have been developed over the last few decades using different concepts and data. The most robust results are obtained by waveform modelling methods. Even though techniques based on polarities depend strongly on the network geometry and the station azimuthal coverage, they can still be very useful in determining the focal mechanisms of small earthquakes and aftershock sequences using local networks (Shearer, 1998). Focal mechanisms based on first motion polarities reflect the geometry of the seismic fault at the initial breaking of the rupture, whereas waveform modelling techniques usually consider group of phases (body waves and/or surface waves) and provide source mechanisms closer to the dominant component of the entire rupture geometry.

Moreover, different techniques follow different concepts on determining the source model of a point source. Some algorithms solve directly for the geometry of a planar fault, meaning the strike, dip and rake of the fault and auxiliary planes assuming a pure double couple mechanism. This is more common in first motion polarity based techniques (i.e., Reasenberg and Oppenheimer, 1985, which is used by PNSN), but it can also be the case in waveform modelling methods such as the SCARDEC technique (Vallée et al., 2010) reported by agency IPGP. These techniques usually depend on a pre-determined location. Other techniques determine the six components of the moment tensor which is a mathematical representation of the equivalent body forces acting on a seismic point source, and can be decomposed into an isotropic component, a compenstated linear vector dipole (CLVD) and a best fitting double couple mechanism which describes the geometry of a planar fault. Centroid based techniques like the GCMT, the MedNet Regional Centroid Moment Tensors (MED-RCMT), the Zurich Moment Tensors (ZUR-RMT) and others applied by the NEIC (Dziewonski et al., 1981; Ekström et al., 2012; Braunmiller et al., 2002; Pondrelli et al., 2011; Kanamori and Rivera, 2008; Duputel et al., 2012; Benz and Herrmann, 2014) use this concept and simultaneously determine the centroid location. Source models for all the above mentioned techniques can be found in the ISC Bulletin (see Fig. 2). Other automated moment tensors which depend on a pre-determined hypocentre location are also routinely reported in the ISC Bulletin, for example, by NIED in Japan (Fukuyama and Kawai, 1998). Moreover, taking into

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consideration additional differences in velocity models, station distribution and observations in different waveform frequency bands that are being used by different techniques, some variation among source mechanisms reported by different agencies for the same seismic event has to be expected.

Figure 4 shows the frequency distribution of available source mechanism solutions per event in the ISC Bulletin, and the frequency distribution of maximum intra-event rotation angle for the events having at least two reported mechanism solutions. The rotation angle describes the transformation of a double couple mechanism into another arbitrary mechanism through 3-D rotations (Kagan, 1991). The vast majority peak between 10° and 20°. Cases showing large differences, above 40°, are not rare and can be partly explained by earthquakes showing complex rupture, such as the 2002 November 3, M_W 7.9, Denali Central Alaska earthquake (Ozacar et al., 2003) and the doublet 2012 December 7, M_W 7.2, east coast of Honshu earthquake (Lay et al., 2013) which show intra-event rotation angles up to 60° and 90° respectively, or comparing automatic source mechanism solutions such as the 2015 May 25, M_W 5.2, eastern Honshu earthquake which shows intra-event rotation angles up to ∼90°. Substantial intra-event differences are also very common as a result of multiple solutions reported by PNSN for small earthquakes with poorly constrained source mechanisms, such as the 1981 February 11, M_d 2.5, Washington earthquake where the maximum intra-event rotation angle can be as high as 100°.

As source mechanisms are used in a variety of studies (e.g., tectonics, stress patterns, cluster analysis), in Figure 5 we show the annual number of earthquakes grouped by the faulting styles proposed by Zoback (1992) with the sole intent of showcasing one of the possible uses for the source mechanisms in the ISC Bulletin. Not surprisingly, the thrust earthquakes dominate the annual occurrences, with the only exceptions for year 2000 (significant strike-slip aftershock sequence following the 2000 Tottori, Japan, earthquake) and 2011 (aftershocks of the 2011 Tohoku earthquake, due to the stress field change, were characterized by many normal-fault earthquakes, as shown, e.g., by Hasegawa et al. (2012)). Figure 5 also shows the annual number of earthquakes for which we could not assign a fault style. This is due to large intra-event variability of the source mechanisms due to complexities, as mentioned earlier, or to conflicting reports. Note that classifications different from Zoback (1992) have been proposed (see, e.g., Célérier, 2010, for an overview), and users can apply their preferred classification from the source mechanisms within the ISC Bulletin.

4 Data availability

The earthquake source mechanisms summarized in this work are freely available within the ISC Bulletin websearch at http://doi.org/10.31905/D808B830. All data used in this paper are maintained at the ISC (www.isc.ac.uk, last accessed 20 November 2018).

