Summary of the Bulletin of the International Seismological Centre

2021

July – December

Volume 58 Issue II

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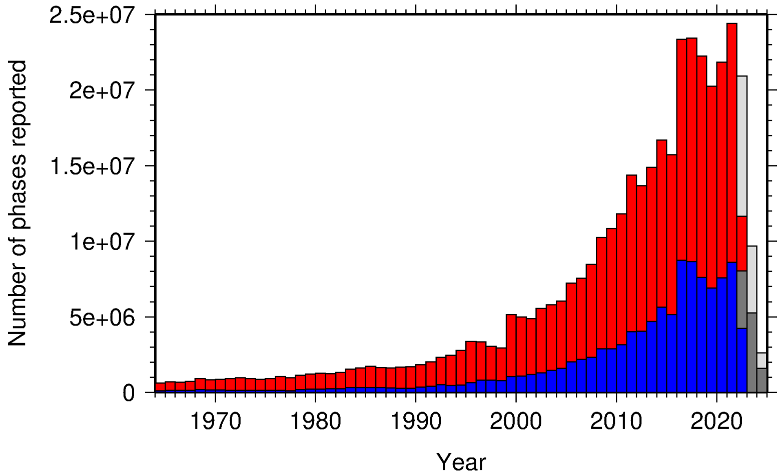
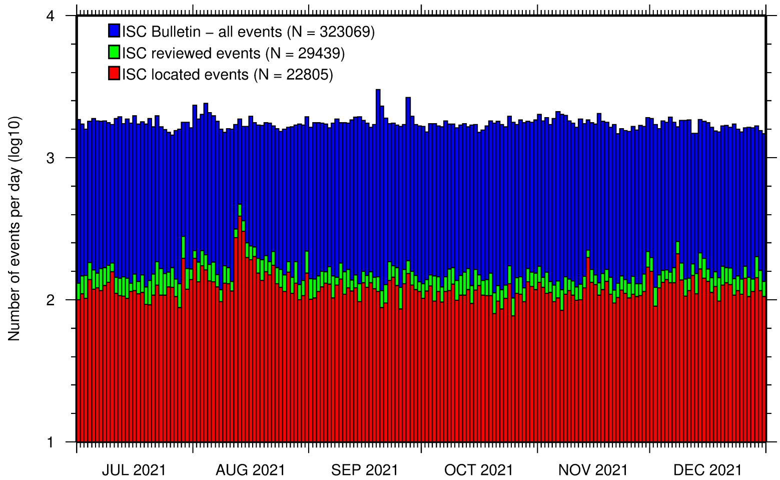
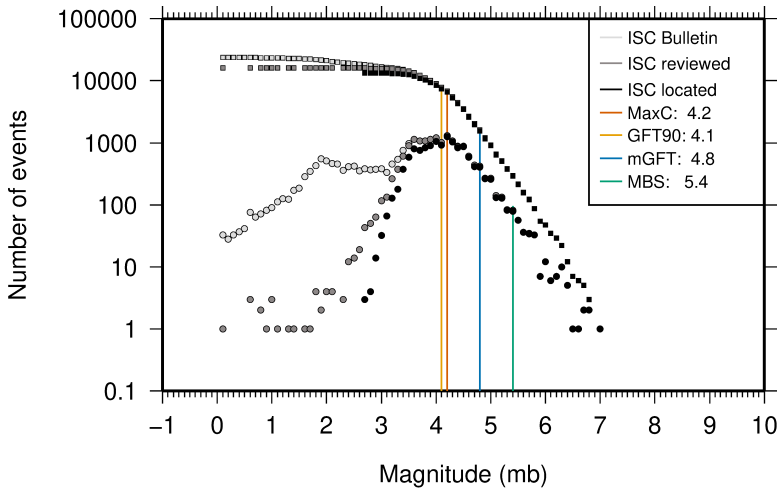
2025



The number of phases (red) and number of amplitudes (blue) collected by the ISC for events each year since 1964. The data in grey covers the current period where data are still being collected before the ISC review takes place and are accurate at the time of publication. See Section 7.3.



The number of events within the Bulletin for the current summary period. The vertical scale is logarithmic. See Section 8.1.



Frequency and cumulative frequency magnitude distribution for all events in the ISC Bulletin, ISC reviewed events and events located by the ISC. The magnitude of completeness (M_C) is shown for the ISC Bulletin. Note: only events with values of m_b are represented in the figure. See Section 8.4.

Summary of the Bulletin of the International Seismological Centre

2021

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Produced and edited by:
Kathrin Lieser, James Harris and Dmitry Storchak

International Seismological Centre

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ISC Data Products

http://www.isc.ac.uk/products/

ISC Bulletin:

http://www.isc.ac.uk/iscbulletin/search

ISC Bulletin and Catalogue monthly files, to the last reviewed month in ISF2 format:

http://download.isc.ac.uk/isf2/[bulletin|catalogue]/*yyyy*/*yyyymm*.gz

ftp://www.isc.ac.uk/pub/isf2/[bulletin|catalogue]/*yyyy*/*yyyymm*.gz

Datafiles for the ISC data before the rebuild in isf or ffb formats:

http://download.isc.ac.uk//prerebuild/[isf|ffb]/[bulletin|catalogue]/*yyyy*/*yyyymm*.gz

ftp://www.isc.ac.uk/pub/prerebuild/[isf|ffb]/[bulletin|catalogue]/*yyyy*/*yyyymm*.gz

ISC-EHB Bulletin:

http://www.isc.ac.uk/isc-ehb/search/

IASPEI Reference Event List (GT bulletin):

http://www.isc.ac.uk/gtevents/search/

ISC-GEM Global Instrumental Earthquake Catalogue:

http://www.isc.ac.uk/iscgem/download.php

ISC Event Bibliography:

http://www.isc.ac.uk/event_bibliography/bibsearch.php

International Seismograph Station Registry:

http://www.isc.ac.uk/registries/search/

Seismological Contacts:

http://www.isc.ac.uk/projects/seismocontacts/

International Seismological Centre
Pipers Lane
Thatcham
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www.isc.ac.uk

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Contents

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Preface

Dear Colleague,

This is the second 2021 issue of the Summary of the ISC Bulletin, which remains the most fundamental reason for continued operations at the ISC. This issue covers earthquakes and other seismic events that occurred during the period from July to December 2021. Users can search the ISC Bulletin on the ISC website. The monthly Bulletin files are available from the ISC ftp site. For instructions, please see the www.isc.ac.uk/iscbulletin/.

This publication contains information on the ISC, its staff, Members, Sponsors and Data providers. It offers analysis of the data contributed to the ISC by many seismological agencies worldwide as well as analysis of the data in the ISC Bulletin itself. This somewhat smaller issue misses some of the standard information on routine procedures usually published in the first issue of each year.

I would like to reiterate here that all ISC hypocenter solutions (1964-present) are now based on the *ak135* velocity model and all ISC magnitudes (1964-present) are based on the latest robust procedures.

We usually publish invited articles on notable seismic events as well as articles describing the history, status and operational procedures at networks that report parametric data to the ISC. This time, the topic of an invited article is somewhat different – long-term statistics of reported teleseismic phases.

We hope that you find this publication useful in your work. If your home-institution or company is unable, for one reason or another, to support the long-term international operations of the ISC in full by becoming a Member or a Sponsor, then, please, consider subscribing to this publication by contacting us at admin@isc.ac.uk.

With kind regards to our Data Contributors, Members, Sponsors and users,

Dr Dmitry A. Storchak
Director
International Seismological Centre (ISC)

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2

The International Seismological Centre

2.1 The ISC Mandate

The International Seismological Centre (ISC) was set up in 1964 with the assistance of UNESCO as a successor to the International Seismological Summary (ISS) to carry forward the pioneering work of Prof. John Milne, Sir Harold Jeffreys and other British scientists in collecting, archiving and processing seismic station and network bulletins and preparing and distributing the definitive summary of world seismicity.

Under the umbrella of the International Association of Seismology and Physics of the Earth Interior (IASPEI/IUGG), the ISC has played an important role in setting international standards such as the International Seismic Bulletin Format (ISF), the IASPEI Standard Seismic Phase List (SSPL) and both the old and New IASPEI Manual of the Seismological Observatory Practice (NMSOP-2) (https://doi.org/10.2312/GFZ.NMSOP-2).

The ISC has contributed to scientific research and prominent scientists such as John Hodgson, Eugine Herrin, Hal Thirlaway, Jack Oliver, Anton Hales, Ola Dahlman, Shigeji Suehiro, Nadia Kondorskaya, Vit Karnik, Stephan Müller, David Denham, Bob Engdahl, Adam Dziewonski, John Woodhouse and Guy Masters all considered it an important duty to serve on the ISC Executive Committee and the Governing Council.

The current mission of the ISC is to maintain:

- the ISC **Bulletin** – the longest continuous definitive summary of World seismicity (collaborating with 150 seismic networks and data centres around the world). (www.isc.ac.uk/iscbulletin/)
- the International Seismographic Station Registry (**IR**, jointly with the World Data Center for Seismology, Denver). (www.isc.ac.uk/registries/)
- the IASPEI Reference Event List (Ground Truth, **GT**, jointly with IASPEI). (www.isc.ac.uk/gtevents/)

These are fundamentally important tasks. Bulletin data produced, archived and distributed by the ISC for almost 60 years are the definitive source of such information and are used by thousands of seismologists worldwide for seismic hazard estimation, for tectonic studies and for regional and global imaging of the Earth's structure. Key information in global tomographic imaging is derived from the analysis of ISC data. The ISC Bulletin served as a major source of data for such well known products as the ak135 global 1-D velocity model and the ISC-EHB (*Engdahl et al.*, 2020; 1998; *Weston et al.*, 2018) and Centennial (*Engdahl and Villaseñor*, 2002) catalogues. It presents an important quality-control benchmark for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO). Hypocentre parameters from the ISC Bulletin are used by the Data Management Center of the Incorporated Research Institutions for Seismology (IRIS DMC) to serve event-oriented user-requests for waveform data. The ISC-GEM Bulletin is a cornerstone of the ISC-GEM Global Instrumental Reference Earthquake Catalogue for Global Earthquake risk Model (GEM).

The ISC Bulletin contains over 8 million seismic events: earthquakes, chemical and nuclear explosions, mine blasts and mining induced events. Almost 2 million of them are regional and teleseismically recorded events that have been reviewed by the ISC analysts. The ISC Bulletin contains approximately 255 million individual seismic station readings of arrival times, amplitudes, periods, SNR, slowness and azimuth, reported by approximately 19,000 seismic stations currently registered in the IR. Over 9,000 stations have contributed to the ISC Bulletin in recent years. This number includes the numerous sites of the USArray. The IASPEI GT List currently contains 10187 events for which latitude, longitude and depth of origin are known with high confidence (to 5 km or better) and seismic signals were recorded at regional and/or teleseismic distances.

2.2 Brief History of the ISC

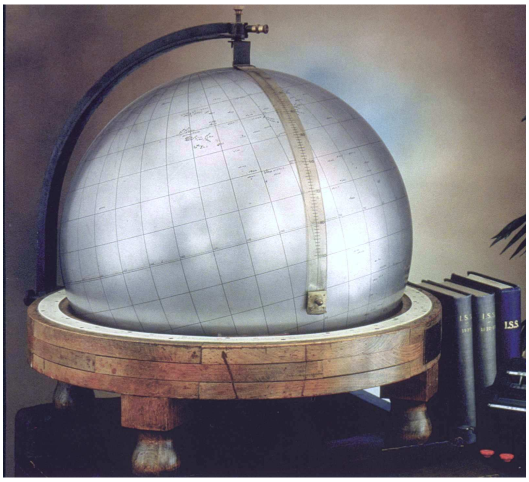


Figure 2.1: *The steel globe bearing positions of early seismic stations was used for locating positions of earthquakes for the International Seismological Summaries.*

Earthquake effects have been noted and documented from the earliest times, but it is only since the development of earthquake recording instruments in the latter half of the 19th century that a proper study of their occurrence has been possible. After the first teleseismic observation of an earthquake in 1889, the need for international exchange of readings was recognised in 1895 by Prof. John Milne and by Ernst von Rebeur Paschwitz together with Georg Gerland, resulting in the publication of the first international seismic bulletins. Milne's "Shide Circulars" were issued under the auspices of the Seismological Committee of the British Association for the Advancement of Science (BAAS), while co-workers of Gerland at the Central Bureau of the International Association of Seismology worked independently in Strasbourg (BCIS).

Following Milne's death in 1913, Seismological Bulletins of the BAAS were continued under Prof. H.H. Turner, later based at Oxford University. Upon formal post-war dissolution of the International Association of Seismology in 1922 the newly founded Seismological Section of the International Union of Geodesy and Geophysics (IUGG) set up the International Seismological Summary (ISS) to continue at Oxford under Turner, to produce the definitive global catalogues from the 1918 data-year onwards, under the auspices of IUGG and with the support of the BAAS.

ISS production, led by several professors at Oxford University, and Sir Harold Jeffreys at Cambridge

University, continued until it was superseded by the ISC Bulletin, after the ISC was formed in Edinburgh in 1964 with Dr P.L. Willmore as its first director.

During the period 1964 to 1970, with the help of UNESCO and other international scientific bodies, the ISC was reconstituted as an international non-governmental body, funded by interested institutions from various countries. Initially there were supporting members from seven countries, now there are 80, and member institutions include national academies, research foundations, government departments and research institutes, national observatories and universities. Each member, contributing a minimum unit of subscription or more, appoints a representative to the ISC's Governing Council, which meets every two years to decide the ISC's policy and operational programme. Representatives from the International Association of Seismology and Physics of the Earth's Interior also attend these meetings. The Governing Council appoints the Director and a small Executive Committee to oversee the ISC's operations.

Figure 2.2: *ISC building in Thatcham, Berkshire, UK.*

In 1975, the ISC moved to Newbury in southern England to make use of better computing facilities there. The ISC subsequently acquired its own computer and in 1986 moved to its own building at Pipers Lane, Thatcham, near Newbury. The internal layout of the new premises was designed for the ISC and includes not only office space but provision for the storage of extensive stocks of ISS and ISC publications and a library of seismological observatory bulletins, journals and books collected over many tens of years.

In 1997 the first set of the ISC Bulletin CD-ROMs was produced (not counting an earlier effort at USGS). The first ISC website appeared in 1998 and the first ISC database was put in day-to-day operations from 2001. Major developments also included the introduction of bar-codes to assist ISC analysts reviewing the ISC Bulletin as well as the introduction of the automatic email data capture system to modernise the data collection at the ISC.

During the 2004-2007 period, in search of financial efficiency, the ISC moved its operations from UNIX to a Linux operating system, and the ORACLE database gave way to the PostgreSQL database management system.

The new ISC seismic event locator, ISCloc, was developed, tested and put into operation by the end of 2010. A stable version of the locator was routinely applied to seismic events from data year 2011 with the Jeffreys-Bullen travel-time tables giving way to the use of the ak135 1D velocity model. During the 2009-2020 period, the ISC Bulletin Rebuild project involved a major general bulletin clean-up, sourcing and integrating 90 previously unavailable datasets from around the world, and re-computation of all ISC hypocentres and magnitudes for the period 1964-2010 followed by analyst review.

During the 2010s, in addition to its two traditional products (the Bulletin of the ISC and the International Seismograph Station Registry(IR)), the ISC developed a number of new datasets and services that were designed to serve the individual needs of different scientific research communities: the ISC-GEM Global Instrumental Earthquake Catalogue, the IASPEI Ground Truth (GT) reference event dataset, the ISC-

EHB dataset, the ISC Event Bibliography, the International Contacts in Seismology, and the CTBTO Link to the ISC database.

In 2014, the ISC took over the maintenance of the website of the International Association of Seismology and Physics of the Earth's Interior (IASPEI).

In 2016, a new Visual Bulletin Analysis System (VBAS) revolutionised the work of the ISC Analysts performing manual analysis of the ISC Bulletin by moving it from a paper-based batch-type to a screen-based interactive system.

In April 2020, the ISC was registered as a **Charitable Incorporated Organization** (CIO) with the Charity Commission for England and Wales. The ISC **Constitution**, compliant with UK charity law, was adopted by the ISC Governing Council in May 2020. The **Bye-laws**, fully compliant with the Constitution, provided further details and clarification of exact rules and procedures applicable in the day-to-day operation of the ISC in pursuit of its mission. The Byelaws were adopted by the Governing Council in June 2021 and amended in July 2025.

The ISC **Data Management Policy**, establishing the dynamic character of the ISC data, approach to versioning, and ways of tracking and preserving changes in the ISC database was adopted in July 2023.

The ISC **Data Collection Policy** was adopted in September 2024. It clarified the priority of the ISC to continue the well-established practice of collecting good quality event parameter data from seismic networks and data centres whilst re-confirming the growing practice of the ISC using openly available digital waveform data to constrain event parameters that are not readily available from reporting agencies.

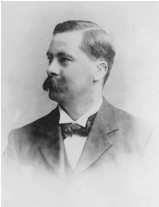
Further ISC products, developed during the 2020s, include the ISC Seismological Dataset Repository, the ISC Electronic Archive of Printed Station / Network Bulletins, and the ISC Station Services that combined the station location data from both the IR and the International Federation of Digital Seismograph Networks (FDSN).

Since 2011, several scientific articles were published by ISC staff that specified the ways individual ISC products were built and maintained for the scientific community's use. All ISC products have been given a digital object identifier (DOI). Ways of appropriate citing of the ISC data have been recommended on the ISC website.

Throughout 2009-2025 a major internal reconstruction of the ISC building in Thatcham was undertaken to allow for more members of staff working in mainstream ISC operations as well as major development projects.

2.3 Former Directors of the ISC and its U.K. Predecessors

John Milne
Publisher of the Shide Cicular Reports on Earthquakes
1899-1913

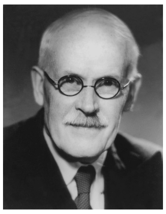


Herbert Hall Turner

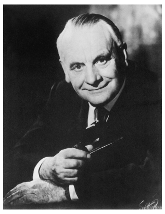
Seismological Bulletins of the BAAS

1913-1922
Director of the ISS
1922-1930

Harry Hemley Plaskett
Director of the ISS
1931-1946



Harold Jeffreys
Director of the ISS
1946-1957



Robert Stoneley
Director of the ISS
1957-1963

P.L. (Pat) Willmore
Director of the ISS
1963-1970
Director of the ISC
1964-1970

Edouard P. Arnold
Director of the ISC
1970-1977

Anthony A. Hughes
Director of the ISC
1977-1997

Raymond J. Willemann
Director of the ISC
1998-2003

Avi Shapira
Director of the ISC
2004-2007

2.4 Member Institutions of the ISC

The ISC Constitution and Bye-laws stipulate that any national academy, agency, scientific institution or other non-profit organisation may become a Member of the ISC on payment to the ISC of a sum equal to at least one unit of subscription and the nomination of a voting representative to serve on the ISC's governing body. Membership shall be effective for one year from the date of receipt at the ISC of the annual contribution of the Member and is thereafter renewable for periods of one year.

The ISC is currently supported by its 80 Member Institutions and Award 2414178 from the US National Science Foundation via the University of Oxford and Grant INT004 from the Royal Society in UK.

Figures 2.3 and 2.4 show major sectors to which the ISC Member Institutions belong and proportional financial contributions that each of these sectors make towards the ISC's annual budget.

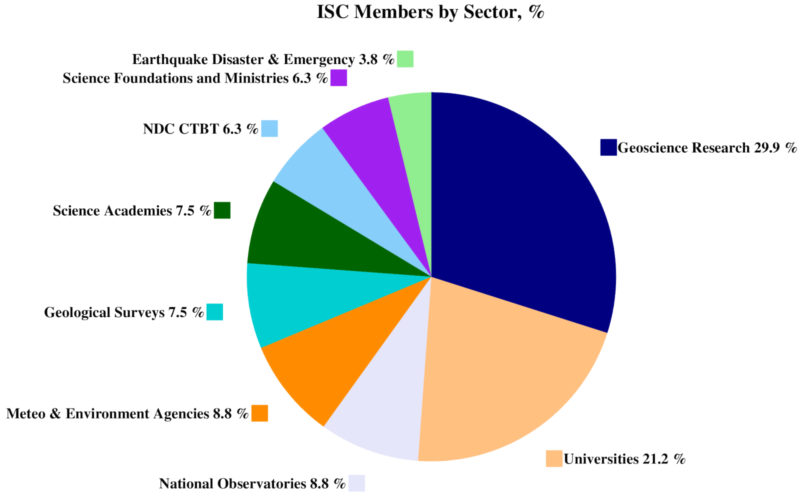


Figure 2.3: *Distribution of the ISC Member Institutions by sector during the review of data in this Summary as a percentage of total number of Members.*

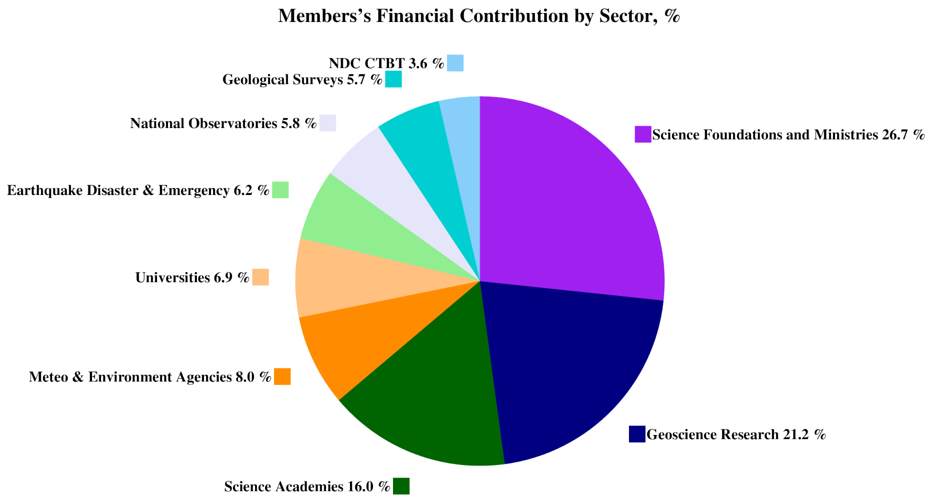


Figure 2.4: *Distribution of Member's financial contributions to the ISC by sector during the review of data in this Summary as a percentage of total annual Member contributions.*

There follows a list of all current Member Institutions with a category (1 through 9) assigned according to the ISC Constitution. Each category relates to the number of membership units contributed.

Institute of Geosciences, Polytechnic University of Tirana
Albania
www.geo.edu.al
Category: 1

Centre de Recherche en Astronomie, Astrophysique et Géophysique (CRAAG)
Algeria
www.craag.dz
Category: 1

Geoscience Australia
Australia
www.ga.gov.au
Category: 4

Geophysics, Research School of Earth Sciences, Australian National University
Australia
earthsciences.anu.edu.au
Category: 1

Federal Ministry for Education, Science and Research
Austria
www.bmbwf.gv.at
Category: 2

Centre of Geophysical Monitoring (CGM) of the National Academy of Sciences of Belarus
Belarus
www.cgm.org.by
Category: 1

Belgian Science Policy Office (BELSPO)
Belgium
www.belspo.be
Category: 1

Seismological Observatory, Institute of Geosciences, University of Brasilia
Brazil
www.obsis.unb.br
Category: 1

Observatorio Nacional
Brazil
www.on.br
Category: 1

Universidade de São Paulo, Centro de Sismologia
Brazil
www.sismo.iag.usp.br
Category: 1

National Institute of Geophysics, Geodesy and Geography (NIGGG), Bulgarian Academy of Sciences
Bulgaria
www.niggg.bas.bg
Category: 1

The Geological Survey of Canada
Canada
gsc.nrcan.gc.ca
Category: 4

Centro Sismologico Nacional, Universidad de Chile
Chile
www.csn.uchile.cl
Category: 1

China Earthquake Administration
China
www.cea.gov.cn
Category: 4

Institute of Earth Sciences, Academia Sinica
Chinese Taipei
www.earth.sinica.edu.tw
Category: 1

Geological Survey Department
Cyprus
www.moa.gov.cy
Category: 1

Institute of Geophysics, Czech Academy of Sciences
Czech Republic
www.ig.cas.cz
Category: 1

Geological Survey of Denmark and Greenland (GEUS)
Denmark
www.geus.dk
Category: 2

National Research Institute for Astronomy and Geophysics (NRIAG), Cairo
Egypt
www.nriag.sci.eg
Category: 1

The University of Helsinki
Finland
www.helsinki.fi
Category: 2

Géoazur, Université Côte d'Azur
France
univ-cotedazur.eu
Category: 1

Autorité de Sûreté Nucléaire et de Radioprotection (formerly IRSN)
France
www.irsn.fr
Category: 1

Laboratoire de Détection et de Géophysique/CEA
France
www-dase.cea.fr
Category: 2

Institute National des Sciences de l'Univers
France
www.insu.cnrs.fr
Category: 4

Bundesanstalt für Geowissenschaften und Rohstoffe
Germany
www.bgr.bund.de
Category: 4

GeoForschungsZentrum Potsdam
Germany
www.gfz-potsdam.de
Category: 2

The Seismological Institute, National Observatory of Athens
Greece
www.noa.gr
Category: 1

HUN-REN Institute of Earth Physics and Space Science
Hungary
epss.hun-ren.hu
Category: 1

The Icelandic Meteorological Office
Iceland
www.vedur.is
Category: 1

National Geophysical Research Institute (NGRI), Council of Scientific and Industrial Research (CSIR)
India
www.ngri.org.in
Category: 2

National Centre for Seismology, Ministry of Earth Sciences of India
India
www.moes.gov.in
Category: 4

Iraqi Meteorological Organization and Seismology
Iraq
www.imos-tm.com
Category: 1

Dublin Institute for Advanced Studies
Ireland
www.dias.ie
Category: 1

Geological Survey of Israel
Israel
www.gov.il
Category: 1

Soreq Nuclear Research Centre (SNRC)
Israel
www.soreq.gov.il
Category: 1

Istituto Nazionale di Oceanografia e di Geofisica Sperimentale
Italy
www.ogs.trieste.it
Category: 1

Istituto Nazionale di Geofisica e Vulcanologia
Italy
www.ingv.it
Category: 3

University of the West Indies at Mona
Jamaica
www.mona.uwi.edu
Category: 1

The Japan Meteorological Agency (JMA)
Japan
www.jma.go.jp
Category: 5

Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
Japan
www.jamstec.go.jp
Category: 2

National Institute of Polar Research (NIPR)
Japan
www.nipr.ac.jp
Category: 1

Earthquake Research Institute, University of Tokyo
Japan
www.eri.u-tokyo.ac.jp
Category: 3

Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE)
Mexico
resnom.cicese.mx
Category: 1

Institute of Geophysics, National University of Mexico
Mexico
www.igeofcu.unam.mx
Category: 1

National Centre for Scientific and Technical Research (CNRST)
Morocco

Category: 1

The Royal Netherlands Meteorological Institute (KNMI)
Netherlands
www.knmi.nl
Category: 2

GNS Science
New Zealand
www.gns.cri.nz
Category: 3

The University of Bergen
Norway
www.uib.no
Category: 2

Stiftelsen NORSAR
Norway
www.norsar.no
Category: 2

Institute of Geophysics, Polish Academy of Sciences
Poland
www.igf.edu.pl
Category: 1

Instituto Português do Mar e da Atmosfera
Portugal
www.ipma.pt
Category: 2

Red Sísmica de Puerto Rico
Puerto Rico
redsismica.uprm.edu
Category: 1

Korean Meterological Administration
Republic of Korea
www.kma.go.kr
Category: 1

National Institute for Earth Physics
Romania
www.infp.ro
Category: 1

Russian Academy of Sciences
Russia
www.ras.ru
Category: 5

Saudi Geological Survey (SGS)
Saudi Arabia
sgs.gov.sa
Category: 2

Earth Observatory of Singapore (EOS), an autonomous Institute of Nanyang Technological University
Singapore
www.earthobservatory.sg
Category: 1

Environmental Agency of Slovenia
Slovenia
www.arso.gov.si
Category: 1

Council for Geoscience South Africa
www.geoscience.org.za
Category: 2

Institut Cartogràfic i Geològic de Catalunya (ICGC)
Spain
www.icgc.cat
Category: 1

Institute of Marine Sciences (ICM-CSIC)
Spain
www.icm.csic.es
Category: 1

Instituto Geografico Nacional
Spain
www.ign.es
Category: 3

Uppsala Universitet
Sweden
www.uu.se
Category: 2

National Defence Research Establishment (FOI)
Sweden
www.foi.se
Category: 1

The Swiss Academy of Sciences
Switzerland
www.scnat.ch
Category: 2

Kandilli Observatory and Earthquake Research Institute
Turkey
www.koeri.boun.edu.tr
Category: 1

Disaster and Emergency Management Authority (AFAD)
Turkey
www.deprem.gov.tr
Category: 2

The Royal Society
United Kingdom
www.royalsociety.org
Category: 6

British Geological Survey
United Kingdom
www.bgs.ac.uk
Category: 2

AWE Blacknest
United Kingdom
www.blacknest.gov.uk
Category: 2

National Earthquake Information Center, U.S. Geological Survey
U.S.A.
www.neic.usgs.gov
Category: 1

Pacific Northwest Seismic Network (PNSN)
U.S.A.
www.pnsn.org
Category: 1

Center for Earthquake Research and Information (CERI), the University of Memphis
U.S.A.
www.memphis.edu
Category: 1

Incorporated Research Institutions for Seismology
U.S.A.
www.iris.edu
Category: 2

The National Science Foundation of the United States. (NSF Award 2414178)
U.S.A.
www.nsf.gov
Category: 9

Lamont-Doherty Earth Observatory, Columbia Climate School, Columbia University
U.S.A.
lamont.columbia.edu
Category: 1

Alaska Earthquake Center (AEC), University of Alaska Fairbanks
U.S.A.
earthquake.alaska.edu
Category: 1

University of Utah Seismograph Stations (UUSS)
U.S.A.
quake.utah.edu
Category: 1

Texas Seismological Network (TexNet), Bureau of Economic Geology, J.A. and K.G. Jackson School of Geosciences, University of Texas at Austin
U.S.A.
www.beg.utexas.edu
Category: 1

Mavlyanov Institute of Seismology, Academy of Sciences, Republic of Uzbekistan
Uzbekistan
seismos.uz
Category: 1

In addition the ISC is currently in receipt of grants from the International Data Centre (IDC) of the

Preparatory Commission of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), FM Global, Lighthill Risk Network, and AXA XL.

2.5 Sponsoring Organisations

Article 9.8.1 of the ISC Constitution stipulates that any organisation with an interest in the work of the ISC may at the discretion of the ISC Executive Committee become a Sponsoring Organisation (Sponsor) upon payment of a mutually agreed annual fee. In line with the Article VI of the ISC Bye-laws, the Sponsors are entitled to attend meetings of the ISC Governing Council without a vote.

`http://www.geosig.com/`

GeoSIG provides earthquake, seismic, structural, dynamic and static monitoring and measuring solutions As an ISO Certified company, GeoSIG is a world leader in design and manufacture of a diverse range of high quality, precision instruments for vibration and earthquake monitoring. GeoSIG instruments are at work today in more than 100 countries around the world with well-known projects such as the NetQuakes installation with USGS and Oresund Bridge in Denmark. GeoSIG offers off-the-shelf solutions as well as highly customised solutions to fulfil the challenging requirements in many vertical markets including the following:

- Earthquake Early Warning and Rapid Response (EEWRR)
- Seismic and Earthquake Monitoring and Measuring
- Industrial Facility Seismic Monitoring and Shutdown

- Structural Analysis and Ambient Vibration Testing
- Induced Vibration Monitoring
- Research and Scientific Applications

sara electronic instruments http://www.sara.pg.it

SARA designs and manufactures seismometers, accelerometers and portable multichannel seismographs for both seismology and applied geophysics. Since 2002 we provided over 5,000 seismic units, 15,000 acceleration transducers and 15,000 geophysical exploration channels, to thousands of professionals and researchers who are using our equipment with success. Providing low-cost instrumentation for developing countries is our main goal. We developed our seismological software SEISMOWIN which provides full support for all international file formats and communication standards like miniSEED, GSE, SeedLink and a number of tools for earthquake location and site assessment. The GEOEXPLORER software suite offers a number of modules for geological surveys.

In 2023 we introduced our new compact broadband seismometer to the market, suitable for surface, posthole and borehole installation, and new versions of our popular SL06 recorder with rack mount housing and ADC with PGA offering 24 or 32 bit streaming.

Visit our web site and download the free tools available at: www.sara.pg.it

GaiaCode https://www.gaiacode.com/

Gaiacode is a science based, forward looking, innovative company designing and building the next generation of seismic instrumentation.

MS&AD MS&AD InterRisk Research & Consulting http://www.irric.co.jp/en/corporate/

MS&AD InterRisk Research & Consulting, Inc. is responsible for the core of risk-related service businesses in the MS&AD group. We provide services which meet various expectations of the clients, including consulting, research and investigation, seminars and publications for risk management in addition to the think-tank functions.

2.6 Data Contributing Agencies

In addition to its Members and Sponsors, the ISC owes its existence and successful long-term operations to its 152 seismic bulletin data contributors. These include government agencies responsible for national seismic networks, geoscience research institutions, geological surveys, meteorological agencies, universities, national data centres for monitoring the CTBT and individual observatories. There would be no ISC Bulletin available without the regular stream of data that are unselfishly and generously contributed to the ISC on a free basis.

Institute of Geosciences, Polytechnic University of Tirana
Albania
TIR

Centre de Recherche en Astronomie, Astrophysique et Géophysique
Algeria
CRAAG

Universidad Nacional de La Plata
Argentina
LPA

Instituto Nacional de Prevención Sísmica
Argentina
SJA

National Survey of Seismic Protection
Armenia
NSSP

Geoscience Australia
Australia
AUST

Curtin University
Australia
CUPWA

International Data Centre, CTBTO
Austria
IDC

Bundesanstalt für Geologie, Geophysik, Klimatologie und Meteorologie
Austria
VIE

Republican Seismic Survey Center of Azerbaijan National Academy of Sciences
Azerbaijan
AZER

Royal Observatory of Belgium
Belgium
UCC

Observatorio San Calixto
Bolivia
SCB

Republic Hydrometeorological Service, Seismological Observatory, Banja Luka
Bosnia and Herzegovina
RHSSO

Botswana Geoscience Institute
Botswana
BGSI

Instituto Astronomico e Geofísico
Brazil
VAO

Observatory Seismological of the University of Brasilia
Brazil
OSUNB

National Institute of Geophysics, Geology and Geography
Bulgaria
SOF

Canadian Hazards Information Service, Natural Resources Canada
Canada
OTT

Centro Sismológico Nacional, Universidad de Chile
Chile
GUC

China Earthquake Networks Center
China
BJI

Institute of Earth Sciences, Academia Sinica
Chinese Taipei
ASIES

Central Weather Bureau (CWB)
Chinese Taipei
TAP

Red Sismológica Nacional de Colombia
Colombia
RSNC

Sección de Sismología, Vulcanología y Exploración Geofísica
Costa Rica
UCR

Seismological Survey of the Republic of Croatia
Croatia
ZAG

Servicio Sismológico Nacional Cubano
Cuba
SSNC

Cyprus Geological Survey Department
Cyprus
NIC

Institute of Geophysics, Czech Academy of Sciences
Czech Republic
PRU

Institute of Geophysics, Czech Academy of Sciences
Czech Republic
WBNET

The Institute of Physics of the Earth (IPEC)
Czech Republic
IPEC

Korea Earthquake Administration
Democratic People's Republic of Korea
KEA

Geological Survey of Denmark and Greenland
Denmark
DNK

Observatorio Sismologico Politecnico Loyola
Dominican Republic
OSPL

Servicio Nacional de Sismología y Vulcanología
Ecuador
IGQ

National Research Institute of Astronomy and Geophysics
Egypt
HLW

Servicio Nacional de Estudios Territoriales
El Salvador
SNET

Institute of Seismology, University of Helsinki
Finland
HEL

Laboratoire de Détection et de Géophysique/CEA
France
LDG

EOST / RéNaSS
France
STR

Institut de Physique du Globe de Paris
France
IPGP

Laboratoire de Géophysique/CEA
French Polynesia
PPT

Institute of Earth Sciences/ National Seismic Monitoring Center
Georgia
TIF

Helmholtz Centre Potsdam GFZ German Research Centre For Geosciences
Germany
GFZ

Geophysikalisches Observatorium Collm
Germany
CLL

Bundesanstalt für Geowissenschaften und Rohstoffe
Germany
BGR

Seismological Observatory Berggießhübel, TU Bergakademie Freiberg
Germany
BRG

Alfred Wegener Institute for Polar and Marine Research
Germany
AWI

National Observatory of Athens
Greece
ATH

University of Patras, Department of Geology
Greece
UPSL

Department of Geophysics, Aristotle University of Thessaloniki
Greece
THE

INSIVUMEH
Guatemala
GCG

Hong Kong Observatory
Hong Kong
HKC

HUN-REN Inst of Earth Physics and Space Science, Kövesligethy Radó Seismo Obs
Hungary
KRSZO

Icelandic Meteorological Office
Iceland
REY

National Centre for Seismology of the Ministry of Earth Sciences of India
India
NDI

National Geophysical Research Institute
India
HYB

Badan Meteorologi, Klimatologi dan Geofisika
Indonesia
DJA

International Institute of Earthquake Engineering and Seismology (IIEES)
Iran
THR

Tehran University
Iran
TEH

Iraqi Meteorological and Seismology Organisation
Iraq
ISN

Dublin Institute for Advanced Studies
Ireland
DIAS

The Geophysical Institute of Israel
Israel
GII

Istituto Nazionale di Geofisica e Vulcanologia
Italy
ROM

Dipartimento per lo Studio del Territorio e delle sue Risorse (RSNI)
Italy
GEN

Laboratory of Research on Experimental and Computational Seimology
Italy
RISSC

SARA Electronic Instrument s.r.l.
Italy
SARA

Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS)
Italy
OGS

MedNet Regional Centroid - Moment Tensors
Italy
MED_RCMT

Jamaica Seismic Network
Jamaica
JSN

National Institute of Polar Research
Japan
SYO

National Research Institute for Earth Science and Disaster Resilience
Japan
NIED

Japan Meteorological Agency
Japan
JMA

Jordan Seismological Observatory
Jordan
JSO

Seismological Experimental Methodological Expedition
Kazakhstan
SOME

National Nuclear Center
Kazakhstan
NNC

Institute of Seismology, Academy of Sciences of Kyrgyz Republic
Kyrgyzstan
KRNET

Kyrgyz Seismic Network
Kyrgyzstan
KNET

Latvian Seismic Network
Latvia
LVSN

National Council for Scientific Research
Lebanon
GRAL

Geological Survey of Lithuania
Lithuania
LIT

Macao Meteorological and Geophysical Bureau
Macao, China
MCO

Antananarivo
Madagascar
TAN

Geological Survey Department Malawi
Malawi
GSDM

Instituto de Geofísica de la UNAM
Mexico
MEX

Centro de Investigación Científica y de Educación Superior de Ensenada
Mexico
ECX

Institute of Hydrometeorology and Seismology of Montenegro
Montenegro
PDG

Centre National de Recherche
Morocco
CNRM

The Geological Survey of Namibia
Namibia
NAM

National Seismological Centre, Nepal
Nepal
DMN

IRD Centre de Nouméa
New Caledonia
NOU

Institute of Geological and Nuclear Sciences
New Zealand
WEL

Central American Tsunami Advisory Center
Nicaragua
CATAC

Seismological Observatory Skopje
North Macedonia
SKO

University of Bergen
Norway
BER

Stiftelsen NORSAR
Norway
NAO

Sultan Qaboos University
Oman
OMAN

Universidad de Panama
Panama
UPA

Philippine Institute of Volcanology and Seismology
Philippines
MAN

Manila Observatory
Philippines
QCP

Institute of Geophysics, Polish Academy of Sciences
Poland
WAR

Private Observatory of Pawel Jacek Wiejacz, D.Sc.
Poland
PJWWP

Instituto Português do Mar e da Atmosfera, I.P.
Portugal
INMG

Sistema de Vigilância Sismológica dos Açores
Portugal
SVSA

Instituto Dom Luiz, University of Lisbon
Portugal
IGIL

Centre of Geophysical Monitoring of the National Academy of Sciences of Belarus
Republic of Belarus
BELR

Inst. of Seismology and Geodynamics, V.I. Vernadsky Crimean Federal University
Republic of Crimea
CFUSG

Korea Meteorological Administration
Republic of Korea
KMA

National Institute for Earth Physics
Romania
BUC

Baykal Regional Seismological Centre, GS SB RAS
Russia
BYKL

Altay-Sayan Branch, Geophysical Survey, Russian Academy of Sciences
Russia
ASGSR

Federal Center for Integrated Arctic Research
Russia
FCIAR

Kola Branch, Geophysical Survey, Russian Academy of Sciences
Russia
KOGSR

Kamchatka Branch of the Geophysical Survey of the RAS
Russia
KRSC

Mining Institute of the Ural Branch of the Russian Academy of Sciences
Russia
MIRAS

Geophysical Survey of Russian Academy of Sciences
Russia
MOS

North Eastern Regional Seismological Centre, Magadan, GS RAS
Russia
NERS

Sakhalin Experimental and Methodological Seismological Expedition, GS RAS
Russia
SKHL

Yakutiya Regional Seismological Center, GS SB RAS
Russia
YARS

Saudi Geological Survey
Saudi Arabia
SGS

Republicki seizmoloski zavod
Serbia
BEO

Geophysical Institute, Slovak Academy of Sciences
Slovakia
BRA

Slovenian Environment Agency
Slovenia
LJU

Council for Geoscience
South Africa
PRE

Real Instituto y Observatorio de la Armada
Spain
SFS

Institut Cartogràfic i Geològic de Catalunya
Spain
MRB

Instituto Geográfico Nacional
Spain
MDD

University of Uppsala
Sweden
UPP

Swiss Seismological Service (SED)
Switzerland
ZUR

Thai Meteorological Department
Thailand
BKK

The Seismic Research Centre
Trinidad and Tobago
TRN

Institut National de la Météorologie
Tunisia
TUN

Kandilli Observatory and Earthquake Research Institute
Turkey
ISK

Disaster and Emergency Management Presidency
Turkey
AFAD

National Earthquake Information Center
U.S.A.
NEIC

Pacific Northwest Seismic Network
U.S.A.
PNSN

The Global CMT Project
U.S.A.
GCMT

Texas Seismological Network, University of Texas at Austin
U.S.A.
TXNET

Pacific Tsunami Warning Center
U.S.A.
PTWC

Red Sísmica de Puerto Rico
U.S.A.
RSPR

Subbotin Institute of Geophysics, National Academy of Sciences
Ukraine
SIGU

Main Centre for Special Monitoring
Ukraine
MCSM

Dubai Seismic Network
United Arab Emirates
DSN

International Seismological Centre Probabilistic Point Source Model
United Kingdom
ISC-PPSM

International Seismological Centre
United Kingdom
ISC

British Geological Survey
United Kingdom
BGS

Institute of Seismology, Academy of Sciences, Republic of Uzbekistan
Uzbekistan
ISU

Fundación Venezolana de Investigaciones Sismológicas
Venezuela
FUNV

Institute of Geophysics, Viet Nam Academy of Science and Technology
Viet Nam
PLV

Goetz Observatory
Zimbabwe
BUL

Data from publications listed in the ISC Event Bibliography

EVBIB

Revision and Continuation of the EHB project	East African Network
ISC-EHB	EAF

2.7 ISC Staff

Listed below are the staff (and their country of origin) who were employed at the ISC during the time period when the ISC worked on the data covered by this issue of the Summary.

- Dmitry Storchak
- Director
- Russia / United Kingdom

- Lynn Elms
- Administration Officer
- United Kingdom

- James Harris
- Senior System and Database Administrator
- United Kingdom

- Oliver Rea
- System Administrator
- United Kingdom

- Calum Clague
- Data Collection Officer
- United Kingdom

- Domenico Di Giacomo
- Senior Seismologist
- Italy/UK

- Tom Garth
- Seismologist / Senior Developer
- United Kingdom

- Ryan Gallacher
- Seismologist / Developer
- United Kingdom

- Natalia Poiata
- Seismologist / Developer
- Moldova

- Adrian Armstrong
- Software Engineer
- United Kingdom

- Rosemary Hulin
- Analyst
- United Kingdom

- Blessing Shumba
- Seismologist / Senior Analyst
- United Kingdom

- Rebecca Verney
- Analyst
- United Kingdom

- Elizabeth Ayres
- Analyst / Historical Data Officer
- United Kingdom

- Kathrin Lieser
- Analyst Administrator / Summary Editor / Seismologist
- Germany

- Burak Sakarya
- Seismologist / Analyst
- Turkey

- Rian Harris
- Historical Data Officer
- United Kingdom

- Susana Carvalho
- Historical Data Officer
- Portugal

3

Availability of the ISC Bulletin

The ISC Bulletin is available from the following sources:

- Web searches
  The entire ISC Bulletin is available directly from the ISC website via tailored searches.
  (www.isc.ac.uk/iscbulletin/search)

  - Bulletin search - provides the most verbose output of the ISC Bulletin in ISF or QuakeML.
  - Event catalogue - only outputs the prime hypocentre for each event, producing a simple list of events, locations and magnitudes.
  - Arrivals - search for arrivals in the ISC Bulletin. Users can search for specific phases for selected stations and events.

- FTP site

  The ISC Bulletin is also available to download from the ISC ftp site, which contains the Bulletin in PDF, ISF and FFB formats.
  (ftp://www.isc.ac.uk)
  and
  (http://download.isc.ac.uk)

4

Citing the International Seismological Centre

Data from the ISC should always be cited. This includes use by academic or commercial organisations, as well as individuals. A citation should show how the data were retrieved and may be in one of these suggested forms:

The ISC is named as a valid data centre for citations within American Geophysical Union (AGU) publications. As such, please follow the AGU guidelines when referencing ISC data in one of their journals. The ISC may be cited as both the institutional author of the Bulletin and the source from which the data were retrieved.