5 Summary and conclusions

The ISC offers the most comprehensive bulletin of global seismicity in terms of hypocentre solutions, phase arrivals, magnitudes and amplitude measurements. In this paper we presented an additional aspect of the ISC Bulletin, namely its source

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mechanism content and the opportunity for ISC users to complement the source mechanism information with all other data included in the ISC Bulletin.

The ISC has a mandate to collect as much parametric data as possible from various sources around the world and make it freely available to the seismological as well as to a broad geoscience community. As a result, the magnitude range of earthquakes covered by available mechanism solutions is larger than individual global catalogues such as GCMT or NEIC. However, this feature inevitably leads to a higher heterogeneity in the solutions due to different methods adopted by each provider. Thus, users are advised to be aware of the techniques being used in the computations of the various source models in the ISC Bulletin. For example, centroid based mechanism solutions should be used together with centroid locations, since: (i) both the centroid mechanism and centroid location are parts of the same output, and (ii) substantial mislocations may exist among centroid locations and standard hypocentre locations fitting the observed phase arrival times of body waves. To facilitate this the CSV format provided by the online ISC Bulletin indicates whether a mechanism solution is centroid or not. Source mechanisms obtained from pre-determined standard hypocentre locations can be used together with the provider's hypocentre solution or the prime hypocentre solution in the ISC Bulletin. However, large differences in depth may be present in some cases among the prime hypocentre solution and the solution provided by the mechanism's agency.

Similar to the variation of hypocentre solutions in the ISC Bulletin, multiple source mechanisms for the same seismic event, when available, can provide a measure of the posterior uncertainties with respect to data errors and modelling techniques. Despite variations in methods and data used to compute the solutions, we showed that in most cases there is a good agreement among multiple solutions provided by different agencies. The intra-event variability in the ISC Bulletin was quantified by the maximum rotation angle and is well constrained up to 20°, which corresponds to a similarity coefficient of ∼90% (Cesca et al., 2013). Different classification techniques and metrics could be applied (i.e., Helffrich, 1997; Frohlich and Davis, 1999) but for the purpose of the current article the rotation angle is considered to be an adequate metric of source mechanism variability. Similarly, by applying Zoback (1992) fault styles classification, we observe for up to 8% of the earthquakes per year a large intra-event variability.

Source mechanisms are currently not reviewed by ISC analysts, and the user should pick, if required, the preferred one when multiple solutions are available for an event. The ISC values all agencies reporting source mechanism solutions and encourages new ones to submit theirs. In parallel, we recommend researchers to make a more systematic use of the earthquake source mechanisms in the ISC Bulletin in future studies.

Author contributions. KL was the leading author of the paper and compiled four figures. DDG prepared one figure, JH maintains the database and webservices and DAS obtained the funding for the work and established connections with several data providers. All authors contributed to the manuscript and approved the final version.

Competing interests. The authors declare that they have no conflict of interest.

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References

Adam, J.-C. and Romanowicz, B.: Global scale observations of scattered energy near the inner-core boundary: Seismic constraints on the base of the outer-core, Physics of the Earth and Planetary Interiors, 245, 103–116, https://doi.org/10.1016/j.pepi.2015.06.005, https://doi.org/10.1016/j.pepi.2015.06.005, 2015.

Benz, H. M. and Herrmann, R. B.: Rapid Estimates of the Source Time Function and Mw using Empirical Green's Function Deconvolution-Rapid Estimates of the Source Time Function and Mw using EGF Deconvolution, Bulletin of the Seismological Society of America, 104, 1812, https://doi.org/10.1785/0120130325, http://dx.doi.org/10.1785/0120130325, 2014.

Bondár, I. and Storchak, D. A.: Improved location procedures at the International Seismological Centre, Geophysical Journal International, 186, 1220–1244, https://doi.org/10.1111/j.1365-246x.2011.05107.x, https://doi.org/10.1111/j.1365-246x.2011.05107.x, 2011.

Bormann, P., Liu, R., Xu, Z., Ren, K., Zhang, L., and Wendt, S.: First Application of the New IASPEI Teleseismic Magnitude Standards to Data of the China National Seismographic Network, Bulletin of the Seismological Society of America, 99, 1868–1891, https://doi.org/10.1785/0120080010, https://doi.org/10.1785/0120080010, 2009.

Braunmiller, J., Kradolfer, U., Baer, M., and Giardini, D.: Regional moment tensor determination in the European–Mediterranean area — initial results, Tectonophysics, 356, 5–22, https://doi.org/10.1016/s0040-1951(02)00374-8, https://doi.org/10.1016/s0040-1951(02)00374-8, 2002.

Célérier, B.: Remarks on the relationship between the tectonic regime, the rake of the slip vectors, the dip of the nodal planes, and the plunges of the P, B, and T axes of earthquake focal mechanisms, Tectonophysics, 482, 42–49, https://doi.org/10.1016/j.tecto.2009.03.006, https://doi.org/10.1016/j.tecto.2009.03.006, 2010.