4.1 The ISC Bulletin

International Seismological Centre (2025), On-line Bulletin, `https://doi.org/10.31905/D808B830`

The procedures used for producing the ISC Bulletin have been described in a number of scientific articles. Depending on the use of the Bulletin, users are encouraged to follow the citation suggestions below:

a) For current ISC location procedure:

Bondár, I. and D.A. Storchak (2011). Improved location procedures at the International Seismological Centre, *Geophys. J. Int.*, *186*, 1220-1244, `https://doi.org/10.1111/j.1365-246X.2011.05107.x`

b) For Rebuilt ISC Bulletin:

Storchak, D.A., Harris, J., Brown, L., Lieser, K., Shumba, B., Verney, R., Di Giacomo, D., Korger, E. I. M. (2017). Rebuild of the Bulletin of the International Seismological Centre (ISC), part 1: 1964–1979. *Geosci. Lett.* (2017) 4: 32. `https://doi.org/10.1186/s40562-017-0098-z`

Storchak, D.A., Harris, J., Brown, L., Lieser, K., Shumba, B., Di Giacomo, D. (2020) Rebuild of the Bulletin of the International Seismological Centre (ISC), part 2: 1980–2010. *Geosci. Lett.* (2020) 7: 18, `https://doi.org/10.1186/s40562-020-00164-6`

c) For principles of the ISC data collection process:

R J Willemann, D A Storchak (2001). Data Collection at the International Seismological Centre, *Seis. Res. Lett.*, *72*, 440-453, `https://doi.org/10.1785/gssrl.72.4.440`

d) For interpretation of magnitudes:

Di Giacomo, D., and D.A. Storchak (2016). A scheme to set preferred magnitudes in the ISC Bulletin, *J. Seism.*, *20(2)*, 555-567, `https://doi.org/10.1007/s10950-015-9543-7`

e) For use of source mechanisms:

Lentas, K., Di Giacomo, D., Harris, J., and Storchak, D. A. (2020). The ISC Bulletin as a comprehensive source of earthquake source mechanisms, *Earth Syst. Sci. Data*, *11*, 565-578,https://doi.org/10.5194/essd-11-565-2020

Lentas, K. (2018). Towards routine determination of focal mechanisms obtained from first motion P-wave arrivals, *Geophys. J. Int.*, *212(3)*, 1665–1686.https://doi.org/10.1093/gji/ggx503

f) For use of the original (pre-Rebuild) ISC Bulletin as a historical perspective:

Adams, R.D., Hughes, A.A., and McGregor, D.M. (1982). Analysis procedures at the International Seismological Centre. *Phys. Earth Planet. Inter. 30:* 85-93,https://doi.org/10.1016/0031-9201(82)90093-0

4.2 The Summary of the Bulletin of the ISC

International Seismological Centre (2025), Summary of the Bulletin of the International Seismological Centre, July - December 2021, *58(II)*,https://doi.org/10.31905/O98BYKYC

4.3 The historical printed ISC Bulletin (1964-2009)

International Seismological Centre, Bull. Internatl. Seismol. Cent., 46(9-12), Thatcham, United Kingdom, 2009.

4.4 The IASPEI Reference Event List

International Seismological Centre (2025), IASPEI Reference Event (GT) List, https://doi.org/10.31905/32NSJF7V

Gallacher, R., Garth, T., Harris, J., Bondár, I., McLaughlin, K., and Storchak, D. A. (2025). Revising the Seismic Ground Truth Reference Event Identification Criteria. Seismica, 4(1). https://doi.org/10.26443/seismica.v4i1.1536

Bondár, I. and K.L. McLaughlin (2009). A New Ground Truth Data Set For Seismic Studies, *Seismol. Res. Lett.*, *80*, 465-472, https://doi.org/10.1785/gssrl.80.3.465

Bondár, E. Engdahl, X. Yang, H. Ghalib, A. Hofstetter, V. Kirichenko, R. Wagner, I. Gupta, G. Ekström, E. Bergman, H. Israelsson, and K. McLaughlin (2004). Collection of a reference event set for regional and teleseismic location calibration, *Bull. Seismol. Soc. Am.*, *94*, 1528-1545, https://doi.org/10.1785/012003128

Bondár, E. Bergman, E. Engdahl, B. Kohl, Y.-L. Kung, and K. McLaughlin (2008). A hybrid multiple event location technique to obtain ground truth event locations, *Geophys. J. Int.*, *175*, https://doi.org/10.1111/j.1365-246X.2011.05011.x

4.5 The ISC-GEM Catalogue

International Seismological Centre (2025), ISC-GEM Earthquake Catalogue, `https://doi.org/10.31905/d808b825`, 2025.

Depending on the use of the Catalogue, to quote the appropriate scientific articles, as suggested below.

a) For a general use of the catalogue, please quote the following three papers (Storchak et al., 2013; 2015; Di Giacomo et al., 2018):

Storchak, D.A., D. Di Giacomo, I. Bondár, E.R. Engdahl, J. Harris, W.H.K. Lee, A. Villaseñor and P. Bormann (2013). Public Release of the ISC-GEM Global Instrumental Earthquake Catalogue (1900-2009). *Seism. Res. Lett.*, *84*, 5, 810-815, `https://doi.org/10.1785/0220130034`

Storchak, D.A., D. Di Giacomo, E.R. Engdahl, J. Harris, I. Bondár, W.H.K. Lee, P. Bormann and A. Villaseñor (2015). The ISC-GEM Global Instrumental Earthquake Catalogue (1900-2009): Introduction, *Phys. Earth Planet. Int.*, *239*, 48-63, `https://doi.org/10.1016/j.pepi.2014.06.009`

Di Giacomo, D., E.R. Engdahl and D.A. Storchak (2018). The ISC-GEM Earthquake Catalogue (1904–2014): status after the Extension Project, *Earth Syst. Sci. Data*, *10*, 1877-1899, `https://doi.org/10.5194/essd-10-1877-2018`

b) For use of location parameters, please quote (Bondár et al., 2015):

Bondár, I., E.R. Engdahl, A. Villaseñor, J. Harris and D.A. Storchak, 2015. ISC-GEM: Global Instrumental Earthquake Catalogue (1900-2009): II. Location and seismicity patterns, *Phys. Earth Planet. Int.*, *239*, 2-13, `https://doi.org/10.1016/j.pepi.2014.06.002`

c) For use of magnitude parameters, please quote (Di Giacomo et al., 2015a; 2018):

Di Giacomo, D., I. Bondár, D.A. Storchak, E.R. Engdahl, P. Bormann and J. Harris (2015a). ISC-GEM: Global Instrumental Earthquake Catalogue (1900-2009): III. Re-computed MS and mb, proxy MW, final magnitude composition and completeness assessment, *Phys. Earth Planet. Int.*, *239*, 33-47, `https://doi.org/10.1016/j.pepi.2014.06.005`

Di Giacomo, D., E.R. Engdahl and D.A. Storchak (2018). The ISC-GEM Earthquake Catalogue (1904–2014): status after the Extension Project, *Earth Syst. Sci. Data*, *10*, 1877-1899, `https://doi.org/10.5194/essd-10-1877-2018`

d) For use of station data from historical bulletins, please quote (Di Giacomo et al., 2015b; 2018):

Di Giacomo, D., J. Harris, A. Villaseñor, D.A. Storchak, E.R. Engdahl, W.H.K. Lee and the Data Entry Team (2015b). ISC-GEM: Global Instrumental Earthquake Catalogue (1900-2009), I. Data collection from early instrumental seismological bulletins, *Phys. Earth Planet. Int.*, *239*, 14-24, `https://doi.org/10.1016/j.pepi.2014.06.005`

Di Giacomo, D., E.R. Engdahl and D.A. Storchak (2018). The ISC-GEM Earthquake Catalogue (1904–2014): status after the Extension Project, *Earth Syst. Sci. Data*, *10*, 1877-1899, `https://doi.org/10.5194/essd-10-1877-2018`

e) For use of direct values of M0 from the literature, please quote (Lee and Engdahl, 2015):

Lee, W.H.K. and E.R. Engdahl (2015). Bibliographical search for reliable seismic moments of large earthquakes during 1900-1979 to compute MW in the ISC-GEM Global Instrumental Reference Earthquake Catalogue (1900-2009), *Phys. Earth Planet. Int.*, *239*, 25-32, https://doi.org/10.1016/j.pepi.2014.06.004

4.6 The ISC-EHB Dataset

International Seismological Centre (2025), ISC-EHB Dataset, https://doi.org/10.31905/PY08W6S3

Engdahl, E.R., R. van der Hilst, and R. Buland (1998). Global teleseismic earthquake relocation with improved travel times and procedures for depth determination, *Bull. Seism. Soc. Am.*, *88*, 3, 722-743. http://www.bssaonline.org/content/88/3/722.abstract

Weston, J., Engdahl, E.R., Harris, J., Di Giacomo, D. and Storchack, D.A. (2018). ISC-EHB: Reconstruction of a robust earthquake dataset, *Geophys. J. Int.*, *214*, 1, 474-484, https://doi.org/10.1093/gji/ggy155

Engdahl, E. R., Di Giacomo, D., Sakarya, B., Gkarlaouni, C. G., Harris, J., and Storchak, D. A. (2020). ISC-EHB 1964-2016, an Improved Data Set for Studies of Earth Structure and Global Seismicity, *Earth and Space Science*, *7(1)*, e2019EA000897, https://doi.org/10.1029/2019EA000897

4.7 The ISC Event Bibliography

International Seismological Centre (2025), On-line Event Bibliography, https://doi.org/10.31905/EJ3B5LV6

Also, please reference the following SRL article that describes the details of this service:

Di Giacomo, D., Storchak, D.A., Safronova, N., Ozgo, P., Harris, J., Verney, R. and Bondár, I., 2014. A New ISC Service: The Bibliography of Seismic Events, *Seismol. Res. Lett.*, *85*, 2, 354-360, https://doi.org/10.1785/0220130143

4.8 International Registry of Seismograph Stations

International Seismological Centre (2025), International Seismograph Station Registry (IR), https://doi.org/10.31905/EL3FQQ40

4.9 Seismological Dataset Repository

International Seismological Centre (2025), Seismological Dataset Repository, https://doi.org/10.31905/6TJZECEY

4.10 Data transcribed from ISC CD-ROMs/DVD-ROMs

International Seismological Centre, Bulletin Disks 1-30 [CD-ROM], Internatl. Seismol. Cent., Thatcham, United Kingdom, 2025.

The ISC is named as a valid data centre for citations within American Geophysical Union (AGU) publications. As such, please follow the AGU guidelines when referencing ISC data in one of their journals. The ISC may be cited as both the institutional author of the Bulletin and the source from which the data were retrieved.

5

Notes from ISC Data Users

5.1 Reported Teleseismic Phase Statistics at the ISC Over the Last Four Decades

Jens Havskov[1] and Kathrin Lieser[2]

(1) University of Bergen, Department of Earth Science, Bergen, Norway

(2) International Seismological Centre, Thatcham, UK

Jens Havskov

Kathrin Lieser

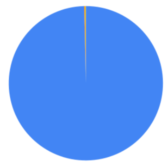
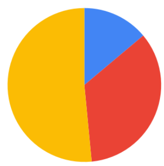
The ISC has seen a steady increase in the number of stations and phases reported over the decades (Figures 5.4 and 5.5). However, the number of teleseismic phases reported to the ISC is decreasing. Here, we will look at the statistics of all teleseismic phases reported from stations with an epicentral distance of at least 20 degrees for the time period 1970 to 2021. The purpose is to see if there have been any significant changes in the type and number of phases reported. We will be looking at time-defining phases identified by the ISC's location algorithm (ISCloc) and at the most common phase types where the ISC phase type differs from the phase originally reported. Events for which an ISC location is created typically have a magnitude larger than 3.5. For more information on how to use the ISC's data and on the Operational Procedures of the ISC, please refer to *Havskov and Lieser* (2022) and the Appendix of the Summary of the ISC (*International Seismological Centre*, 2024; available in the first issue of each volume).

5.1.1 Phase Types Identified by the ISC

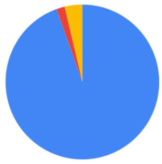
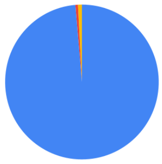
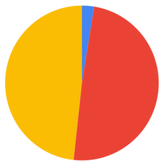
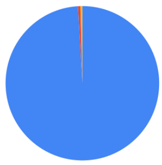
Throughout the ISC's history different sets of seismic phases were used. In the beginning, only P phases were utilised for hypcentre estimations (1964 to 2000), from data year 2001 S phases were included and the current location algorithm ISCloc makes use of all IASPEI standard phases (*Storchak et al.* 2003, 2011) with a valid travel time prediction in the ak135 velocity model. This latest procedure came into full operation from data year 2011 onwards. To homogenise the ISC Bulletin, the time period from 1964 to 2010 was relocated during the Rebuild project. As part of this, the phase names reported to the ISC were reviewed, corrected and translated into distinct and standard phase names. Typical amendments included updating obsolete notations, adding missing characters, and fixing upper and lower cases. More information on the Rebuild of the ISC Bulletin can be found in *Storchak et al.* (2017, 2020).

The most common time defining phases in the Reviewed ISC Bulletin for the time period 1970 to 2021 are listed in Table 5.1 and the complete list is shown in Table S1.1 in the supplementary material. Duplicates, i.e. multiple arrivals of the same phase type at the same station are ignored and amplitude phases are not included. Figure 5.1 gives a graphical overview of the percentage of the individual phases.

Table 5.1: *The most common phases for teleseismic earthquakes used by the ISC in relocations for the period 1970 to 2021.* Used in ISC locations*: The number of phases identified and used for location (excluding duplicates).* Reported as*: Pie chart breaking down how the phase was reported to the ISC, including how often the phase was reported as such, and the next most common phase type (including duplicated reports).*

Phase	Used in ISC locations	Reported as
P	32,803,509	• P 40,735,109 (99.6%) • pP 30,626 (0.1%) • Other 123,704 (0.3%) 
PKPdf	2,537,130	• PKPdf 1,591,966 (53%) • P 1,036,401 (35%) • Other 368,241 (12%) 
PKPbc	1,100,918	• PKPbc 665,221 (53%) • P 442,679 (35%) • Other 151,450 (12%) 
PKPab	863,118	• PKPab 541,918 (56%) • P 270,168 (28%) • Other 151,277 (15%) 
PKiKP	1,872,615	• PKiKP 311,025 (14%) • P 774,039 (35%) • Other 1,153,171 (52%)  Note: 43% of PKiKP phases were reported as a PKP type phase (included in 'Other')
pP	820,015	• pP 876,259 (91%) • sP 39,488 (4%) • Other 40,807 (4%) 

Continued on next page

Phase	Used in ISC locations	Reported as	
PcP	723,496	• PcP 745,035 (91%) • pP 41,602 (5%) • Other 34,107 (4%)	
PP	548,485	• PP 565,838 (95%) • pP 10,385 (2%) • Other 22,338 (4%)	
Pdif	452,488	• Pdif 168,471 (31%) • P 375,623 (68%) • Other 4,403 (1%)	
S	1,651,533	• S 1,911,049 (98.6%) • SKS 10,428 (0.5%) • Other 16,116 (0.8%)	
SKSac	135,616	• SKSac 86,956 (58%) • S 48,866 (33%) • Other 13,059 (9%)	
SKiKP	34,052	• SKiKP 975 (3%) • S 18,853 (49%) • Other 18,509 (48%)	
SS	229,272	• SS 244,696 (99%) • ScS 1,224 (0.5%) • Other 1,055 (0.4%)	
sP	404,905	• sP 201,640 (43%) • pP 215,401 (46%) • Other 47,033 (10%)	
ScS	104,476	• ScS 87,340 (77%) • S 14,535 (13%) • Other 11,630 (10%)	

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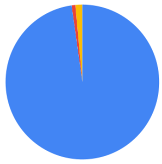
Phase	Used in ISC locations	Reported as
ScP	199,327	• ScP 217,626 (98%) • SS 1,730 (1%) • Other 3,285 (1%) 

From the table it can clearly be seen that it is a common practice to label the first arrival as P, irrespective of it being a P phase or a teleseismic core phase. A large amount of PKPdf/bc/ab, PKiKP and Pdif phases, have been reported as P and while PKP phase types were mostly reported as such (53% to 56%), the majority of PKiKP (87%) and Pdif (69%) phases were originally reported as P phases or "Other" to the ISC. Secondary phases (S, pP, PP and PcP, ScP, sP, SS) have nearly all been reported with the correct phase type (over 95%). When reporting secondary phases, a common practice is to use epicentre locations and travel time tables to identify phases. However, even then it can be difficult to distinguish the different P phases while pP and PcP are easier to identify; this may explain why they have been correctly reported more often. This is the case for S type phases as well where many SKSac, Sdif and SKiKP phases were reported as S phases. It seems that agencies assign the general type of phase rather than the specific type for convenience when picking only one or two phases.

ISCloc can re-interpret phases in every distance range, e.g. P phases can become Pn, Pb, Pg, PP, PnPn, PKiKP, Pdif, PcP, PKP(ab/bc/df) etc. as well as depth phases, with a similar list of allowed re-interpretation for S phases. There are certain additional rules that are followed, e.g. depth phases cannot be set as first arrivals by ISCloc and P phases cannot be renamed as S phases (*Havskov and Lieser*, 2022).

There are 45.5 million identified time-defining phases and the first 10 phase types in the list make up 95% of the phases. The P phases dominate with 72% of the time defining phases identified as P and including other first arrival P phase types, such as PKPdf, PKiKP, PKPbc, PKPab, and Pdif, 87% of all time defining phases (Figure 5.1). On average over the recent time period from 2010 to 2021, 19 phase types are reported less than once a month and 28 types less than 10 times per month while there are typically 119,262 P phases per month, see supplementary material.

5.1.2 Time Statistics of Number of Phases

Figure 5.2 shows the number of teleseismic phases per year for P and S. There has been a steady increase in number of phases since 1970. It seems that until the year 2000, the number of S phases did not increase as much as the number of P phases and a drop in reported S phases can be observed in the most recent years. We will look into this in more detail in Figure 5.6. Figure 5.3(a) shows the monthly number of P and P-type phases and Figure 5.3(b) shows the monthly median over a year.

The two curves are correlated, however, the median curve is smoother and better displays the overall trend of the average amount of reported P phases per year without the outliers caused by major earthquakes. The relatively high activity in 1995-1996 that is clearly observed in both curves is due to the establishment and testing of the prototype of the International Data Center (IDC) for the Comprehensive Test-Ban Treaty (CTBT). The IDC came into full operation from 2000.

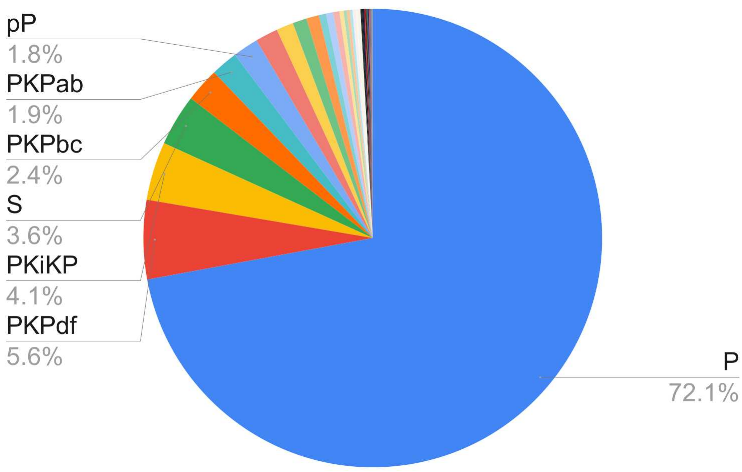


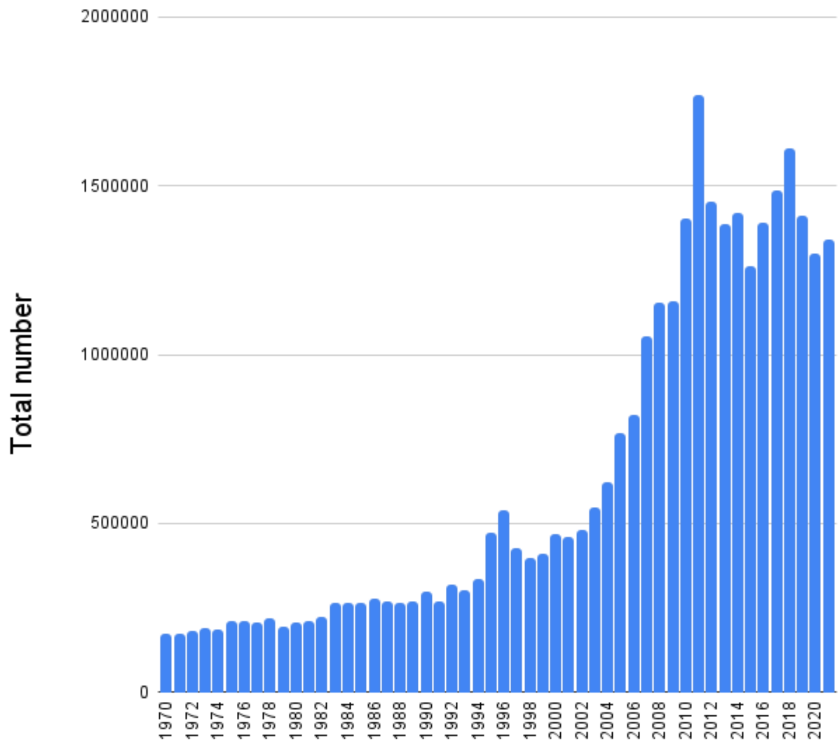
Figure 5.1: *Distribution of time defining phase types as listed in the supplementary material.*

The largest monthly number of P phases (483,514) was in March 2011 and is related to the Tohoku sequence whose main shock (Mw=9.1) triggered a destructive tsunami. It was the largest earthquake ever recorded in Japan and among the four largest in the world since 1900. The spike in December 2004 is related to another large earthquake that was one of the four largest recorded and that triggered a devastating tsunami: the Mw 9.2 Sumatra, Indonesia earthquake. Many other spikes are also related to major events (e.g. the Mw 8.8 Maule, Chile, earthquake in February 2010, the Mw 8.1 and Mw 7.7 sequence in Iquique, Chile in April 2014, the Mw 7.9 earthquake in Alaska in May 1986 etc.). From this plot it can thus be seen that in general spikes are not due to uneven reporting.

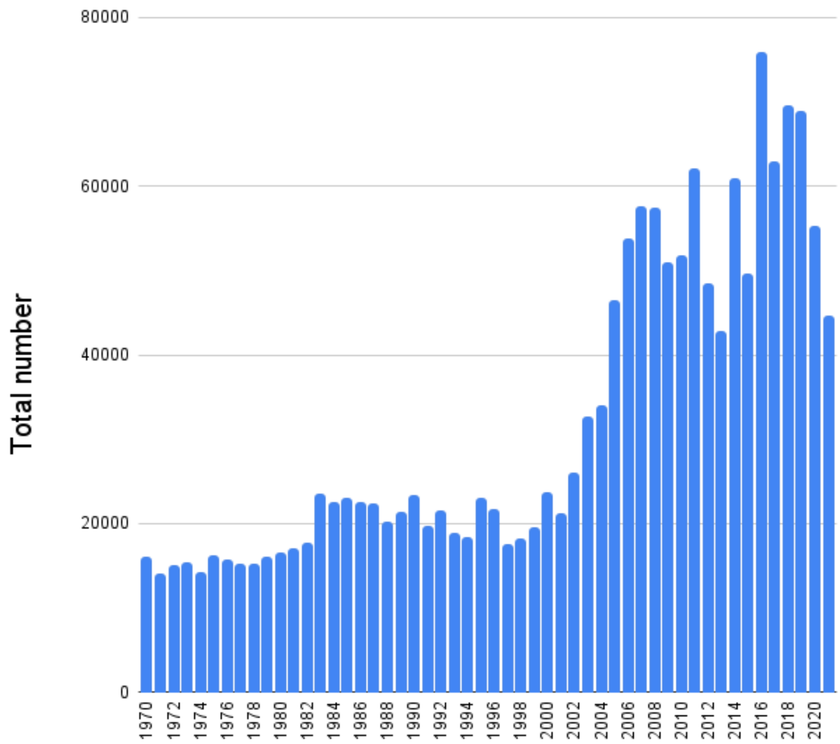
Figures 5.2(a) and 5.2(b) show a constant number of phase reports from 2010 and onward, while Figure 5.4 shows an increasing number of phases until 2015 and then a consistent number of phases reported. This difference may be a result of the total number of reported phases including data from local networks and small events. Figure 5.4 also shows that variation in amplitude reporting is correlated with the variation in phase reporting. In order to investigate if the number of reports is related to the number of stations reporting to the ISC, the number of stations reporting has been plotted in Figure 5.5.

As can be seen, there has been a steady increase in the number of stations reported to the ISC until 2018. This correlates with the increase in the total number of phases until 2018, again this might reflect the inclusion of many phases from local networks and small events. For the teleseismic phases there is no increase after 2010 despite the number of stations increasing. This is likely a result of the increased number of stations not being reported teleseismically or that the stations do not report all phases and only pick first arrivals. The sudden increase in seismic stations from data year 2021 can be explained by the implementation of the IASPEI station coding standard ADSL (Agency.Deployment.Station.Location) at the ISC. Before, only stations registered in the International Station Registry (FDSN network code IR), maintained by the ISC, could be used. Now, stations that are not registered in IR but registered with FDSN using a different network code can be used.

In order to better visualise the reporting of different phases as a function of time, the number of reported phases for selected phase types relative to the number of P phases is calculated (Figure 5.6). The purpose is to check if more P phases also result in a similar increase in the number of other common secondary

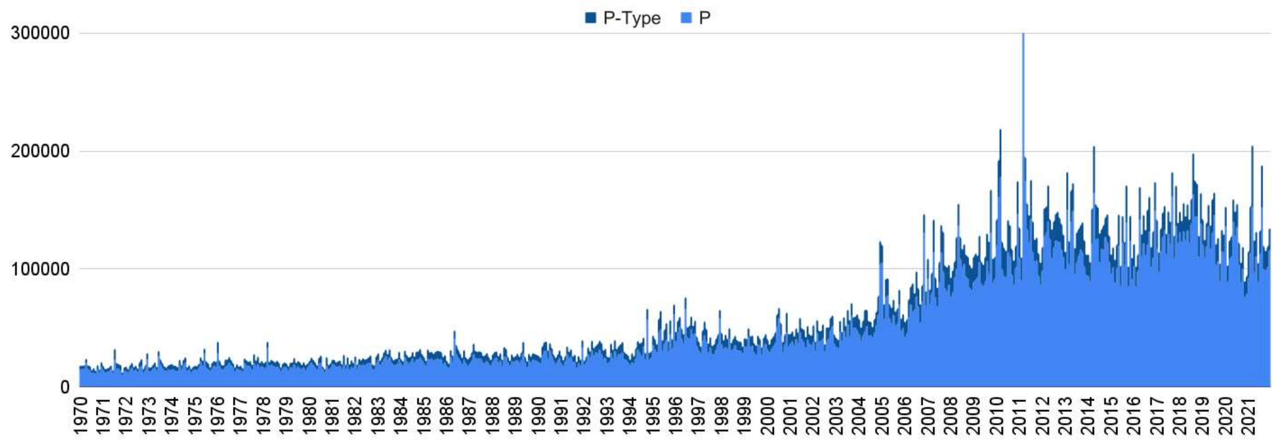


(a) P phases

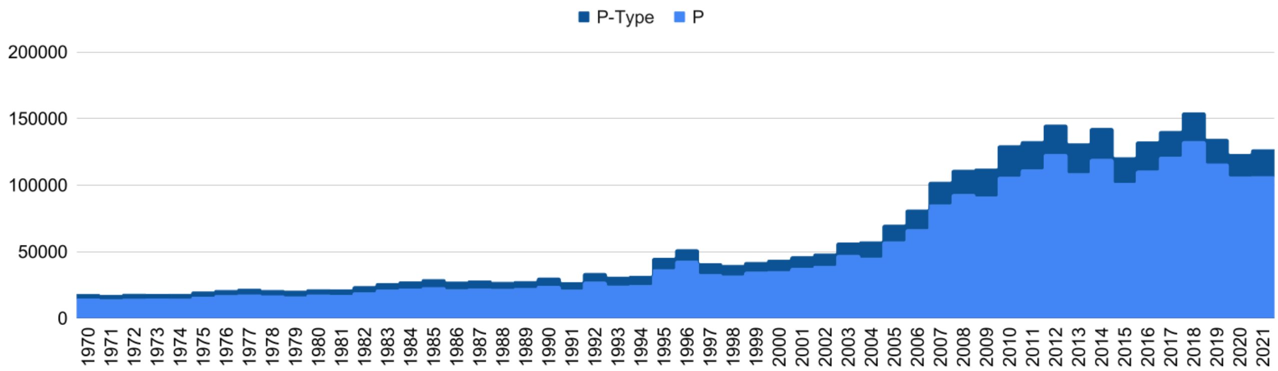


(b) S phases

Figure 5.2: *Number of teleseismic P and S phases used in ISC locations per year.*



(a) Monthly number of teleseismic phases. The peak in 2011 extends to 483,514 and relates to the Tohoku event.



(b) Yearly median of teleseismic phases.

Figure 5.3: *Stacked bar chart of teleseismic P and P type (PKiKP, PKPab/df/bc, Pdif) phase arrivals.*

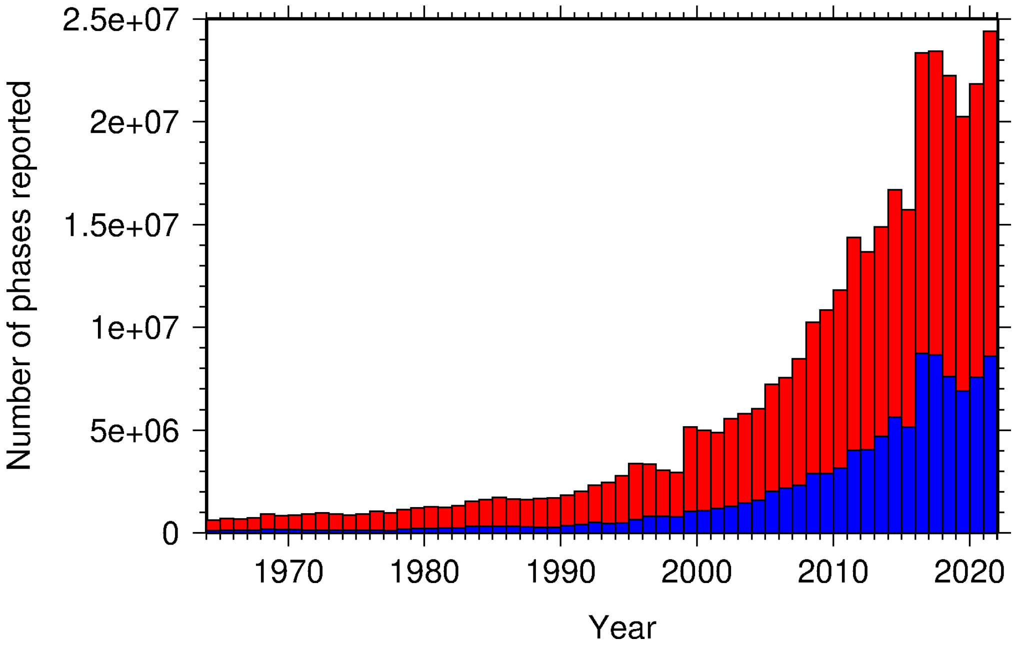


Figure 5.4: *Histogram showing the yearly number of phases (red) and number of amplitudes (blue) collected by the ISC from 1964 to 2021. The number of phases and amplitudes is the total number from all events (local and teleseismic) and includes duplicates.*

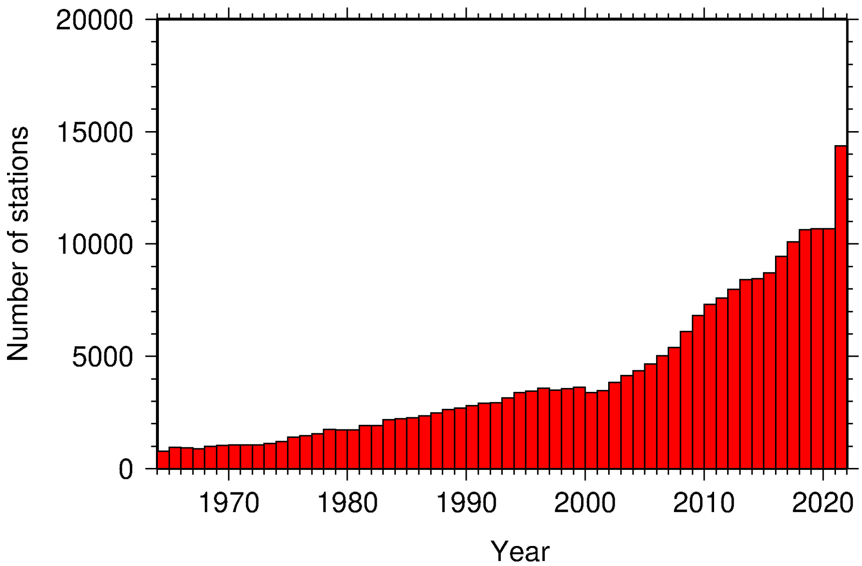


Figure 5.5: *Histogram showing the number of stations reporting to the ISC per year from 1964 to 2021.*

phases. The phases selected are S, PcP, PP, SS, pP, sP, ScS and ScP and it is assumed that most of these phases have been reported as such to the ISC. As seen from Table 5.1, this seems to be the case at least for phases S, PcP and pP.

For all phase types, except SS, PcP and ScP, the number of secondary phases relative to the number of P phases has declined overall with time, e.g. before 1990, there were twice as many S phases relative to the number of P phases as compared to 2021. Until the year 2000, the number of S phases (Figure 5.2(b)) remained relatively stable before increasing around 2000. However, this increase is less than the rise in P phase reports and thus the relative number decreased in recent years which unfortunately can impair depth determination.

All the plots have time periods with prominent peaks, e.g. for ScS around 1990. Since there is no similar decline in the number of P phases, it can be concluded that relatively more ScS readings were reported around 1990. The different phase types have peaks in different time periods and there does not seem to be a similar decline in number of P phases which could explain the peaks. It therefore seems likely that the change in the relative number of phases is caused by changes in reporting of these phases before 2010. After 2010, the number of P phases remained fairly stable (Figures 5.2 and 5.3) and the relative number of other phases has also remained stable, indicating that picking practice has not changed much since 2010.

As an example, the absolute number of pP and sP phases is shown in Figure 5.7. It can be seen that after approximately 2008, there is a clear reduction in the number of depth phases even though the number of P phases has not declined. The reduction in depth phases has a negative impact for the accuracy of the hypocentral depths. To remedy this, the ISC from data year 2016 onwards picks teleseismically observed depth phases from freely available waveforms from global seismic networks. The impact of this activity can be clearly seen in the increase of depth phases from 2016 onward in Figure 5.7. However, the number of depth phases still remains below the peak observed for 2000-2010.

A lack of secondary phases in reports to the ISC has been observed before (e.g. *Bormann*, 2013). Between 1974 and 1984, the first S-wave arrivals were reported on average to the ISC about twenty

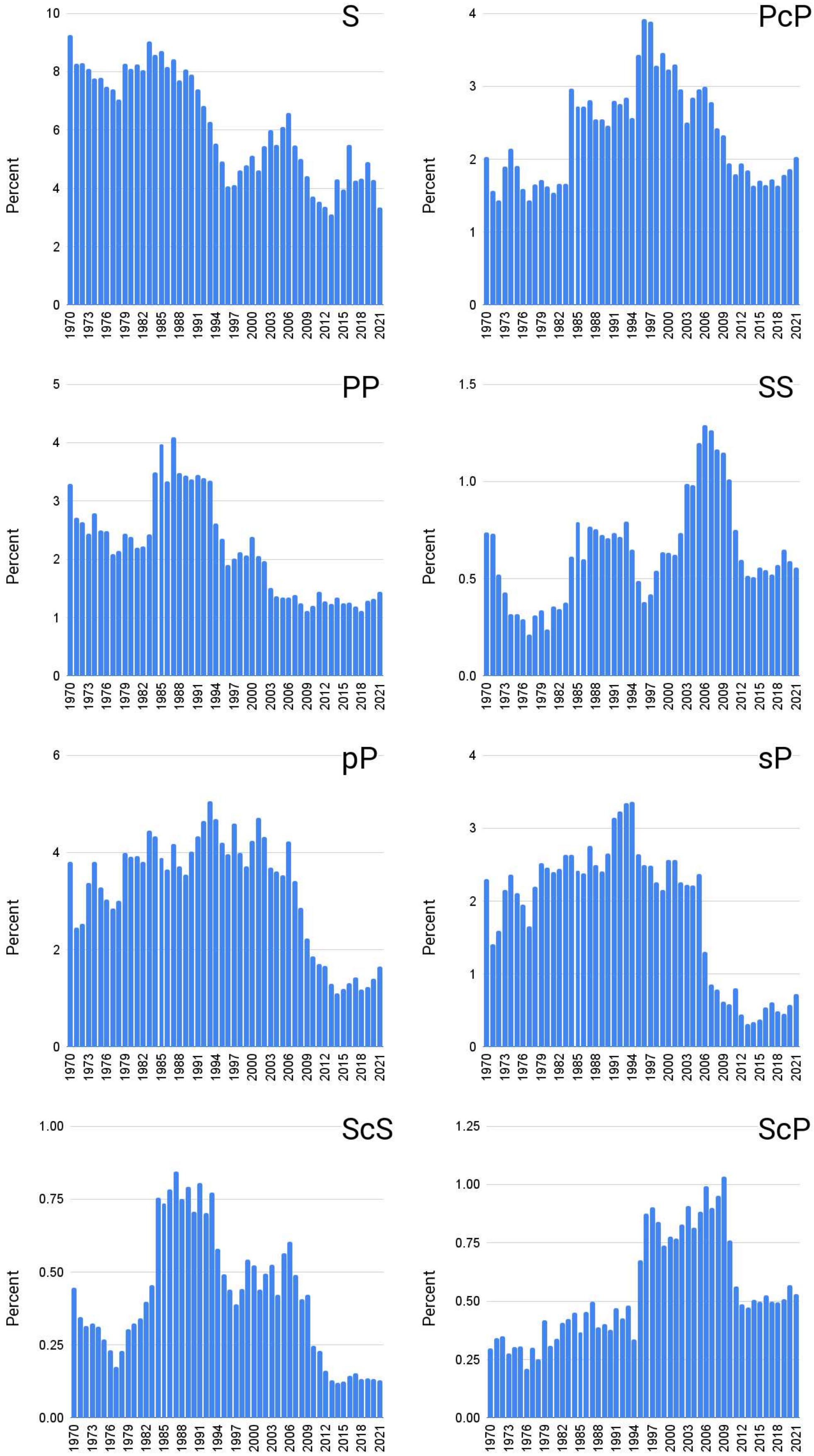


Figure 5.6: *Ratio of number of phases of each type relative to number of P phases in percent. Teleseismic phases used in ISC locations are shown.*

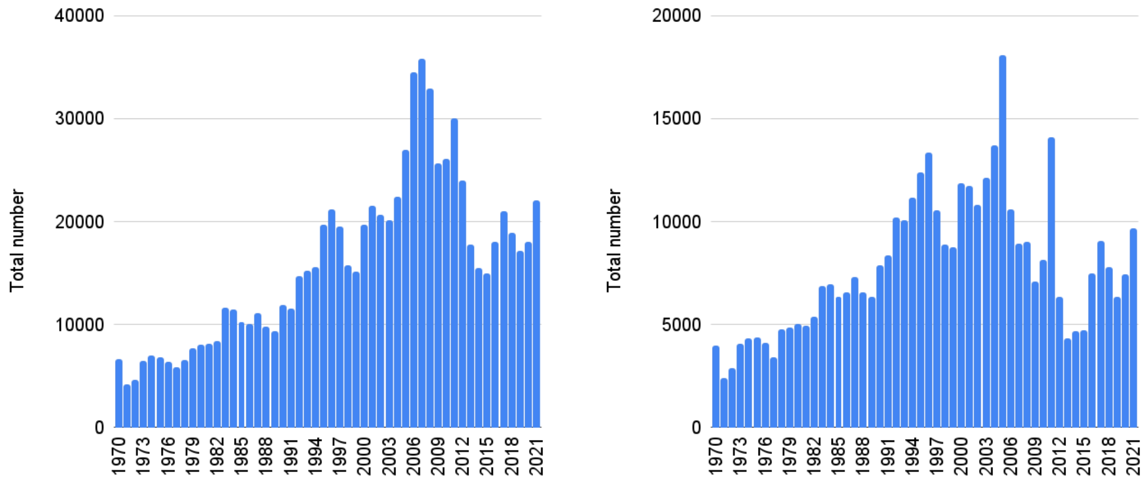


Figure 5.7: *Yearly total number of teleseismic pP (left) and sP (right) phases used in ISC locations.*

times less frequently than P. For teleseismic phases used in ISC locations, we observe about 13 times less for the same period and down to 25 times in current times.

5.1.3 Discussion

The number of stations worldwide that are reported to the ISC has increased steadily since 1964 and particularly since 2019. However, the reporting of teleseismic phases has not followed this trend. This is particularly apparent between 2010 and 2021 where the number of stations reporting has almost doubled but the absolute number of P phases has kept nearly constant. This could indicate that, despite the number of stations in a network increasing, phases are reported on the same number of stations or fewer. It is particularly noticeable that reporting of secondary phases has sharply declined since 2010. One explanation for this is that it is more time consuming to manually pick secondary phases than only P phases.

At the same time modern networks are more capable of producing reliable secondary teleseismic picks. In the travel time plot of 2010-2021 in Figure 5.8, the secondary phases cover a much wider range of epicentral distances than in the earlier time period because they can be better recorded and identified with advanced modern equipment and processing software (eg. PKiKP, PKKP, PKPPKP).

Figure 5.9 shows the average number of local agencies per event reporting teleseismic phases. Global agencies have been excluded (NEIC, MOS, IRIS and IDC) from this plot. From data year 2013 to 2019 fewer agencies reported teleseismic phases, however, there has been a slight increase in the number of reporters since the nadir in 2018-2019. This is most likely due to the change to the ADSL data format, as more stations became available. In addition, the ISC started a project in 2019 dedicated to filling a notable gap in teleseismic data coverage by picking teleseismic phases, particularly from African stations.

The decline in the number of reporting agencies per event may indicate that fewer agencies are picking teleseismic phases. Temporary networks for a local study may not process data that is not considered relevant to their study. The prevailing reasons may be that these networks are designed for local studies, and that they do not have the time, funding, staff, or feel an obligation to report teleseismic events. This

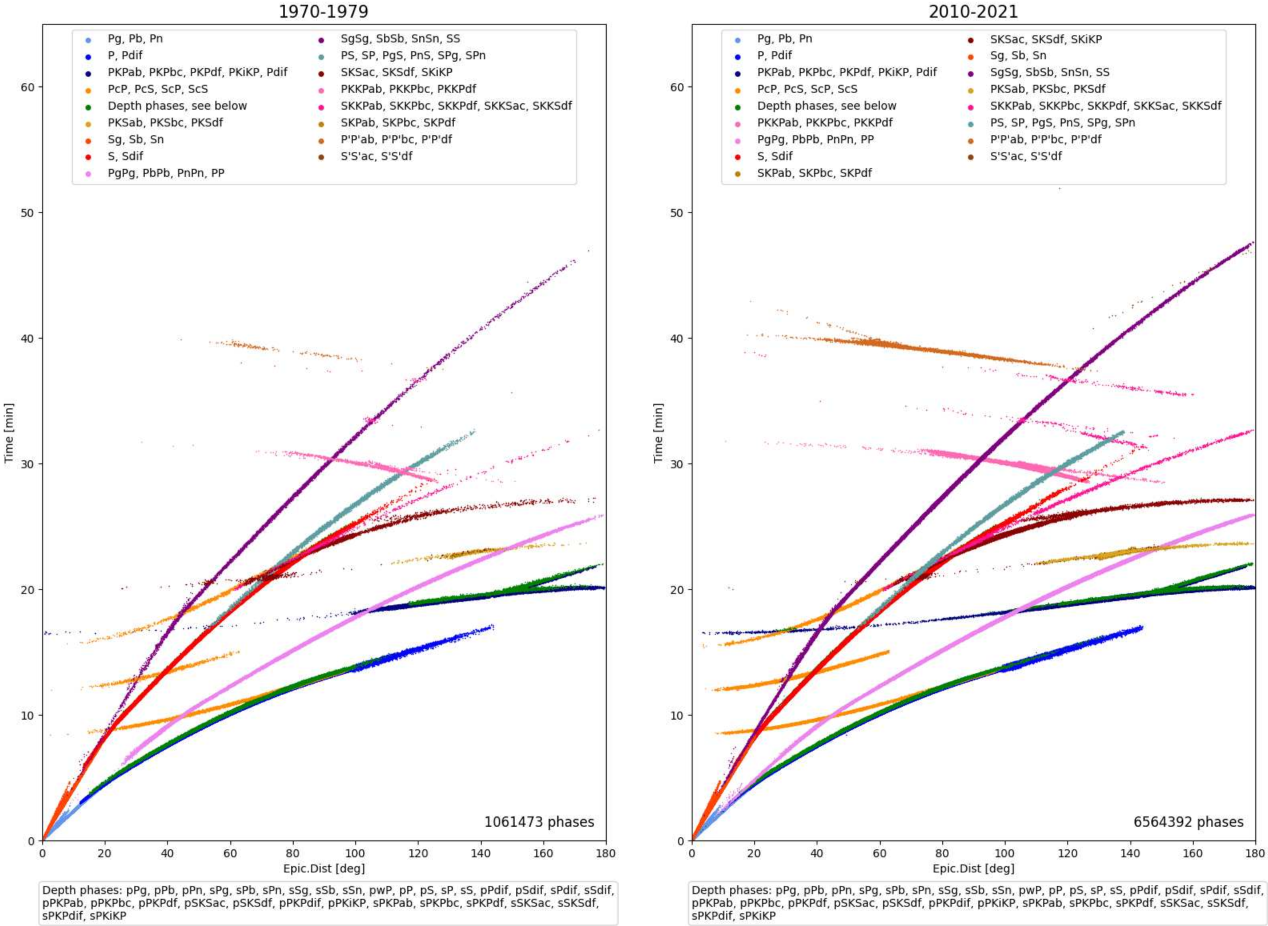


Figure 5.8: *Travel time plots of time defining phases used in ISC locations of events with a magnitude larger than 5.5 and with a depth less than 35 km from the 1970s compared to 2010-2021.*

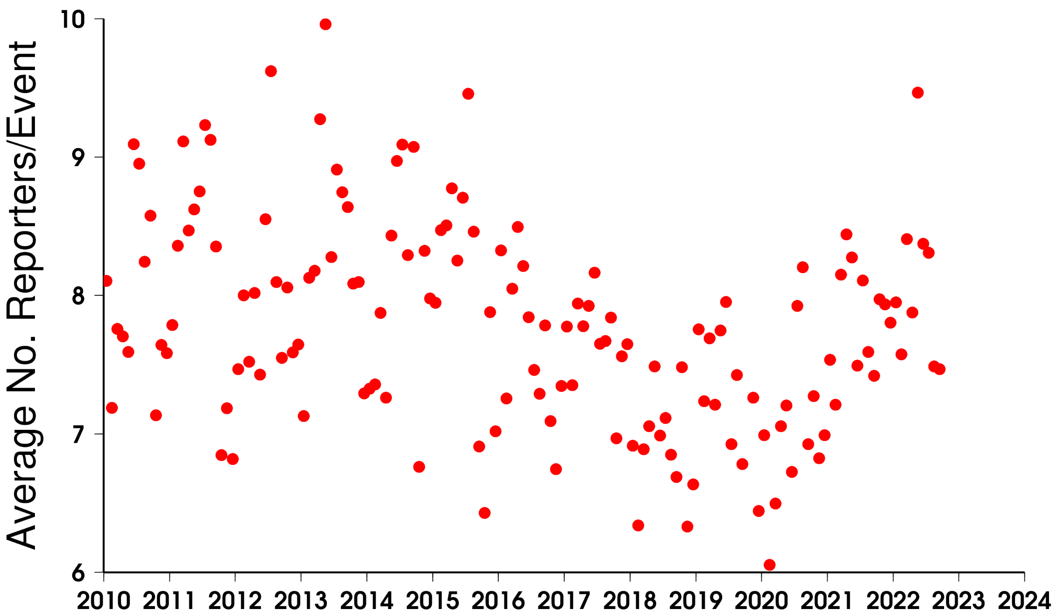


Figure 5.9: *Monthly average number of agencies per event for recent years reporting teleseismic phases, including ISC. Agencies reporting global data (NEIC, MOS, IRIS and IDC) have been excluded.*

issue even extends to some national networks in countries with established programmes in seismology which have stopped reporting teleseismic events. They report that it is too time consuming to continue picking teleseismic events despite having a long tradition of doing so. These issues seem to be reflected in Figure 5.9, some expanding networks may have chosen to only report the largest teleseismic events and only for a select number of stations. Fortunately, many seismic stations share waveform data with other countries, and thus reports at these stations are still made. However, this can result in data duplication while not improving the station coverage for the event and this is failing to reverse the decline in reporting of teleseismic phases.

Another reason for reading less teleseismic events might be related to the way the data is processed. Some networks are set up to primarily trigger for local and regional events and the processing is geared towards these events. In these cases the teleseismic data would not enter the data stream for manual processing. Since the triggers might be used for automated alerts, there is a risk that teleseismic events might generate false local events due to the limited extent of the local network.

Further, both the decrease in secondary phases relative to first arrivals and the reduced number of agencies reporting teleseismic phases could be caused by the rise of automatic and machine learning phase pickers that mostly focus on P and S phases for local seismicity. The ISC does not include fully automatic picks, (that it is aware of). In reality, the phases reported as manual phases are likely to be an unknown mix of manual, automatic reviewed picks and unreviewed automated picks.

Another reason for the decline may be that the current generation of seismologists have not been exposed to teleseismic observations as much as older generations of seismologists were and therefore do not see the importance of teleseismic data.

As we have detailed above, there are many potential explanations for the decline in the reporting of secondary phases and for the stagnation of reporting of teleseismic P phases. While we acknowledge that it may be a challenge for local agencies to include teleseismic first or secondary phases in their routine procedures, we encourage them to pick and report teleseismic arrivals on selected stations for moderate to large events. This will benefit the whole seismological community and ensure that we are making the best use of the enhanced networks that are available today.

5.1.4 Conclusion

- Reporting of teleseismic P phases has had a steady increase from 1970 until 2010. After 2010 the number of teleseismic P phases per year seems to be constant.
- A lot of the P type phases (P, PKiKP, PKPab/df/bc, Pdif) are mostly reported as P.
- The number of the phases S, PcP, PP, SS, pP, sP, ScS and ScP relative to the number of P phases has seen large variations over the years indicating changing picking practices.
- For all phases except SS, PcP and ScP, the relative and for some also the absolute number of reported phases is at the lowest level compared to any period before.
- We encourage more agencies to pick teleseismic first and secondary phases.

Acknowledgements

We thank James Harris for his efforts in extracting the data for this study from the vast ISC database.

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Supplementary Material

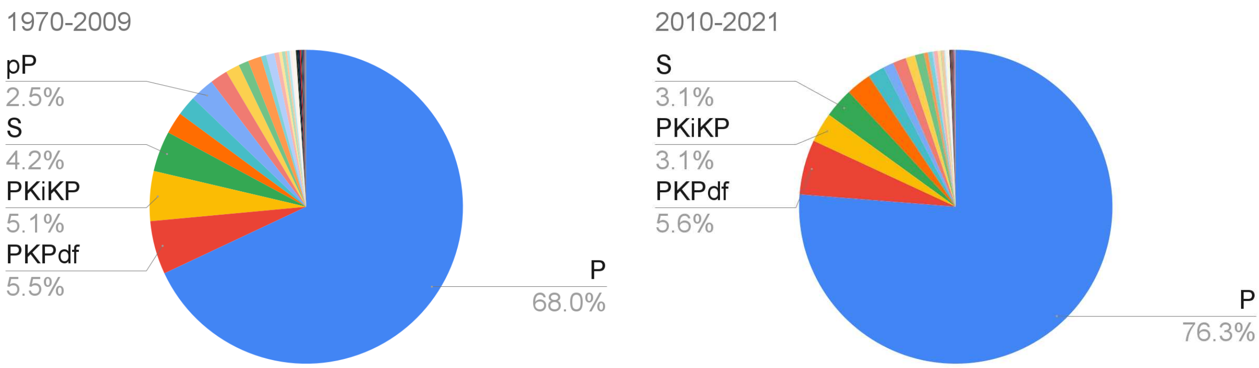

Figure S1.1: *Pie charts of reported phases in different time intervals shown in Table S1.1*

Table S1.1: *Total number of phase types reported and monthly average in different time intervals.*

Phase	Total number 1970-2021	Average number of phases per month 1970 – 2021	1970 – 2009	2010 – 2021
P	32,803,509	52,569.73	32,561.91	119,262.43
PKPdf	2,537,130	4,065.91	2,637.00	8,828.97
PKiKP	1,872,615	3,000.99	2,457.82	4,811.54
S	1,651,533	2,646.69	2,001.10	4,798.66
PKPbc	1,100,918	1,764.29	1,075.66	4,059.74
PKPab	863,118	1,383.20	982.78	2,717.94
pP	820,015	1,314.13	1,203.20	1,683.90
PcP	723,496	1,159.45	868.71	2,128.58
PP	548,485	878.98	687.59	1,516.97
Pdif	452,448	725.08	497.18	1,484.74
sP	404,905	648.89	656.92	622.12
SS	229,272	367.42	257.63	733.41
pwP	228,234	365.76	410.20	217.63
ScP	199,327	319.43	225.07	633.97
SKSac	135,616	217.33	151.90	435.45
ScS	104,476	167.43	162.89	182.56
PKKPbc	93,401	149.68	84.00	368.61
pPKPdf	84,395	135.25	125.88	166.49
SnSn	52,689	84.44	58.16	172.01
sS	49,871	79.92	70.39	111.69
PnPn	45,384	72.73	48.45	153.67
SKPbc	35,928	57.58	26.65	160.67
PcS	35,895	57.52	57.89	56.30
pPKPab	34,874	55.89	50.87	72.60
SKiKP	34,052	54.57	42.31	95.44
PnS	33,656	53.94	61.51	28.69
PS	31,895	51.11	47.59	62.87
sPKPdf	28,929	46.36	46.05	47.41
SKKSac	26,970	43.22	38.83	57.85
pPKPbc	25,597	41.02	32.05	70.92
PKKPab	25,152	40.31	24.43	93.23
SKSdf	24,795	39.74	31.77	66.30
PKSdf	22,771	36.49	33.69	45.82
PKKPdf	22,112	35.44	21.13	83.13
P'P'df	15,239	24.42	3.26	94.97
sPKPab	13,080	20.96	20.84	21.38
SP	11,811	18.93	16.67	26.47
SKPab	11,686	18.73	11.64	42.37
sPKPbc	10,827	17.35	16.19	21.21
SPn	7,323	11.74	14.19	3.54
SKPdf	6,671	10.69	3.50	34.65
pS	6,372	10.21	9.40	12.92
Sdif	5,879	9.42	5.73	21.72
Pn	5,376	8.62	6.98	14.06
pPdif	4,219	6.76	5.58	10.71
SKKPbc	3,723	5.97	2.72	16.80
pPKiKP	3,239	5.19	3.37	11.27
sPKiKP	2,064	3.31	3.81	1.65
SKKSdf	1,706	2.73	1.17	7.94
sPdif	1,659	2.66	2.44	3.40
P'P'bc	1,448	2.32	0.26	9.19
P'P'ab	880	1.41	0.79	3.47
SKKPab	657	1.05	0.38	3.31
PKSbc	574	0.92	0.81	1.28
SKKPdf	371	0.59	0.09	2.28
Sn	320	0.51	0.50	0.54
PKSab	259	0.42	0.32	0.72
sSKSac	197	0.32	0.26	0.51
S'S'ac	119	0.19	0.09	0.51
pSKSac	101	0.16	0.16	0.17
sSdif	82	0.13	0.06	0.36
PKKSbc	30	0.05	0.01	0.16
SPg	29	0.05	0.06	0.01
PgS	26	0.04	0.03	0.07
sSKSdf	25	0.04	0.04	0.05
PKKSdf	24	0.04	0.01	0.13
pSdif	23	0.04	0.05	0.01
pSKSdf	8	0.01	0.01	0.03
S'S'df	5	0.01	0.01	0.01
PKKSab	5	0.01	0.01	0.00
sPn	5	0.01	0.01	0.01
pPn	4	0.01	0.00	0.01
sSn	4	0.01	0.00	0.01
Pb	1	0.00	0.00	0.01

6

Summary of Seismicity, July - December 2021

The second six months of 2021 produced 12 earthquakes with $M_W \geq 7$; these are listed in Table 6.1. The largest event occurring during this Summary's time period was the M_W 8.3 South Sandwich Islands earthquake on 12/08/2021 (18:35:19.64 UTC, 58.3665°S, 25.3650°W, 38 km depth, 718 stations (ISC)). This event was a highly complex sequence of several subevents with a duration of more than 220 seconds lasting an unusually long time for an event of this size. The earthquake triggered a tsunami that spread unexpectedly far as initial reports of the earthquake showed earthquake parameters that usually would not generate global tsunamis. Studies showed that this was due to the convoluted rupture processes of long shallow slow slip in between regular deeper slip at the northern and southern ends of the rupture zone (*Jia et al.*, 2022; *Metz et al.*, 2022).

The most discussed earthquake in the scientific community during this Summary's time period, with currently 47 entries in the ISC Event Bibliography (*Di Giacomo et al.*, 2014; *International Seismological Centre*, 2025), was the M_W 8.2 Chignik megathrust earthquake rupturing the Aleutian-Alaska subduction zone on 29/07/21 (06:15:47.49 UTC, 55.4449°N, 157.9970°W, 22 km depth, 4319 stations (ISC)). It was also the second largest event in this Summary's time period. Large earthquakes are not uncommon in this area and an earthquake of similar size to the Chignik earthquake occurred in November 1938 within 40 km of its epicentre. Most recently, two M_W 7.8 and 7.6 earthquakes struck the area in July and October 2020 within 150 km of the Chignik epicentre and can be considered its foreshocks (*USGS*, 2025). These two events were the largest events in the second half of 2020 and were summarised in the Summary of the ISC for that time period (*International Seismological Centre*, 2023).

Table 6.1: *Summary of the earthquakes of magnitude Mw ≥ 7 between July and December 2021.*

Date	lat	lon	depth	Mw	Flinn-Engdahl Region
2021-08-12 18:35:19	-58.37	-25.37	38	8.3	South Sandwich Islands region
2021-07-29 06:15:47	55.44	-158.00	21	8.2	Alaska Peninsula
2021-08-12 18:32:52	-57.67	-24.93	28	7.5	South Sandwich Islands region
2021-11-28 10:52:13	-4.50	-76.82	118	7.5	Northern Peru
2021-12-14 03:20:23	-7.62	122.28	14	7.4	Flores Sea
2021-12-29 18:25:53	-7.58	127.58	177	7.3	Banda Sea
2021-10-02 06:29:18	-21.11	174.95	540	7.3	Vanuatu Islands region
2021-08-14 12:29:08	18.34	-73.55	11	7.2	Haiti region
2021-08-22 21:33:19	-60.29	-25.04	6	7.1	South Sandwich Islands region
2021-08-11 17:46:13	6.42	126.70	58	7.1	Mindanao
2021-08-14 11:57:43	55.19	-157.70	20	7.0	Alaska Peninsula
2021-09-08 01:47:46	16.87	-99.84	18	7.0	Near coast of Guerrero

The number of events in this Bulletin Summary categorised by type are given in Table 6.2. The distribution of the number of earthquakes should follow the Gutenberg-Richter law. Figure 6.1 shows the number of moderate and large earthquakes in the second half of 2021. Figures 6.2 to 6.6 show the geographical distribution of moderate and large earthquakes in various magnitude ranges.

Table 6.2: *Summary of events by type between July and December 2021.*

felt earthquake	321
known earthquake	169530
known chemical explosion	5177
known induced event	1349
known mine explosion	9103
known rockburst	1887
known experimental explosion	198
known ice-quake	2
suspected collapse	2
suspected earthquake	122202
suspected chemical explosion	5685
suspected induced event	33
suspected mine explosion	6842
suspected rockburst	99
suspected experimental explosion	500
suspected ice-quake	142
unknown	1
total	323073

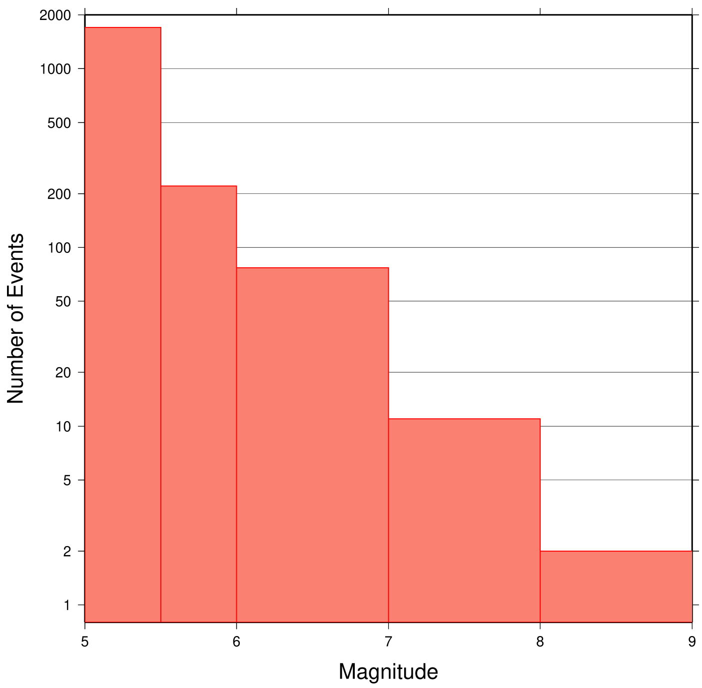

Figure 6.1: *Number of moderate and large earthquakes between July and December 2021. The non-uniform magnitude bias here correspond with the magnitude intervals used in Figures 6.2 to 6.6.*

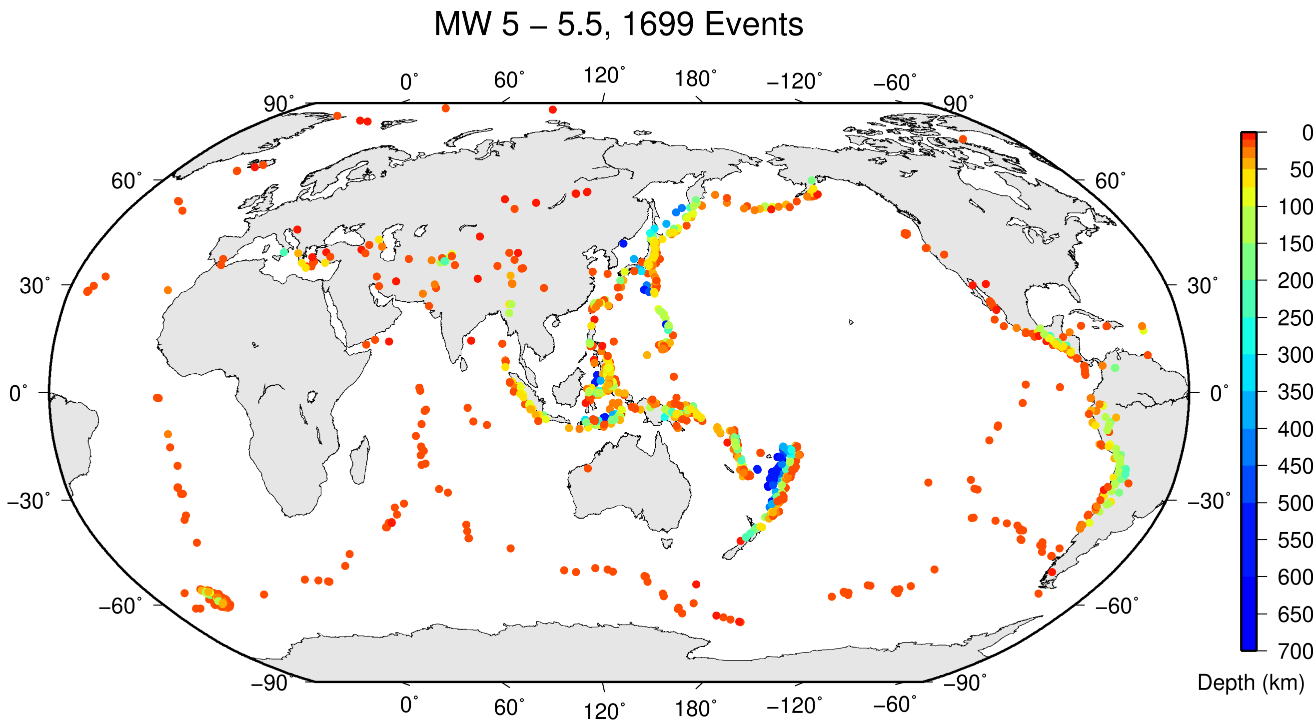

Figure 6.2: *Geographic distribution of magnitude 5-5.5 earthquakes between July and December 2021.*

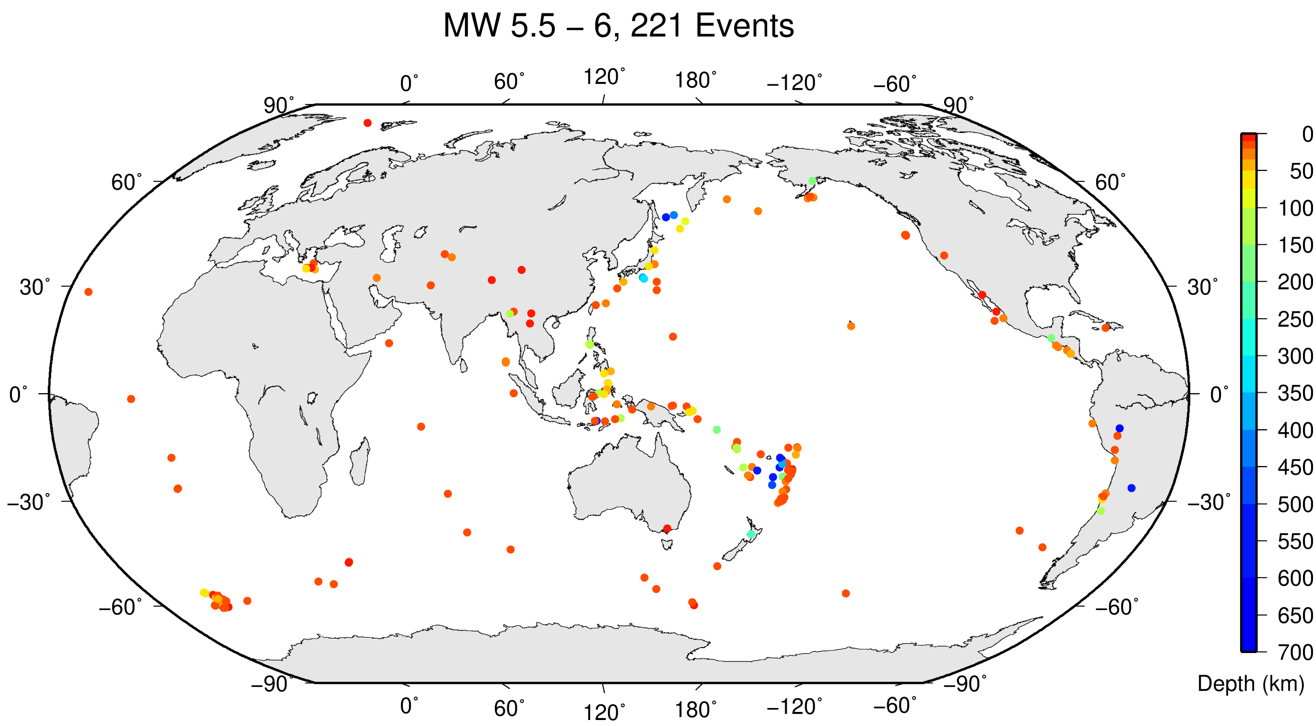

Figure 6.3: *Geographic distribution of magnitude 5.5-6 earthquakes between July and December 2021.*

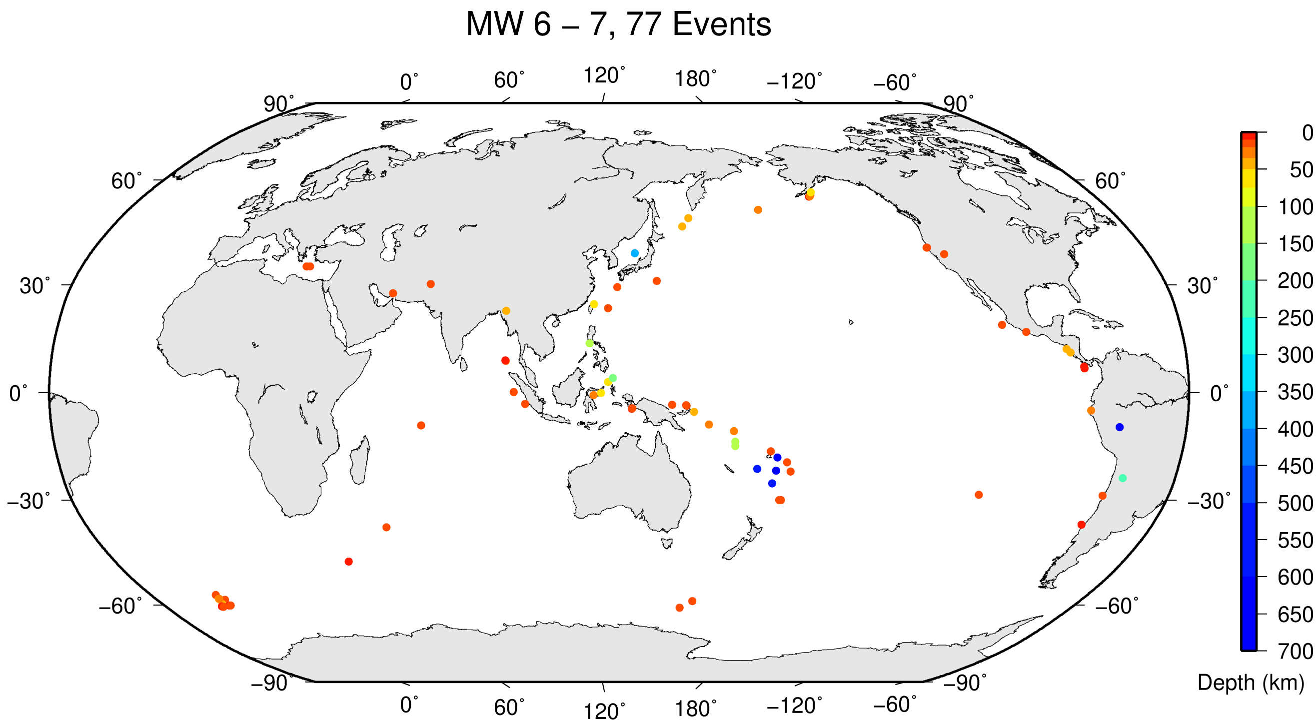

Figure 6.4: *Geographic distribution of magnitude 6-7 earthquakes between July and December 2021.*

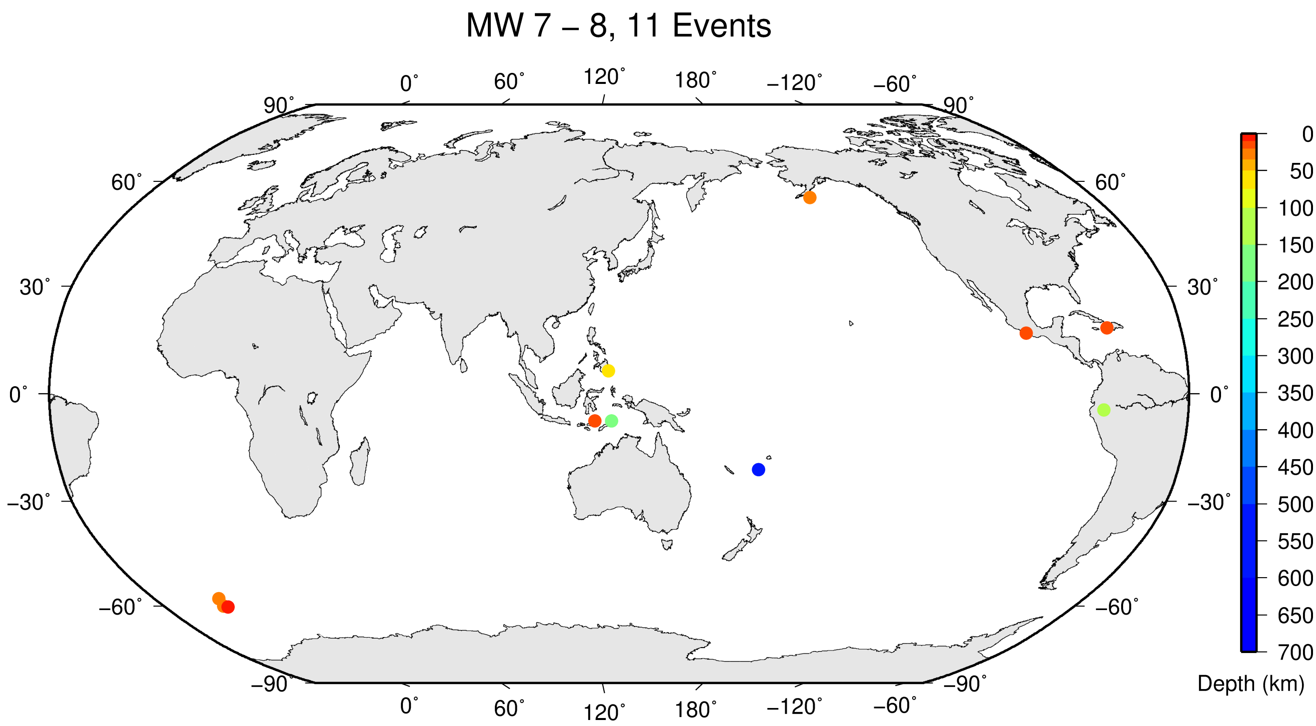

Figure 6.5: *Geographic distribution of magnitude 7-8 earthquakes between July and December 2021.*

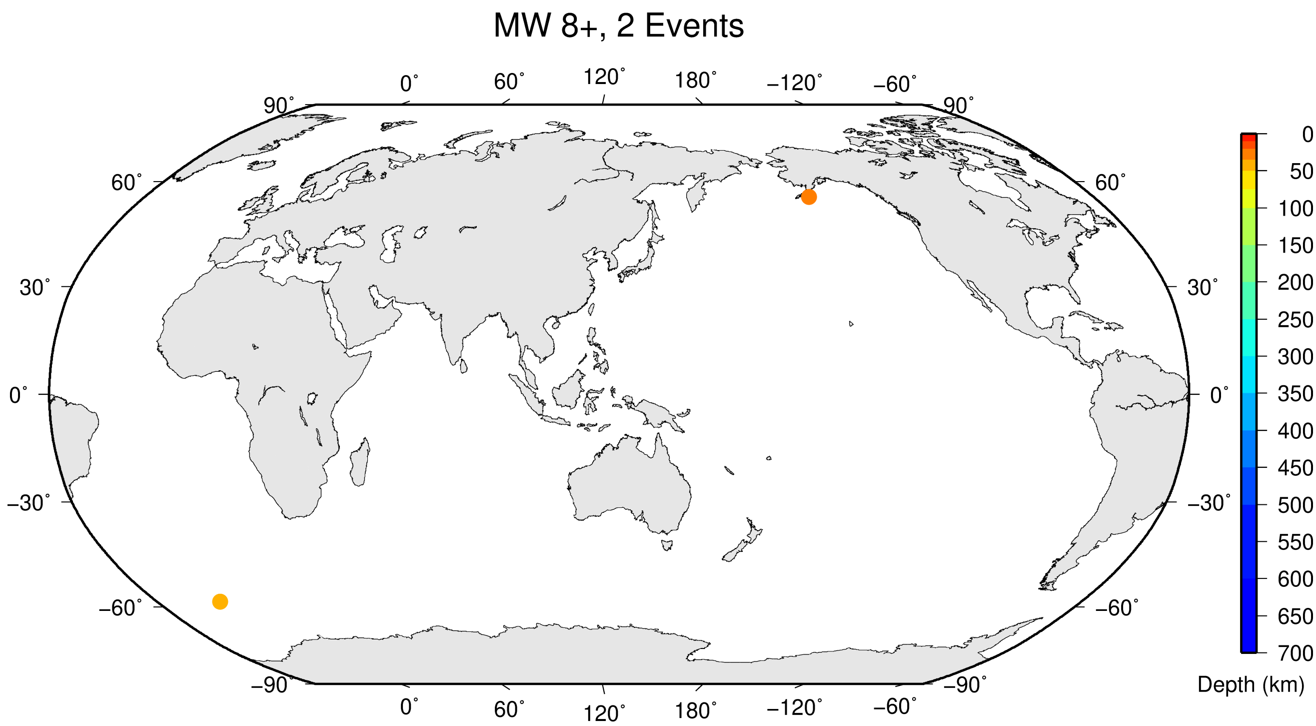

Figure 6.6: *Geographic distribution of magnitude 8+ earthquakes between July and December 2021.*

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Jia, Z., Z. Zhan and H. Kanamori (2022), The 2021 South Sandwich Island Mw 8.2 earthquake: A slow event sandwiched between regular ruptures, *Geophys. Res. Lett.*, *49*, e2021GL097104, https://doi.org/10.1029/2021GL097104.

Metz, M., F. Vera, A. Carrillo Ponce, S. Cesca, A. Babeyko, T. Dahm, J. Saul and F. Tilmann (2022), Seismic and tsunamigenic characteristics of a multimodal rupture of rapid and slow stages: The example of the complex 12 August 2021 South Sandwich earthquake, *J. Geophys. Res. Solid Earth*, *127*, e2022JB024646, https://doi.org/10.1029/2022JB024646.

USGS (2025), https://earthquake.usgs.gov/earthquakes/eventpage/ak0219neiszm/executive, (accessed 13/10/25).

7

Statistics of Collected Data

7.1 Introduction

The ISC Bulletin is based on the parametric data reports received from seismological agencies around the world. With rare exceptions, these reports include the results of waveform review done by analysts at network data centres and observatories. These reports include combinations of various bulletin elements such as event hypocentre estimates, moment tensors, magnitudes, event type and felt and damaging data as well as observations of the various seismic waves recorded at seismic stations.

Data reports are received in different formats that are often agency specific. Once an authorship is recognised, the data are automatically parsed into the ISC database and the original reports filed away to be accessed when necessary. Any reports not recognised or processed automatically are manually checked, corrected and re-processed. This chapter describes the data that are received at the ISC before the production of the reviewed Bulletin.

Notably, the ISC integrates all newly received data reports into the automatic ISC Bulletin (available on-line) soon after these reports are made available to ISC, provided it is done before the submission deadline that currently stands at 12 months following an event occurrence.

With data constantly being reported to the ISC, even after the ISC has published its review, the total data shown as collected, in this chapter, is limited to two years after the time of the associated reading or event, i.e. any hypocentre data collected two years after the event are not reflected in the figures below.

7.2 Summary of Agency Reports to the ISC

A total of 152 agencies have reported data for July 2021 to December 2021. The parsing of these reports into the ISC database is summarised in Table 7.1.

Table 7.1: *Summary of the parsing of reports received by the ISC from a total of 152 agencies, containing data for this summary period.*

	Number of reports
Total collected	8275
Automatically parsed	7187
Manually parsed	1088

Data collected by the ISC consists of multiple data types. These are typically one of:

- Bulletin, hypocentres with associated phase arrival observations.

- Catalogue, hypocentres only.
- Unassociated phase arrival observations.

In Table 7.2, the number of different data types reported to the ISC by each agency is listed. The number of each data type reported by each agency is also listed. Agencies reporting indirectly have their data type additionally listed for the agency that reported it. The agencies reporting indirectly may also have 'hypocentres with associated phases' but with no associated phases listed - this is because the association is being made by the agency reporting directly to the ISC. Summary maps of the agencies and the types of data reported are shown in Figure 7.1 and Figure 7.2.

Table 7.2: *Agencies reporting to the ISC for this summary period. Entries in bold are for new or renewed reporting by agencies since the previous six-month period.*

Agency	Country	Directly or indirectly reporting (D/I)	Hypocentres with associated phases	Hypocentres without associated phases	Associated phases	Unassociated phases	Amplitudes
TIR	Albania	D	2613	343	41603	0	12020
CRAAG	Algeria	D	190	0	1519	0	0
LPA	Argentina	D	0	0	0	1398	0
SJA	Argentina	D	3448	12	142495	12	42615
NSSP	Armenia	D	58	0	1216	0	0
AUST	Australia	D	2997	2	314157	0	292724
CUPWA	Australia	D	42	0	580	6	0
IDC	Austria	D	18184	0	680204	0	576160
VIE	Austria	D	5145	74	59899	0	59393
AZER	Azerbaijan	D	2137	0	35984	0	0
UCC	Belgium	D	1184	1	8262	7	2589
SCB	Bolivia	D	814	0	13080	0	1753
RHSSO	Bosnia and Herzegovina	D	698	0	11568	2685	0
BGSI	Botswana	D	509	0	8156	0	2688
OSUNB	Brazil	D	154	0	5398	0	0
VAO	Brazil	D	990	24	23089	0	0
SOF	Bulgaria	D	341	0	4170	1892	0
OTT	Canada	D	1646	34	34717	0	2024
PGC	Canada	I OTT	1144	0	23862	0	0
GUC	Chile	D	4354	429	127457	8732	37850
BJI	China	D	1373	0	106898	30754	76007
ASIES	Chinese Taipei	D	0	46	0	0	0
TAP	Chinese Taipei	D	7632	0	549207	0	0
RSNC	Colombia	D	11621	1	322561	205	76901
UCR	Costa Rica	D	498	2	19309	0	0
ZAG	Croatia	D	0	0	0	62674	0
SSNC	Cuba	D	4238	2	74671	35	26311
NIC	Cyprus	D	421	0	11864	0	4713
IPEC	Czech Republic	D	477	0	7326	21625	2349
PRU	Czech Republic	D	4453	0	55162	116	14778
WBNET	Czech Republic	D	111	0	2188	0	2188
KEA	Democratic People's Republic of Korea	D	160	0	1899	0	911
DNK	Denmark	D	2315	990	32024	26401	7536
OSPL	Dominican Republic	D	1804	1	25307	3	7309
IGQ	Ecuador	D	77	0	3888	0	0
HLW	Egypt	D	382	0	2944	0	0
SNET	El Salvador	D	12935	971	88292	1859	0
EST	Estonia	I HEL	160	30	0	0	0
HEL	Finland	D	6736	1739	181342	0	33941
CSEM	France	I AWI	3697	351	0	0	0
IPGP	France	D	0	148	0	0	0
LDG	France	D	1981	53	35781	0	11156
STR	France	D	4438	0	86349	27	0
PPT	French Polynesia	D	2335	2428	13646	25	13052

Table 7.2: *(continued)*

Agency	Country	Directly or indirectly reporting (D/I)	Hypocentres with associated phases	Hypocentres without associated phases	Associated phases	Unassociated phases	Amplitudes
TIF	Georgia	D	0	132	0	2853	0
AWI	Germany	D	6074	0	23142	153	23189
BGR	Germany	D	644	206	16289	0	5530
BNS	Germany	I BGR	2	27	0	0	0
BRG	Germany	D	0	0	0	9876	3067
CLL	Germany	D	2661	0	12814	948	5195
GDNRW	Germany	I BGR	0	3	0	0	0
GFZ	Germany	D	2696	875	152851	0	215883
LEDBW	Germany	I BGR	19	5	0	0	0
ATH	Greece	D	13196	7	625143	0	142751
THE	Greece	D	4815	24	174637	3760	93191
UPSL	Greece	D	0	2	0	0	0
GCG	Guatemala	D	3439	0	29776	10	461
HKC	Hong Kong	D	0	0	0	25	0
BUD	**Hungary**	**I BRA**	**4**	**0**	**0**	**0**	**0**
KRSZO	Hungary	D	1280	173	21943	0	5985
REY	Iceland	D	70	0	3375	0	0
HYB	India	D	1197	1	3469	0	34
NDI	India	D	893	0	27955	742	8754
DJA	Indonesia	D	6572	10	260971	0	137764
TEH	Iran	D	1453	0	30335	0	10871
THR	Iran	D	34	0	966	0	355
ISN	Iraq	D	167	0	1486	0	399
DIAS	Ireland	D	0	0	0	1293	0
GII	Israel	D	3168	0	70359	0	0
GEN	Italy	D	948	0	22800	26	0
MED_RCMT	Italy	D	0	84	0	0	0
RISSC	Italy	D	9	0	167	0	0
ROM	Italy	D	8072	94	746835	262344	504065
SARA	Italy	D	277	0	2826	0	0
TRI	Italy	D	0	0	0	9570	0
JSN	Jamaica	D	296	0	2541	0	0
JMA	Japan	D	103528	15180	622089	0	15304
NIED	Japan	D	0	698	0	0	0
SYO	Japan	D	0	0	0	810	0
JSO	Jordan	D	460	0	7308	0	3120
NNC	Kazakhstan	D	8633	0	79169	0	73307
SOME	Kazakhstan	D	3921	121	45613	34	38920
KNET	Kyrgyzstan	D	969	0	8109	0	3597
KRNET	Kyrgyzstan	D	5125	0	68953	7	0
LVSN	Latvia	D	315	0	4884	200	3111
GRAL	Lebanon	D	87	0	906	1234	0
LIT	Lithuania	D	828	828	4406	714	0
MCO	Macao, China	D	0	0	0	24	0
TAN	Madagascar	D	948	99	9373	6	0
GSDM	Malawi	D	0	0	0	251	0
ECX	Mexico	D	1212	0	32476	2	6078
MEX	Mexico	D	15665	123	237215	8	0
PDG	Montenegro	D	544	0	14415	0	4999
CNRM	Morocco	D	8981	0	91317	7	0
NAM	Namibia	D	243	0	2988	40	861
DMN	Nepal	D	1880	0	21156	0	16428
DBN	Netherlands	I BGR	0	4	0	0	0
NOU	New Caledonia	D	2153	748	45431	0	31921
WEL	New Zealand	D	9638	55	543236	73579	233100
CATAC	Nicaragua	D	2511	50	105100	2175	0
SKO	North Macedonia	D	0	689	7770	3066	2053
BER	Norway	D	3404	2047	51940	8337	7735
NAO	Norway	D	2519	718	6295	0	2332
OMAN	Oman	D	761	0	32530	0	0
UPA	Panama	D	518	0	8580	39	61
ARE	Peru	I RSNC	8	0	0	0	0
MAN	Philippines	D	57	272	5778	17615	1154
QCP	Philippines	D	0	0	0	167	0
PJWWP	Poland	D	109	4	247	3	16
WAR	Poland	D	0	0	0	5908	176
IGIL	Portugal	D	803	0	2959	0	909

Table 7.2: *(continued)*

Agency	Country	Directly or indirectly reporting (D/I)	Hypocentres with associated phases	Hypocentres without associated phases	Associated phases	Unassociated phases	Amplitudes
INMG	Portugal	D	2471	0	110593	7673	53600
PDA	**Portugal**	**I SVSA**	**1**	**0**	**0**	**0**	**0**
SVSA	Portugal	D	622	0	20066	2319	13068
BELR	Republic of Belarus	D	0	0	0	23170	5969
CFUSG	Republic of Crimea	D	94	0	2229	21	1354
KMA	Republic of Korea	D	14	0	344	0	0
BUC	Romania	D	674	0	24258	114755	7713
ASGSR	Russia	D	269	5097	10555	0	2990
BYKL	Russia	D	187	0	17378	6	6110
DAGSR	Russia	I MOS	204	153	0	0	0
FCIAR	Russia	D	98	1	1188	162	257
IDG	Russia	I MOS	0	54	0	0	0
IGKRC	Russia	I MOS	0	12	0	0	0
KOGSR	Russia	D	2493	1028	20254	32	0
KRSC	Russia	D	545	1	19722	0	0
MIRAS	Russia	D	175	0	4751	0	2293
MOS	Russia	D	2596	6824	279806	0	93371
NERS	Russia	D	117	158	2633	0	1207
NOGSR	Russia	I MOS	101	124	0	0	0
SKHL	Russia	D	822	932	16560	30	6804
YARS	Russia	D	212	77	5044	0	3136
SGS	Saudi Arabia	D	1207	0	17905	0	0
BEO	Serbia	D	1202	0	31560	32	0
BRA	Slovakia	D	3747	0	18239	0	2557
LJU	Slovenia	D	1213	3	18854	4135	6893
PRE	South Africa	D	2080	0	33740	68	9993
MDD	Spain	D	14943	20	441117	0	116297
MRB	Spain	D	702	0	28138	0	7897
SFS	Spain	D	1008	0	29623	12	0
UPP	Sweden	D	1694	817	22098	0	0
ZUR	Switzerland	D	670	31	24607	0	9737
BKK	Thailand	D	338	3	5815	0	6179
TRN	Trinidad and Tobago	D	4577	11	25571	25415	0
TUN	Tunisia	D	28	0	180	0	0
AFAD	Turkey	D	11635	0	302362	3	104999
ISK	Turkey	D	13238	0	272369	755	95561
AEIC	U.S.A.	I NEIC	5	3292	108697	0	0
BUT	U.S.A.	I NEIC	0	217	3443	0	0
GCMT	U.S.A.	D	0	2812	0	0	0
HVO	U.S.A.	I NEIC	1	910	32524	0	0
NCEDC	U.S.A.	I NEIC	0	748	50686	0	0
NEIC	U.S.A.	D	23442	10070	1942514	0	980298
PAS	U.S.A.	I NEIC	0	199	20090	0	0
PNSN	U.S.A.	D	0	76	0	0	0
PTWC	U.S.A.	D	188	0	2989	0	0
REN	U.S.A.	I NEIC	0	409	7383	0	0
RSPR	U.S.A.	D	1459	327	46201	0	0
SEA	U.S.A.	I NEIC	0	44	2495	0	0
SLM	U.S.A.	I NEIC	0	81	1313	0	0
TXNET	U.S.A.	D	2174	0	118396	0	30458
UUSS	U.S.A.	I NEIC	0	80	1310	0	0
MCSM	Ukraine	D	2013	0	110800	32694	133435
SIGU	Ukraine	D	23	23	822	0	423
DSN	United Arab Emirates	D	596	0	7422	0	0
BGS	United Kingdom	D	370	16	11507	61	5091
ISC-PPSM	United Kingdom	D	0	88	0	0	0
EAF	Unknown	D	239	0	1600	1575	237
EVBIB	**Unknown**	**D**	**0**	**4**	**0**	**0**	**0**
ISU	Uzbekistan	D	746	0	8827	0	0
FUNV	Venezuela	D	861	0	8139	0	0
PLV	Viet Nam	D	136	0	1259	0	484

Table 7.2: *(continued)*

Agency	Country	Directly or indirectly reporting (D/I)	Hypocentres with associated phases	Hypocentres without associated phases	Associated phases	Unassociated phases	Amplitudes
BUL	Zimbabwe	D	8	0	55	9	0

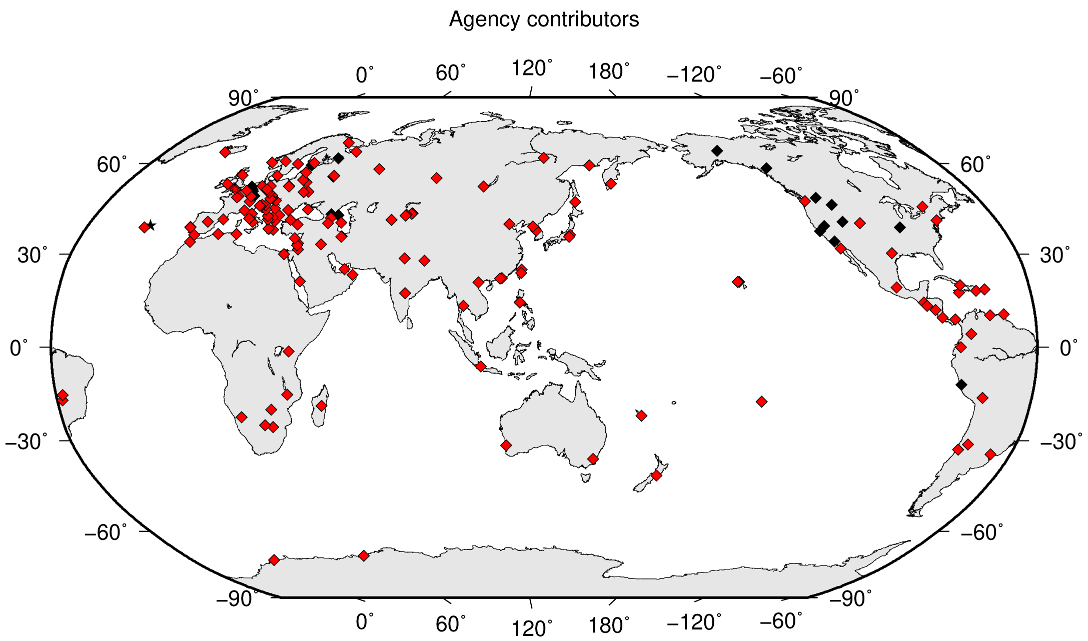


Figure 7.1: *Map of agencies that have contributed data to the ISC for this summary period. Agencies that have reported directly to the ISC are shown in red. Those that have reported indirectly (via another agency) are shown in black. Any new or renewed agencies, since the last six-month period, are shown by a star. Each agency is listed in Table 7.2.*

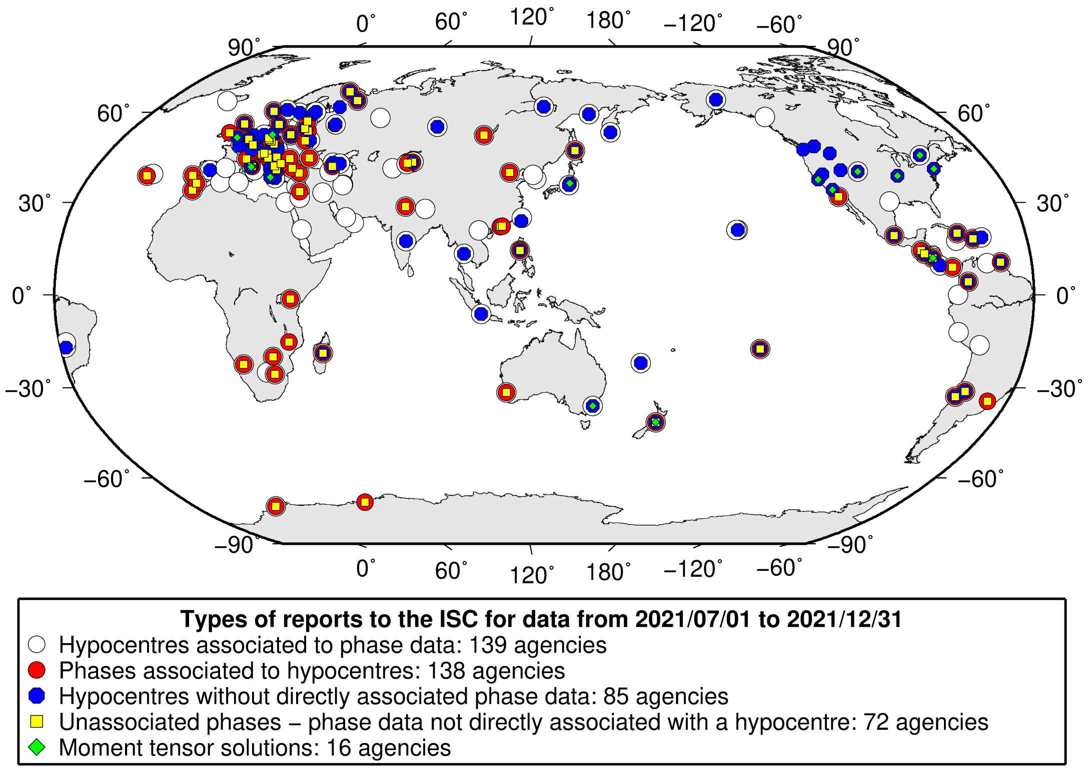


Figure 7.2: *Map of the different data types reported by agencies to the ISC. A full list of the data types reported by each agency is shown in Table 7.2.*

7.3 Arrival Observations

The collection of phase arrival observations at the ISC has increased dramatically with time. The increase in reported phase arrival observations is shown in Figure 7.3.