Cesca, S., Şen, A. T., and Dahm, T.: Seismicity monitoring by cluster analysis of moment tensors, Geophysical Journal International, 196, 1813–1826, https://doi.org/10.1093/gji/ggt492, https://doi.org/10.1093/gji/ggt492, 2013.

Chen, P. F., Nettles, M., Okal, E. A., and Ekström, G.: Centroid moment tensor solutions for intermediate-depth earthquakes of the WWSSN–HGLP era (1962–1975), Physics of the Earth and Planetary Interiors, 124, 1–7, https://doi.org/10.1016/s0031-9201(00)00220-x, https://doi.org/10.1016/s0031-9201(00)00220-x, 2001.

Di Giacomo, D. and Storchak, D. A.: A scheme to set preferred magnitudes in the ISC Bulletin, Journal of Seismology, 20, 555–567, https://doi.org/10.1007/s10950-015-9543-7, https://doi.org/10.1007/s10950-015-9543-7, 2015.

Duputel, Z., Rivera, L., Kanamori, H., and Hayes, G.: W phase source inversion for moderate to large earthquakes (1990-2010), Geophysical Journal International, 189, 1125–1147, https://doi.org/10.1111/j.1365-246x.2012.05419.x, https://doi.org/10.1111/j.1365-246x.2012.05419.x, 2012.

Dziewonski, A. M., Chou, T.-A., and Woodhouse, J. H.: Determination of earthquake source parameters from waveform data for studies of global and regional seismicity, Journal of Geophysical Research: Solid Earth, 86, 2825–2852, https://doi.org/10.1029/jb086ib04p02825, https://doi.org/10.1029/jb086ib04p02825, 1981.

Ekström, G., Nettles, M., and Dziewoński, A.: The global CMT project 2004–2010: Centroid-moment tensors for 13, 017 earthquakes, Physics of the Earth and Planetary Interiors, 200-201, 1–9, https://doi.org/10.1016/j.pepi.2012.04.002, https://doi.org/10.1016/j.pepi.2012.04.002, 2012.

Euler, G. G. and Wysession, M. E.: Geographic variations in lowermost mantle structure from the ray parameters and decay constants of core-diffracted waves, Journal of Geophysical Research: Solid Earth, 122, 5369–5394, https://doi.org/10.1002/2017jb013930, https://doi.org/10.1002/2017jb013930, 2017.

Frohlich, C. and Davis, S. D.: How well constrained are well-constrained T, B, and P axes in moment tensor catalogs?, Journal of Geophysical Research: Solid Earth, 104, 4901–4910, https://doi.org/10.1029/1998jb900071, https://doi.org/10.1029/1998jb900071, 1999.

Fukuyama, E., S. I. D. S. D. and Kawai, H.: Automated seismic moment tensor determination by using on-line broadband seismic waveforms, Journal of the Seismological Society of Japan, 2, 149–156, 1998.

Hasegawa, A., Yoshida, K., Asano, Y., Okada, T., Iinuma, T., and Ito, Y.: Change in stress field after the 2011 great Tohoku-Oki earthquake, Earth and Planetary Science Letters, 355-356, 231–243, https://doi.org/10.1016/j.epsl.2012.08.042, https://doi.org/10.1016/j.epsl.2012.08.042, 2012.

Hayes, G. P., Wald, D. J., and Johnson, R. L.: Slab1.0: A three-dimensional model of global subduction zone geometries, Journal of Geophysical Research: Solid Earth, 117, https://doi.org/10.1029/2011jb008524, https://doi.org/10.1029/2011jb008524, 2012.

Helffrich, G. R.: How good are routinely determined focal mechanisms? Empirical statistics based on a comparison of Harvard, USGS and ERI moment tensors, Geophysical Journal International, 131, 741–750, https://doi.org/10.1111/j.1365-246x.1997.tb06609.x, https://doi.org/10.1111/j.1365-246x.1997.tb06609.x, 1997.

Huang, W.-c., Okal, E. A., Ekström, G., and Salganik, M. P.: Centroid moment tensor solutions for deep earthquakes predating the digital era: the World-Wide Standardized Seismograph Network dataset (1962–1976), Physics of the Earth and Planetary Interiors, 99, 121–129, https://doi.org/10.1016/s0031-9201(96)03177-9, https://doi.org/10.1016/s0031-9201(96)03177-9, 1997.

International Seismological Centre: On-line Bulletin, Internatl. Seismol. Cent., Thatcham, United Kingdom, http://www.isc.ac.uk, 2018.

Kagan, Y. Y.: 3-D rotation of double-couple earthquake sources, Geophysical Journal International, 106, 709–716, https://doi.org/10.1111/j.1365-246x.1991.tb06343.x, https://doi.org/10.1111/j.1365-246x.1991.tb06343.x, 1991.