The reports with phase data are summarised in Table 7.3. This table is split into three sections, providing information on the reports themselves, the phase data, and the stations reporting the phase data. A map of the stations contributing these phase data is shown in Figure 7.4.

The ISC encourages the reporting of phase arrival times together with amplitude and period measurements whenever feasible. Figure 7.5 shows the percentage of events for which phase arrival times from each station are accompanied with amplitude and period measurements.

Figure 7.6 indicates the number of amplitude and period measurement for each station.

Together with the increase in the number of phases (Figure 7.3), there has been an increase in the number of stations reported to the ISC. The increase in the number of stations is shown in Figure 7.7. This increase can also be seen on the maps for stations reported each decade in Figure 7.8.

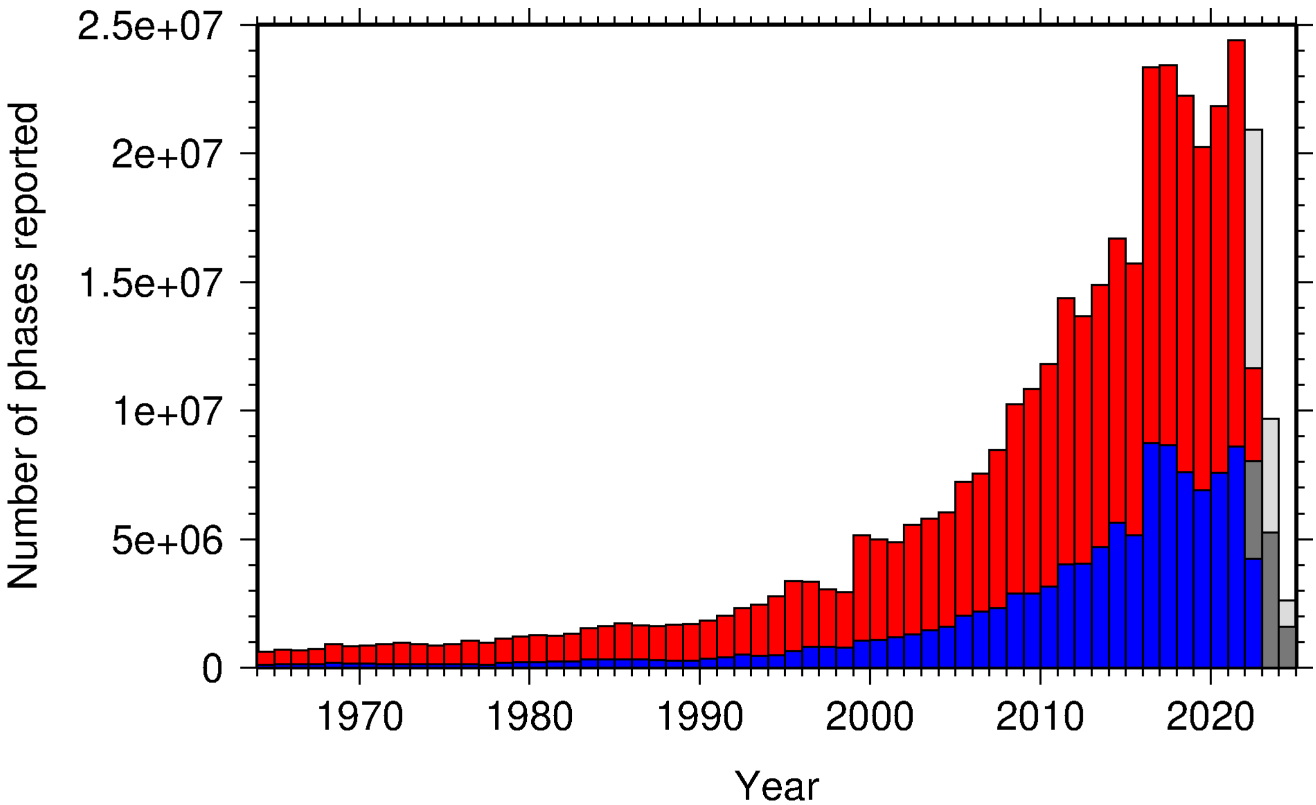


Figure 7.3: *Histogram showing the number of phases (red) and number of amplitudes (blue) collected by the ISC for events each year since 1964. The data in grey covers the current period where data are still being collected before the ISC review takes place and is accurate at the time of publication.*

Table 7.3: *Summary of reports containing phase arrival observations.*

Reports with phase arrivals	7865
Reports with phase arrivals including amplitudes	7257
Reports with only phase arrivals (no hypocentres reported)	165
Total phase arrivals received	12099910
Total phase arrival-times received	10649260
Number of duplicate phase arrival-times	843276 (7.9%)
Number of amplitudes received	4618055
Stations reporting phase arrivals	13523
Stations reporting phase arrivals with amplitude data	7393
Max number of stations per report	3001

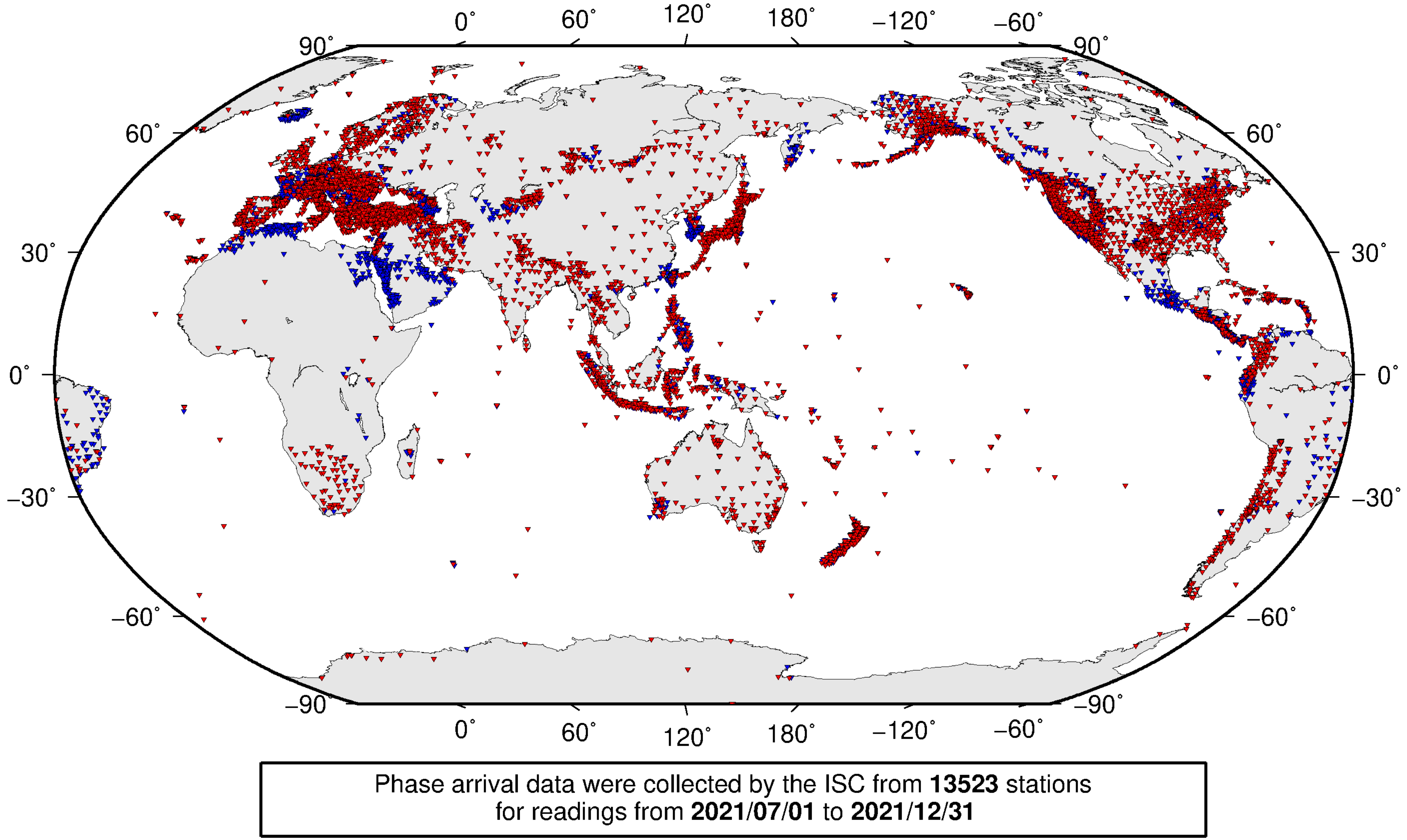
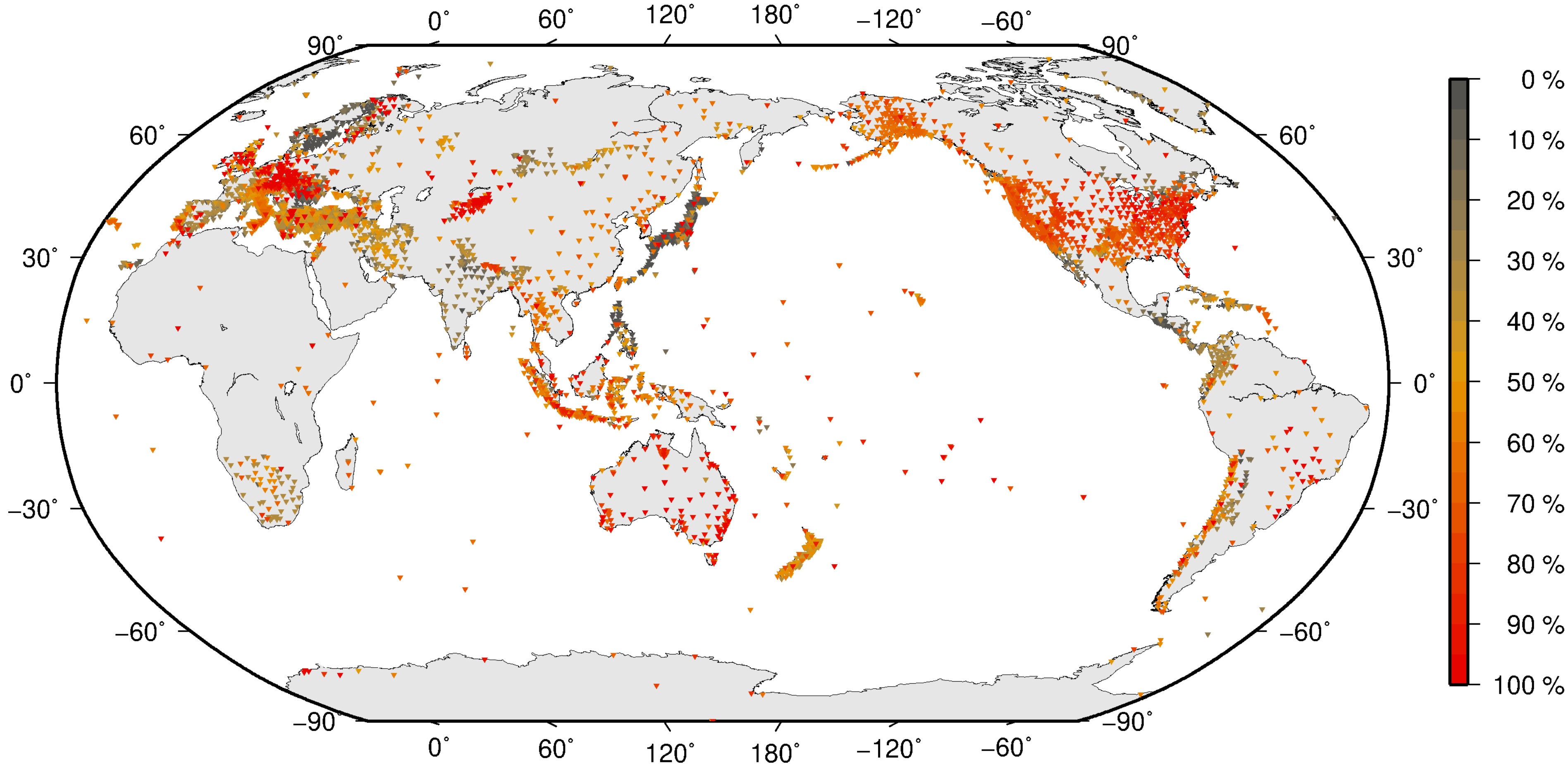
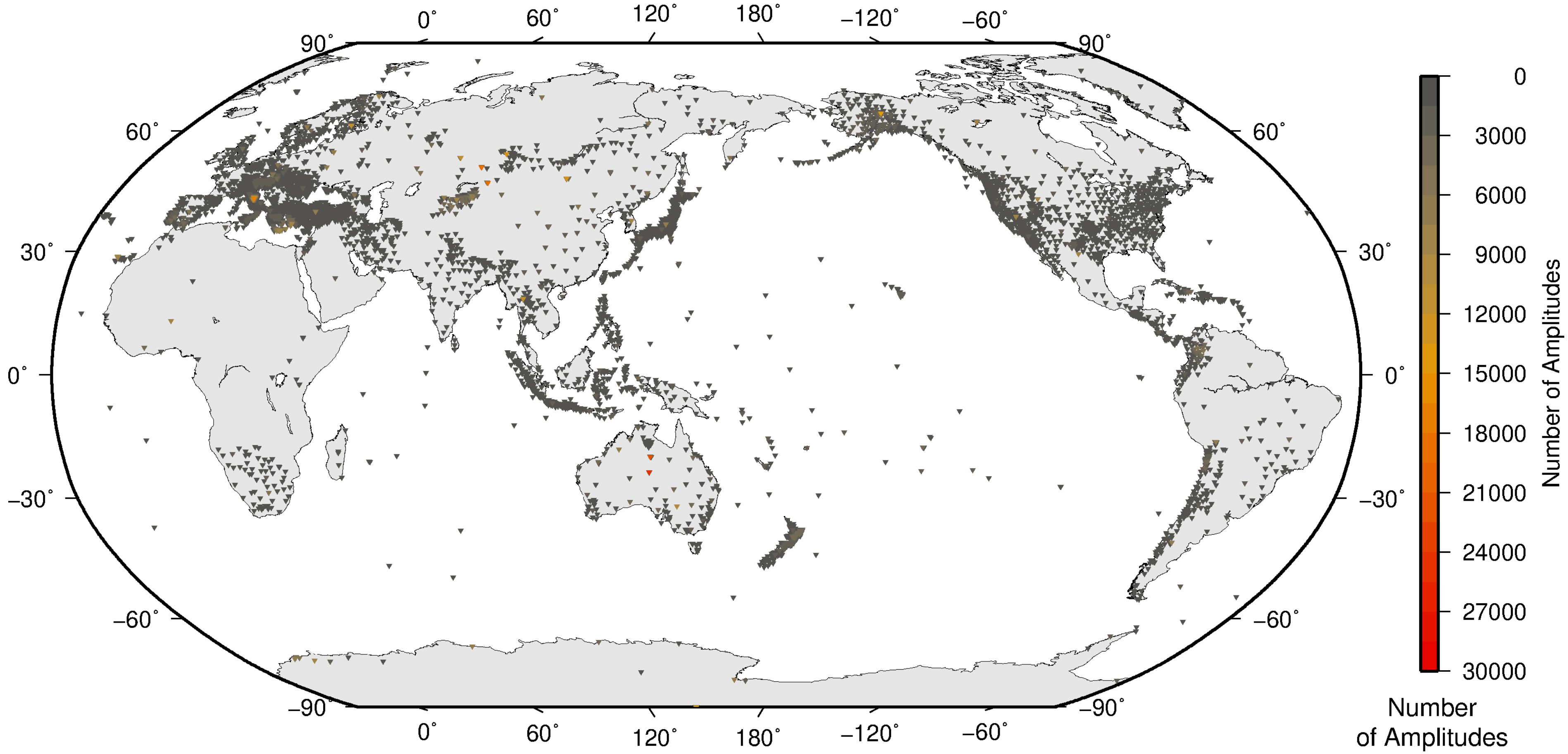


Figure 7.4: *Stations contributing phase data to the ISC for readings from July 2021 to the end of December 2021. Stations in blue provided phase arrival times only; stations in red provided both phase arrival times and amplitude data.*



Amplitude data were collected by the ISC from **7286** stations sent by **89** agencies for readings from **2021/07/01** to **2021/12/31**

Figure 7.5: *Percentage of events for which phase arrival times from each station are accompanied with amplitude and period measurements.*



Amplitude data were collected by the ISC from **7286** stations sent by **89** agencies for readings from **2021/07/01** to **2021/12/31**

Figure 7.6: *Number of amplitude and period measurements for each station.*

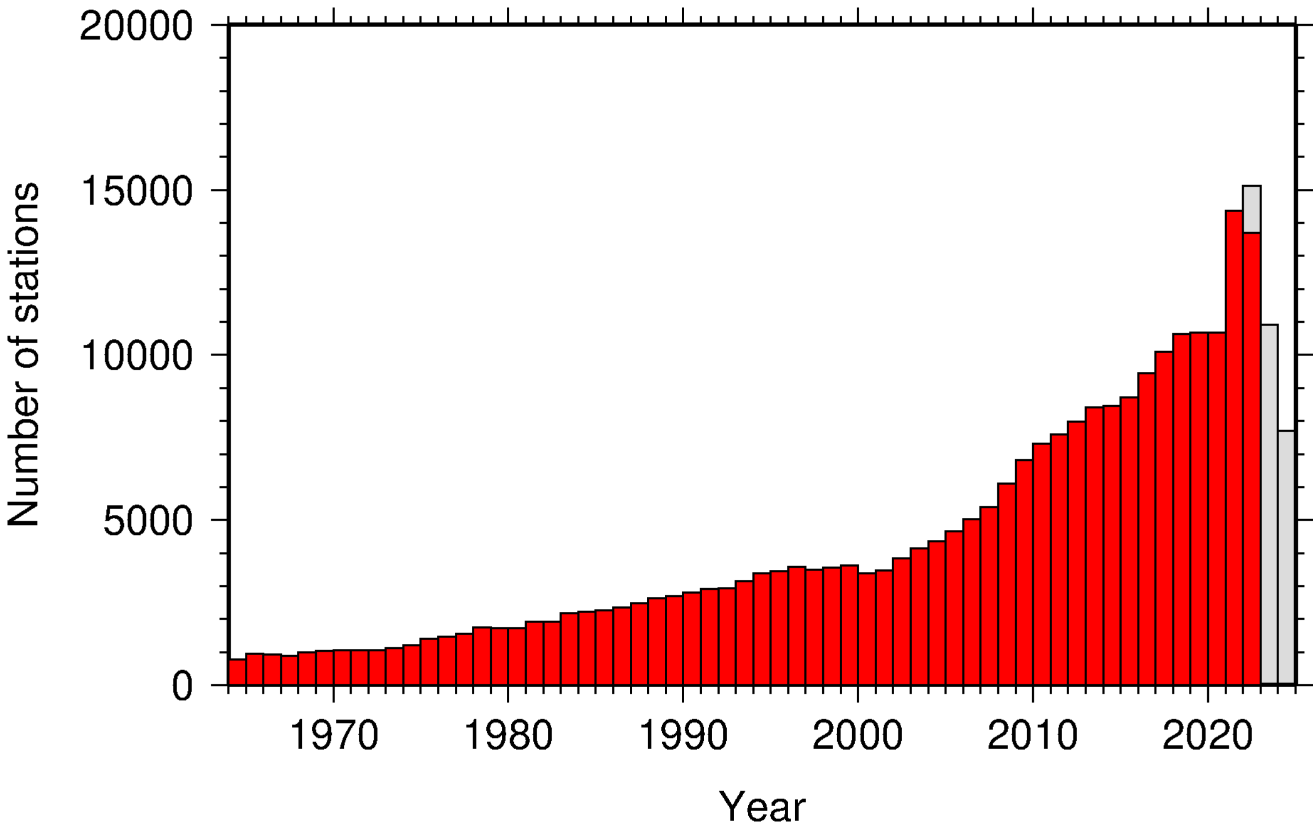
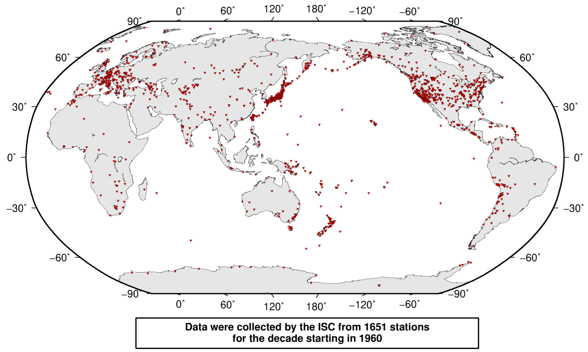
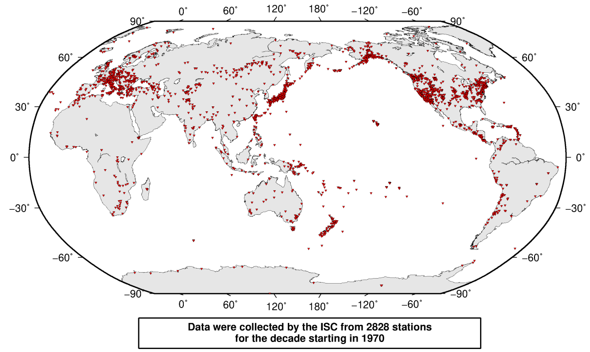


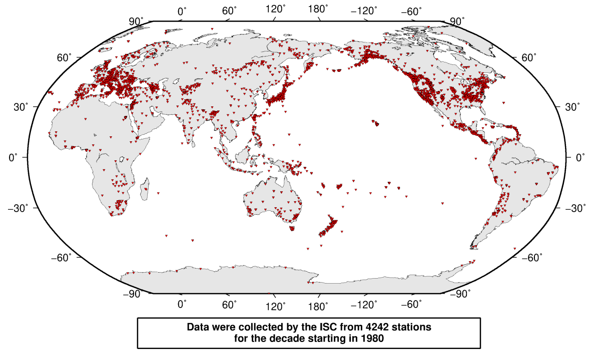
Figure 7.7: *Histogram showing the number of stations reporting to the ISC each year since 1964. The data in grey covers the current period where station information is still being collected before the ISC review of events takes place and is accurate at the time of publication.*



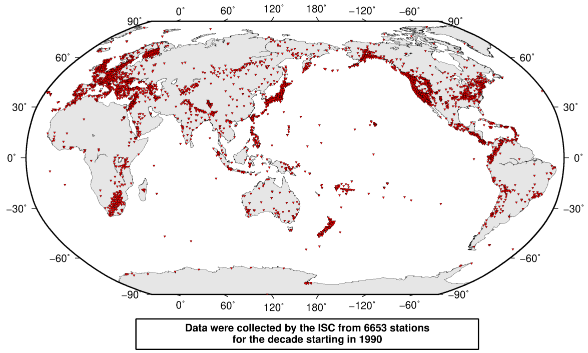
(a)



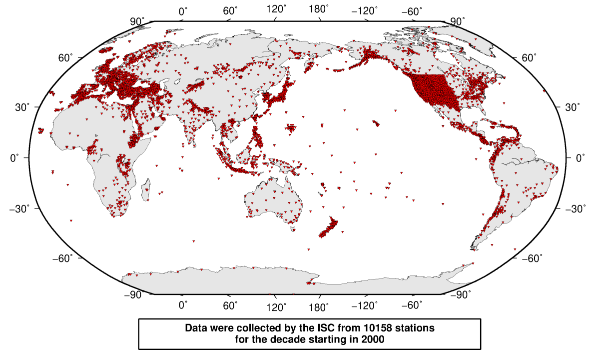
(b)



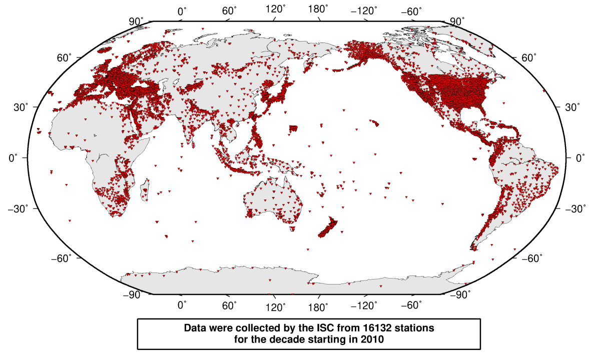
(c)



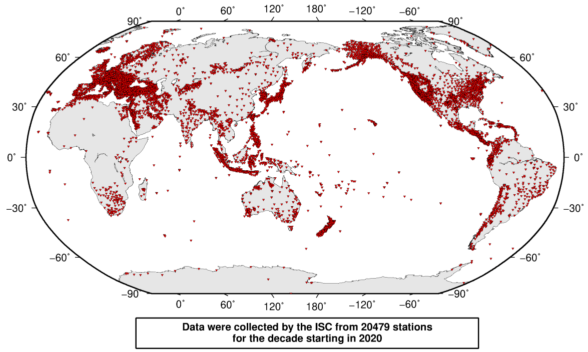
(d)



(e)



(f)



(g)

Figure 7.8: *Maps showing the stations reported to the ISC for each decade since 1960. Note that the last map covers a shorter time period.*

7.4 Hypocentres Collected

The ISC Bulletin groups multiple estimates of hypocentres into individual events, with an appropriate prime hypocentre solution selected. The collection of these hypocentre estimates are described in this section.

The reports containing hypocentres are summarised in Table 7.4. The number of hypocentres collected by the ISC has also increased significantly since 1964, as shown in Figure 7.9. A map of all hypocentres reported to the ISC for this summary period is shown in Figure 7.10. Where a network magnitude was reported with the hypocentre, this is also shown on the map, with preference given to reported values, first of M_W followed by M_S, m_b and M_L respectively (where more than one network magnitude was reported).

Table 7.4: *Summary of the reports containing hypocentres.*

Reports with hypocentres	8110
Reports of hypocentres only (no phase readings)	410
Total hypocentres received	482680
Number of duplicate hypocentres	10006 (2.1%)
Agencies determining hypocentres	161

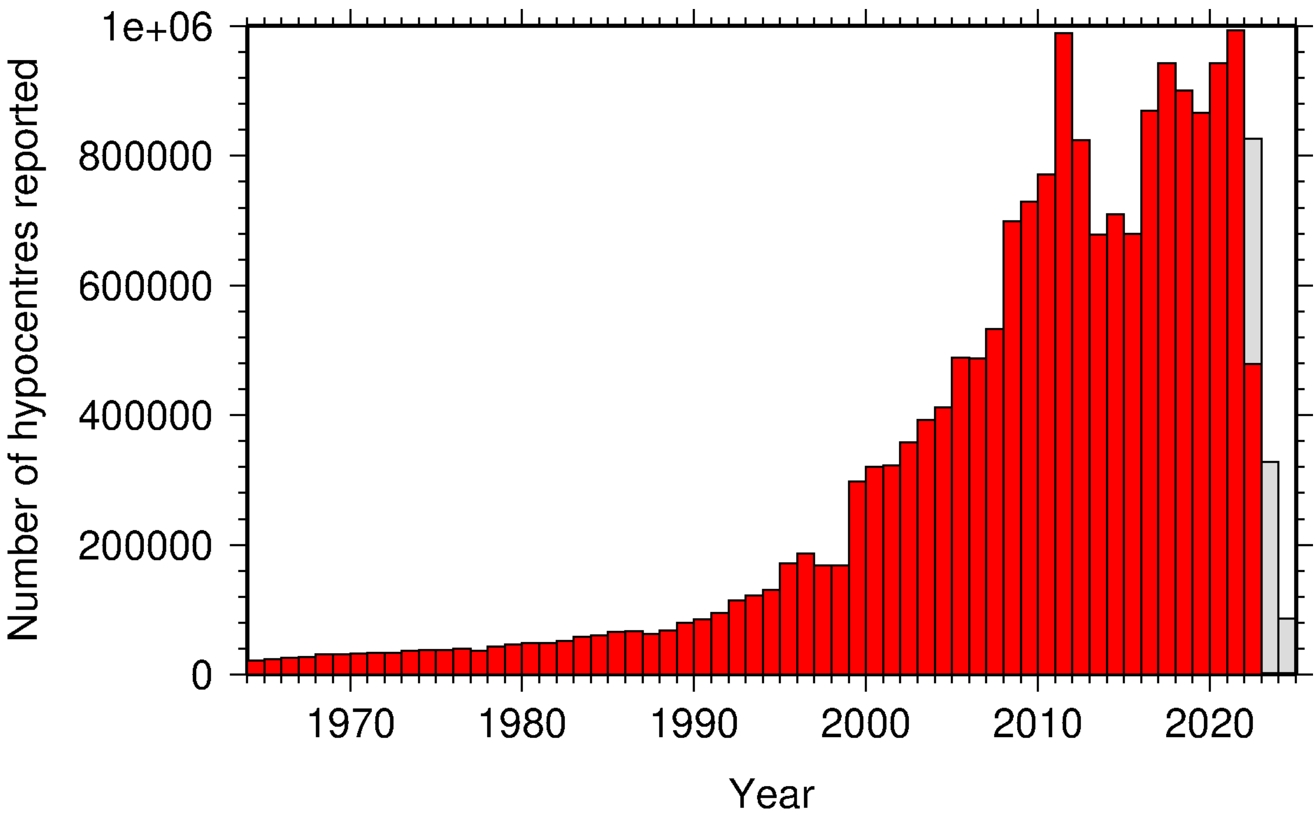


Figure 7.9: *Histogram showing the number of hypocentres collected by the ISC for events each year since 1964. For each event, multiple hypocentres may be reported.*

All the hypocentres that are reported to the ISC are automatically grouped into events, which form the basis of the ISC Bulletin. For this summary period 511038 hypocentres (including ISC) were grouped into 340293 events, the largest of these having 65 hypocentres in one event. The total number of events

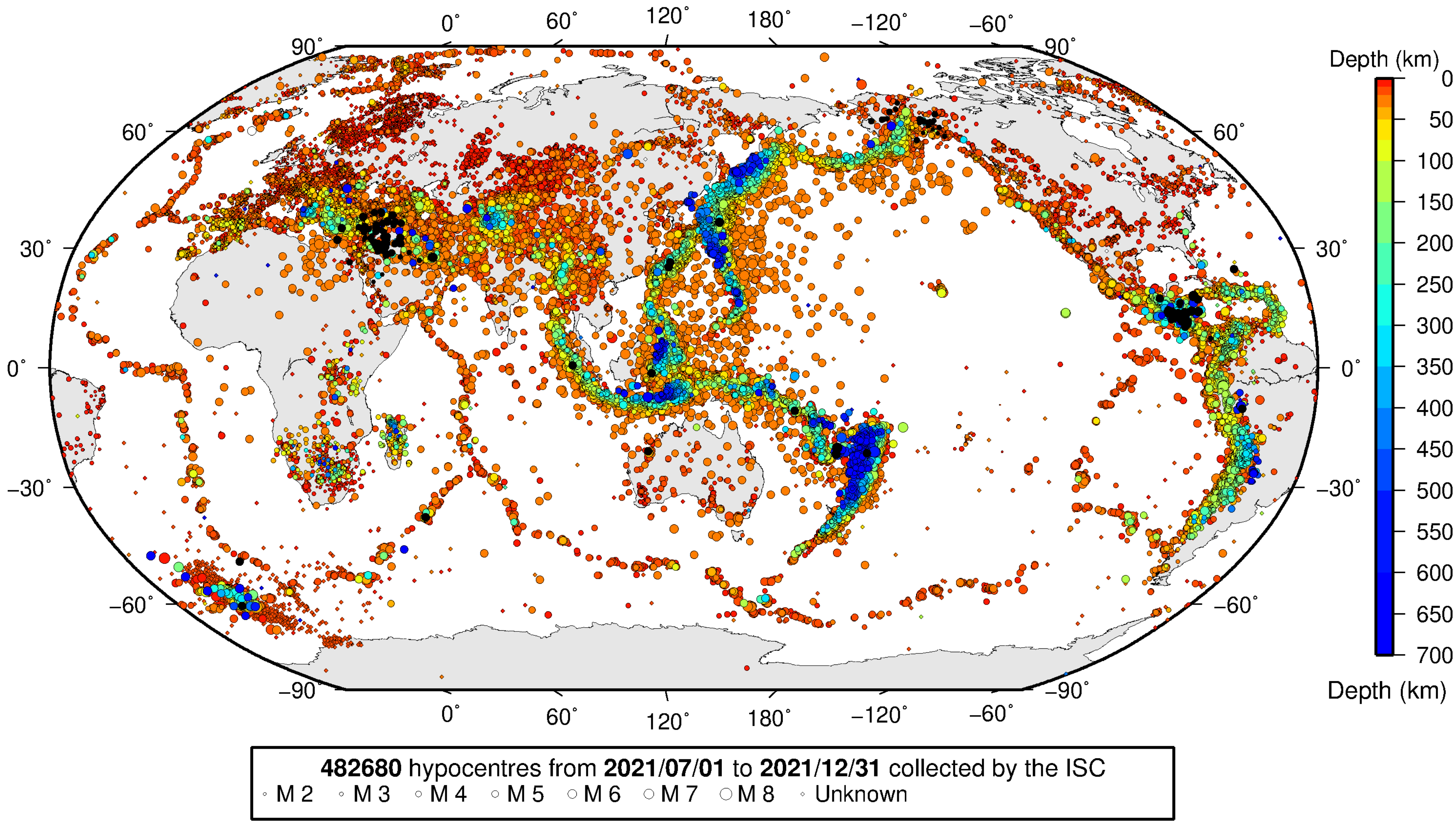


Figure 7.10: *Map of all hypocentres collected by the ISC. The scatter shows the large variation of the multiple hypocentres that are reported for each event. The magnitude corresponds with the reported network magnitude. If more than one network magnitude type was reported, preference was given to values of* M_W*,* M_S*,* m_b *and* M_L *respectively. Compare with Figure 8.2*

shown here is the result of an automatic grouping algorithm, and will differ from the total events in the published ISC Bulletin, where both the number of events and the number of hypocentre estimates will have changed due to further analysis. The process of grouping is detailed in Section 10.1.3 of Volume 58 Issue I of the ISC Summary. Figure 8.2 on page 77 shows a map of all prime hypocentres.

7.5 Collection of Network Magnitude Data

Data contributing agencies normally report earthquake hypocentre solutions along with magnitude estimates. For each seismic event, each agency may report one or more magnitudes of the same or different types. This stems from variability in observational practices at regional, national and global level in computing magnitudes based on a multitude of wave types. Differences in the amplitude measurement algorithm, seismogram component(s) used, frequency range, station distance range as well as the instrument type contribute to the diversity of magnitude types. Table 7.5 provides an overview of the complexity of reported network magnitudes reported for seismic events during the summary period.

Table 7.5: *Statistics of magnitude reports to the ISC; M – average magnitude of estimates reported for each event.*

	M<3.0	3.0≤M<5.0	M≥5.0
Number of seismic events	254175	51207	658
Average number of magnitude estimates per event	1.3	3.1	20.0
Average number of magnitudes (by the same agency) per event	1.2	1.9	2.8
Average number of magnitude types per event	1.2	2.4	11.1
Number of magnitude types	29	39	35

Table 7.6 gives the basic description, main features and scientific paper references for the most commonly reported magnitude types.

Table 7.6: *Description of the most common magnitude types reported to the ISC.*

Magnitude type	Description	References	Comments
M	Unspecified		Often used in real or near-real time magnitude estimations
mB	Medium-period and Broad-band body-wave magnitude	*Gutenberg* (1945a); *Gutenberg* (1945b); *IASPEI* (2005); *IASPEI* (2013); *Bormann et al.* (2009); *Bormann and Dewey* (2012)	
mb	Short-period body-wave magnitude	*IASPEI* (2005); *IASPEI* (2013); *Bormann et al.* (2009); *Bormann and Dewey* (2012)	Classical mb based on stations between 21°-100° distance

Table 7.6: *continued*

Magnitude type	Description	References	Comments
mb1	Short-period body-wave magnitude	*IDC* (1999) and references therein	Reported only by the IDC; also includes stations at distances less than 21°
mb1mx	Maximum likelihood short-period body-wave magnitude	*Ringdal* (1976); *IDC* (1999) and references therein	Reported only by the IDC
mbtmp	short-period body-wave magnitude with depth fixed at the surface	*IDC* (1999) and references therein	Reported only by the IDC
mbLg	Lg-wave magnitude	*Nuttli* (1973); *IASPEI* (2005); *IASPEI* (2013); *Bormann and Dewey* (2012)	Also reported as MN
Mc	Coda magnitude		
MD (Md)	Duration magnitude	*Bisztricsany* (1958); *Lee et al.* (1972)	
ME (Me)	Energy magnitude	*Choy and Boatwright* (1995)	Reported only by NEIC
MJMA	JMA magnitude	*Tsuboi* (1954)	Reported only by JMA
ML (Ml)	Local (Richter) magnitude	*Richter* (1935); *Hutton and Boore* (1987); *IASPEI* (2005); *IASPEI* (2013)	
MLSn	Local magnitude calculated for Sn phases	*Balfour et al.* (2008)	Reported by PGC only for earthquakes west of the Cascadia subduction zone
MLv	Local (Richter) magnitude computed from the vertical component		Reported only by DJA and BKK
MN (Mn)	Lg-wave magnitude	*Nuttli* (1973); *IASPEI* (2005)	Also reported as mbLg
MS (Ms)	Surface-wave magnitude	*Gutenberg* (1945c); *Vaněk et al.* (1962); *IASPEI* (2005)	Classical surface-wave magnitude computed from station between 20°-160° distance
Ms1	Surface-wave magnitude	*IDC* (1999) and references therein	Reported only by the IDC; also includes stations at distances less than 20°
ms1mx	Maximum likelihood surface-wave magnitude	*Ringdal* (1976); *IDC* (1999) and references therein	Reported only by the IDC

Table 7.6: *continued*

Magnitude type	Description	References	Comments
Ms7	Surface-wave magnitude	*Bormann et al.* (2007)	Reported only by BJI and computed from records of a Chinese-made long-period seismograph in the distance range 3°-177°
MW (Mw)	Moment magnitude	*Kanamori* (1977); *Dziewonski et al.* (1981)	Computed according to the *IASPEI* (2005) and *IASPEI* (2013) standard formula
Mw(mB)	Proxy Mw based on mB	*Bormann and Saul* (2008)	Reported only by DJA and BKK
Mwp	Moment magnitude from P-waves	*Tsuboi et al.* (1995)	Reported only by DJA and BKK and used in rapid response
mbh	Unknown		
mbv	Unknown		
MG	Unspecified type		Contact contributor
Mm	Unknown		
msh	Unknown		
MSV	Unknown		

Table 7.7 lists all magnitude types reported, the corresponding number of events in the ISC Bulletin and the agency codes along with the number of earthquakes.

Table 7.7: *Summary of magnitude types in the ISC Bulletin for this summary period. The number of events with values for each magnitude type is listed. The agencies reporting these magnitude types are listed, together with the total number of values reported.*

Magnitude type	Events	Agencies reporting magnitude type (number of values)
M	19603	WEL (8473), MOS (5673), GFZ (2544), CATAC (2136), SNET (2032), BKK (292), OTT (192), JSO (123), IGQ (45), PRU (23), INMG (4), TAN (3), OSUNB (1)
MB	172	NAO (132), SCB (39), IPEC (1)
mB	1985	BJI (1105), DJA (598), GFZ (309), WEL (238), CATAC (141), BKK (100), SNET (12), OSUNB (3), SFS (3), IGQ (2), OTT (2), MCSM (1)
mb	27415	IDC (16687), NEIC (8967), KRNET (5118), NNC (3772), GFZ (2495), VIE (2303), MOS (1343), DJA (1154), BJI (1124), VAO (323), BGR (274), OMAN (245), MAN (227), CATAC (225), NOU (204), AUST (161), MCSM (140), BKK (111), MDD (94), CFUSG (53), SFS (51), SNET (32), NDI (25), DSN (15), SIGU (10), THE (6), OSUNB (5), SSNC (5), CRAAG (5), INMG (5), OTT (3), YARS (3), PDG (3), PTWC (3), DMN (3), IGQ (3), DNK (1), CSEM (1), BGS (1), KMA (1), PGC (1)
mB_BB	27	BGR (27)
mb_Lg	15479	MDD (14826), NEIC (626), OTT (30)

Table 7.7: *Continued.*

Magnitude type	Events	Agencies reporting magnitude type (number of values)
mBc	1	SNET (1)
mbR	69	VAO (69)
mbtmp	17889	IDC (17889)
Mc	21	KRSC (21)
MD	13899	SSNC (3639), GCG (3319), LDG (1785), RSPR (1589), TRN (1149), ECX (693), NCEDC (515), JMA (370), SOF (328), JSN (216), MEX (121), ROM (118), GRAL (87), PDG (84), SLM (80), CFUSG (79), PNSN (62), EAF (57), HVO (42), TUN (27), HLW (25), UPA (19), GII (18), UUSS (8), STR (6), ISK (2), BER (2), DNK (2), BUT (1)
Mjma	2471	SNET (1656), DJA (1039), BKK (279), IGQ (50), RSNC (2), SFS (1)
ML	131133	ISK (13230), ATH (13190), AFAD (11326), RSNC (11231), IDC (10619), WEL (8333), ROM (7818), TAP (7630), NEIC (7225), HEL (7100), GUC (4670), CNRM (4296), SSNC (3898), SJA (3377), AEIC (3334), VIE (3293), INMG (2439), UPP (2407), TXNET (2174), AZER (2141), PRE (2001), KOGSR (1929), OSPL (1801), SFS (1618), TEH (1453), TIR (1358), LDG (1300), DNK (1263), SGS (1197), BEO (1196), LJU (1151), ECX (1140), BER (1104), BRA (1009), PGC (946), GEN (878), HVO (869), KRSZO (846), TAN (808), SCB (800), MRB (699), RHSSO (698), BUC (674), SKO (667), KRSC (544), PDG (494), IPEC (474), BGSI (455), IGIL (433), NDI (431), NIC (420), REN (409), NAO (395), OMAN (395), AUST (344), KNET (291), DSN (288), SARA (277), MAN (272), SNET (261), GCG (251), UCC (233), BKK (227), BUT (217), YARS (212), GFZ (192), BJI (187), PAS (184), HLW (183), NCEDC (177), MIRAS (174), LVSN (172), CRAAG (164), ISN (164), BGS (148), PLV (136), DJA (125), BGR (121), WBNET (111), SKHL (104), PPT (96), UUSS (72), SEA (66), NAM (51), KEA (44), OTT (37), DMN (35), THR (34), EAF (33), CUPWA (33), BNS (29), UPA (28), IGQ (23), PTWC (14), RISSC (9), RSPR (8), STR (7), VAO (3), CLL (1), KMA (1)
MLh	4992	THE (4727), ASGSR (264), RSNC (1)
MLhc	619	ZUR (619)
MLSn	189	PGC (189)
MLv	25834	WEL (9030), DJA (5273), STR (4425), RSNC (2393), CATAC (2195), SNET (2052), SFS (815), NOU (806), BKK (313), MCSM (205), OTT (163), IGQ (97), GFZ (59), OS-UNB (8), AUST (1)
MN	464	OTT (464)
mpv	4214	NNC (4214)
MPVA	270	NOGSR (224), MOS (163)
mR	91	OSUNB (91)

Table 7.7: *Continued.*

Magnitude type	Events	Agencies reporting magnitude type (number of values)
MS	8636	IDC (8430), BJI (896), MOS (426), MAN (272), BGR (160), GCMT (61), NSSP (58), OMAN (26), VIE (19), SOME (17), KEA (14), YARS (5), DSN (5), SSNC (1), INMG (1), DNK (1), IPEC (1)
Ms(BB)	55	IGQ (44), SNET (6), BKK (3), RSNC (2)
Ms7	884	BJI (884)
Ms_20	209	NEIC (209)
MsBB	19	OTT (19)
MSH	79	CFUSG (79)
MV	112840	JMA (112840)
MW	8043	SJA (3146), GCMT (1405), NIED (698), FUNV (642), GFZ (569), BER (450), UPA (447), UCR (443), AFAD (293), PGC (190), SSNC (181), NDI (162), IPGP (148), DJA (114), TIR (101), JMA (87), MED_RCMT (84), WEL (54), ASIES (46), GCG (29), ROM (15), SNET (8), MEX (8), JSN (4), EVBIB (3), OSUNB (2), OTT (2), RSNC (2), UPSL (2), OSPL (1), INMG (1)
Mw(mB)	730	GFZ (290), WEL (219), CATAC (132), BKK (99), SNET (10), SFS (3), IGQ (2)
Mwb	202	NEIC (202)
Mwc	12	NEIC (12)
MwMwp	72	CATAC (43), NOU (17), BKK (10), SNET (5), SFS (1), AUST (1)
Mwp	641	SARA (277), PTWC (165), DJA (128), GFZ (122), CATAC (46), BKK (11), RSNC (11), OMAN (11), SNET (7), THE (1), AUST (1), SFS (1)
Mwr	426	NEIC (291), GUC (94), NCEDC (56), SLM (36), PAS (15), OTT (7), VIE (1)
Mws	595	GII (595)
Mww	617	NEIC (617), GUC (10), AEIC (1)

The most commonly reported magnitude types are short-period body-wave, surface-wave, local (or Richter), moment, duration and JMA magnitude type. For a given earthquake, the number and type of reported magnitudes greatly vary depending on its size and location. The large earthquake of October 25, 2010 gives an example of the multitude of reported magnitude types for large earthquakes (Listing 7.1). Different magnitude estimates come from global monitoring agencies such as the IDC, NEIC and GCMT, a local agency (GUC) and other agencies, such as MOS and BJI, providing estimates based on the analysis of their networks. The same agency may report different magnitude types as well as several estimates of the same magnitude type, such as NEIC estimates of Mw obtained from W-phase, centroid and body-wave inversions.

Listing 7.1: *Example of reported magnitudes for a large event*

```
Event    15264887  Southern  Sumatera
   Date         Time        Err   RMS Latitude Longitude  Smaj  Smin  Az Depth   Err Ndef Nsta Gap  mdist  Mdist Qual   Author      OrigID
2010/10/25 14:42:22.18    0.27 1.813  -3.5248  100.1042 4.045 3.327  54  20.0  1.37 2102 2149  23   0.76 176.43 m i de ISC       01346132
 (#PRIME)
```

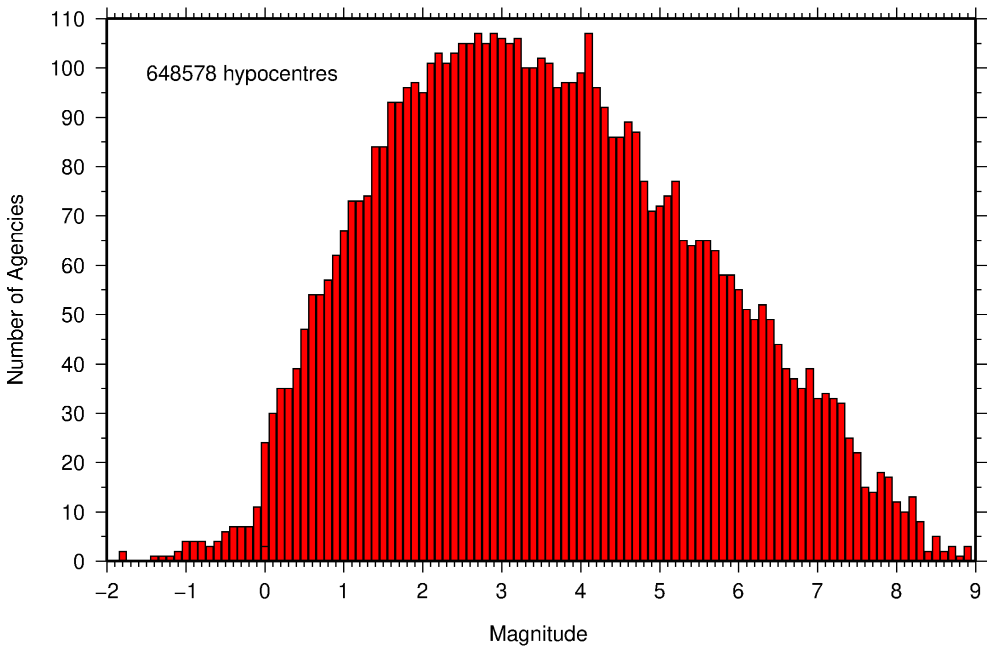


Figure 7.11: *Histogram showing the number of agencies that reported network magnitude values. All magnitude types are included.*

```
Magnitude  Err Nsta Author       OrigID
mb      6.1       61 BJI       15548963
mB      6.9       68 BJI       15548963
Ms      7.7       85 BJI       15548963
Ms7     7.5       86 BJI       15548963
mb      5.3 0.1   48 IDC       16686694
mb1     5.3 0.1   51 IDC       16686694
mb1mx   5.3 0.0   52 IDC       16686694
mbtmp   5.3 0.1   51 IDC       16686694
ML      5.1 0.2    2 IDC       16686694
MS      7.1 0.0   31 IDC       16686694
Ms1     7.1 0.0   31 IDC       16686694
ms1mx   6.9 0.1   44 IDC       16686694
mb      6.1      243 ISCJB     01677901
MS      7.3      228 ISCJB     01677901
M       7.1      117 DJA       01268475
mb      6.1 0.2  115 DJA       01268475
mB      7.1 0.1  117 DJA       01268475
MLv     7.0 0.2   26 DJA       01268475
        7.1 0.4  117 DJA       01268475
Mwp     6.9 0.2  102 DJA       01268475
mb      6.4       49 MOS       16742129
MS      7.2       70 MOS       16742129
mb      6.5      110 NEIC      01288303
ME      7.3          NEIC      01288303
MS      7.3      143 NEIC      01288303
MW      7.7          NEIC      01288303
MW      7.8      130 GCMT      00125427
mb      5.9          KLM       00255772
ML      6.7          KLM       00255772
MS      7.6          KLM       00255772
mb      6.4       20 BGR       16815854
Ms      7.2        2 BGR       16815854
mb      6.3 0.3  250 ISC       01346132
MS      7.3 0.1  237 ISC       01346132
```

An example of a relatively small earthquake that occurred in northern Italy for which we received magnitude reports of mostly local and duration type from six agencies in Italy, France and Austria is given in Listing 7.2.

Listing 7.2: *Example of reported magnitudes for a small event*

```
Event 15089710 Northern Italy
   Date       Time        Err   RMS Latitude Longitude  Smaj  Smin  Az Depth   Err Ndef Nsta Gap  mdist  Mdist Qual   Author      OrigID
2010/08/08 15:20:46.22   0.94 0.778  45.4846    8.3212 2.900 2.539 110  28.6  9.22  172  110  82   0.41   5.35 m i ke ISC       01249414
 (#PRIME)

Magnitude  Err Nsta Author      OrigID
ML      2.4       10 ZUR       15925566
Md      2.6 0.2   19 ROM       16861451
Ml      2.2 0.2    9 ROM       16861451
ML      2.5          GEN       00554757
ML      2.6 0.3   28 CSEM      00554756
Md      2.3 0.0    3 LDG       14797570
Ml      2.6 0.3   32 LDG       14797570
```

Figure 7.11 shows a distribution of the number of agencies reporting magnitude estimates to the ISC according to the magnitude value. The peak of the distribution corresponds to small earthquakes where many local agencies report local and/or duration magnitudes. The number of contributing agencies rapidly decreases for earthquakes of approximately magnitude 5.5 and above, where magnitudes are mostly given by global monitoring agencies.

7.6 Moment Tensor Solutions

The ISC Bulletin publishes moment tensor solutions, which are reported to the ISC by other agencies. The collection of moment tensor solutions is summarised in Table 7.8. A histogram showing all moment tensor solutions collected throughout the ISC history is shown in Figure 7.12. Several moment tensor solutions from different authors and different moment tensor solutions calculated by different methods from the same agency may be present for the same event.

Table 7.8: *Summary of reports containing moment tensor solutions.*

Reports with Moment Tensors	2139
Total moment tensors received	11512
Agencies reporting moment tensors	15

The number of moment tensors for this summary period, reported by each agency, is shown in Table 7.9. The moment tensor solutions are plotted in Figure 7.13.

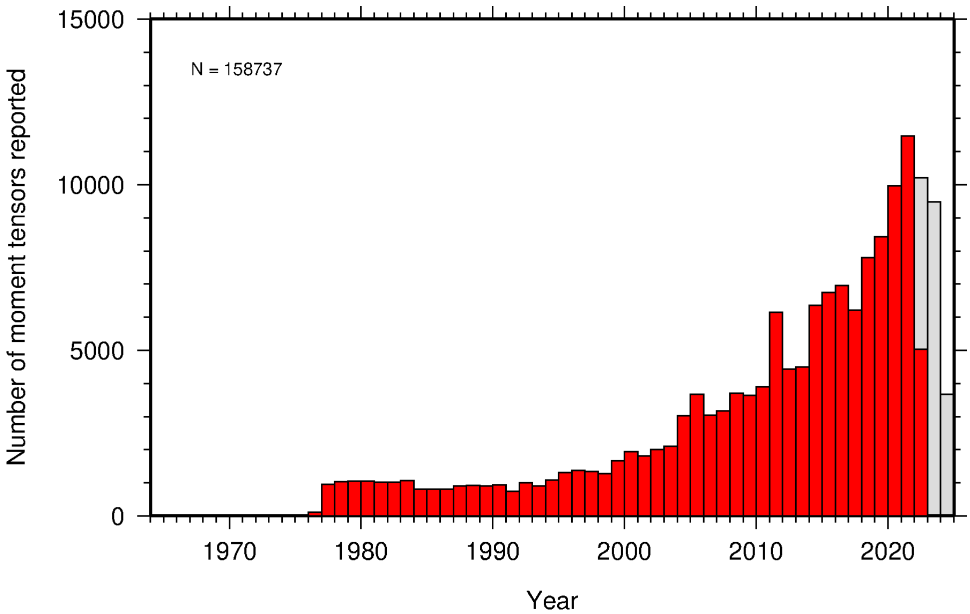


Figure 7.12: *Histogram showing the number of moment tensors reported to the ISC since 1964. The regions in grey represent data that are still being actively collected.*

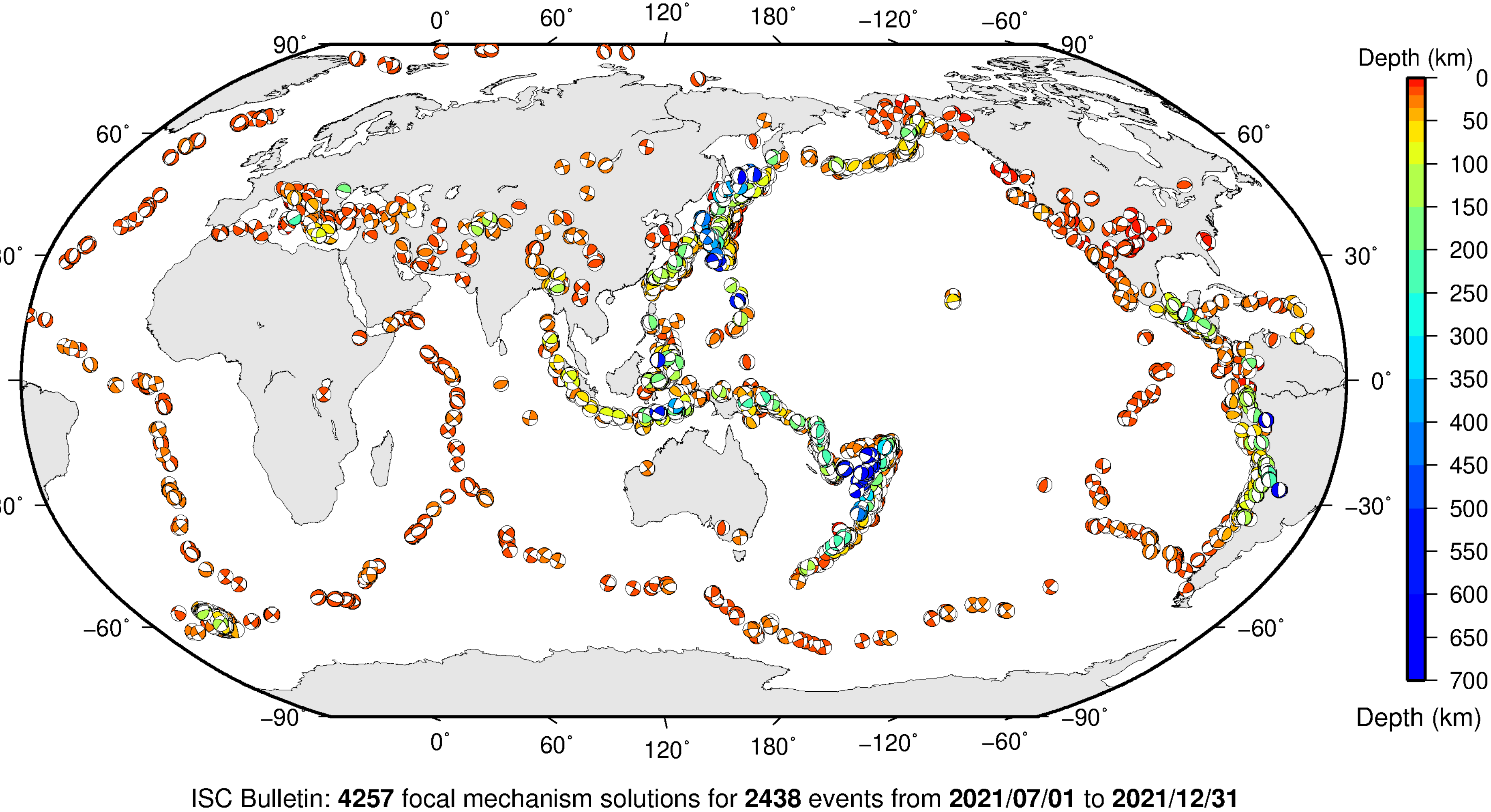


Figure 7.13: *Map of all moment tensor solutions in the ISC Bulletin for this summary period.*

Table 7.9: *Summary of moment tensor solutions in the ISC Bulletin reported by each agency.*

Agency	Number of moment tensor solutions
GCMT	1405
NEIC	912
TAN	808
NIED	698
GFZ	501
CATAC	443
IPGP	296
ASIES	92
ISC-PPSM	88
MED_RCMT	84
PNSN	62
WEL	54
SLM	35
MOS	16
ROM	15
MEX	10
NCEDC	10
UCR	9
OTT	6
UPA	5
GCG	4
EVBIB	3
OSPL	2
UPSL	2
PLV	1
ECX	1
JSN	1
TIR	1
PAS	1

7.7 Timing of Data Collection

Here we present the timing of reports to the ISC. Please note, this does not include provisional alerts, which are replaced at a later stage. Instead, it reflects the final data sent to the ISC. The absolute timing of all hypocentre reports, regardless of magnitude, is shown in Figure 7.14. In Figure 7.15 the reports are grouped into one of six categories - from within three days of an event origin time, to over one year. The histogram shows the distribution with magnitude (for hypocentres where a network magnitude was reported) for each category, whilst the map shows the geographic distribution of the reported hypocentres.

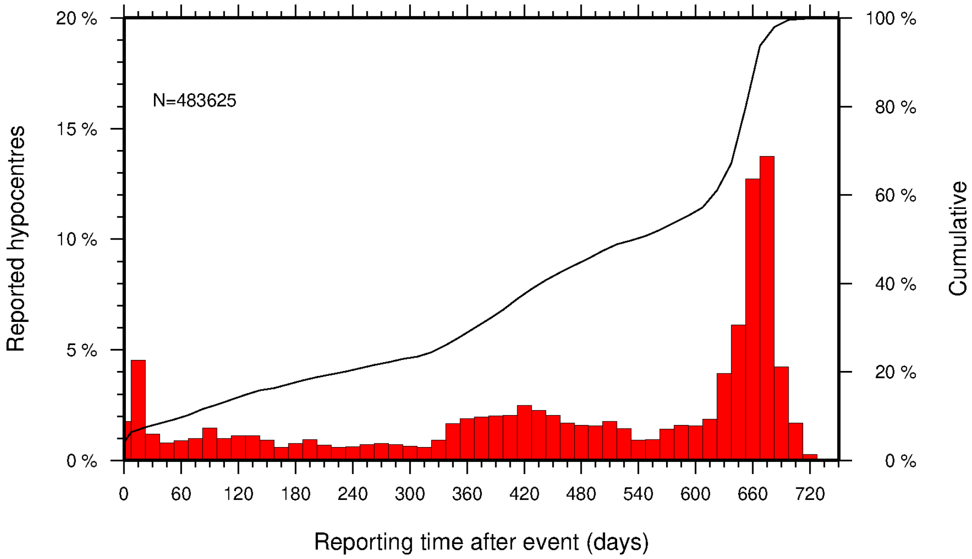


Figure 7.14: *Histogram showing the timing of final reports of the hypocentres (total of N) to the ISC. The cumulative frequency is shown by the solid line.*

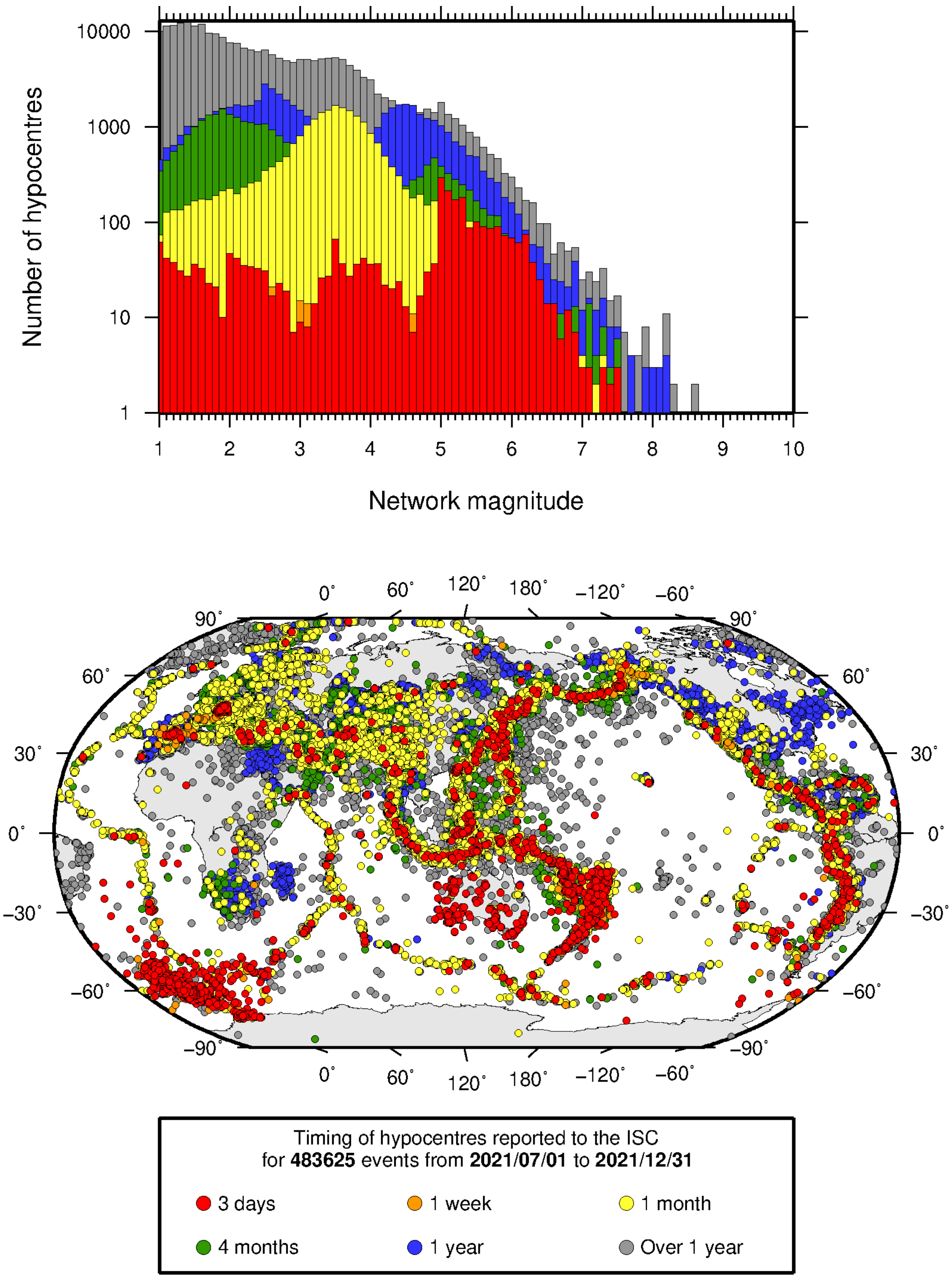


Figure 7.15: *Timing of hypocentres reported to the ISC. The colours show the time after the origin time that the corresponding hypocentre was reported. The histogram shows the distribution with magnitude. If more than one network magnitude was reported, preference was given to a value of M_W followed by M_S, m_b and M_L respectively; all reported hypocentres are included on the map. Note: early reported hypocentres are plotted over later reported hypocentres, on both the map and histogram.*

8

Overview of the ISC Bulletin

This chapter provides an overview of the seismic event data in the ISC Bulletin. We indicate the differences between all ISC events and those ISC events that are reviewed or located. We describe the wealth of phase arrivals and phase amplitudes and periods observed at seismic stations worldwide, reported in the ISC Bulletin and often used in the ISC location and magnitude determination. Finally, we make some comparisons of the ISC magnitudes with those reported by other agencies, and discuss magnitude completeness of the ISC Bulletin.

8.1 Events

The ISC Bulletin had 323078 reported events in the summary period between July and December 2021. Some 90% (292058) of the events were identified as earthquakes, the rest (31020) were of anthropogenic origin (including mining and other chemical explosions, rockbursts and induced events) or of unknown origin. In this summary period 9% of the events were reviewed and 7% of the events were located by the ISC. For events that are not located by the ISC, the prime hypocentre is identified according to the rules described in Section 10.1.3 of Volume 58 Issue I of the ISC Summary.

Of the 12,238,647 reported phase observations, 36% are associated to ISC-reviewed events, and 35% are associated to events selected for ISC location. Note that all large events are reviewed and located by the ISC. Since large events are globally recorded and thus reported by stations worldwide, they will provide the bulk of observations. This explains why only a small percentage of the events in a month is reviewed although the number of phases associated to reviewed events has increased nearly exponentially in the past decades.

Figure 8.1 shows the daily number of events throughout the summary period. Figure 8.2 shows the locations of the events in the ISC Bulletin; the locations of ISC-reviewed and ISC-located events are shown in Figures 8.3 and 8.4, respectively.

Figure 8.5 shows the hypocentral depth distributions of events in the ISC Bulletin for the summary period. The vast majority of events occur in the Earth's crust. Note that the peaks at 0, 10, 35 km, and at every 50 km intervals deeper than 100 km are artifacts of analyst practices of fixing the depth to a nominal value when the depth cannot be reliably resolved.

Figure 8.6 shows the depth distribution of free-depth solutions in the ISC Bulletin. The depth of a hypocentre reported to the ISC is assumed to be determined as a free parameter, unless it is explicitly labelled as a fixed-depth solution. On the other hand, as described in Section 10.1.4 of Volume 58 Issue I of the ISC Summary, the ISC locator attempts to get a free-depth solution if, and only if, there is resolution for the depth in the data, i.e. if there is a local network and/or sufficient depth-sensitive phases are reported.

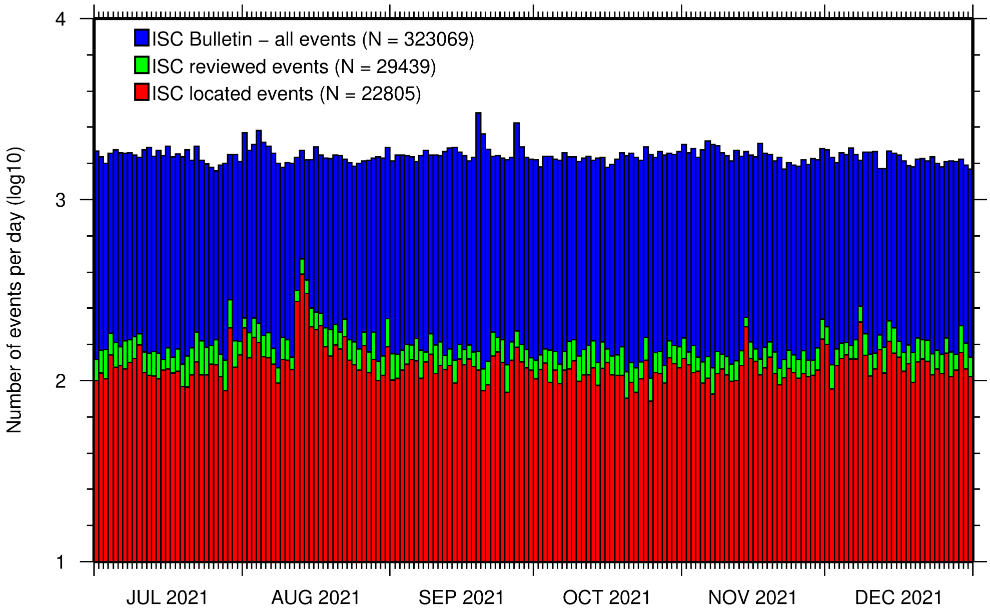


Figure 8.1: *Histogram showing the number of events in the ISC Bulletin for the current summary period. The vertical scale is logarithmic.*

Figure 8.7 shows the depth distribution of fixed-depth solutions in the ISC Bulletin. Except for a fraction of events whose depth is fixed to a shallow depth, this set comprises mostly ISC-located events. If there is no resolution for depth in the data, the ISC locator fixes the depth to a value obtained from the ISC default depth grid file, or if no default depth exists for that location, to a nominal default depth assigned to each Flinn-Engdahl region (see details in Section 10.1.4 of Volume 58 Issue I of the ISC Summary). If during review the ISC analysts find these depth to be a poor fit, the depth will usually be fixed to a round number, preferably divisible by 50.

For events selected for ISC location, the number of stations typically increases as arrival data reported by several agencies are grouped together and associated to the prime hypocentre. Consequently, the network geometry, characterised by the secondary azimuthal gap (the largest azimuthal gap a single station closes), is typically improved. Figure 8.8 illustrates that the secondary azimuthal gap is indeed generally smaller for ISC-located events than that for all events in the ISC Bulletin. Figure 8.9 shows the distribution of the number of associated stations. For large events the number of associated stations is usually larger for ISC-located events than for any of the reported event bulletins. On the other hand, events with just a few reporting stations are rarely selected for ISC location. The same is true for the number of defining stations (stations with at least one defining phase that were used in the location). Figure 8.10 indicates that because the reported observations from multiple agencies are associated to the prime, large ISC-located events typically have a larger number of defining stations than any of the reported event bulletins.

The formal uncertainty estimates are also typically smaller for ISC-located events. Figure 8.11 shows the distribution of the area of the 90% confidence error ellipse for ISC-located events during the summary period. The distribution suffers from a long tail indicating a few poorly constrained event locations. Nevertheless, half of the events are characterised by an error ellipse with an area less than 161 km^2, 90% of the events have an error ellipse area less than 1084 km^2, and 95% of the events have an error ellipse area less than 2158 km^2.

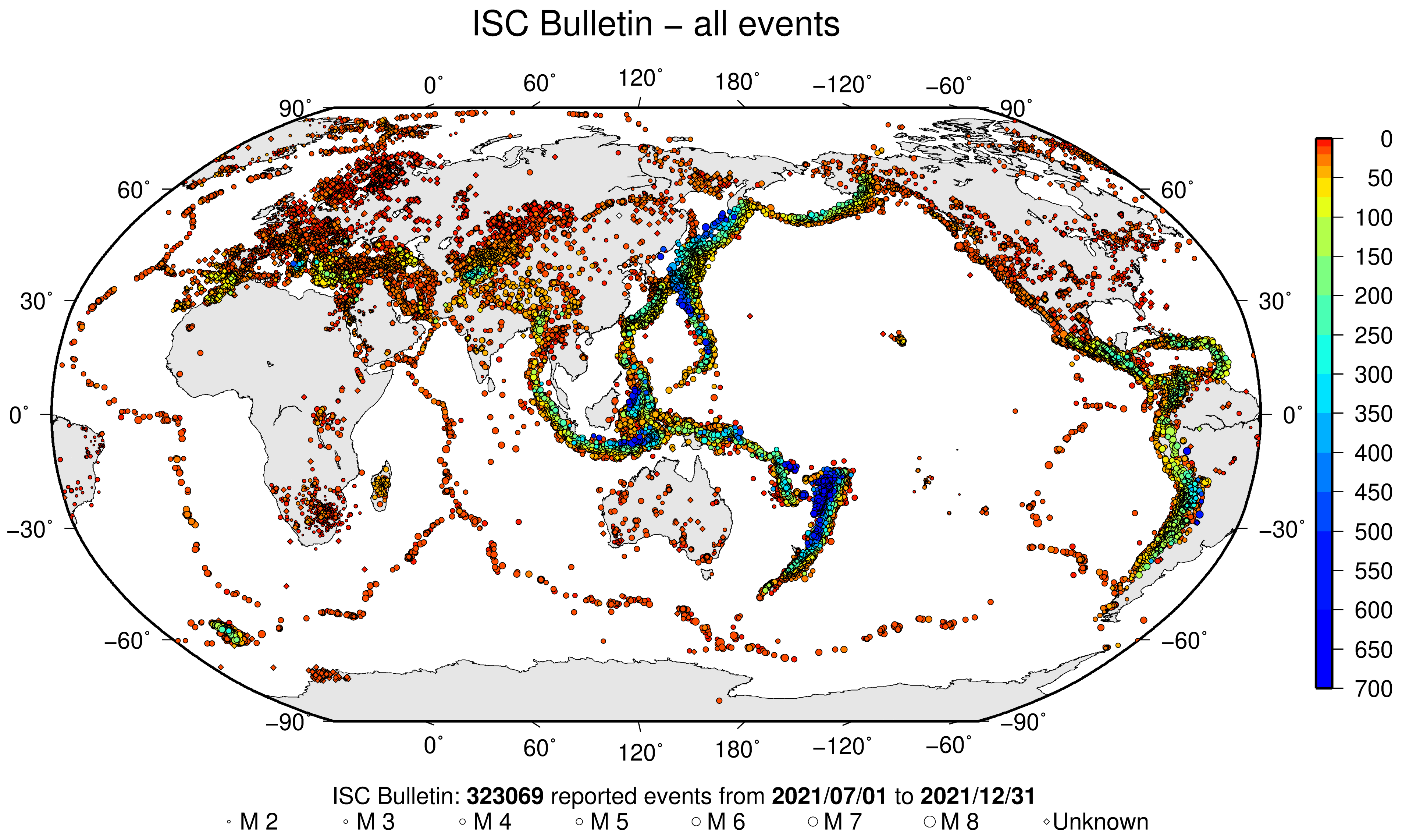


Figure 8.2: *Map of all events in the ISC Bulletin. Prime hypocentre locations are shown. Compare with Figure 7.10.*

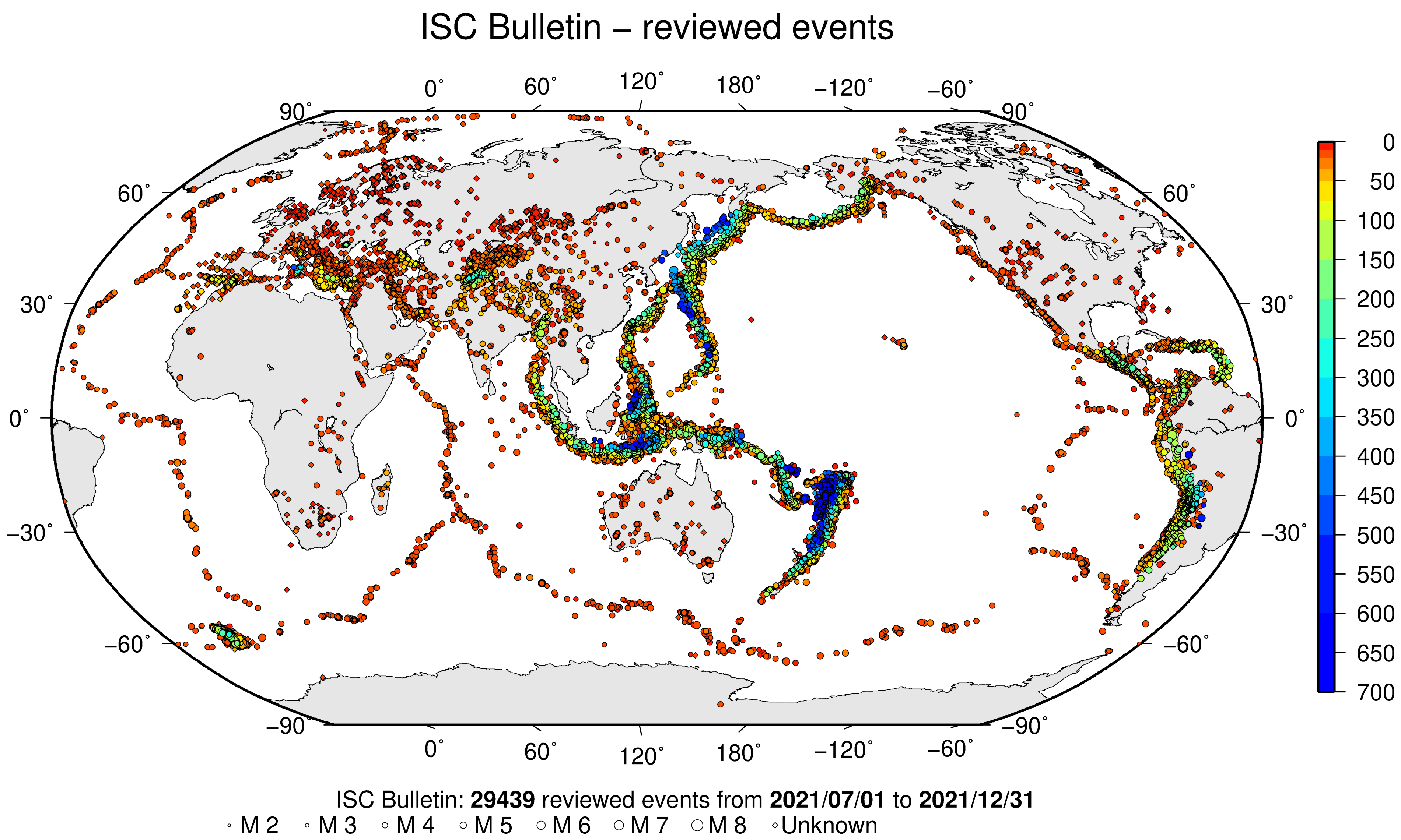


Figure 8.3: *Map of all events reviewed by the ISC for this time period. Prime hypocentre locations are shown.*

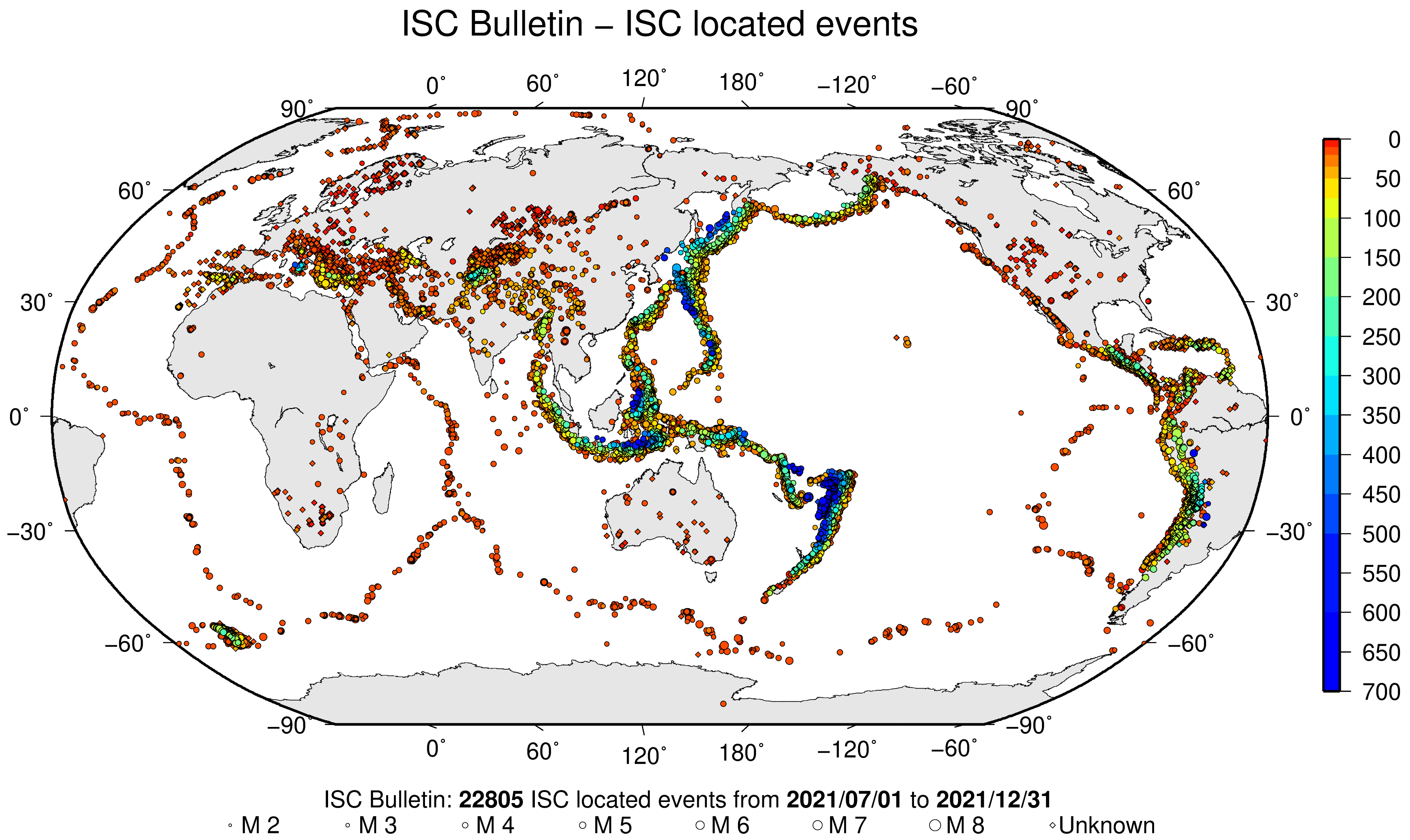


Figure 8.4: *Map of all events located by the ISC for this time period. ISC determined hypocentre locations are shown.*

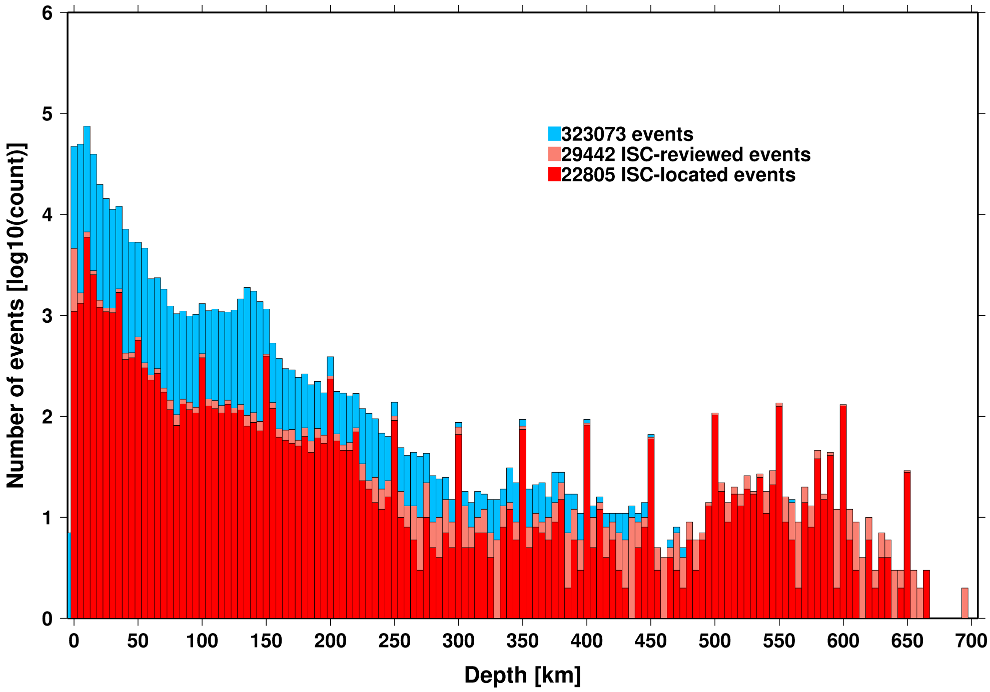


Figure 8.5: *Distribution of event depths in the ISC Bulletin (blue) and for the ISC-reviewed (pink) and the ISC-located (red) events during the summary period. All ISC-located events are reviewed, but not all reviewed events are located by the ISC. The vertical scale is logarithmic.*

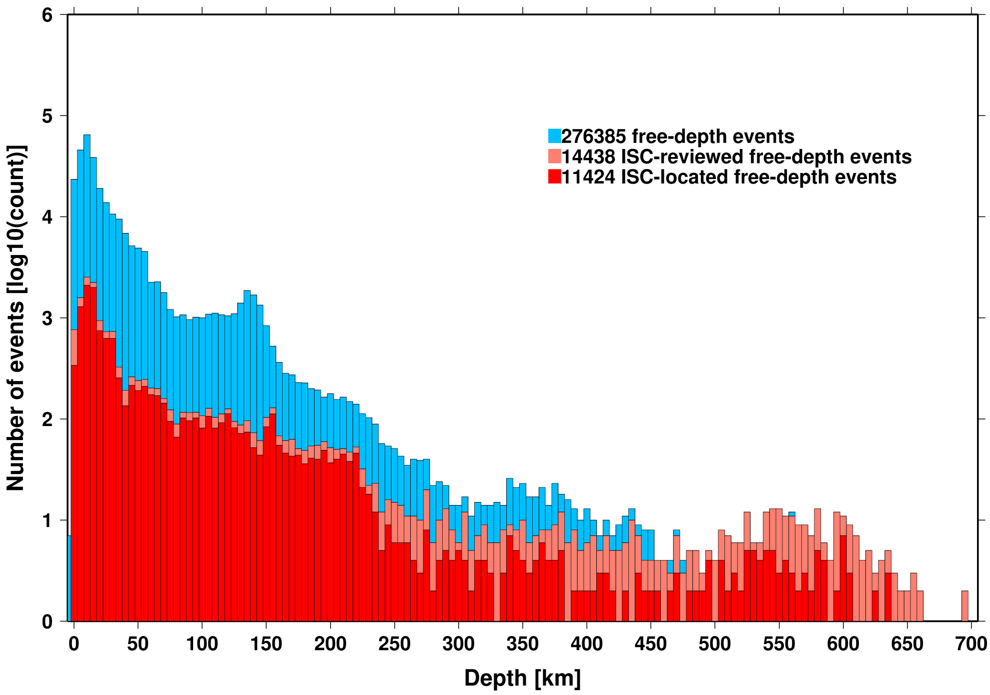


Figure 8.6: *Hypocentral depth distribution of events where the prime hypocentres are reported/located with a free-depth solution in the ISC Bulletin. The vertical scale is logarithmic.*

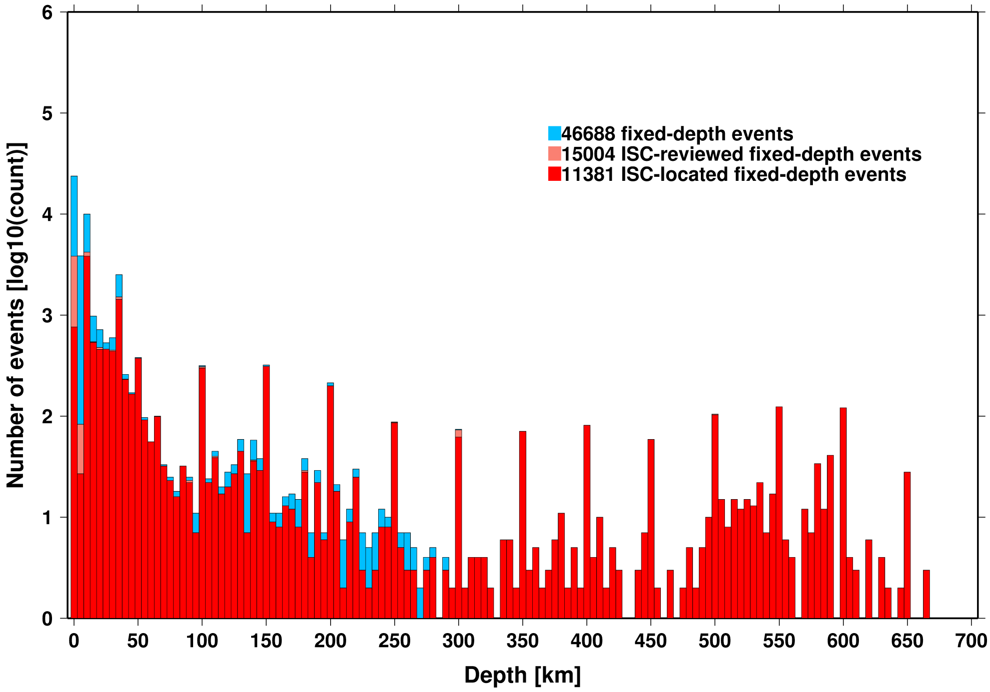


Figure 8.7: *Hypocentral depth distribution of events where the prime hypocentres are reported/located with a fixed-depth solution in the ISC Bulletin. The vertical scale is logarithmic.*

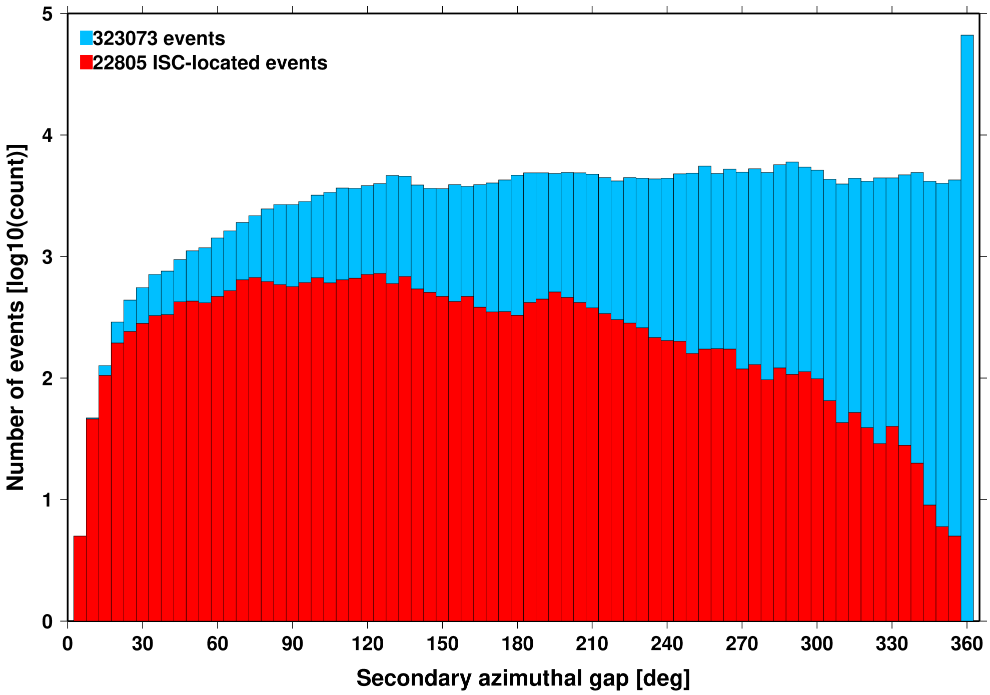


Figure 8.8: *Distribution of secondary azimuthal gap for events in the ISC Bulletin (blue) and those selected for ISC location (red). The vertical scale is logarithmic.*

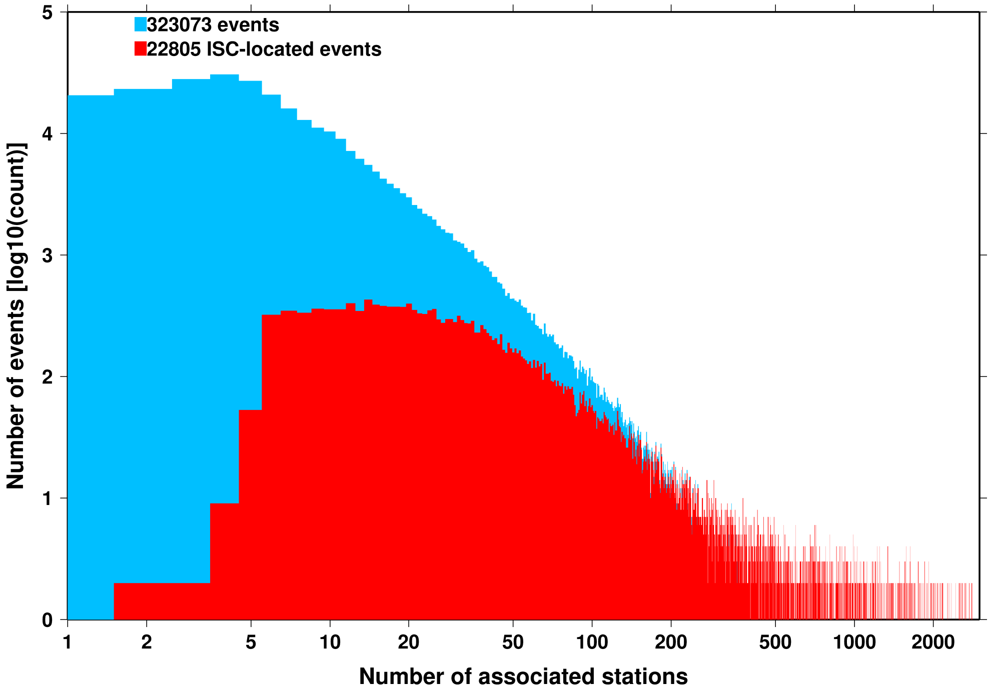


Figure 8.9: *Distribution of the number of associated stations for events in the ISC Bulletin (blue) and those selected for ISC location (red). The vertical scale is logarithmic.*

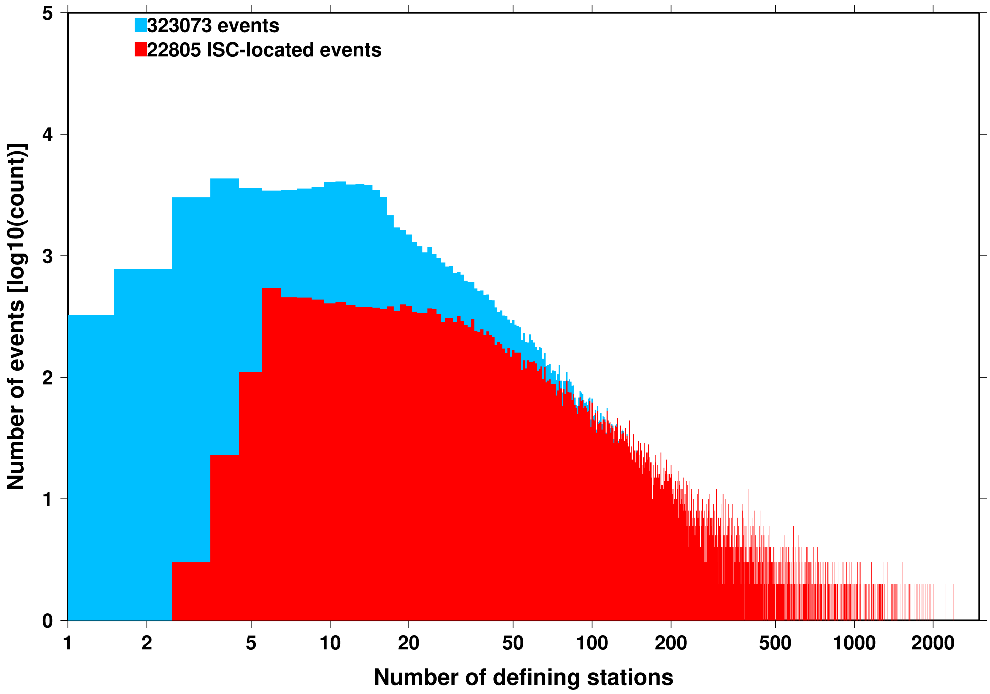


Figure 8.10: *Distribution of the number of defining stations for events in the ISC Bulletin (blue) and those selected for ISC location (red). The vertical scale is logarithmic.*

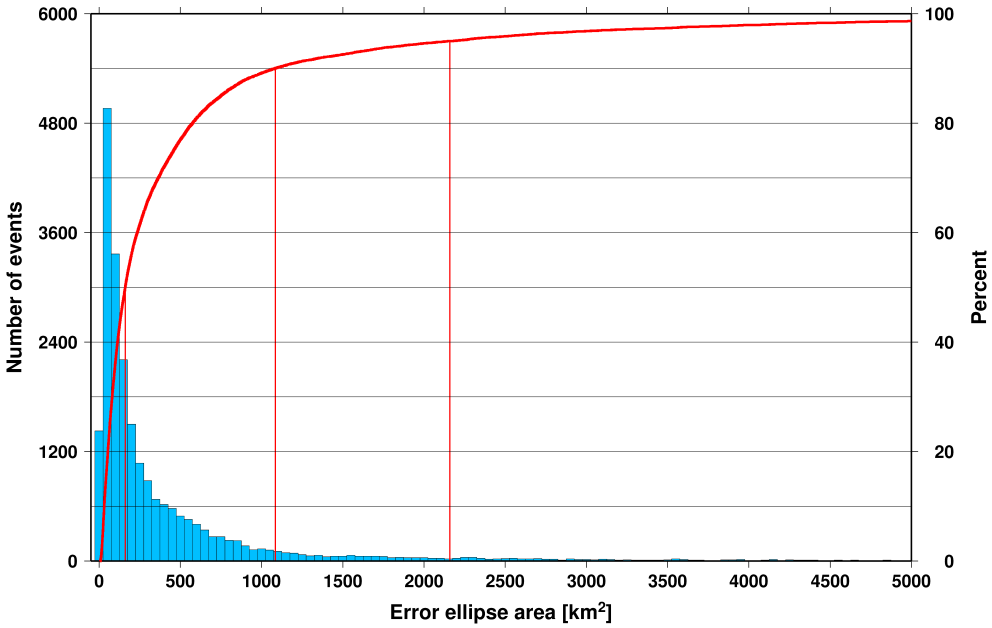


Figure 8.11: *Distribution of the area of the 90% confidence error ellipse of the ISC-located events. Vertical red lines indicate the 50th, 90th and 95th percentile values.*

Figure 8.12 shows one of the major characteristic features of the ISC location algorithm (Bondár and Storchak, 2011). Because the ISC locator accounts for correlated travel-time prediction errors due to unmodelled velocity heterogeneities along similar ray paths, the area of the 90% confidence error ellipse does not decrease indefinitely with increasing number of stations, but levels off once the information carried by the network geometry is exhausted, thus providing more realistic uncertainty estimates.