Kanamori, H. and Rivera, L.: Source inversion of W phase: speeding up seismic tsunami warning, Geophysical Journal International, 175, 222–238, https://doi.org/10.1111/j.1365-246x.2008.03887.x, https://doi.org/10.1111/j.1365-246x.2008.03887.x, 2008.

Kennett, B. L. N., Engdahl, E. R., and Buland, R.: Constraints on seismic velocities in the Earth from traveltimes, Geophysical Journal International, 122, 108–124, https://doi.org/10.1111/j.1365-246x.1995.tb03540.x, https://doi.org/10.1111/j.1365-246x.1995.tb03540.x, 1995.

Lay, T., Duputel, Z., Ye, L., and Kanamori, H.: The December 7, 2012 Japan Trench intraplate doublet (Mw 7.2, 7.1) and interactions between near-trench intraplate thrust and normal faulting, Physics of the Earth and Planetary Interiors, 220, 73–78, https://doi.org/10.1016/j.pepi.2013.04.009, https://doi.org/10.1016/j.pepi.2013.04.009, 2013.

Lay, T., Ye, L., Koper, K. D., and Kanamori, H.: Assessment of teleseismically-determined source parameters for the April 25, 2015 M_W 7.9 Gorkha, Nepal earthquake and the May 12, 2015 M_W 7.2 aftershock, Tectonophysics, 714-715, 4–20, https://doi.org/10.1016/j.tecto.2016.05.023, https://doi.org/10.1016/j.tecto.2016.05.023, 2017.

Lentas, K.: Towards routine determination of focal mechanisms obtained from first motion P-wave arrivals, Geophysical Journal International, 212, 1665–1686, https://doi.org/10.1093/gji/ggx503, https://doi.org/10.1093/gji/ggx503, 2017.

Ozacar, A. A., Beck, S. L., and Christensen, D. H.: Source process of the 3 November 2002 Denali fault earthquake (central Alaska) from teleseismic observations, Geophysical Research Letters, 30, https://doi.org/10.1029/2003gl017272, https://doi.org/10.1029/2003gl017272, 2003.

Pondrelli, S., Salimbeni, S., Morelli, A., Ekström, G., Postpischl, L., Vannucci, G., and Boschi, E.: European–Mediterranean Regional Centroid Moment Tensor catalog: Solutions for 2005–2008, Physics of the Earth and Planetary Interiors, 185, 74–81, https://doi.org/10.1016/j.pepi.2011.01.007, https://doi.org/10.1016/j.pepi.2011.01.007, 2011.

Reasenberg, P. and Oppenheimer, D.: FPFIT, FPPLOT and FPPAGE; Fortran computer programs for calculating and displaying earthquake fault-plane solutions, https://doi.org/10.3133/ofr85739, https://doi.org/10.3133/ofr85739, 1985.

Rezapour, M. and Pearce, R. G.: Bias in surface-wave magnitude Ms due to inadequate distance corrections, Bulletin of the Seismological Society of America, 88, 43–61, 1998.

Shearer, P. M.: Evidence from a cluster of small earthquakes for a fault at 18 km depth beneath Oak Ridge, southern California, Bulletin of the Seismological Society of America, 88, 1327–1336, 1998.

Storchak, D. A., Harris, J., Brown, L., Kathrin, L., Shumba, B., Verney, R., Di Giacomo, D., and Korger, E. I. M.: Rebuild of the Bulletin of the International Seismological Centre (ISC), part 1: 1964–1979, Geoscience Letters, 4, https://doi.org/10.1186/s40562-017-0098-z, https://doi.org/10.1186/s40562-017-0098-z, 2017.

Vallée, M., Charléty, J., Ferreira, A. M. G., Delouis, B., and Vergoz, J.: SCARDEC: a new technique for the rapid determination of seismic moment magnitude, focal mechanism and source time functions for large earthquakes using body-wave deconvolution, Geophysical Journal International, 184, 338–358, https://doi.org/10.1111/j.1365-246x.2010.04836.x, https://doi.org/10.1111/j.1365-246x.2010.04836.x, 2010.

Wessel, P., Smith, W. H. F., Scharroo, R., Luis, J., and Wobbe, F.: Generic Mapping Tools: Improved Version Released, Eos, Transactions American Geophysical Union, 94, 409–410, https://doi.org/10.1002/2013eo450001, 2013.

Weston, J., Engdahl, E., Harris, J., Di Giacomo, D., and Storchak, D.: ISC-EHB: reconstruction of a robust earthquake data set, Geophysical Journal International, 214, 474–484, https://doi.org/10.1093/gji/ggy155, https://doi.org/10.1093/gji/ggy155, 2018.