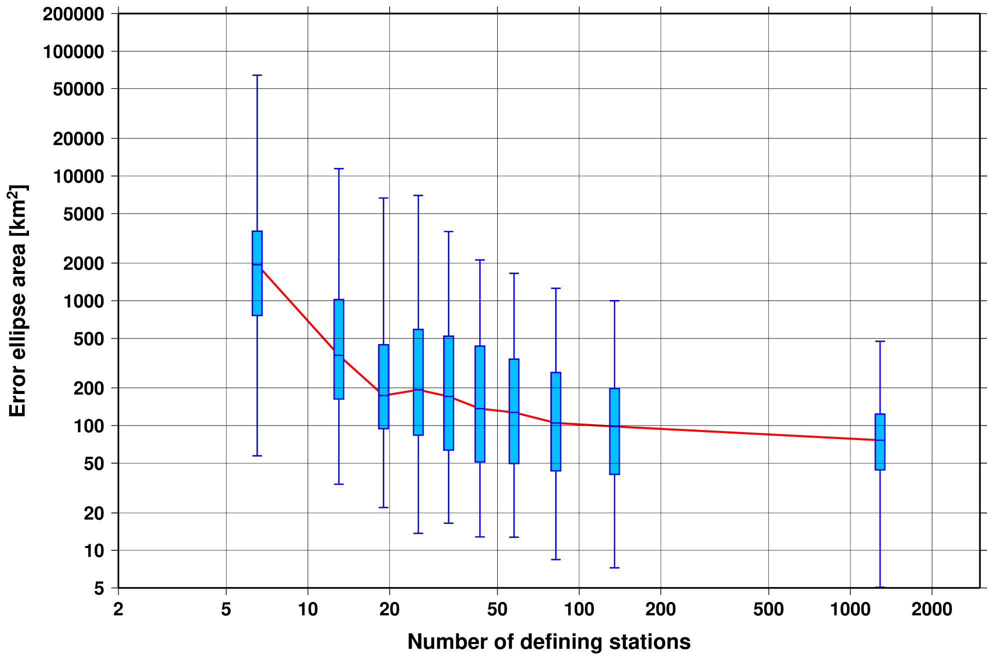


Figure 8.12: *Box-and-whisker plot of the area of the 90% confidence error ellipse of the ISC-located events as a function of the number of defining stations. Each box represents one-tenth-worth of the total number of data. The red line indicates the median 90% confidence error ellipse area.*

8.2 Seismic Phases and Travel-Time Residuals

The number of phases that are associated to events over the summary period in the ISC Bulletin is shown in Figure 8.13. Phase types and their total number in the ISC Bulletin is shown in the Appendix, Table 10.2. A summary of phase types is indicated in Figure 8.14.

In computing ISC locations, the current (for events since 2009) ISC location algorithm (*Bondár and Storchak*, 2011) uses all *ak135* phases where possible. Within the Bulletin, the phases that contribute to an ISC location are labelled as *time defining*. In this section, we summarise these time defining phases.

In Figure 8.15, the number of defining phases is shown in a histogram over the summary period. Each defining phase is listed in Table 8.1, which also provides a summary of the number of defining phases per event. A pie chart showing the proportion of defining phases is shown in Figure 8.16. Figure 8.17 shows travel times of seismic waves. The distribution of residuals for these defining phases is shown for the top five phases in Figures 8.18 through 8.22.

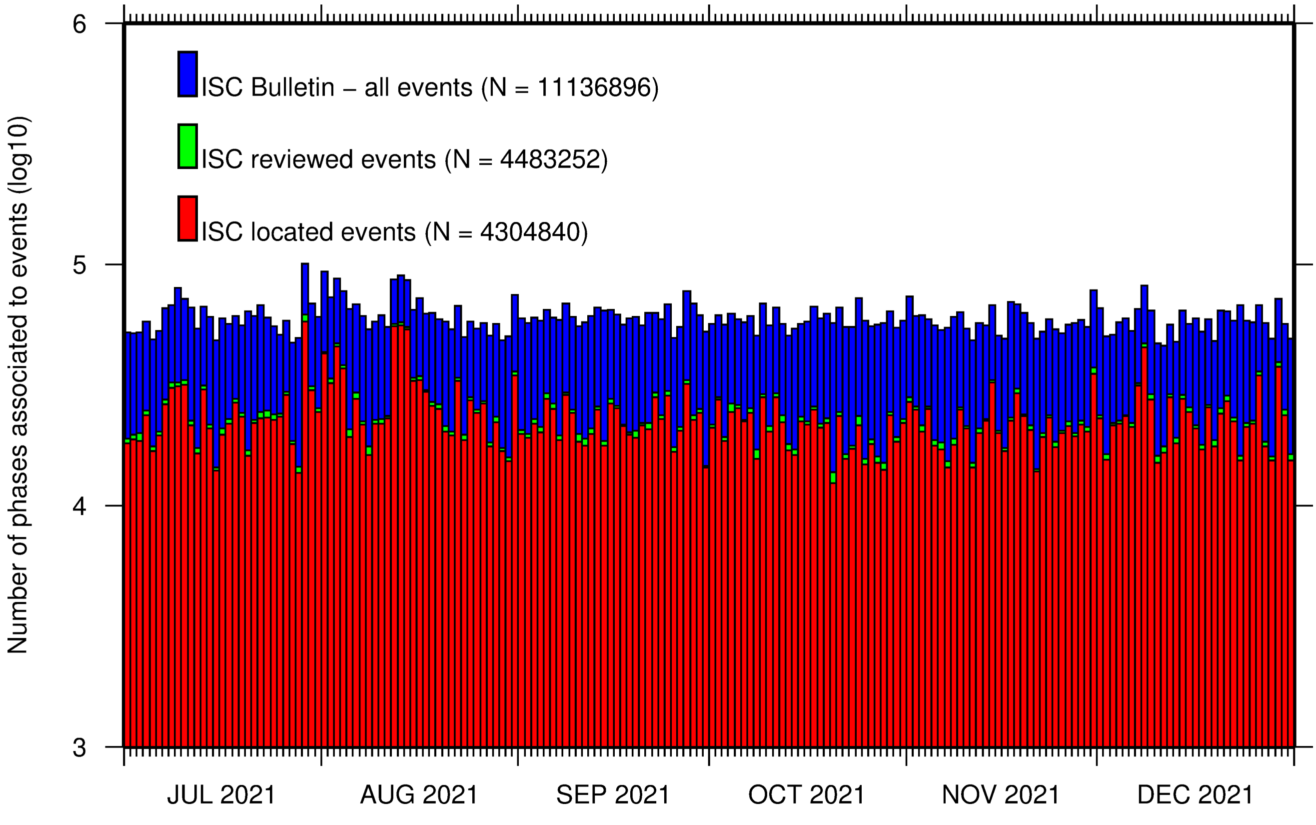


Figure 8.13: *Histogram showing the number of phases (N) that the ISC has associated to events within the ISC Bulletin for the current summary period.*

Table 8.1: *Numbers of 'time defining' phases (N) within the ISC Bulletin for 22805 ISC located events.*

Phase	Number of 'defining' phases	Number of events	Max per event	Median per event
P	1057207	14747	2701	20
Pn	782081	21117	922	18
Sn	251576	16902	199	8
Pb	117279	9960	171	7
Pg	90597	7682	273	6
Sb	78483	9346	98	6
Sg	70285	7289	178	6
PKPdf	61277	5230	517	3

Table 8.1: *(continued)*

Phase	Number of 'defining' phases	Number of events	Max per event	Median per event
S	37290	3551	304	3
PKiKP	36203	4236	310	2
PKPbc	25465	4589	236	2
PKPab	17202	2825	150	2
PcP	16800	3791	76	2
pP	12297	1663	153	3
PP	10191	1364	218	2
Pdif	8873	1091	421	2
sP	5846	1361	152	2
ScP	4990	1059	73	2
SS	3834	907	51	3
SKSac	2765	452	80	2
pwP	2520	719	31	2
PKKPbc	2491	499	115	2
SKPbc	1257	389	64	2
SnSn	892	512	8	1
ScS	836	272	49	2
PnPn	781	494	11	1
P'P'df	775	166	35	2
pPKPdf	751	287	67	1
sS	737	375	27	1
PKKPab	666	236	48	1
PKKPdf	618	274	30	1
SKiKP	578	301	17	1
PS	538	186	25	2
pPKPbc	471	179	35	1
pPKPab	453	175	20	1
SKPdf	402	178	41	1
sPKPdf	313	198	10	1
SKPab	284	167	28	1
SKSdf	260	189	15	1
P'P'bc	177	113	4	1
SKKSac	166	110	8	1
pPKiKP	160	56	20	1
PKSdf	158	80	23	1
PnS	134	115	7	1
sPKPab	126	71	15	1
sPKPbc	121	75	21	1
SKKPbc	118	38	15	1
SP	118	41	28	1
SKKSdf	110	80	15	1
PcS	95	77	4	1
Sdif	91	59	7	1
pPdif	72	30	18	1
pS	64	59	2	1
P'P'ab	57	37	10	1
SKKPdf	35	25	9	1
SKKPab	30	10	12	2
SPn	28	13	12	1
PbPb	25	18	5	1
sPKiKP	15	12	3	1
sPdif	14	14	1	1
SbSb	8	8	1	1
PKSbc	7	6	2	1
S'S'ac	5	5	1	1
sSKSac	4	4	1	1
pPn	2	2	1	1
pSKSac	2	2	1	1
PKSab	1	1	1	1
PgPg	1	1	1	1
sSdif	1	1	1	1
sSKSdf	1	1	1	1
sPn	1	1	1	1

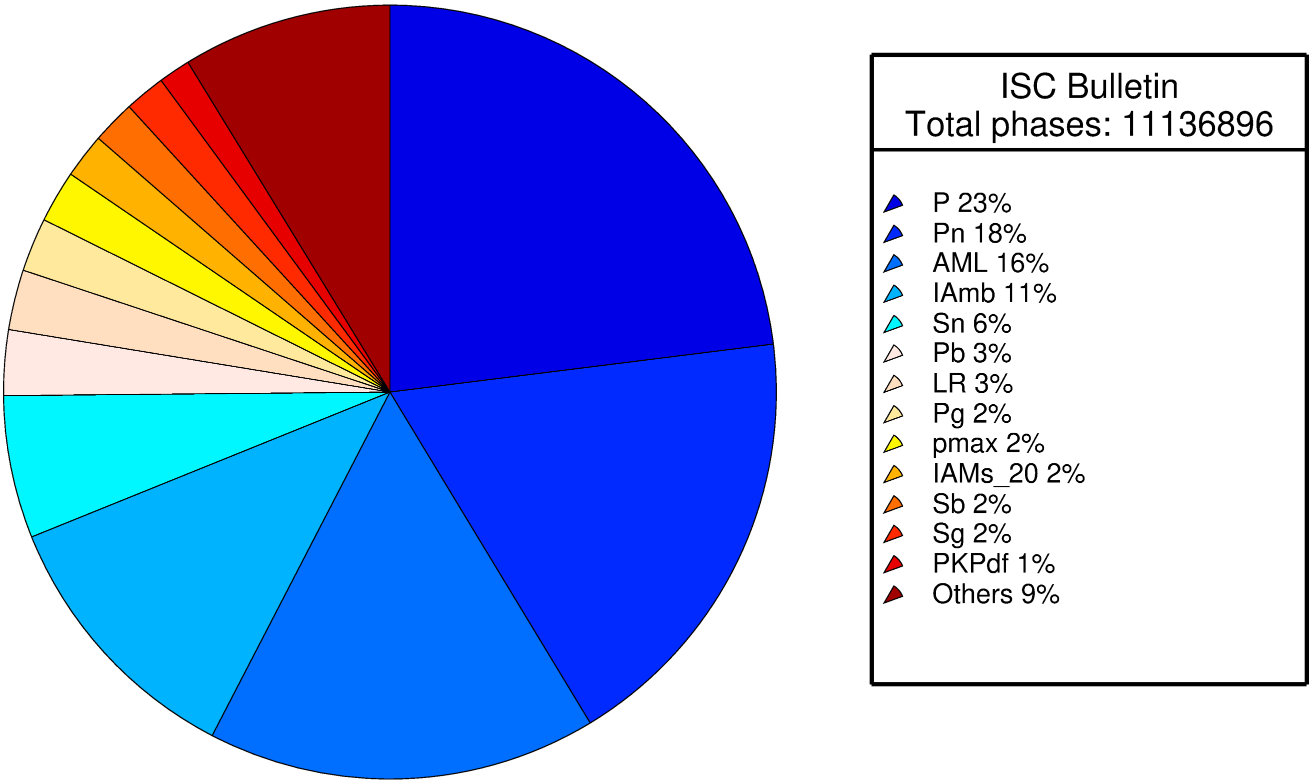


Figure 8.14: *Pie chart showing the fraction of various phase types in the ISC Bulletin for this summary period.*

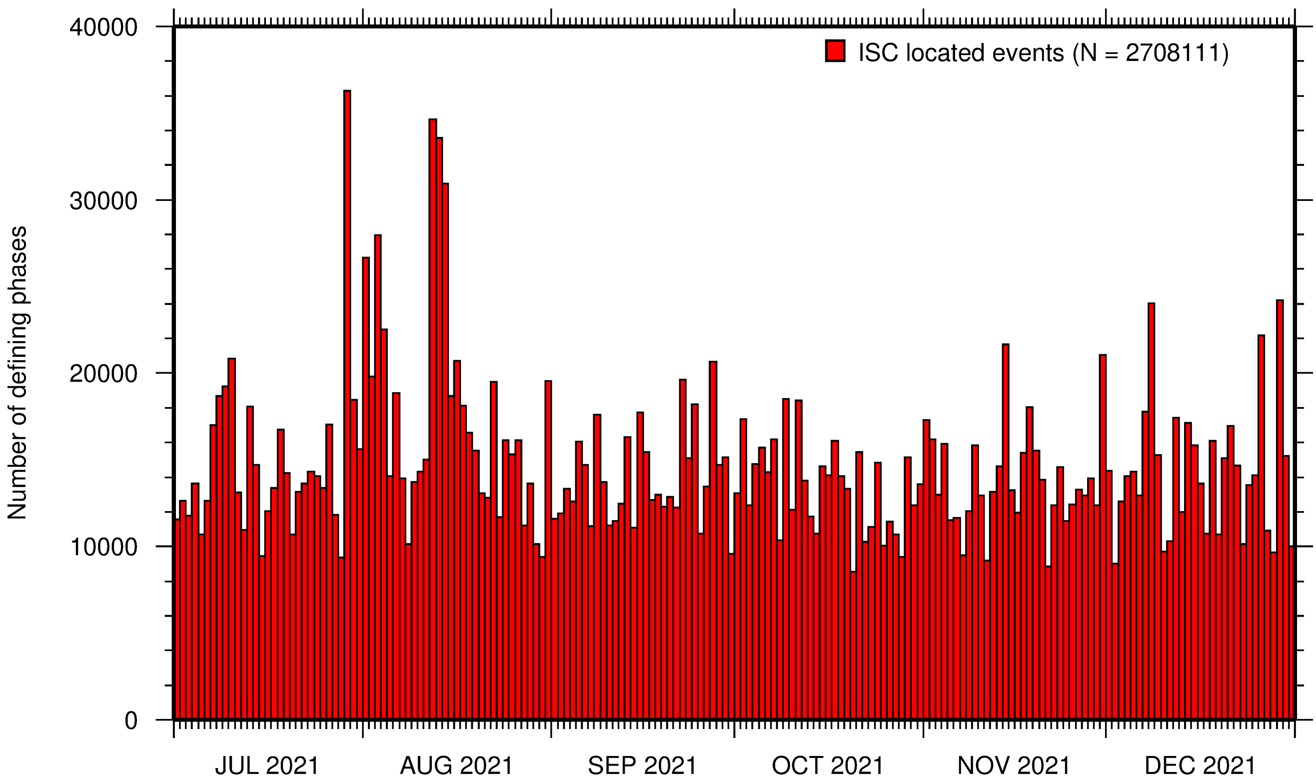


Figure 8.15: *Histogram showing the number of defining phases in the ISC Bulletin, for events located by the ISC.*

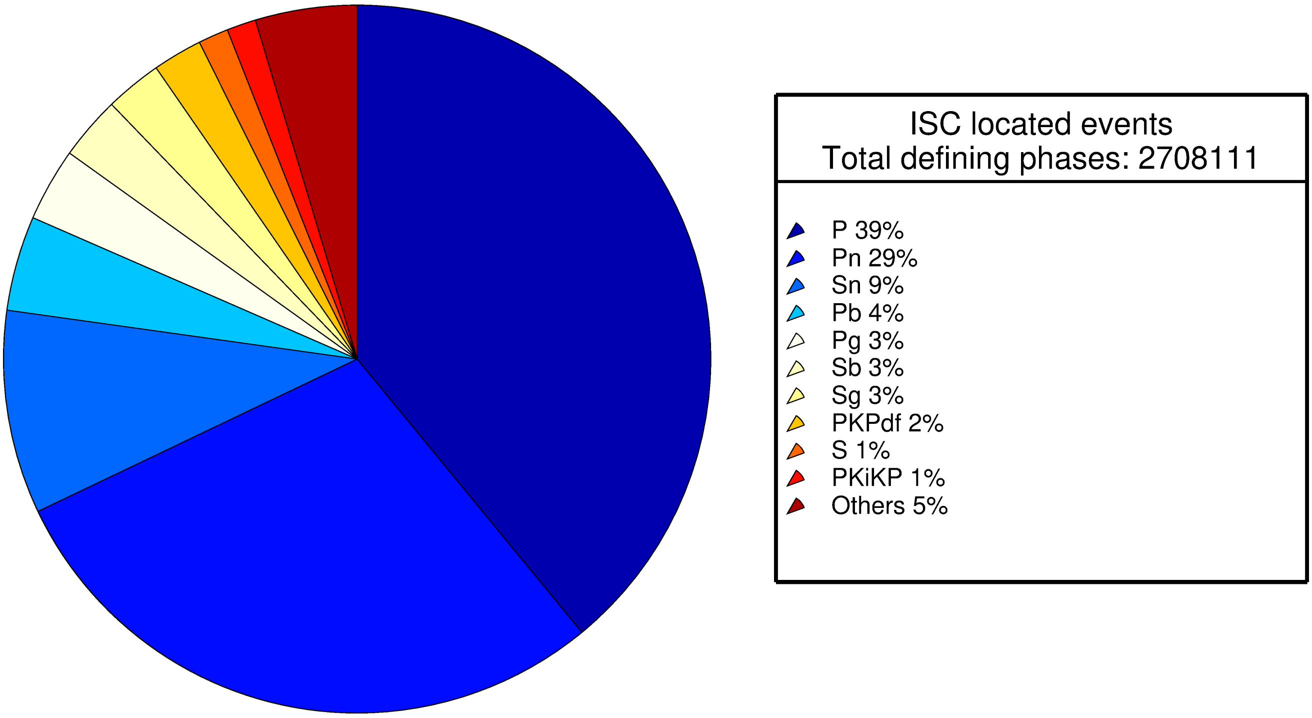


Figure 8.16: *Pie chart showing the defining phases in the ISC Bulletin, for events located by the ISC. A complete list of defining phases is shown in Table 8.1.*

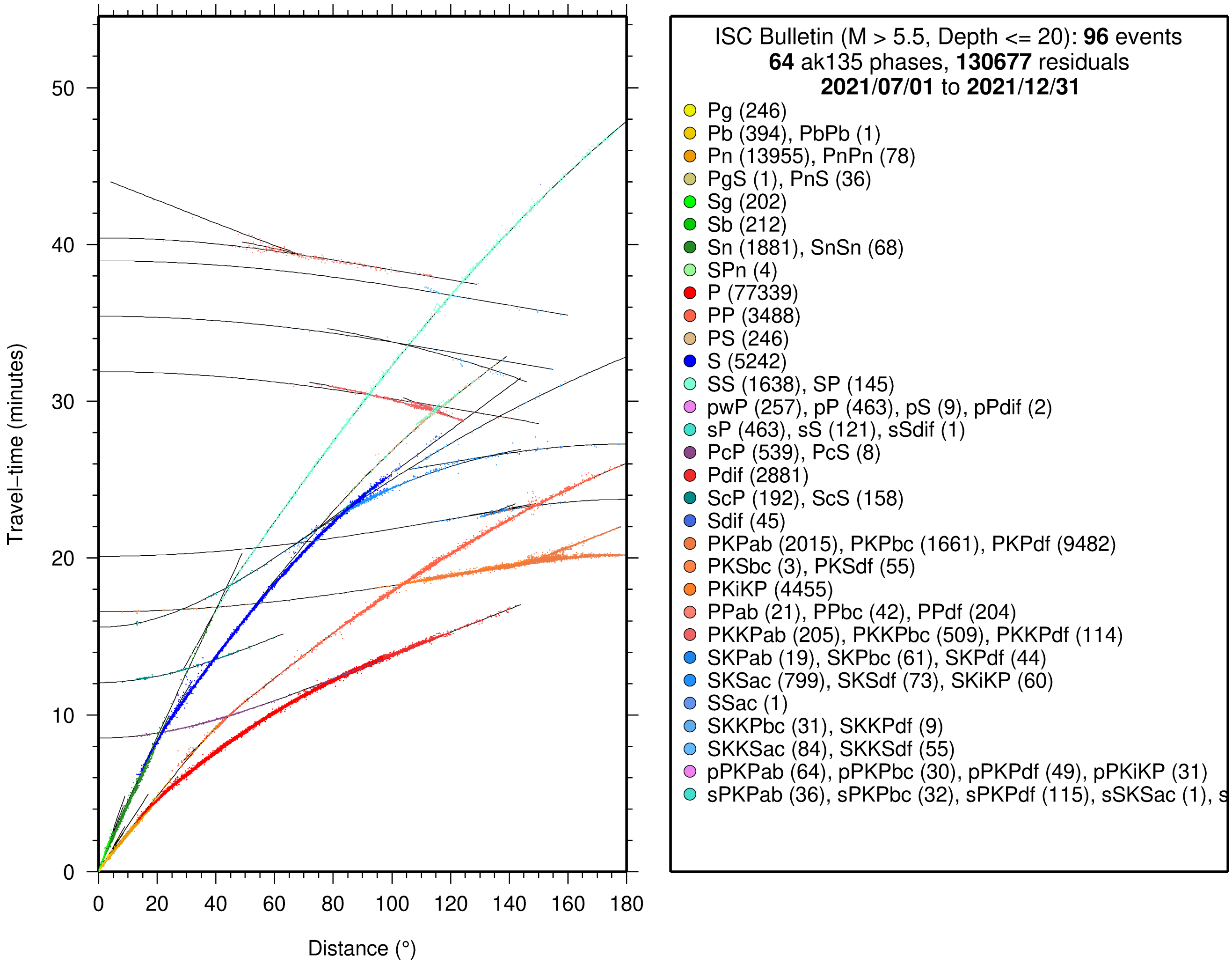


Figure 8.17: *Distribution of travel-time observations in the ISC Bulletin for events with M > 5.5 and depth less than 20 km. The travel-time observations are shown relative to a 0 km source and compared with the theoretical ak135 travel-time curves (solid lines). The legend lists the number of each phase plotted.*

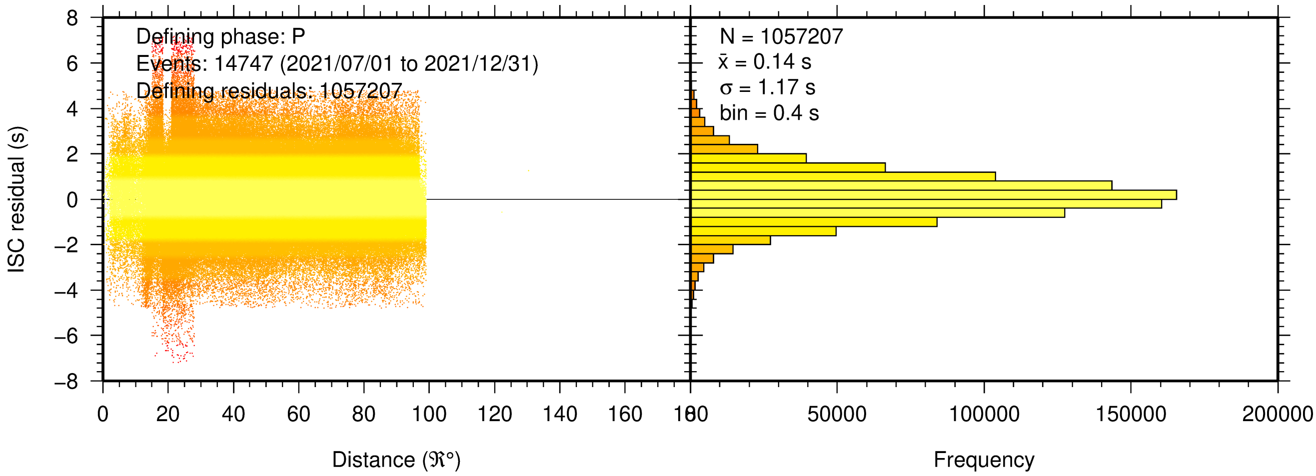


Figure 8.18: *Distribution of travel-time residuals for the defining P phases used in the computation of ISC located events in the Bulletin.*

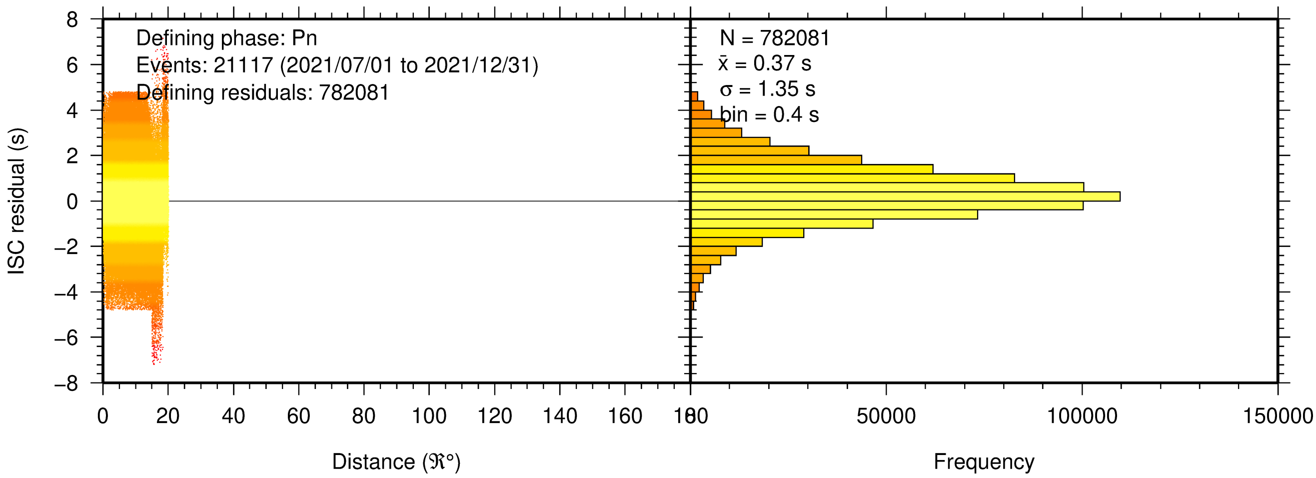


Figure 8.19: *Distribution of travel-time residuals for the defining Pn phases used in the computation of ISC located events in the Bulletin.*

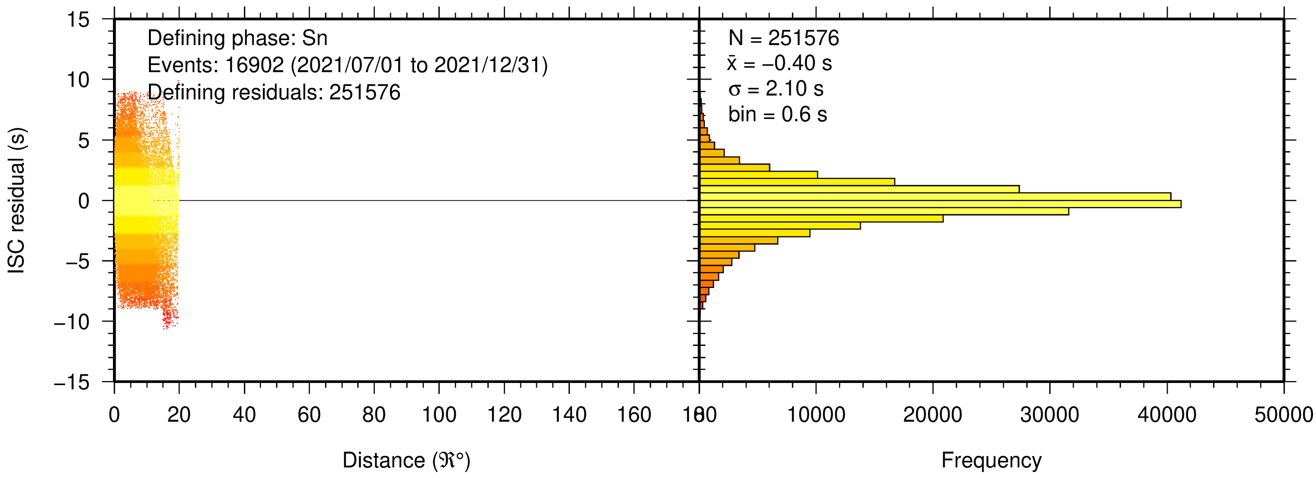


Figure 8.20: *Distribution of travel-time residuals for the defining Sn phases used in the computation of ISC located events in the Bulletin.*

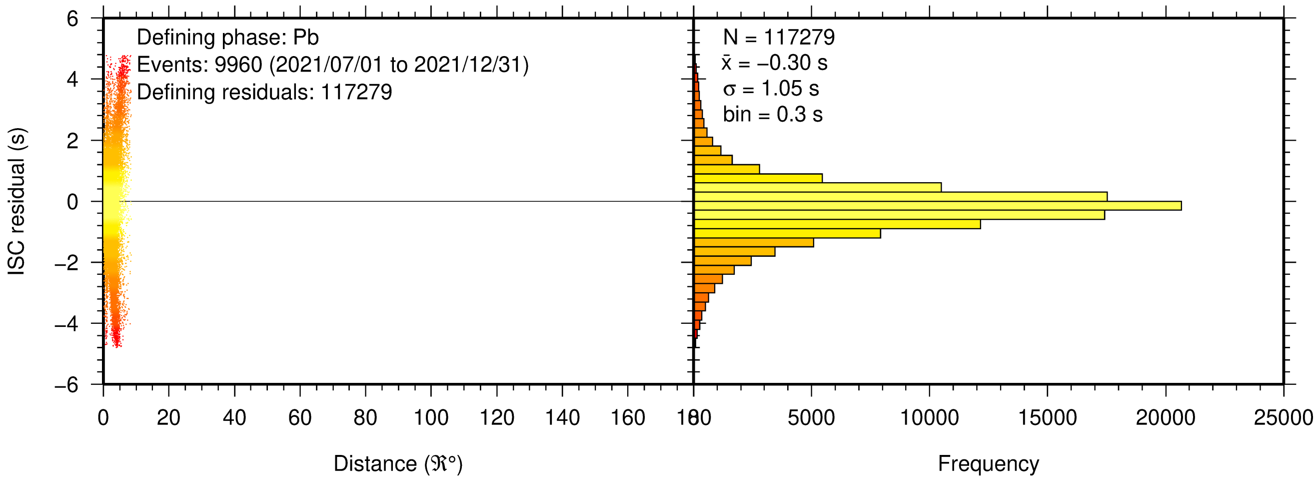


Figure 8.21: *Distribution of travel-time residuals for the defining Pb phases used in the computation of ISC located events in the Bulletin.*

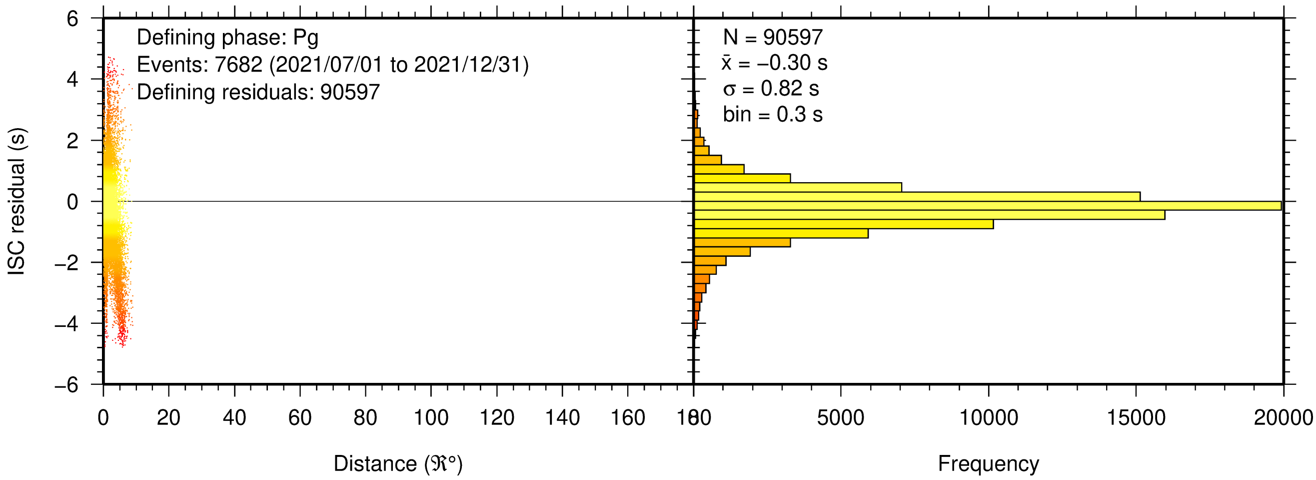


Figure 8.22: *Distribution of travel-time residuals for the defining Pg phases used in the computation of ISC located events in the Bulletin.*

8.3 Seismic Wave Amplitudes and Periods

The ISC Bulletin contains a variety of seismic wave amplitudes and periods measured by reporting agencies. For this Bulletin Summary, the total of collected amplitudes and periods is 4,618,055 (see Section 7.3). For the determination of the ISC magnitudes MS and mb, only a fraction of such data can be used. Indeed, the ISC network magnitudes are computed only for ISC located events. Here we recall the main features of the ISC procedure for MS and mb computation (see detailed description in Section 10.1.4 of Volume 58 Issue I of the ISC Summary). For each amplitude-period pair in a reading the ISC algorithm computes the magnitude (a reading can include several amplitude-period measurements) and the reading magnitude is assigned to the maximum A/T in the reading. If more than one reading magnitude is available for a station, the station magnitude is the median of the reading magnitudes. The network magnitude is computed then as the 20% alpha-trimmed median of the station magnitudes (at least three required). MS is computed for shallow earthquakes (depth $\leq$ 60 km) only and using amplitudes and periods on all three components (when available) if the period is within 10-60 s and the epicentral distance is between 20° and 160°. mb is computed also for deep earthquakes (depth down to 700 km) but only with amplitudes on the vertical component measured at periods $\leq$ 3 s in the distance range 21°-100°.

Table 8.2 is a summary of the amplitude and period data that contributed to the computation of station and ISC MS and mb network magnitudes for this Bulletin Summary.

Table 8.2: *Summary of the amplitude-period data used by the ISC Locator to compute MS and mb.*

	MS	mb
Number of amplitude-period data	172187	713167
Number of readings	151573	708709
Percentage of readings in the ISC located events with qualifying data for magnitude computation	13.4	52.9
Number of station magnitudes	146047	555523
Number of network magnitudes	4177	13244

A small percentage of the readings with qualifying data for MS and mb calculation have more than one amplitude-period pair. Notably, only 13% of the readings for the ISC located (shallow) events included qualifying data for MS computation, whereas for mb the percentage is much higher at 53%. This is due to the seismological practice of reporting agencies. Agencies contributing systematic reports of amplitude and period data are listed in Appendix Table 10.3. Obviously the ISC Bulletin would benefit if more agencies included surface wave amplitude-period data in their reports.

Figure 8.23 shows the distribution of the number of station magnitudes versus distance. For mb there is a significant increase in the distance range 70°-90°, whereas for MS most of the contributing stations are below 100°. The increase in number of station magnitude between 70°-90° for mb is partly due to the very dense distribution of seismic stations in North America and Europe with respect to earthquake occurring in various subduction zones around the Pacific Ocean.

Finally, Figure 8.24 shows the distribution of network MS and mb as well as the median number of stations for magnitude bins of 0.2. Clearly with increasing magnitude the number of events is smaller

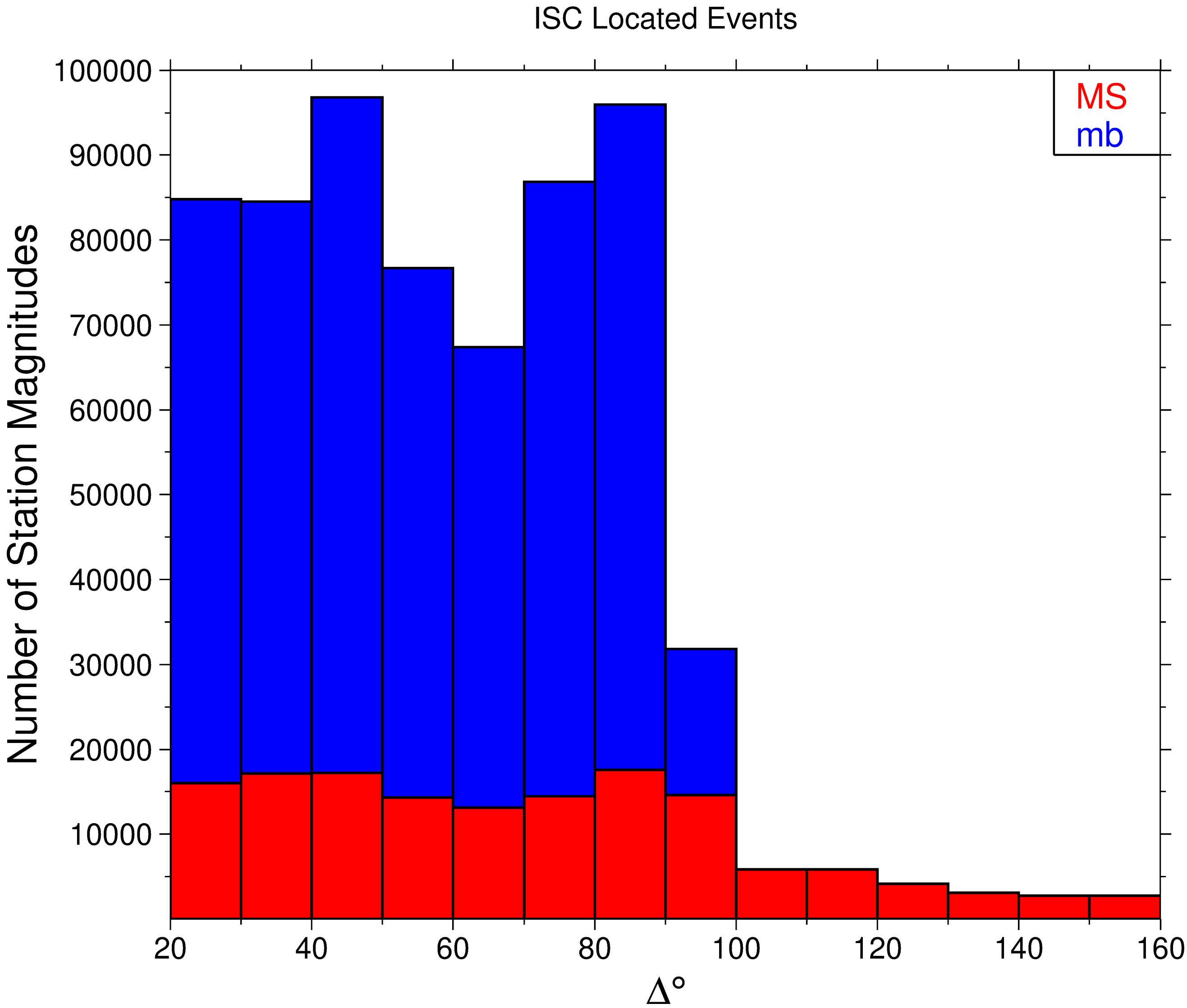


Figure 8.23: *Distribution of the number of station magnitudes computed by the ISC Locator for mb (blue) and MS (red) versus distance.*

but with a general tendency of having more stations contributing to the network magnitude.

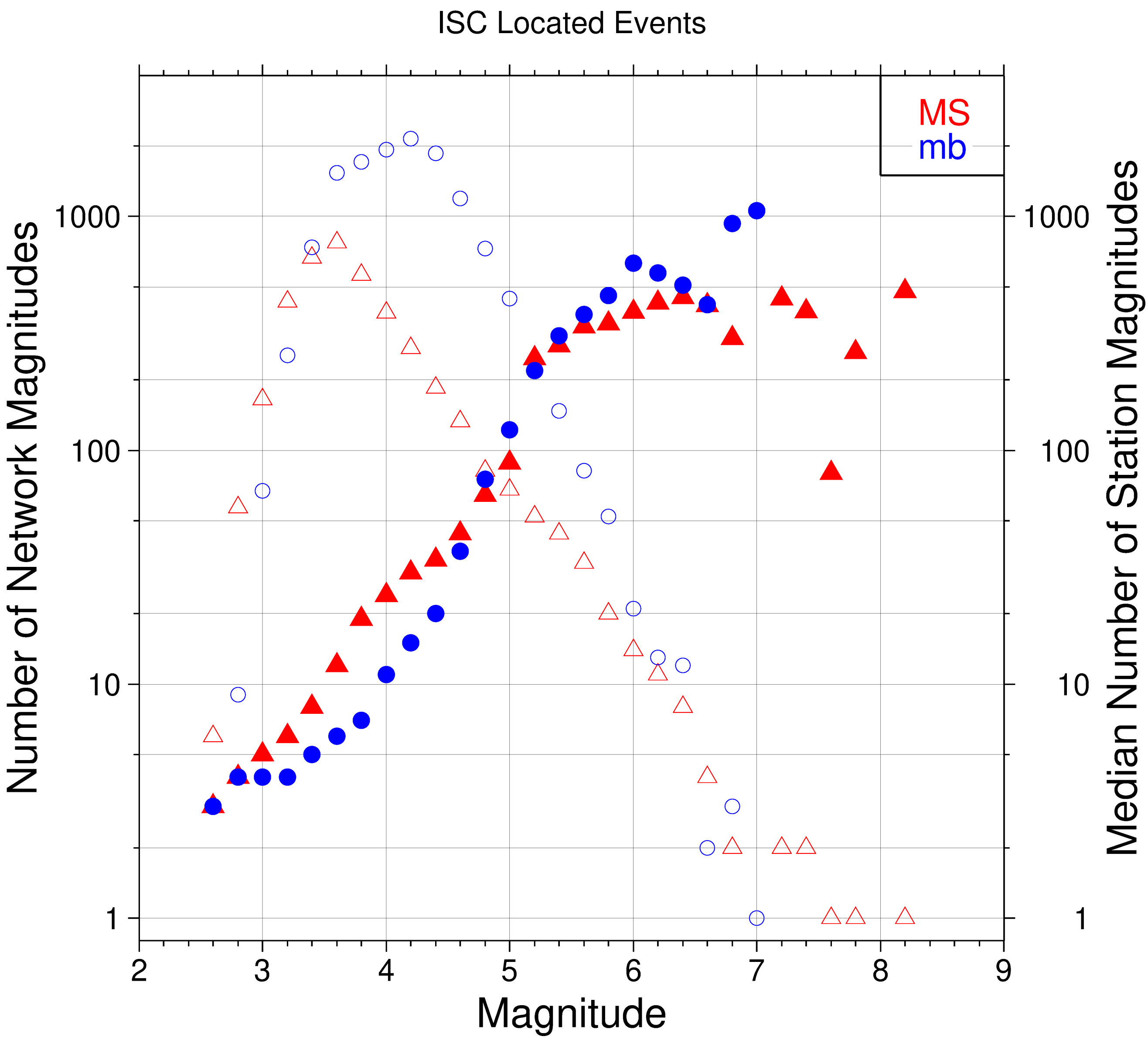


Figure 8.24: *Number of network magnitudes (open symbols) and median number of stations magnitudes (filled symbols). Blue circles refer to mb and red triangles to MS. The width of the magnitude interval δM is 0.2, and each symbol includes data with magnitude in $M \pm \delta M/2$.*

8.4 Completeness of the ISC Bulletin

We define the magnitude of completeness (hereafter M_C) as the lowest magnitude threshold above which all events are believed to be recorded. The Bulletin with events bigger than the defined M_C is assumed to be complete.

Until Issue 53, Volume II (July - December 2016) of the Summary of the ISC an estimation of M_C was computed only with the maximum curvature technique (*Woessner and Wiemer*, 2005). After the completion of the Rebuild Project and relocation of ISC hypocenters from data years 1964 to 2010 (*Storchak et al.*, 2017), the estimate of M_C for the entire ISC Bulletin is re-computed using four catalogue based methodologies (*Adamaki*, 2017, and references therein): the previously used maximum curvature for comparison (maxC), Mc based on the b-value stability (MBS technique), the Goodness of Fit Test with a 90% level of fit (GFT90) and the modified Goodness of Fit Test (mGFT). Further details on each of these methodologies and their statistical behaviour can be found in *Leptokaropoulos et al.* (2018).

The magnitudes of completeness of the ISC Bulletin for this Summary period is shown in Figure 8.25. How M_C varies for the ISC Bulletin over the years is shown in Figure 8.26. The step change in 1996 corresponds with the inclusion of the Prototype IDC (EIDC) Bulletin, followed by the Reviewed Event Bulletin (REB) of the IDC.

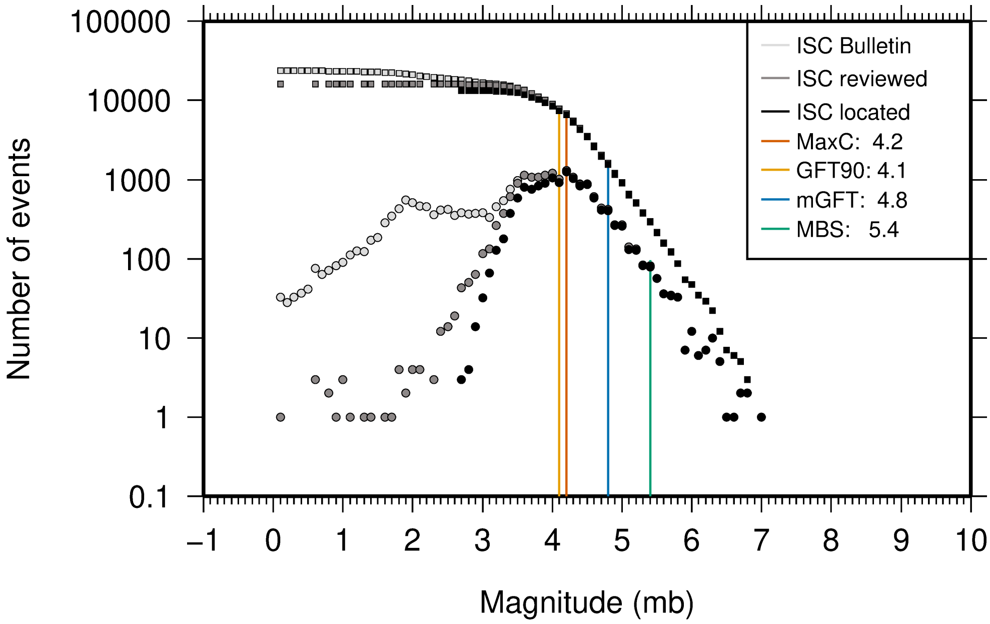


Figure 8.25: *Frequency and cumulative frequency magnitude distribution for all events in the ISC Bulletin, ISC reviewed events and events located by the ISC. The magnitude of completeness (M_C) is shown for the ISC Bulletin. Note: only events with values of mb are represented in the figure.*

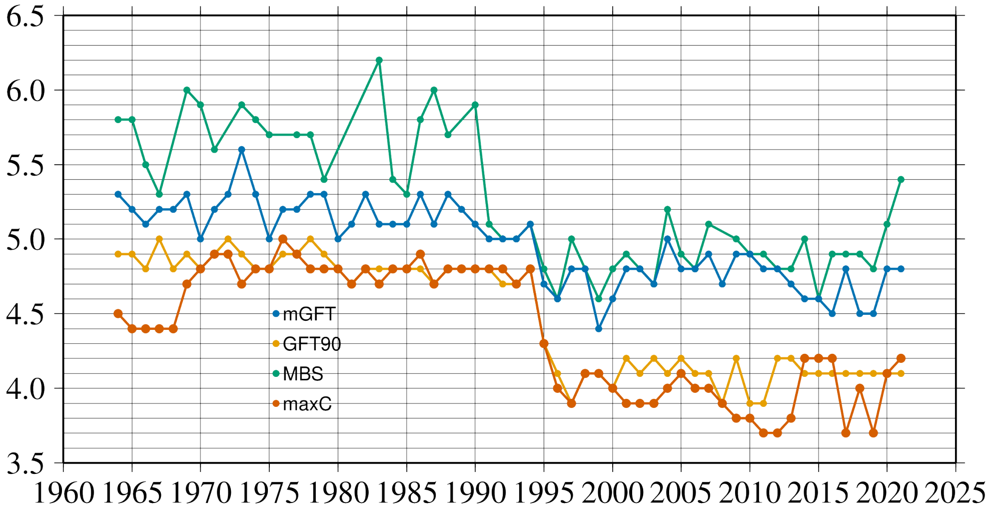


Figure 8.26: *Variation of magnitude of completeness (M_C) for each year in the ISC Bulletin. Note: M_C is calculated only using those events with values of mb.*

8.5 Magnitude Comparisons

The ISC Bulletin publishes network magnitudes reported by multiple agencies to the ISC. For events that have been located by the ISC, where enough amplitude data has been collected, the MS and mb magnitudes are calculated by the ISC (MS is computed only for depths $\leq$ 60 km). In this section, ISC magnitudes and some other reported magnitudes in the ISC Bulletin are compared.

The comparison between MS and mb computed by the ISC locator for events in this summary period is shown in Figure 8.27, where the large number of data pairs allows a colour coding of the data density. The scatter in the data reflects the fundamental differences between these magnitude scales.

Similar plots are shown in Figure 8.28 and 8.29, respectively, for comparisons of ISC mb and ISC MS with M_W from the GCMT catalogue. Since M_W is not often available below magnitude 5, these distributions are mostly for larger, global events. Not surprisingly, the scatter between mb and M_W is larger than the scatter between MS and M_W. Also, the saturation effect of mb is clearly visible for earthquakes with $M_W > 6.5$. In contrast, MS scales well with $M_W > 6$, whereas for smaller magnitudes MS appears to be systematically smaller than M_W.

In Figure 8.30 ISC values of mb are compared with all reported values of mb, values of mb reported by NEIC and values of mb reported by IDC. Similarly in Figure 8.31, ISC values of MS are compared with all reported values of MS, values of MS reported by NEIC and values of MS reported by IDC. There is a large scatter between the ISC magnitudes and the mb and MS reported by all other agencies.

The scatter decreases both for mb and MS when ISC magnitudes are compared just with NEIC and IDC magnitudes. This is not surprising as the latter two agencies provide most of the amplitudes and periods used by the ISC locator to compute MS and mb. However, ISC mb appears to be smaller than NEIC mb for $mb < 4$ and larger than IDC mb for $mb > 4$. Since NEIC does not include IDC amplitudes, it seems these features originate from observations at the high-gain, low-noise sites reported by the IDC. A good scaling is generally observed for the MS comparisons between ISC and IDC.

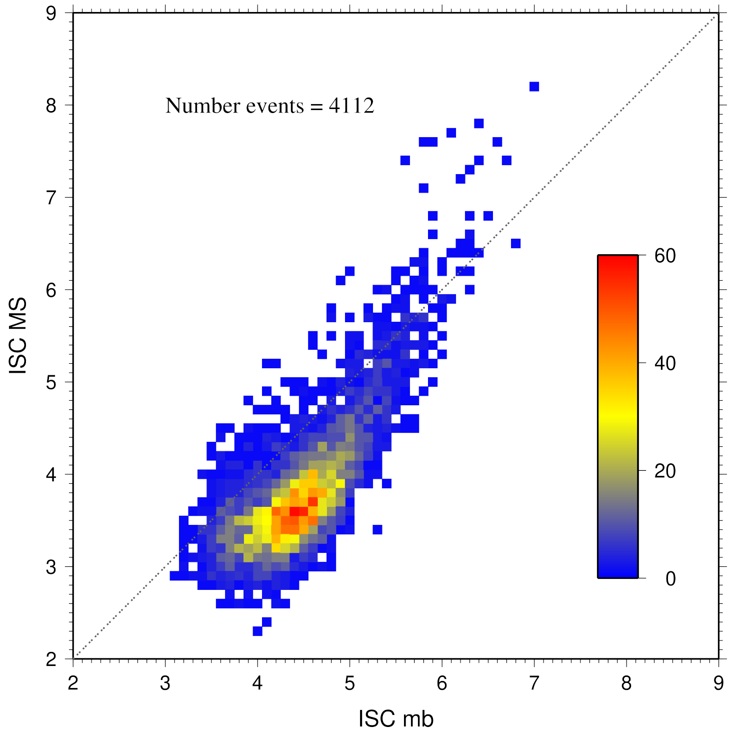


Figure 8.27: *Comparison of ISC values of MS with mb for common event pairs.*

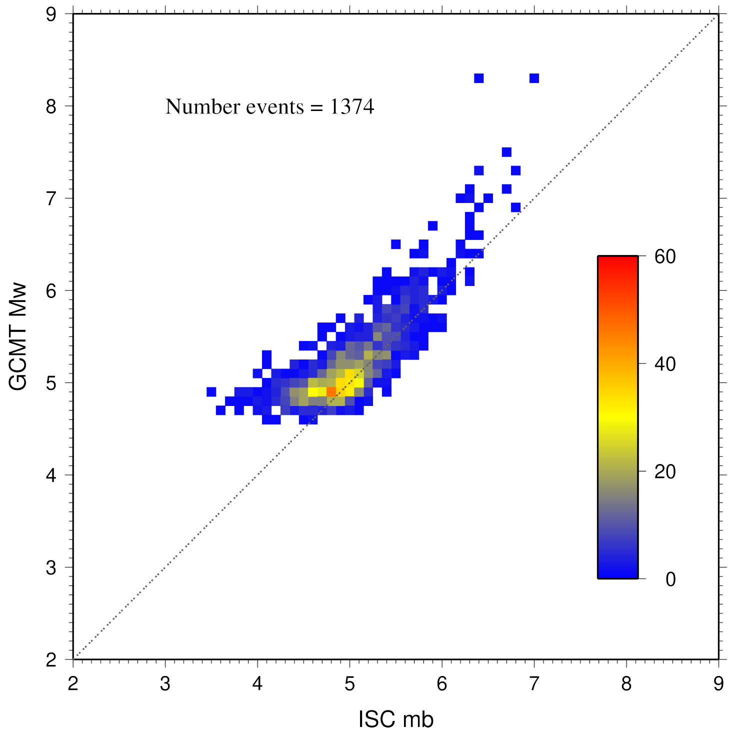


Figure 8.28: *Comparison of ISC values of mb with GCMT M_W for common event pairs.*

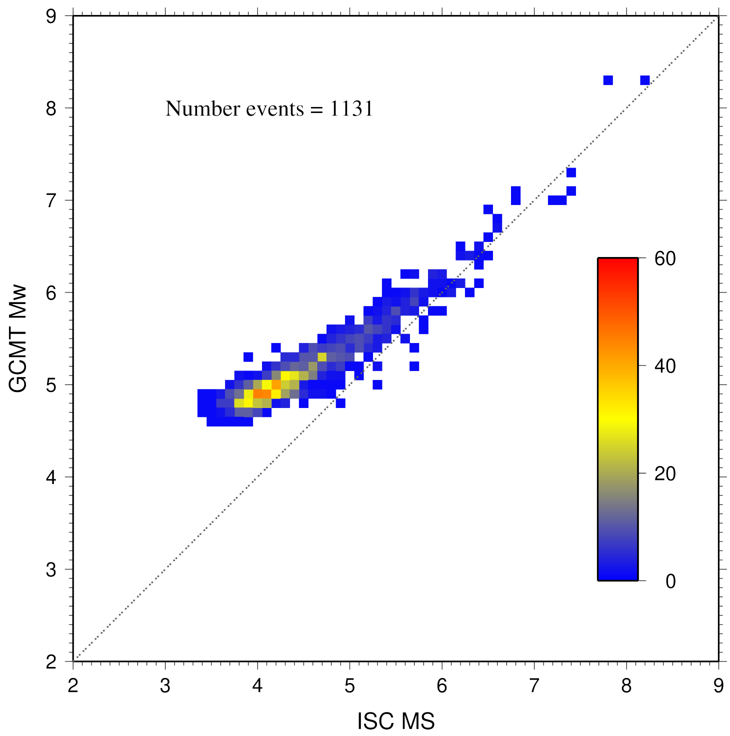
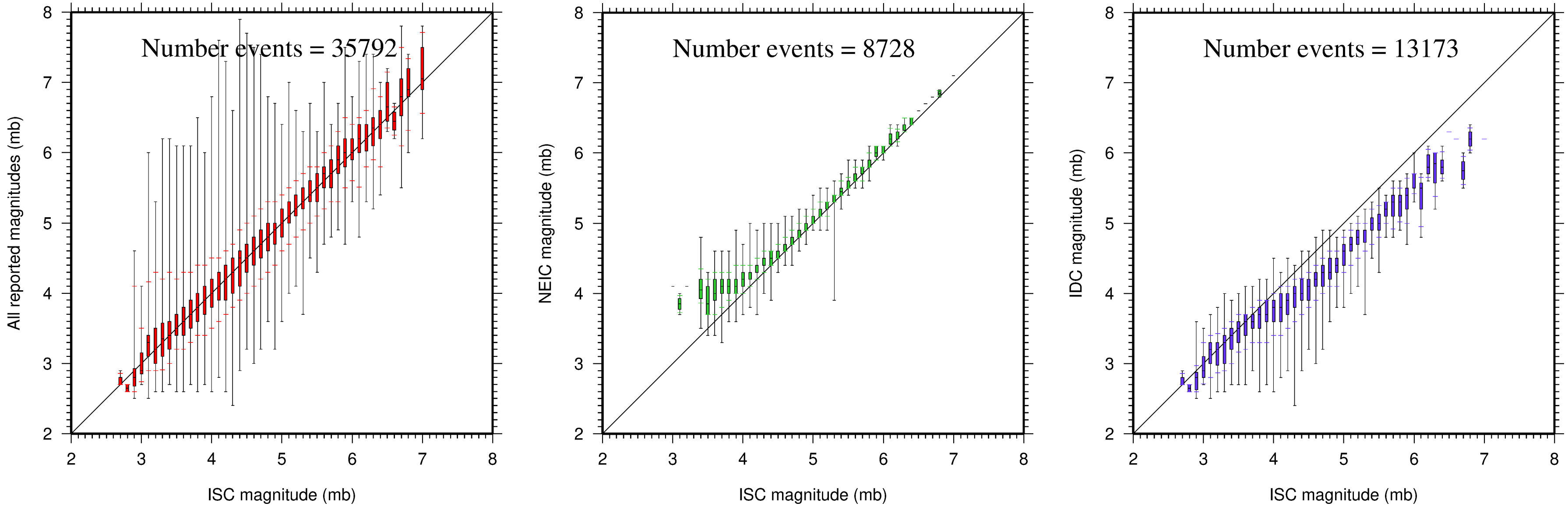
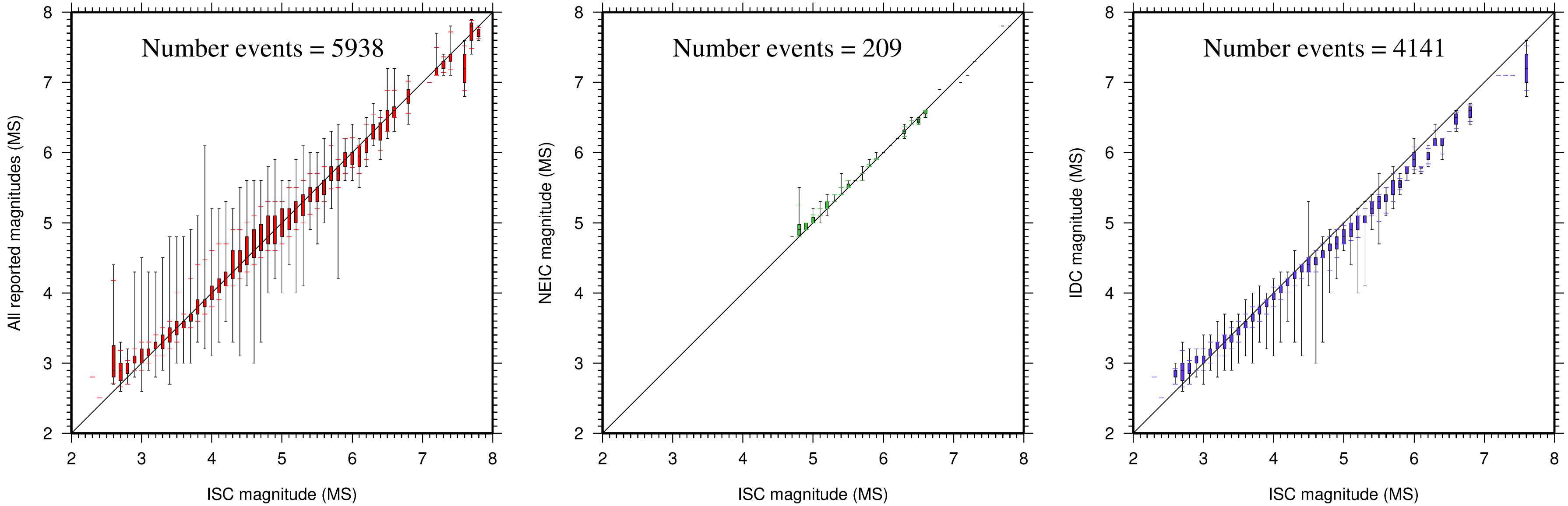


Figure 8.29: *Comparison of ISC values of MS with GCMT M_W for common event pairs.*



(a) (b) (c)

Figure 8.30: *Comparison of ISC magnitude data (mb) with additional agency magnitudes (mb). The statistical summary is shown in box-and-whisker plots where the 10th and 90th percentiles are shown in addition to the max and min values. (a): All magnitudes reported; (b): NEIC magnitudes; (c): IDC magnitudes.*



(a) (b) (c)

Figure 8.31: *Comparison of ISC magnitude data (MS) with additional agency magnitudes (MS). The statistical summary is shown in the box-and-whisker plots where the 10th and 90th percentiles are shown in addition to the max and min values. (a): All magnitudes reported; (b): NEIC magnitudes; (c): IDC magnitudes.*

9

The Leading Data Contributors

For the current six-month period, 150 agencies reported related bulletin data. Although we are grateful for every report, we nevertheless would like to acknowledge those agencies that made the most useful or distinct contributions to the contents of the ISC Bulletin. Here we note those agencies that:

- provided a comparatively large volume of parametric data (see Section 9.1),
- reported data that helped quite considerably to improve the quality of the ISC locations or magnitude determinations (see Section 9.2),
- helped the ISC by consistently reporting data in one of the standard recognised formats and in-line with the ISC data collection schedule (see Section 9.3).

We do not aim to discourage those numerous small networks who provide comparatively smaller yet still most essential volumes of regional data regularly, consistently and accurately. Without these reports the ISC Bulletin would not be as comprehensive and complete as it is today.

9.1 The Largest Data Contributors

We acknowledge the contribution of IDC, NEIC, GFZ, CLL, BJI, MCSM and a few others (Figure 9.1) that reported the majority of moderate to large events recorded at teleseismic distances. The contributions of NEIC, IDC, MEX, DJA and several others are also acknowledged with respect to smaller seismic events. The contributions of JMA, AFAD, ISK, ATH, MDD, RSNC, CNRM, WEL and a number of others are also acknowledged with respect to small seismic events. Note that the NEIC bulletin accumulates a contribution of all regional networks in the USA. Several agencies monitoring highly seismic regions routinely report large volumes of small to moderate magnitude events, such as those in Japan, Turkey, Italy, Greece, New Zealand, Mexico and Columbia. Contributions of small magnitude events by agencies in regions of low seismicity, such as Finland are also gratefully received.

We also would like to acknowledge contributions of those agencies that report a large portion of arrival time and amplitude data (Figure 9.2). For small magnitude events, these are local agencies in charge of monitoring local and regional seismicity. For moderate to large events, contributions of NEIC, GFZ, MOS, IDC, DJA are especially acknowledged. Notably, four agencies (NEIC, GFZ, IDC and MOS) together reported over 70% of all amplitude measurements made for teleseismically recorded events. We hope that other agencies would also be able to update their monitoring routines in the future to include the amplitude reports for teleseismic events compliant with the IASPEI standards.

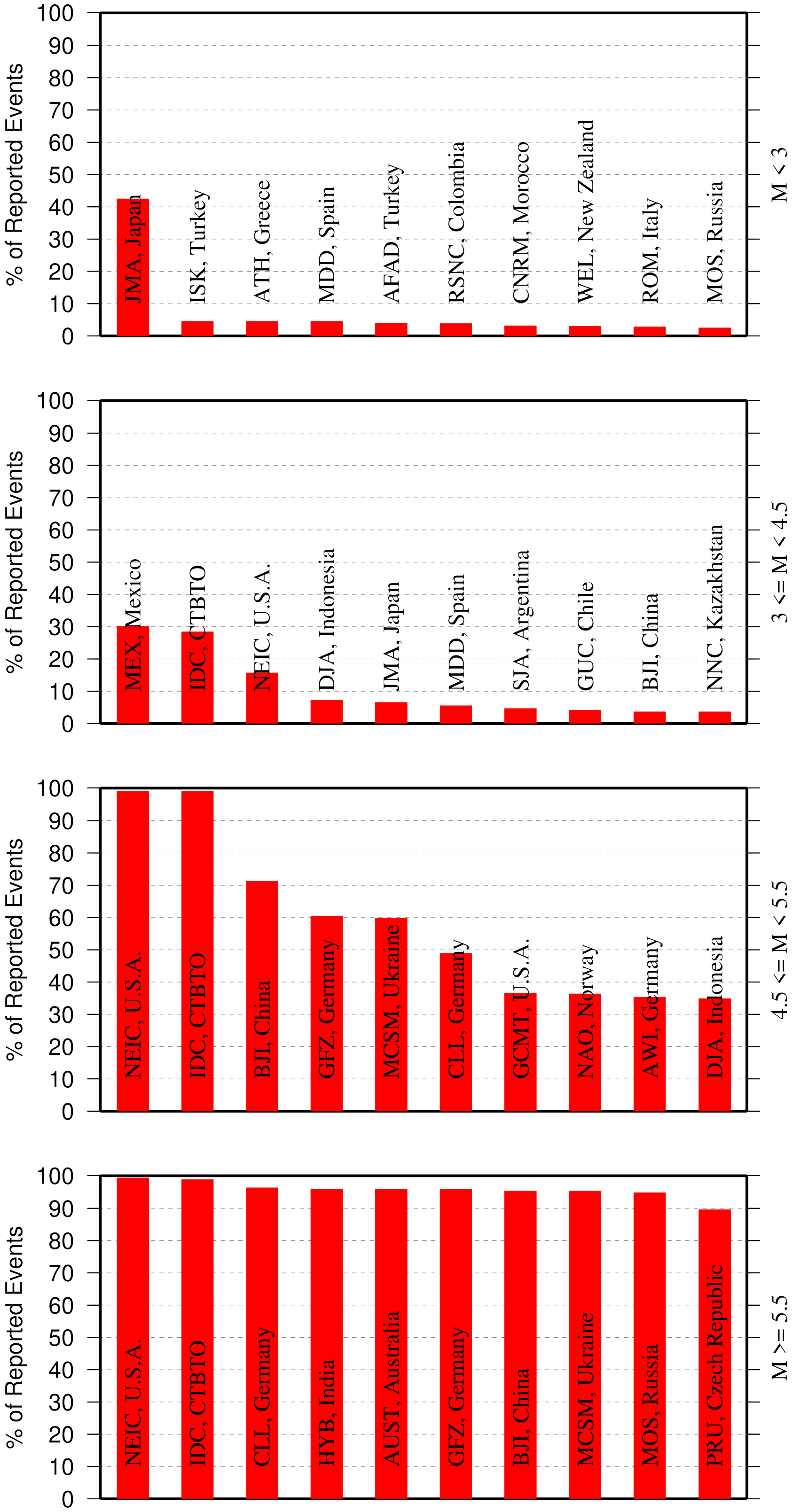


Figure 9.1: *Frequency of events in the ISC Bulletin for which an agency reported at least one item of data: a moment tensor, a hypocentre, a station arrival time or an amplitude. The top ten agencies are shown for four magnitude intervals.*

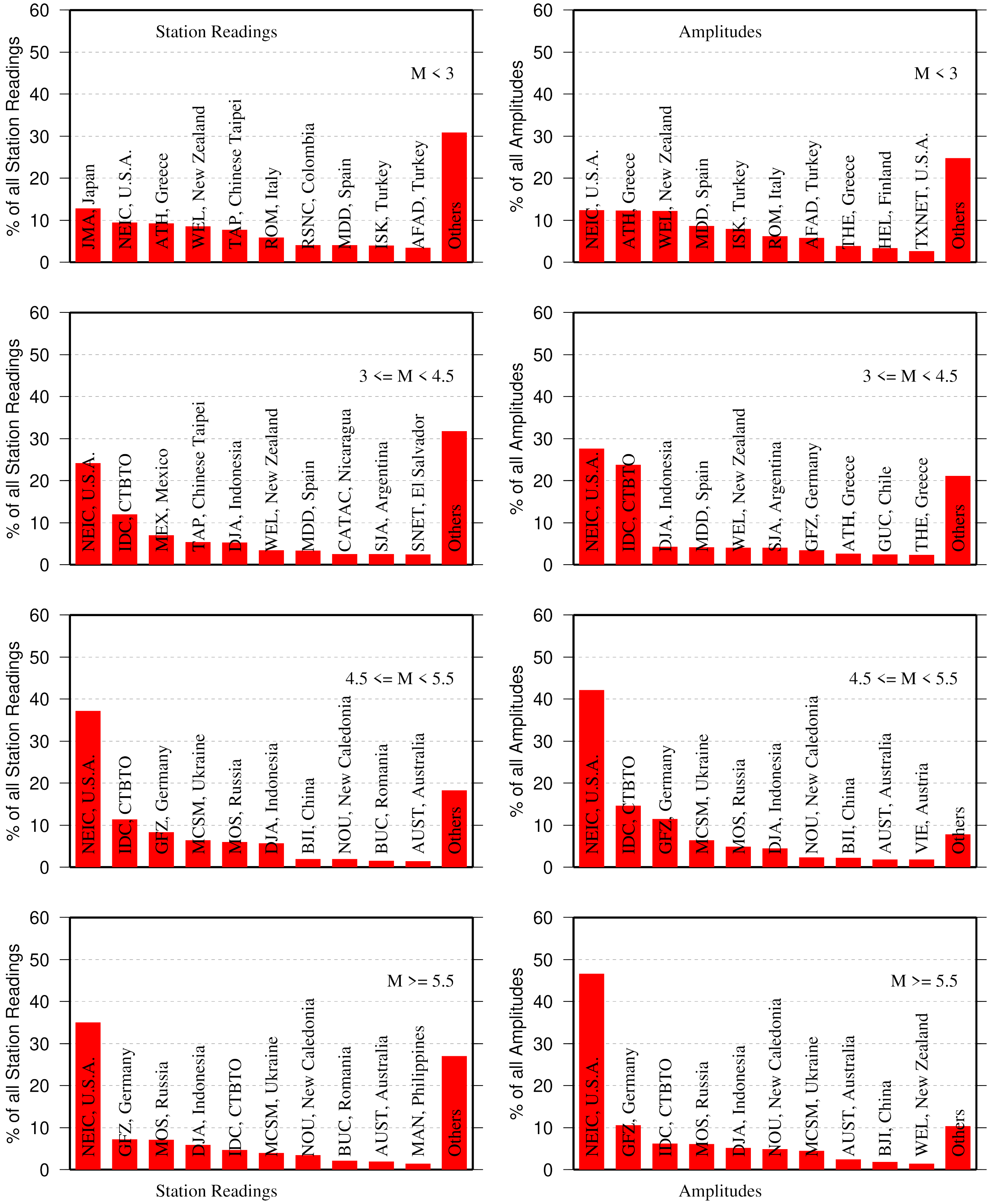


Figure 9.2: *Contributions of station arrival time readings (left) and amplitudes (right) of agencies to the ISC Bulletin. Top ten agencies are shown for four magnitude intervals.*

9.2 Contributors Reporting the Most Valuable Parameters

One of the main ISC duties is to re-calculate hypocentre estimates for those seismic events where a collective wealth of all station reports received from all agencies is likely to improve either the event location or depth compared to the hypocentre solution from each single agency. For areas with a sparse local seismic network or an unfavourable station configuration, readings made by other networks at teleseismic distances are very important. All events near mid-oceanic ridges as well as those in the majority of subduction zones around the world fall into this category. Hence we greatly appreciate the effort made by many agencies that report data for remote earthquakes (Figure 9.3). For some agencies, such as the IDC and the NEIC, it is part of their mission. For instance, the IDC reports almost every seismic event that is large enough to be recorded at teleseismic distance (20 degrees and beyond). This is largely because the International Monitoring System of primary arrays and broadband instruments is distributed at quiet sites around the world in order to be able to detect possible violations of the Comprehensive Nuclear-Test-Ban Treaty. The NEIC reported over 50% of those events as their mission requires them to report events above magnitude 4.5 outside the United States of America. For other agencies reporting distant events it is an extra effort that they undertake to notify their governments and relief agencies as well as to help the ISC and academic research in general. Hence these agencies usually report on the larger magnitude events. BJI, MCSM, GFZ, CLL, NAO, MOS, VIE, DMN each reported individual station arrivals for several percent of all relevant events. We encourage other agencies to report distant events to us.

In addition to the first arriving phase we encourage reporters to contribute observations of secondary seismic phases that help constrain the event location and depth: S, Sn, Sg and pP, sP, PcP (Figure 9.4). We expect though that these observations are actually made from waveforms, rather than just predicted by standard velocity models and modern software programs. It is especially important that these arrivals are manually reviewed by an operator (as we know takes place at the IDC and NEIC), as opposed to some lesser attempts to provide automatic phase readings that are later rejected by the ISC due to a generally poor quality of unreviewed picking.

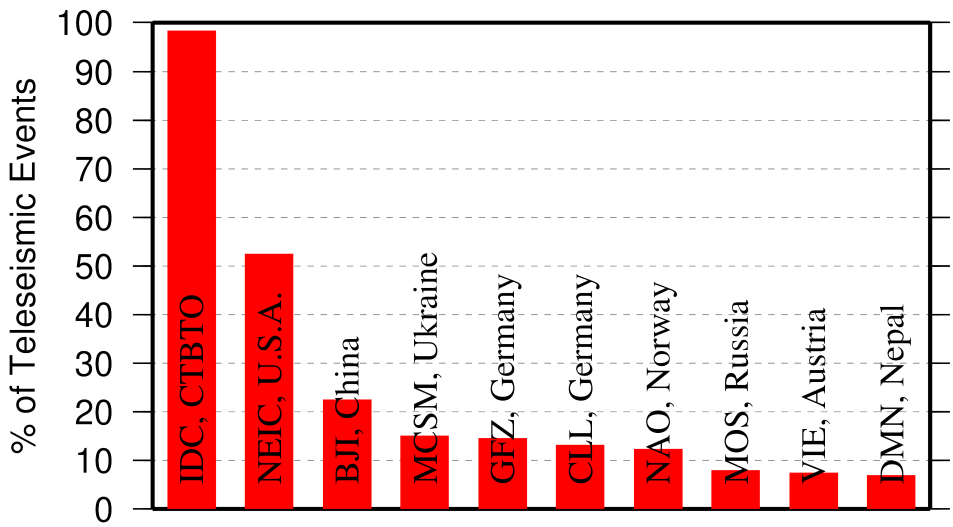


Figure 9.3: *Top ten agencies that reported teleseismic phase arrivals for a large portion of ISC events.*

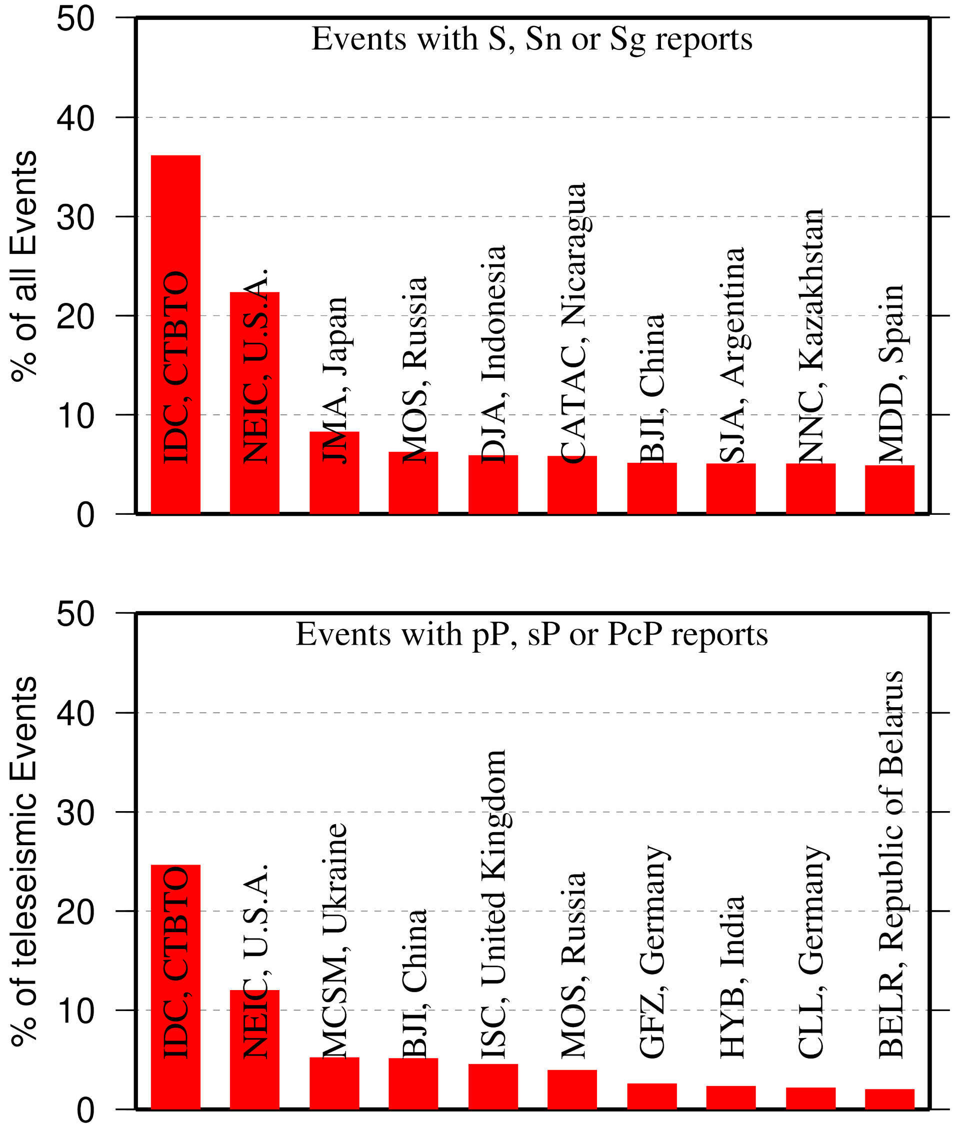


Figure 9.4: *Top ten agencies that reported secondary phases important for an accurate epicentre location (top) and focal depth determination (bottom).*

Another important long-term task that the ISC performs is to compute the most definitive values of MS and mb network magnitudes that are considered reliable due to removal of outliers and consequent averaging (using alpha-trimmed median) across the largest network of stations, generally not feasible for a single agency. Despite concern over the bias at the lower end of mb introduced by the body wave amplitude data from the IDC, other agencies are also known to bias the results. This topic is further discussed in Section 8.5.

Notably, the IDC reports almost 100% of all events for which MS and mb are estimated. This is due to the standard routine that requires determination of body and surface wave magnitudes useful for discrimination purposes. NEIC, BJI, CLL, GFZ, MOS and a few other agencies (Figure 9.5) are also responsible for the majority of the amplitude and period reports that contribute towards the ISC magnitudes.

The top ten agencies that most frequently report seismic moment tensor determinations and moment magnitude are shown in Figure 9.6. The ISC calculates moment tensors, along with the earthquake source

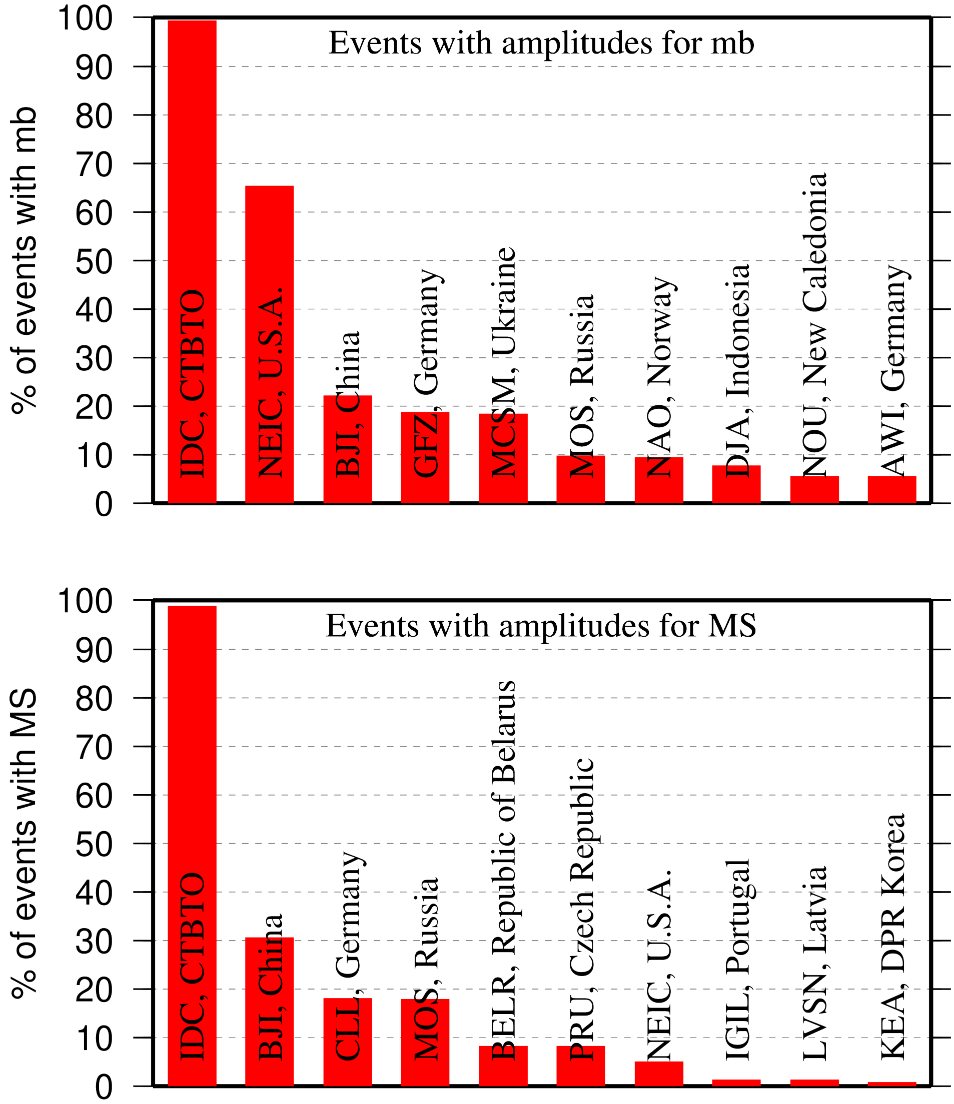


Figure 9.5: *Agencies that report defining body (top) and surface (bottom) wave amplitudes and periods for the largest fraction of those ISC Bulletin events with MS/mb determinations.*

time function and depth for moderate magnitude earthquakes (M_W 5.8 - 7.2) using the ISC-PPSM (ISC-Probabilistic Point Source Model) methodology developed in collaboration with the seismology group at the University of Oxford (*Garth et al.*, 2023).

Among other event parameters the ISC Bulletin also contains information on event type. We cannot independently verify the type of each event in the Bulletin and thus rely on other agencies to report the event type to us. Practices of reporting non-tectonic events vary greatly from country to country. Many agencies do not include anthropogenic events in their reports. Suppression of such events from reports to the ISC may lead to a situation where a neighbouring agency reports the anthropogenic event as an earthquake for which expected data are missing. This in turn is detrimental to ISC Bulletin users studying natural seismic hazard. Hence we encourage all agencies to join the agencies listed on Figure 9.7 and several others in reporting both natural and anthropogenic events to the ISC.

The ISC Bulletin also contains felt and damaging information when local agencies have reported it to us. Agencies listed on Figure 9.8 provide such information for the majority of all felt or damaging events in the ISC Bulletin.