Willemann, R. J. and Storchak, D. A.: Data Collection at the International Seismological Centre, Seismological Research Letters, 72, 440–453, https://doi.org/10.1785/gssrl.72.4.440, https://doi.org/10.1785/gssrl.72.4.440, 2001.

Zhan, Z. and Kanamori, H.: Recurring large deep earthquakes in Hindu Kush driven by a sinking slab, Geophysical Research Letters, 43, 7433–7441, https://doi.org/10.1002/2016gl069603, https://doi.org/10.1002/2016gl069603, 2016.

Zoback, M. L.: First- and second-order patterns of stress in the lithosphere: The World Stress Map Project, Journal of Geophysical Research, 97, 11 703–11 728, https://doi.org/10.1029/92jb00132, https://doi.org/10.1029/92jb00132, 1992.

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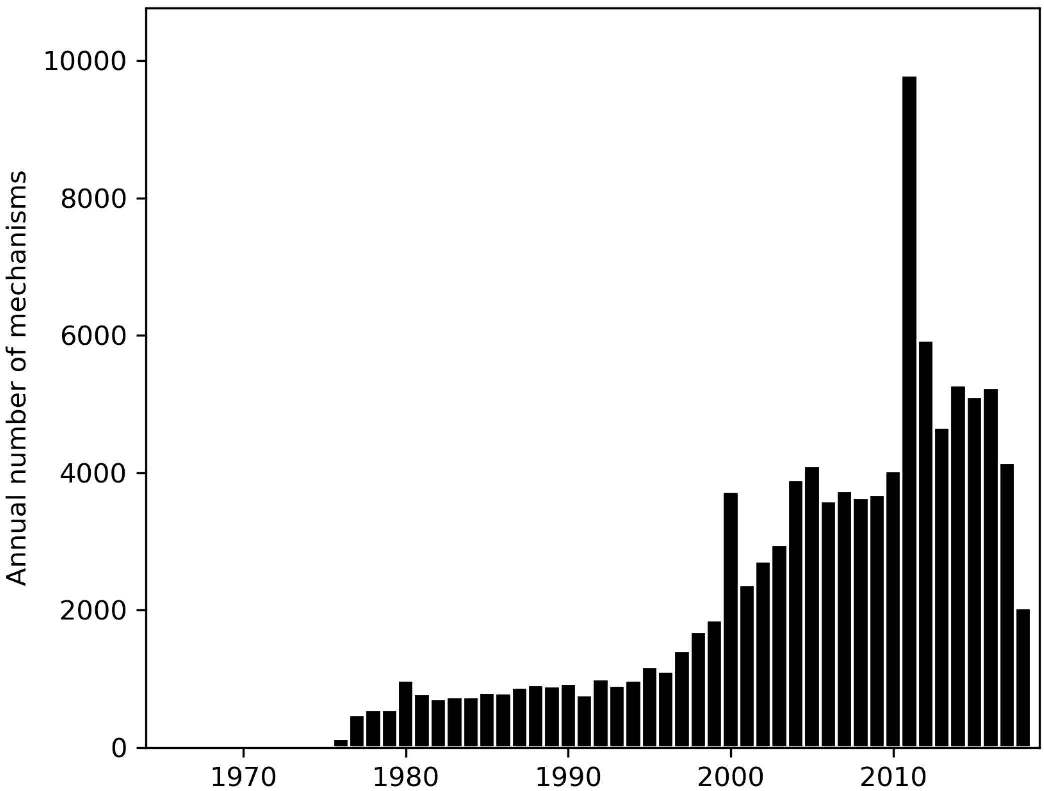

Figure 1. Number of source mechanisms in the ISC Bulletin from January 1964 to October 2018. Note the high peak in 2011 which is associated with the 2011 Tohoku earthquake aftershock sequence. The dip for year 2018 is only apparent as the data collection is not complete yet.

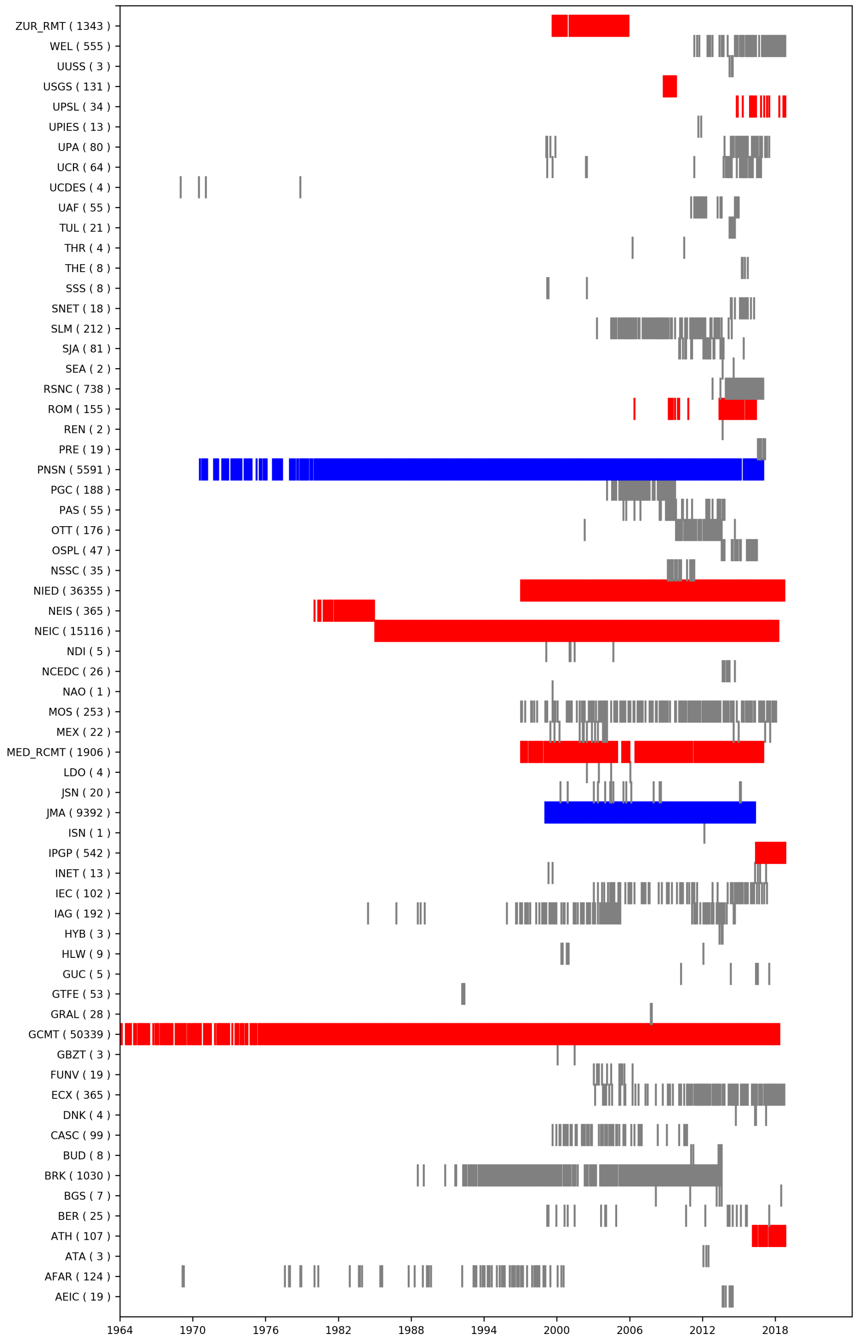

Figure 2. Time distribution of source mechanisms in the ISC Bulletin (January 1964 – October 2018) reported by different agencies. The numbers in brackets next to each agency code shows the total number of reported source mechanism solutions. Red lines indicate waveform inversion techniques, blue lines indicate first motion polarity techniques and grey colour shows cases where there is no information available on the techniques being used or we could not verify them. A detailed list of the reporting agencies can be found at: http://www.isc.ac.uk/iscbulletin/agencies/.

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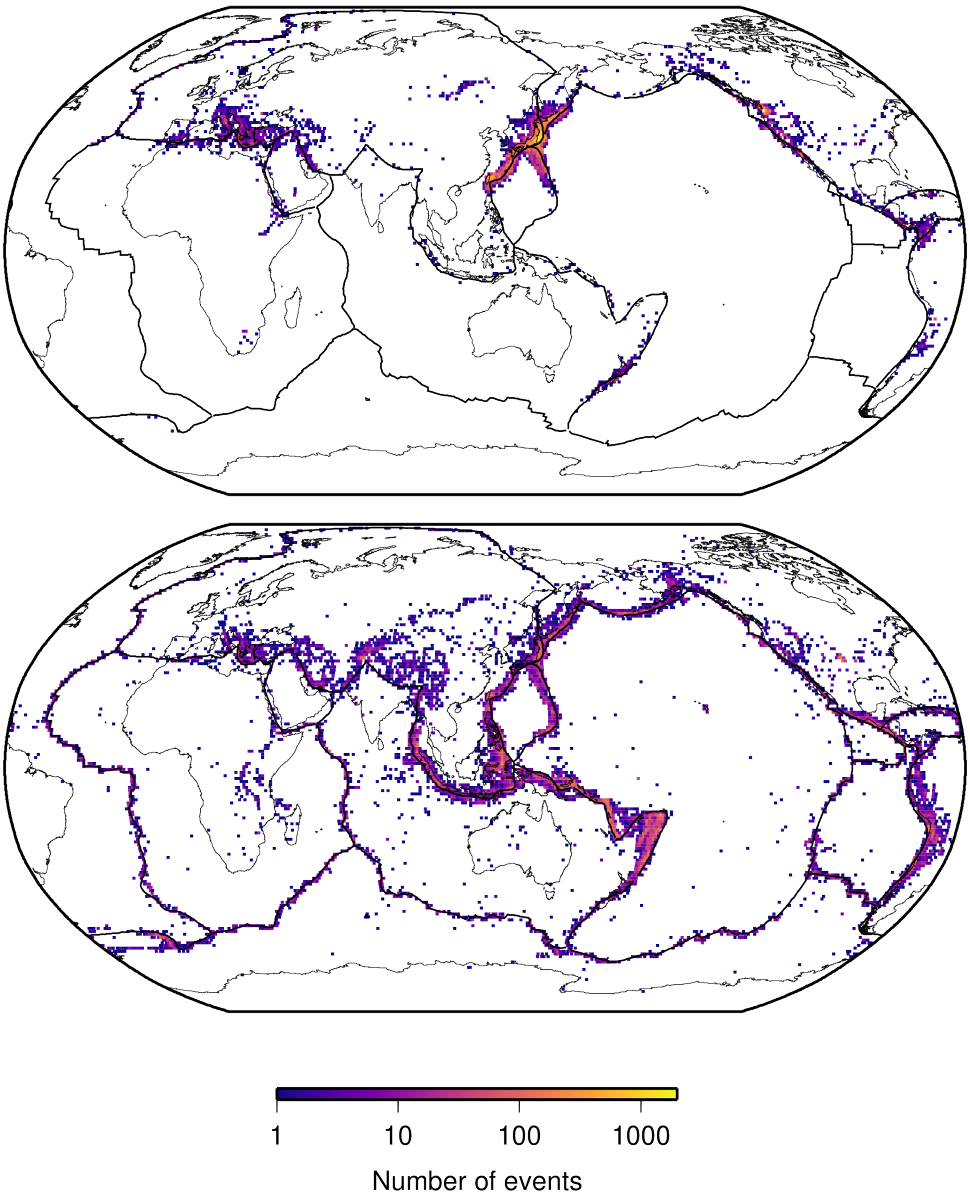

Figure 3. Global maps showing the number of events with at least one source mechanism reported in the ISC Bulletin for the time period from January 1964 to October 2018, in a 1° by 1° grid, for mechanism solutions reported by local and regional agencies (top), and global agencies (bottom, [HRVD, GCMT, NEIS, NEIC, IPGP]).

Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2018-143
Manuscript under review for journal Earth Syst. Sci. Data
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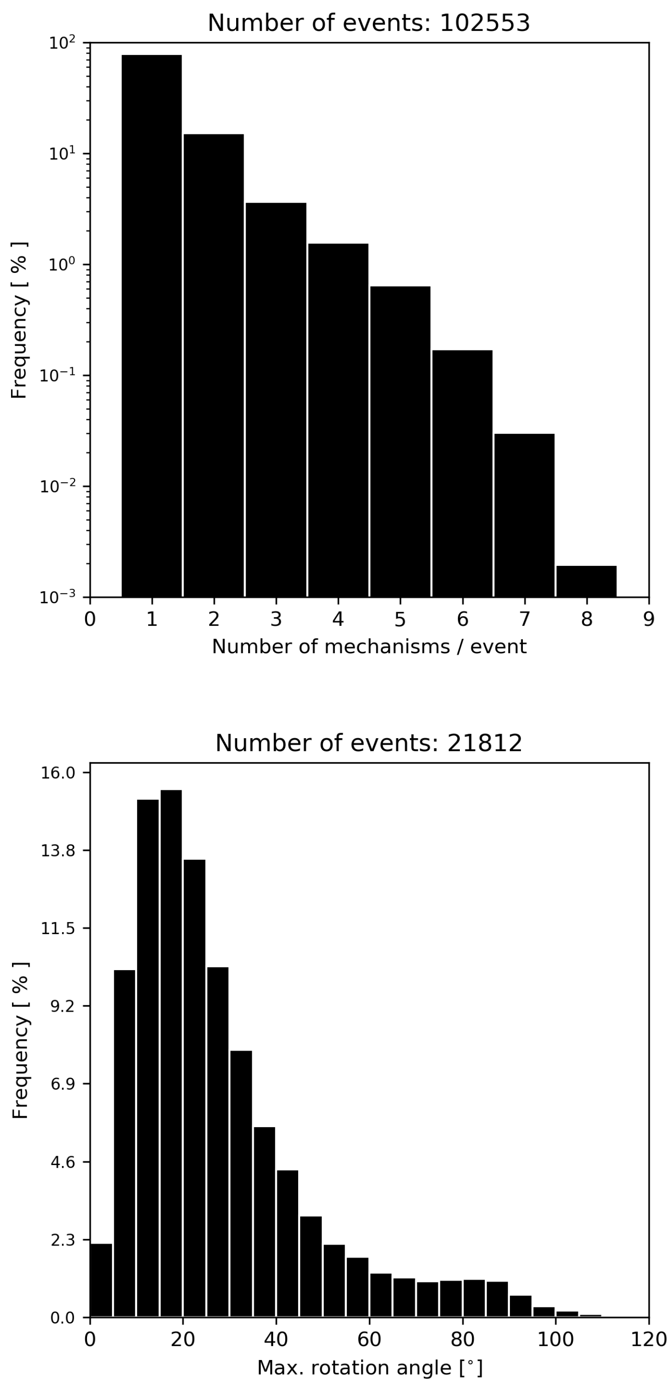

Figure 4. Frequency distribution of available source mechanisms per event in the ISC Bulletin for the time period from January 1964 to October 2018 (top), and intra-event maximum rotation angle frequency distribution for the seismic events having at least two mechanism solutions available (bottom).

Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2018-143
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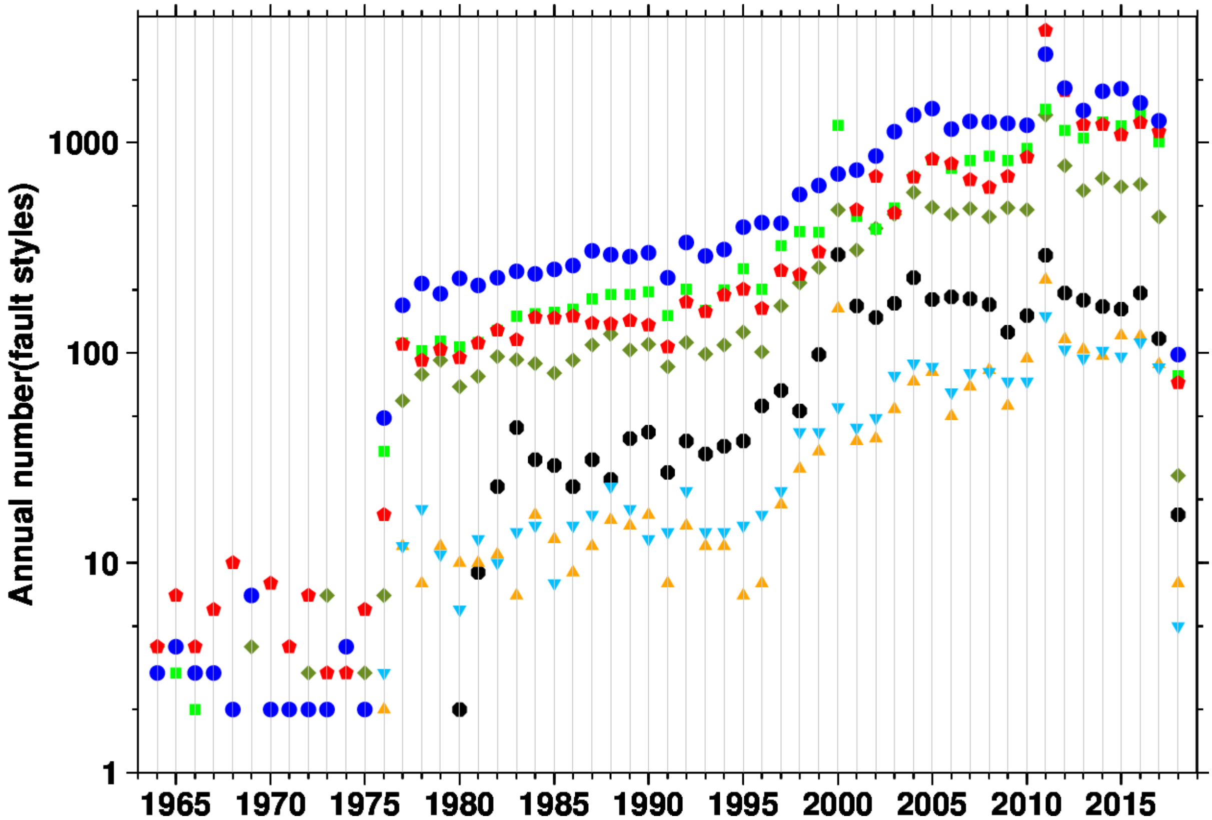

Figure 5. Annual number of source mechanisms grouped by Zoback (1992) fault styles. Dark blue circles, red pentagons, green squares, orange triangles, light blue inverted triangles and olive diamonds represent, respectively, thrust, normal, strike-slip, normal with strike-slip component, thrust with strike-slip component and undefined earthquakes. Black octagons are earthquakes for which the intra-variability of the source mechanisms does not allow us to assign an earthquake to a fault style. These are earthquakes with large rotation angles (see Figure 4). The percentage of such earthquakes goes up to 8% of earthquakes per year.