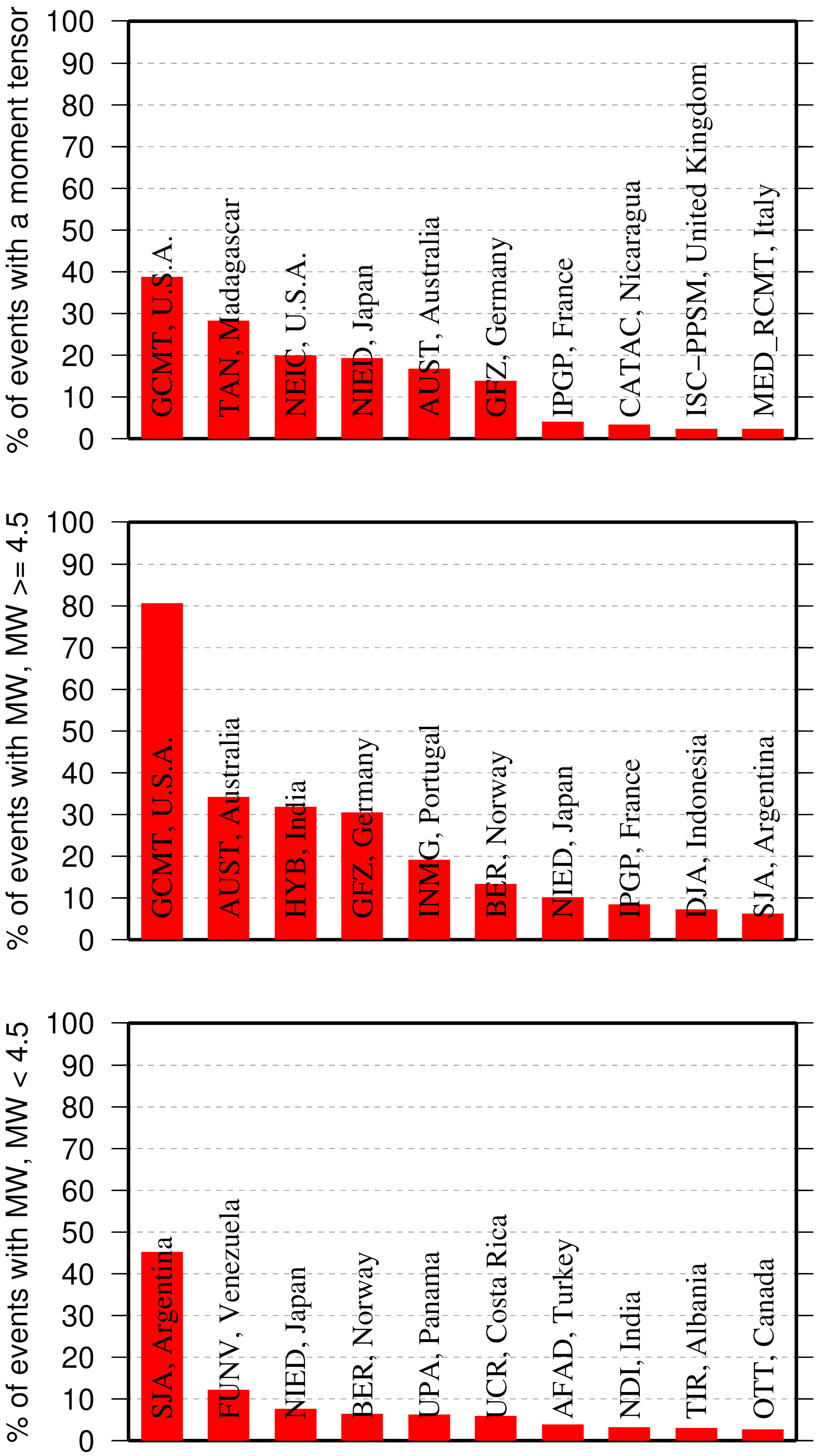


Figure 9.6: *Top ten agencies that most frequently report determinations of seismic moment tensor (top) and moment magnitude (middle/bottom for M greater/smaller than 4.5).*

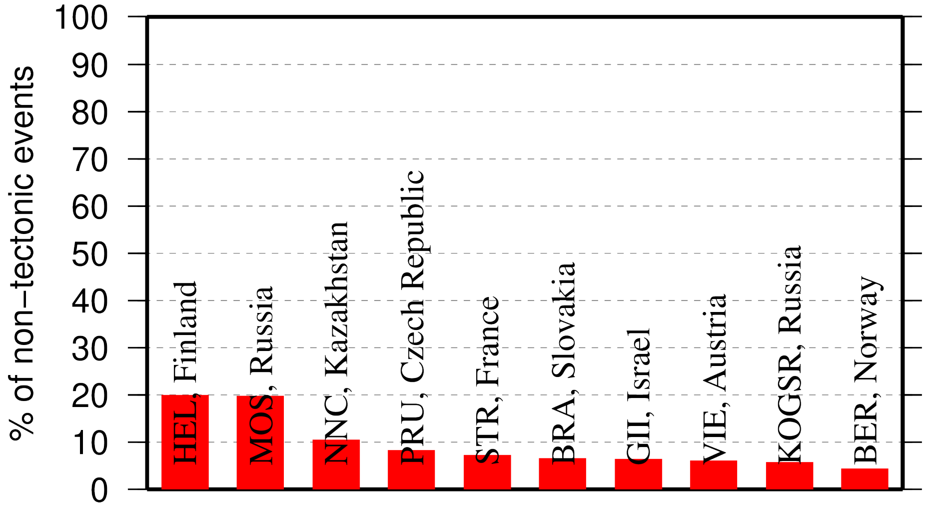


Figure 9.7: *Top ten agencies that most frequently report non-tectonic seismic events to the ISC.*

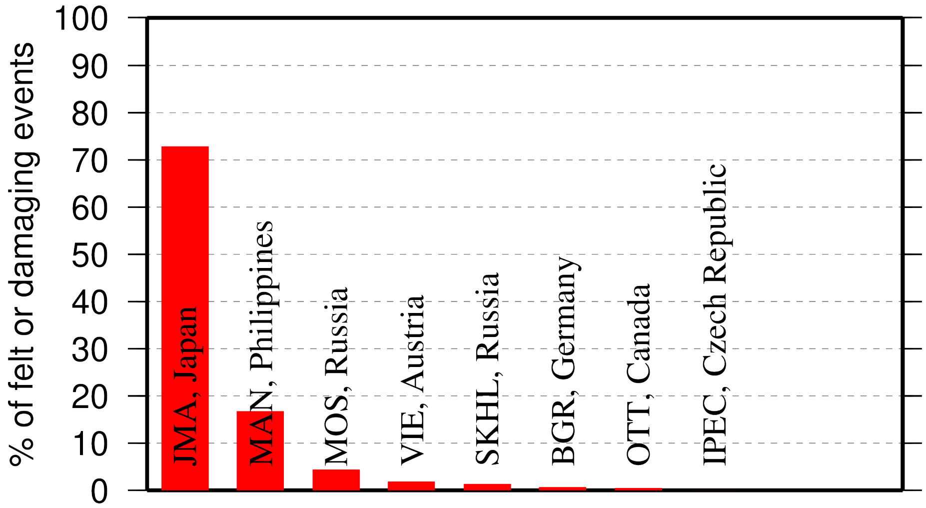


Figure 9.8: *Top agencies that most frequently report macroseismic information to the ISC.*

9.3 The Most Consistent and Punctual Contributors

During this six-month period, 27 agencies reported their bulletin data in one of the standard seismic formats (ISF, IMS, GSE, Nordic or QuakeML) and within the current 12-month deadline. Here we must reiterate that the ISC accepts reviewed bulletin data after a final analysis as soon as they are ready. These data, even if they arrive before the deadline, are immediately parsed into the ISC database, grouped with other data and become available to the ISC users on-line as part of the preliminary ISC Bulletin. There is no reason to wait until the deadline to send the data to the ISC. Table 9.1 lists all agencies that have been helpful to the ISC in this respect during the six-month period.

Table 9.1: *Agencies that contributed reviewed bulletin data to the ISC in one of the standard international formats before the submission deadline.*

Agency Code	Country	Average Delay from real time (days)
AUST	Australia	15
ZUR	Switzerland	17
WEL	New Zealand	18
IDC	Austria	28
ATH	Greece	28
IGIL	Portugal	31
PPT	French Polynesia	34
LDG	France	35
ECX	Mexico	35
BUC	Romania	37
NAO	Norway	44
KNET	Kyrgyzstan	49
BGS	United Kingdom	61
MDD	Spain	69
TIR	Albania	82
NEIC	U.S.A.	100
ISK	Turkey	109
SVSA	Portugal	126
INMG	Portugal	134
DSN	United Arab Emirates	167
BJI	China	167
KEA	Democratic People's Republic of Korea	175
VIE	Austria	250
NDI	India	288
BER	Norway	295
UCC	Belgium	321
IPEC	Czech Republic	328

10

Appendix

10.1 Tables

Table 10.1: *Listing of all 396 agencies that have directly reported to the ISC. The 152 agencies highlighted in bold have reported data to the ISC Bulletin for the period of this Bulletin Summary.*

Agency Code	Agency Name
AAA	Alma-ata, Kazakhstan
AAE	University of Addis Ababa, Ethiopia
AAM	University of Michigan, USA
ADE	Primary Industries and Resources SA, Australia
ADH	Observatorio Afonso Chaves, Portugal
AEIC	Alaska Earthquake Information Center, USA
AFAD	**Disaster and Emergency Management Presidency, Turkey**
AFAR	The Afar Depression: Interpretation of the 1960-2000 Earthquakes, Israel
AFUA	University of Alabama, USA
ALG	Algiers University, Algeria
ANDRE	, USSR
ANF	USArray Array Network Facility, USA
ANT	Antofagasta, Chile
ARE	Instituto Geofisico del Peru, Peru
ARO	Observatoire Géophysique d'Arta, Djibouti
ASGSR	**Altay-Sayan Branch, Geophysical Survey, Russian Academy of Sciences, Russia**
ASIES	**Institute of Earth Sciences, Academia Sinica, Chinese Taipei**
ASL	Albuquerque Seismological Laboratory, USA
ASM	University of Asmara, Eritrea
ATA	The Earthquake Research Center Ataturk University, Turkey
ATH	**National Observatory of Athens, Greece**
AUST	**Geoscience Australia, Australia**
AVETI	, USSR
AWI	**Alfred Wegener Institute for Polar and Marine Research, Germany**
AZER	**Republican Seismic Survey Center of Azerbaijan National Academy of Sciences, Azerbaijan**
BCIS	Bureau Central International de Sismologie, France
BDF	Observatório Sismológico da Universidade de Brasília, Brazil
BELR	**Centre of Geophysical Monitoring of the National Academy of Sciences of Belarus, Republic of Belarus**
BEO	**Republicki seizmoloski zavod, Serbia**
BER	**University of Bergen, Norway**
BERK	Berkheimer H, Germany
BGR	**Bundesanstalt für Geowissenschaften und Rohstoffe, Germany**
BGS	**British Geological Survey, United Kingdom**

Table 10.1: Continued.

Agency Code	Agency Name
BGSI	**Botswana Geoscience Institute**, **Botswana**
BHUJ2	Study of Aftershocks of the Bhuj Earthquake by Japanese Research Team, Japan
BIAK	Biak earthquake aftershocks (17-Feb-1996), USA
BJI	**China Earthquake Networks Center**, **China**
BKK	**Thai Meteorological Department**, **Thailand**
BNS	Erdbebenstation, Geologisches Institut der Universität, Köl, Germany
BOG	Universidad Javeriana, Colombia
BRA	**Geophysical Institute, Slovak Academy of Sciences**, **Slovakia**
BRG	**Seismological Observatory Berggießhübel, TU Bergakademie Freiberg**, **Germany**
BRK	Berkeley Seismological Laboratory, USA
BRS	Brisbane Seismograph Station, Australia
BUC	**National Institute for Earth Physics**, **Romania**
BUD	Geodetic and Geophysical Research Institute, Hungary
BUEE	Earth & Environment, USA
BUG	Institute of Geology, Mineralogy & Geophysics, Germany
BUL	**Goetz Observatory**, **Zimbabwe**
BUT	Montana Bureau of Mines and Geology, USA
BYKL	**Baykal Regional Seismological Centre, GS SB RAS**, **Russia**
CADCG	Central America Data Centre, Costa Rica
CAN	Australian National University, Australia
CANSK	Canadian and Scandinavian Networks, Sweden
CAR	Instituto Sismologico de Caracas, Venezuela
CASC	Central American Seismic Center, Costa Rica
CATAC	**Central American Tsunami Advisory Center**, **Nicaragua**
CENT	Centennial Earthquake Catalog, USA
CERI	Center for Earthquake Research and Information, USA
CFUSG	**Inst. of Seismology and Geodynamics, V.I. Vernadsky Crimean Federal University**, **Republic of Crimea**
CLL	**Geophysikalisches Observatorium Collm**, **Germany**
CNG	Seismographic Station Changalane, Mozambique
CNRM	**Centre National de Recherche**, **Morocco**
COSMOS	Consortium of Organizations for Strong Motion Observations, USA
CRAAG	**Centre de Recherche en Astronomie, Astrophysique et Géophysique**, **Algeria**
CSC	University of South Carolina, USA
CSEM	Centre Sismologique Euro-Méditerranéen (CSEM/EMSC), France
CUPWA	**Curtin University**, **Australia**
DAGSR	Dagestan Branch, Geophysical Survey, Russian Academy of Sciences, Russia
DASA	Defense Atomic Support Agency, USA
DBN	Koninklijk Nederlands Meteorologisch Instituut, Netherlands
DDA	General Directorate of Disaster Affairs, Turkey
DHMR	Yemen National Seismological Center, Yemen
DIAS	**Dublin Institute for Advanced Studies**, **Ireland**
DJA	**Badan Meteorologi, Klimatologi dan Geofisika**, **Indonesia**
DMN	**National Seismological Centre, Nepal**, **Nepal**
DNAG	, USA

Table 10.1: Continued.

Agency Code	Agency Name
DNK	**Geological Survey of Denmark and Greenland, Denmark**
DSN	**Dubai Seismic Network, United Arab Emirates**
DUSS	Damascus University, Syria, Syria
EAF	**East African Network, Unknown**
EAGLE	Ethiopia-Afar Geoscientific Lithospheric Experiment, Unknown
EBR	Observatori de l'Ebre, Spain
EBSE	Ethiopian Broadband Seismic Experiment, Unknown
ECGS	European Center for Geodynamics and Seismology, Luxembourg
ECX	**Centro de Investigación Científica y de Educación Superior de Ensenada, Mexico**
EFATE	OBS Experiment near Efate, Vanuatu, USA
EHB	Engdahl, van der Hilst and Buland, USA
EIDC	Experimental (GSETT3) International Data Center, USA
EKA	Eskdalemuir Array Station, United Kingdom
ENT	Geological Survey and Mines Department, Uganda
EPSI	Reference events computed by the ISC for EPSI project, United Kingdom
ERDA	Energy Research and Development Administration, USA
EST	Geological Survey of Estonia, Estonia
EUROP	, Unknown
EVBIB	**Data from publications listed in the ISC Event Bibliography, Unknown**
FBR	Fabra Observatory, Spain
FCIAR	**Federal Center for Integrated Arctic Research, Russia**
FDF	Fort de France, Martinique
FIA0	Finessa Array, Finland
FOR	Unknown Historical Agency, Unknown - historical agency
FUBES	Earth Science Dept., Geophysics Section, Germany
FUNV	**Fundación Venezolana de Investigaciones Sismológicas, Venezuela**
FUR	Geophysikalisches Observatorium der Universität München, Germany
GBZT	Marmara Research Center, Turkey
GCG	**INSIVUMEH, Guatemala**
GCMT	**The Global CMT Project, USA**
GDNRW	Geologischer Dienst Nordrhein-Westfalen, Germany
GEN	**Dipartimento per lo Studio del Territorio e delle sue Risorse (RSNI), Italy**
GEOAZ	UMR Géoazur, France
GEOMR	GEOMAR, Germany
GFZ	**Helmholtz Centre Potsdam GFZ German Research Centre For Geosciences, Germany**
GII	**The Geophysical Institute of Israel, Israel**
GOM	Observatoire Volcanologique de Goma, Democratic Republic of the Congo
GRAL	**National Council for Scientific Research, Lebanon**
GSDM	**Geological Survey Department Malawi, Malawi**
GSET2	Group of Scientific Experts Second Technical Test 1991, April 22 - June 2, Unknown
GTFE	German Task Force for Earthquakes, Germany
GUC	**Centro Sismológico Nacional, Universidad de Chile, Chile**

Table 10.1: *Continued.*

Agency Code	Agency Name
HAN	Hannover, Germany
HDC	Observatorio Vulcanológico y Sismológico de Costa Rica, Costa Rica
HEL	**Institute of Seismology, University of Helsinki, Finland**
HFS	Hagfors Observatory, Sweden
HFS1	Hagfors Observatory, Sweden
HFS2	Hagfors Observatory, Sweden
HIMNT	Himalayan Nepal Tibet Experiment, USA
HKC	**Hong Kong Observatory, Hong Kong**
HLUG	Hessisches Landesamt für Umwelt und Geologie, Germany
HLW	**National Research Institute of Astronomy and Geophysics, Egypt**
HNR	Ministry of Mines, Energy and Rural Electrification, Solomon Islands
HON	Pacific Tsunami Warning Center - NOAA, USA
HRVD	Harvard University, USA
HRVD_LR	Department of Geological Sciences, Harvard University, USA
HVO	Hawaiian Volcano Observatory, USA
HYB	**National Geophysical Research Institute, India**
HYD	National Geophysical Research Institute, India
IAG	Instituto Andaluz de Geofisica, Spain
IASBS	Institute for Advanced Studies in Basic Sciences, Iran
IASPEI	IASPEI Working Group on Reference Events, USA
ICE	Instituto Costarricense de Electricidad, Costa Rica
IDC	**International Data Centre, CTBTO, Austria**
IDG	Institute of Dynamics of Geosphere, Russian Academy of Sciences, Russia
IEC	Institute of the Earth Crust, SB RAS, Russia
IEPN	Institute of Environmental Problems of the North, Russian Academy of Sciences, Russia
IFREE	Institute For Research on Earth Evolution, Japan
IGGSL	Seismology Lab, Institute of Geology & Geophysics, Chinese Academy of Sciences, China
IGIL	**Instituto Dom Luiz, University of Lisbon, Portugal**
IGKR	Institute of Geology,Komi Science Centre,Ural Branch,Russian Academy of Sciences, Russia
IGKRC	Institute of Geology, Karelian Research Centre, Russian Academy of Sciences, Russia
IGQ	**Servicio Nacional de Sismología y Vulcanología, Ecuador**
IGS	Institute of Geological Sciences, United Kingdom
INAM	Instituto Nacional de Meteorologia e Geofisica - INAMET, Angola
INDEPTH3	International Deep Profiling of Tibet and the Himalayas, USA
INET	Instituto Nicaraguense de Estudios Territoriales - INETER, Nicaragua
INMG	**Instituto Português do Mar e da Atmosfera, I.P., Portugal**
INMGC	Instituto Nacional de Meteorologia e Geofísica, Cape Verde
IPEC	**The Institute of Physics of the Earth (IPEC), Czech Republic**
IPER	Institute of Physics of the Earth, Academy of Sciences, Moscow, Russia
IPGP	**Institut de Physique du Globe de Paris, France**
IPRG	Institute for Petroleum Research and Geophysics, Israel
IRIS	IRIS Data Management Center, USA
IRSM	Institute of Rock Structure and Mechanics, Czech Republic

Table 10.1: Continued.

Agency Code	Agency Name
ISC	**International Seismological Centre**, **United Kingdom**
ISC-PPSM	**International Seismological Centre Probabilistic Point Source Model**, **United Kingdom**
ISK	**Kandilli Observatory and Earthquake Research Institute**, **Turkey**
ISN	**Iraqi Meteorological and Seismology Organisation**, **Iraq**
ISS	International Seismological Summary, United Kingdom
IST	Institute of Physics of the Earth, Technical University of Istanbul, Turkey
ISU	**Institute of Seismology, Academy of Sciences, Republic of Uzbekistan**, **Uzbekistan**
ITU	Faculty of Mines, Department of Geophysical Engineering, Turkey
JEN	Geodynamisches Observatorium Moxa, Germany
JMA	**Japan Meteorological Agency**, **Japan**
JOH	Bernard Price Institute of Geophysics, South Africa
JSN	**Jamaica Seismic Network**, **Jamaica**
JSO	**Jordan Seismological Observatory**, **Jordan**
KBC	Institut de Recherches Géologiques et Minières, Cameroon
KEA	**Korea Earthquake Administration**, **Democratic People's Republic of Korea**
KEW	Kew Observatory, United Kingdom
KHC	Institute of Geophysics, Czech Academy of Sciences, Czech Republic
KISR	Kuwait Institute for Scientific Research, Kuwait
KLM	Malaysian Meteorological Service, Malaysia
KMA	**Korea Meteorological Administration**, **Republic of Korea**
KMGSR	Kavkazskie Mineralnye Vody Branch, Geophysical Survey, RAS, Russia
KNET	**Kyrgyz Seismic Network**, **Kyrgyzstan**
KOGSR	**Kola Branch, Geophysical Survey, Russian Academy of Sciences**, **Russia**
KRAR	Krasnoyarsk Scientific Research Inst. of Geology and Mineral Resources, Russia, Russia
KRL	Geodätisches Institut der Universität Karlsruhe, Germany
KRNET	**Institute of Seismology, Academy of Sciences of Kyrgyz Republic**, **Kyrgyzstan**
KRSC	**Kamchatka Branch of the Geophyiscal Survey of the RAS**, **Russia**
KRSZO	**Geodetic and Geophysical Reasearch Institute, Hungarian Academy of Sciences**, **Hungary**
KSA	Observatoire de Ksara, Lebanon
KUK	Geological Survey Department of Ghana, Ghana
LAO	Large Aperture Seismic Array, USA
LDG	**Laboratoire de Détection et de Géophysique/CEA**, **France**
LDN	University of Western Ontario, Canada
LDO	Lamont-Doherty Earth Observatory, USA
LED	Landeserdbebendienst Baden-Württemberg, Germany
LEDBW	Landeserdbebendienst Baden-Württemberg, Germany
LER	Besucherbergwerk Binweide Station, Germany
LIB	Tripoli, Libya
LIC	Station Géophysique de Lamto, Ivory Coast
LIM	Lima, Peru

Table 10.1: *Continued.*

Agency Code	Agency Name
LIS	Instituto de Meteorologia, Portugal
LIT	**Geological Survey of Lithuania**, **Lithuania**
LJU	**Slovenian Environment Agency**, **Slovenia**
LPA	**Universidad Nacional de La Plata**, **Argentina**
LPZ	Observatorio San Calixto, Bolivia
LRSM	Long Range Seismic Measurements Project, Unknown
LSZ	Geological Survey Department of Zambia, Zambia
LVSN	**Latvian Seismic Network**, **Latvia**
MAN	**Philippine Institute of Volcanology and Seismology**, **Philippines**
MAT	The Matsushiro Seismological Observatory, Japan
MATSS	, USSR
MCO	**Macao Meteorological and Geophysical Bureau**, **Macao, China**
MCSM	**Main Centre for Special Monitoring**, **Ukraine**
MDD	**Instituto Geográfico Nacional**, **Spain**
MED_RCMT	**MedNet Regional Centroid - Moment Tensors**, **Italy**
MERI	Maharashta Engineering Research Institute, India
MES	Messina Seismological Observatory, Italy
MEX	**Instituto de Geofísica de la UNAM**, **Mexico**
MIRAS	**Mining Institute of the Ural Branch of the Russian Academy of Sciences**, **Russia**
MNH	Institut für Angewandte Geophysik der Universitat Munchen, Germany
MOLD	Institute of Geophysics and Geology, Moldova
MOS	**Geophysical Survey of Russian Academy of Sciences**, **Russia**
MOZ	Direccao Nacional de Geologia, Mozambique
MOZAR	, Mozambique
MRB	**Institut Cartogràfic i Geològic de Catalunya**, **Spain**
MSI	Messina Seismological Observatory, Italy
MSSP	Micro Seismic Studies Programme, PINSTECH, Pakistan
MSUGS	Michigan State University, Department of Geological Sciences, USA
MUN	Mundaring Observatory, Australia
NAI	University of Nairobi, Kenya
NAM	**The Geological Survey of Namibia**, **Namibia**
NAO	**Stiftelsen NORSAR**, **Norway**
NCEDC	Northern California Earthquake Data Center, USA
NDI	**National Centre for Seismology of the Ministry of Earth Sciences of India**, **India**
NEGSR	North East (Magadan) Branch, Geophysical Survey, Russian Academy of Sciences, Russia
NEIC	**National Earthquake Information Center**, **USA**
NEIS	National Earthquake Information Service, USA
NERS	**North Eastern Regional Seismological Centre, Magadan, GS RAS**, **Russia**
NIC	**Cyprus Geological Survey Department**, **Cyprus**
NIED	**National Research Institute for Earth Science and Disaster Resilience**, **Japan**
NKSZ	, USSR
NNC	**National Nuclear Center**, **Kazakhstan**
NOGSR	North Ossetia (Alania) Branch, Geophysical Survey, Russian Academy of Sciences, Russia

Table 10.1: *Continued.*

Agency Code	Agency Name
NOU	**IRD Centre de Nouméa**, **New Caledonia**
NSSC	National Syrian Seismological Center, Syria
NSSP	**National Survey of Seismic Protection**, **Armenia**
OBGSR	Central (Obninsk) Branch, Geophysical Survey, Russian Academy of Sciences, Russia
OBM	Institute of Astronomy and Geophysics, Mongolian Academy of Sciences, Mongolia
OGAUC	Centro de Investigação da Terra e do Espaço da Universidade de Coimbra, Portugal
OGSO	Ohio Geological Survey, USA
OMAN	**Sultan Qaboos University**, **Oman**
ORF	Orfeus Data Center, Netherlands
OSPL	**Observatorio Sismologico Politecnico Loyola**, **Dominican Republic**
OSUB	Osservatorio Sismologico Universita di Bari, Italy
OSUNB	**Observatory Seismological of the University of Brasilia**, **Brazil**
OTT	**Canadian Hazards Information Service, Natural Resources Canada**, **Canada**
PAL	Palisades, USA
PAS	California Institute of Technology, USA
PDA	Universidade dos Açores, Portugal
PDG	**Institute of Hydrometeorology and Seismology of Montenegro**, **Montenegro**
PEK	Peking, China
PGC	Pacific Geoscience Centre, Canada
PJWWP	**Private Observatory of Pawel Jacek Wiejacz, D.Sc.**, **Poland**
PLV	**Institute of Geophysics, Viet Nam Academy of Science and Technology**, **Viet Nam**
PMEL	Pacific seismicity from hydrophones, USA
PMR	Alaska Tsunami Warning Center,, USA
PNNL	Pacific Northwest National Laboratory, USA
PNSN	**Pacific Northwest Seismic Network**, **USA**
PPT	**Laboratoire de Géophysique/CEA**, **French Polynesia**
PRE	**Council for Geoscience**, **South Africa**
PRU	**Institute of Geophysics, Czech Academy of Sciences**, **Czech Republic**
PTO	Instituto Geofísico da Universidade do Porto, Portugal
PTWC	**Pacific Tsunami Warning Center**, **USA**
QCP	**Manila Observatory**, **Philippines**
QUE	Pakistan Meteorological Department, Pakistan
QUI	Escuela Politécnica Nacional, Ecuador
RAB	Rabaul Volcanological Observatory, Papua New Guinea
RBA	Université Mohammed V, Morocco
REN	MacKay School of Mines, USA
REY	**Icelandic Meteorological Office**, **Iceland**
RHSSO	**Republic Hydrometeorological Service, Seismological Observatory, Banja Luka**, **Bosnia and Herzegovina**
RISSC	**Laboratory of Research on Experimental and Computational Seimology**, **Italy**

Table 10.1: *Continued.*

Agency Code	Agency Name
RMIT	Royal Melbourne Institute of Technology, Australia
ROC	Odenbach Seismic Observatory, USA
ROM	**Istituto Nazionale di Geofisica e Vulcanologia**, **Italy**
RRLJ	Regional Research Laboratory Jorhat, India
RSMAC	Red Sísmica Mexicana de Apertura Continental, Mexico
RSNC	**Red Sismológica Nacional de Colombia**, **Colombia**
RSPR	**Red Sísmica de Puerto Rico**, **USA**
RYD	King Saud University, Saudi Arabia
SAGSR	Sakhalin Branch, Geophysical Survey, Russian Academy of Sciences, Russia
SAPSE	Southern Alps Passive Seismic Experiment, New Zealand
SAR	Sarajevo Seismological Station, Bosnia and Herzegovina
SARA	**SARA Electronic Instrument s.r.l.**, **Italy**
SBDV	, USSR
SCB	**Observatorio San Calixto**, **Bolivia**
SCEDC	Southern California Earthquake Data Center, USA
SCSIO	Key Laboratory of Ocean and Marginal Sea Geology, South China Sea, China
SDD	Universidad Autonoma de Santo Domingo, Dominican Republic
SEA	Geophysics Program AK-50, USA
SET	Setif Observatory, Algeria
SFS	**Real Instituto y Observatorio de la Armada**, **Spain**
SGS	**Saudi Geological Survey**, **Saudi Arabia**
SHL	Central Seismological Observatory, India
SIGU	**Subbotin Institute of Geophysics, National Academy of Sciences**, **Ukraine**
SIK	Seismic Institute of Kosovo, Unknown
SIO	Scripps Institution of Oceanography, USA
SJA	**Instituto Nacional de Prevención Sísmica**, **Argentina**
SJS	Instituto Costarricense de Electricidad, Costa Rica
SKHL	**Sakhalin Experimental and Methodological Seismological Expedition, GS RAS**, **Russia**
SKL	Sakhalin Complex Scientific Research Institute, Russia
SKO	**Seismological Observatory Skopje**, **North Macedonia**
SLC	Salt Lake City, USA
SLM	Saint Louis University, USA
SLUB	Seismological Laboratory of University of Basrah, Iraq
SNET	**Servicio Nacional de Estudios Territoriales**, **El Salvador**
SNM	New Mexico Institute of Mining and Technology, USA
SNSN	Saudi National Seismic Network, Saudi Arabia
SOF	**National Institute of Geophysics, Geology and Geography**, **Bulgaria**
SOMC	Seismological Observatory of Mount Cameroon, Cameroon
SOME	**Seismological Experimental Methodological Expedition**, **Kazakhstan**
SPA	USGS - South Pole, Antarctica
SPGM	Service de Physique du Globe, Morocco
SPITAK	, Armenia
SRI	Stanford Research Institute, USA

Table 10.1: Continued.

Agency Code	Agency Name
SSN	Sudan Seismic Network, Sudan
SSNC	**Servicio Sismológico Nacional Cubano, Cuba**
SSS	Centro de Estudios y Investigaciones Geotecnicas del San Salvador, El Salvador
STK	Stockholm Seismological Station, Sweden
STR	**EOST / RéNaSS, France**
STU	Stuttgart Seismological Station, Germany
SVSA	**Sistema de Vigilância Sismológica dos Açores, Portugal**
SYO	**National Institute of Polar Research, Japan**
SZGRF	Seismologisches Zentralobservatorium Gräfenberg, Germany
TAC	Estación Central de Tacubaya, Mexico
TAN	**Antananarivo, Madagascar**
TANZANIA	Tanzania Broadband Seismic Experiment, USA
TAP	**Central Weather Bureau (CWB), Chinese Taipei**
TAU	University of Tasmania, Australia
TEH	**Tehran University, Iran**
TEIC	Center for Earthquake Research and Information, USA
THE	**Department of Geophysics, Aristotle University of Thessaloniki, Greece**
THR	**International Institute of Earthquake Engineering and Seismology (IIEES), Iran**
TIF	**Institute of Earth Sciences/ National Seismic Monitoring Center, Georgia**
TIR	**Institute of Geosciences, Polytechnic University of Tirana, Albania**
TRI	**Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS), Italy**
TRN	**The Seismic Research Centre, Trinidad and Tobago**
TTG	Titograd Seismological Station, Montenegro
TUL	Oklahoma Geological Survey, USA
TUN	**Institut National de la Météorologie, Tunisia**
TVA	Tennessee Valley Authority, USA
TXNET	**Texas Seismological Network, University of Texas at Austin, USA**
TZN	University of Dar Es Salaam, Tanzania
UAF	Department of Geosciences, USA
UATDG	The University of Arizona, Department of Geosciences, USA
UAV	Red Sismológica de Los Andes Venezolanos, Venezuela
UCB	University of Colorado, Boulder, USA
UCC	**Royal Observatory of Belgium, Belgium**
UCDES	Department of Earth Sciences, United Kingdom
UCR	**Sección de Sismología, Vulcanología y Exploración Geofísica, Costa Rica**
UCSC	Earth & Planetary Sciences, USA
UESG	School of Geosciences, United Kingdom
UGN	Institute of Geonics AS CR, Czech Republic
ULE	University of Leeds, United Kingdom
UNAH	Universidad Nacional Autonoma de Honduras, Honduras
UPA	**Universidad de Panama, Panama**

Table 10.1: Continued.

Agency Code	Agency Name
UPIES	Institute of Earth- and Environmental Science, Germany
UPP	**University of Uppsala**, **Sweden**
UPSL	**University of Patras, Department of Geology**, **Greece**
UREES	Department of Earth and Environmental Science, USA
USAEC	United States Atomic Energy Commission, USA
USCGS	United States Coast and Geodetic Survey, USA
USGS	United States Geological Survey, USA
UTEP	Department of Geological Sciences, USA
UUSS	The University of Utah Seismograph Stations, USA
UVC	Universidad del Valle, Colombia
UWMDG	University of Wisconsin-Madison, Department of Geoscience, USA
VAO	**Instituto Astronomico e Geofísico**, **Brazil**
VIE	**Zentralanstalt für Meteorologie und Geodynamik (ZAMG)**, **Austria**
VMGSR	Voronezh Crystalline Massif Branch, Geophysical Survey, RAS, Russia
VSI	University of Athens, Greece
VUW	Victoria University of Wellington, New Zealand
WAR	**Institute of Geophysics, Polish Academy of Sciences**, **Poland**
WASN	, USA
WBNET	**Institute of Geophysics, Czech Academy of Sciences**, **Czech Republic**
WEL	**Institute of Geological and Nuclear Sciences**, **New Zealand**
WES	Weston Observatory, USA
WUSTL	Washington University Earth and Planentary Sciences, USA
YAGSR	Yakut (Saha) Branch, Geophysical Survey, Russian Academy of Sciences, Russia
YARS	**Yakutiya Regional Seismological Center, GS SB RAS**, **Russia**
ZAG	**Seismological Survey of the Republic of Croatia**, **Croatia**
ZEMSU	, USSR
ZUR	**Swiss Seismological Service (SED)**, **Switzerland**
ZUR_RMT	Zurich Moment Tensors, Switzerland

Table 10.2: *Phases reported to the ISC. These include phases that could not be matched to an appropriate* ak135 *phases. Those agencies that reported at least 10% of a particular phase are also shown.*

Reported Phase	Total	Agencies reporting
P	4813134	
S	2211513	JMA (14%), TAP (11%)
AML	1250039	ROM (40%), WEL (18%), ATH (11%)
NULL	693386	NEIC (33%), IDC (28%), AEIC (16%)
IAML	681087	NEIC (50%), AFAD (15%)
IAmb	534143	NEIC (97%)
Pn	306519	NEIC (31%), ISK (22%)
Pg	289759	ISK (22%), STR (15%)
Sg	242372	ISK (16%), STR (15%), ZAG (12%)
LR	122698	IDC (88%)
IVmb_Lg	114894	MDD (100%)
Sn	112257	MDD (22%), NEIC (12%)
pmax	103924	MOS (69%), BJI (31%)
IAMs_20	90040	NEIC (98%)
SG	61231	HEL (61%), PRU (26%), IPEC (11%)
PG	58638	HEL (65%), PRU (19%), IPEC (12%)
PKP	48160	IDC (44%), VIE (14%)
Lg	39549	NNC (54%), KRSZO (20%), IDC (17%)
L	37202	BJI (96%)
smax	35399	HEL (80%), MOS (15%)
T	32611	IDC (99%)
IAmb_Lg	30558	NEIC (100%)
PN	25844	MOS (41%), HEL (38%), IPEC (11%)
A	23040	TEH (47%), JMA (33%), SKHL (20%)
pP	21538	ISC1 (22%), BJI (21%), MCSM (11%)
PKPbc	21020	IDC (66%)
SN	19114	HEL (88%)
PKIKP	15776	MOS (93%)
PcP	14795	IDC (59%), ISC1 (16%)
PP	13971	IDC (18%), BJI (18%), BELR (14%)
MLR	13777	MOS (100%)
SB	12232	HEL (100%)
AMS	9299	PRU (50%), CLL (31%), LVSN (17%)
SS	9284	MOS (31%), BELR (23%), BJI (20%)
PB	9131	HEL (100%)
x	8770	BRG (26%), NDI (24%), TRN (24%), CLL (15%)
PKPdf	8755	NEIC (45%), INMG (14%)
sP	7405	BJI (51%), ISC1 (34%)
PKPab	6451	IDC (50%), INMG (15%)
MSG	5321	HEL (100%)
PKiKP	5169	IDC (32%), VIE (31%), BELR (11%)
ScP	4230	IDC (72%), ISC1 (13%)
PPP	3893	MOS (50%), BELR (42%)
SSS	3391	BELR (53%), MOS (35%)
LQ	3253	PPT (49%), BELR (41%)
Smax	3092	BYKL (100%)
Amp	3067	BRG (100%)
LRM	2737	BELR (100%)
PKKPbc	2599	IDC (95%)
Pmax	2458	BYKL (97%)
AMB	2442	SKHL (94%)
PKhKP	2301	IDC (100%)
*PP	2152	MOS (100%)
PKP2	2075	MOS (100%)
Trac	2025	OTT (100%)
I	1883	IDC (100%)
pPKP	1657	VIE (38%), BJI (21%), IDC (16%), BELR (11%)
sS	1595	BJI (59%), BELR (24%)
SKS	1575	BELR (38%), BJI (37%)
Pdiff	1569	VIE (33%), IDC (31%), BGR (16%), BRA (12%)
IVmb_VC	1403	MDD (100%)
SKPbc	1367	IDC (94%)
PKKP	1167	VIE (46%), IDC (34%)
PS	1161	MOS (35%), BELR (20%), CLL (18%)
PKPBC	1084	PRU (100%)
IVmB_BB	963	BER (69%), SSNC (28%)
Sgmax	862	NERS (100%)
AMP	786	BER (81%)
PPMZ	774	BJI (100%)
IVMs_BB	738	BER (89%)

Table 10.2: *(continued)*

Reported Phase	Total	Agencies reporting
PKPPKP	734	IDC (95%)
ScS	694	BJI (62%), BER (13%), IDC (12%)
END	679	ROM (99%)
SKSac	639	BER (28%), HYB (25%), CLL (13%)
PKPAB	632	PRU (100%)
PKHKP	590	MOS (99%)
Pdif	573	BJI (22%), CLL (13%), UCC (13%), INMG (12%)
SKP	571	IDC (47%), BELR (13%), VIE (13%)
LH	566	CLL (100%)
sPKP	556	BJI (78%), BELR (15%)
max	555	BYKL (100%)
SP	511	MOS (22%), BGR (20%), PRU (20%), BER (15%), BRG (11%)
PKPDF	490	PRU (100%)
*SS	435	MOS (100%)
SKKS	433	BJI (49%), BELR (47%)
SKKSac	425	HYB (76%), CLL (12%)
LV	423	CLL (100%)
pPKiKP	410	VIE (60%), BELR (27%)
pPKPbc	396	IDC (61%), BGR (29%)
*SP	386	MOS (100%)
PDIFF	386	PRU (68%), IPEC (27%)
e	377	BRA (100%)
tx	358	INMG (95%)
PKKPab	353	IDC (84%)
Pgmax	343	NERS (100%)
Px	329	MAN (78%), CLL (22%)
PKS	282	BJI (57%), BELR (27%), SVSA (12%)
PPS	271	CLL (62%), MOS (15%), LPA (13%)
PA	265	SSNC (100%)
AmB	240	KEA (100%)
p	232	ROM (61%), MAN (26%), LVSN (12%)
PKP2bc	221	IDC (100%)
SKKPbc	221	IDC (94%)
P'P'	209	VIE (100%)
pPKPdf	203	BER (23%), CLL (21%), INMG (16%)
SSSS	195	CLL (99%)
PmP	180	BGR (59%), ZUR (41%)
X	160	BGR (88%)
P3KPbc	159	IDC (100%)
Pb	150	BYKL (83%)
SKPdf	148	CLL (46%), BER (43%)
SKKP	147	BELR (55%), VIE (19%), IDC (12%)
LG	137	OTT (97%)
BAZ	134	DNK (95%)
SmS	131	BGR (64%), ZUR (36%)
pPP	121	LPA (64%), CLL (28%)
Sb	119	BYKL (76%), CLL (20%)
pPKPab	113	IDC (41%), CLL (40%), AWI (12%)
PCP	110	LPA (65%), PRU (28%)
P4KPbc	109	IDC (100%)
PcS	106	BJI (93%)
PKPpre	98	NEIC (76%), PRU (14%)
Sdif	85	CLL (62%), BRG (19%), BELR (12%)
SKPab	78	IDC (97%)
Sdiff	78	BGR (95%)
SKIKS	78	LPA (100%)
SKIKP	74	LPA (100%)
sPP	74	CLL (88%)
H	72	IDC (100%)
PKIKS	70	LPA (100%)
s	66	MAN (71%), LVSN (29%)
SCS	65	LPA (91%)
SME	64	BJI (100%)
SMN	64	BJI (100%)
PKP2ab	63	IDC (100%)
PPPP	62	CLL (97%)
pPdiff	59	VIE (76%)
sPKiKP	58	BELR (79%), CLL (14%)
Rg	57	NDI (56%), IDC (30%)
sSKS	56	BELR (100%)
PSKS	53	CLL (83%), BRG (17%)

Table 10.2: *(continued)*

Reported Phase	Total	Agencies reporting
m	50	SIGU (100%)
rx	46	INMG (61%), SKHL (22%), SVSA (17%)
r	45	BRG (100%)
(sP)	43	CLL (100%)
pPdif	41	CLL (27%), BELR (24%), BRG (22%), INMG (12%)
PgPg	41	BYKL (100%)
AMb	39	LVSN (100%)
Plp	37	CLL (100%)
PSP	36	LPA (100%)
ASPG	35	OSPL (100%)
ATPG	34	OSPL (100%)
SH	33	SYO (100%)
PKP1	33	PPT (100%)
ASSG	33	OSPL (100%)
SKSdf	33	HYB (61%), CLL (15%), BER (12%)
PKSbc	33	BGR (76%), CLL (15%)
SKPa	32	NAO (100%)
ATSG	32	OSPL (100%)
R2	31	CLL (100%)
PKPmax	30	CLL (100%)
PKPdif	29	CLL (93%)
SgSg	28	BYKL (100%)
sSS	28	CLL (79%), BRG (14%)
PKKPdf	27	CLL (59%), AWI (41%)
(S)	26	CFUSG (100%)
IAmbA	25	BGS (100%)
IAMLHF	25	BER (100%)
sPPP	24	CLL (100%)
BAZ-P	23	DNK (100%)
PKKS	23	BELR (96%)
(PKiKP)	22	CLL (100%)
(PP)	22	CLL (100%)
(P)	21	CFUSG (100%)
SKKSdf	19	CLL (84%)
PKSdf	19	BER (58%), CLL (42%)
SDIFF	19	LPA (100%)
AP	19	MOS (100%)
SPP	19	CLL (42%), BRG (37%), BELR (16%)
PKPPKPdf	18	CLL (100%)
P3KP	18	IDC (100%)
(SSS)	17	CLL (100%)
SDIF	16	PRU (100%)
sPKPdf	16	CLL (81%), BRG (19%)
(SS)	15	CLL (100%)
sPdif	15	CLL (53%), BELR (27%), BRG (13%)
SKKPdf	14	CLL (93%)
SKiKP	14	IDC (79%), UCC (21%)
e1	14	BRA (100%)
(pP)	14	CLL (100%)
(PKPdif)	13	CLL (100%)
(PKPdf)	13	CLL (100%)
PKPlp	13	CLL (100%)
SKSP	13	CLL (62%), BRG (38%)
sSSS	12	CLL (100%)
PPPrev	12	CLL (100%)
E	11	YARS (73%), SSNC (18%)
P*	11	MOS (45%), BGR (27%), BJI (27%)
(SSSS)	10	CLL (100%)
SKKSacre	10	CLL (100%)
(PKPbc)	9	CLL (100%)
P4KP	9	IDC (89%), NAO (11%)
Sx	9	CLL (100%)
BAZ-Pn	9	DNK (100%)
Pg_3	9	ATH (100%)
Sg_2	9	ATH (100%)
(PPS)	9	CLL (100%)
(Pdif)	8	CLL (100%)
(PKP)	8	CLL (100%)
(SKPdf)	8	CLL (100%)
sSdif	8	CLL (75%), BELR (12%), BRG (12%)
sPPS	8	CLL (100%)

Table 10.2: (continued)

Reported Phase	Total	Agencies reporting
SKPPKPdf	8	CLL (100%)
PPlp	8	CLL (100%)
Sglp	8	CLL (100%)
pS	8	CLL (38%), BELR (25%), LJU (25%), UCC (12%)
Pn_2	8	ATH (100%)
sPKPab	8	CLL (62%), AWI (38%)
(Pg)	7	CLL (86%), CFUSG (14%)
PSPS	7	CLL (100%)
PKPdfd	6	PJWWP (100%)
sPS	6	CLL (100%)
SKSSKSac	6	CLL (100%)
BAZ-Sn	6	DNK (100%)
sSSSS	6	CLL (100%)
sPKPbc	6	CLL (33%), BGR (33%), LJU (33%)
S4	6	SSNC (100%)
(PKPab)	6	CLL (100%)
SSmax	6	CLL (100%)
SSP	6	CLL (100%)
(PPPP)	6	CLL (100%)
PPmax	6	CLL (100%)
(pPKPab)	5	CLL (100%)
e2	5	BRA (100%)
Pn_0	5	ATH (100%)
R3	5	CLL (100%)
P'P'df	5	AWI (80%), LJU (20%)
SKKPab	5	IDC (100%)
sSKSac	4	CLL (75%), HYB (25%)
E-	4	INMG (100%)
Sg_1	4	ATH (100%)
(S	4	CFUSG (100%)
(pPKPbc)	4	CLL (100%)
pPKKPdf	4	CLL (100%)
SCP	4	IPEC (100%)
pPDIFF	4	IPEC (100%)
S*	4	BJI (75%), BGR (25%)
pPPS	4	CLL (100%)
(Sn)	4	CLL (100%)
(PS)	4	CLL (100%)
Pn_3	4	ATH (100%)
Pg_2	4	ATH (100%)
(PcP)	4	CLL (100%)
M	4	LJU (100%)
sPcP	4	CLL (100%)
pPKKPbc	4	CLL (100%)
sPKKPbc	4	CLL (100%)
(SKKSdf)	4	CLL (100%)
Sg_3	3	ATH (100%)
(Pn)	3	CLL (100%)
pPKPPKPd	3	CLL (100%)
PKPdfc	3	PJWWP (100%)
pSKSac	3	CLL (100%)
(SKKSac)	3	CLL (100%)
(pPKiKP)	3	CLL (100%)
PSKSrev	3	CLL (100%)
(sPP)	3	CLL (100%)
pPcP	3	CLL (100%)
(SP)	3	CLL (100%)
(PPP)	3	CLL (100%)
(PKSdf)	3	CLL (100%)
pP.	2	MAN (100%)
4	2	INMG (50%), NDI (50%)
(Sg)	2	CFUSG (50%), CLL (50%)
(sPdif)	2	CLL (100%)
SA	2	SJA (100%)
PKPc	2	PJWWP (100%)
(P	2	CFUSG (100%)
Slp	2	CLL (100%)
sSKKPdf	2	CLL (100%)
pPPPrev	2	CLL (100%)
XP	2	MOS (100%)
(sPPP)	2	CLL (100%)

Table 10.2: *(continued)*

Reported Phase	Total	Agencies reporting
(PSKS)	2	CLL (100%)
(SKKPdf)	2	CLL (100%)
pPPP	2	LJU (50%), CLL (50%)
(sPKiKP)	2	CLL (100%)
pSKS	2	BELR (100%)
(pPKPdf)	2	CLL (100%)
PSS	2	CLL (100%)
sSKPbc	2	CLL (100%)
pPn	2	BJI (100%)
(Sdif)	2	CLL (100%)
pPSKS	2	CLL (100%)
pPKKPab	2	CLL (100%)
(pPdif)	2	CLL (100%)
sSKKSacr	2	CLL (100%)
PKPbc(2)	2	CLL (100%)
PKKSbc	2	CLL (100%)
(sSSSS)	2	CLL (100%)
sSKPdf	2	CLL (100%)
pScS	1	CLL (100%)
PKPPKPab	1	CLL (100%)
sPKKPab	1	CLL (100%)
IAM	1	SJA (100%)
pPKSbc	1	CLL (100%)
pSP	1	BRG (100%)
Lq	1	NDI (100%)
Sk	1	CLL (100%)
pPmax	1	CLL (100%)
sPKPPKPd	1	CLL (100%)
Scs	1	NDI (100%)
pSKKSdf	1	CLL (100%)
sScP	1	CLL (100%)
P(2)	1	CLL (100%)
(sSKSac)	1	CLL (100%)
sSKKSdf	1	CLL (100%)
SKKSacr	1	CLL (100%)
sPn	1	BJI (100%)
PKPPcP	1	BRG (100%)
sPSPS	1	CLL (100%)
PSSrev	1	CLL (100%)
Pdifmax	1	CLL (100%)
pSKKPbc	1	CLL (100%)
sPSS	1	CLL (100%)
PKPPKPbc	1	CLL (100%)
Pg_4	1	ATH (100%)
SPS	1	CLL (100%)
PKPfd	1	INMG (100%)
sSKSP	1	CLL (100%)
PKiKPmax	1	CLL (100%)
PKPab(2)	1	CLL (100%)
(SKSac)	1	CLL (100%)
sSKSdf	1	BELR (100%)
(pS)	1	CLL (100%)
Sg_4	1	ATH (100%)
(Sb)	1	CLL (100%)
PKPKP	1	BRG (100%)
PKPPKPma	1	CLL (100%)
SKPd	1	NAO (100%)
P5KP	1	NAO (100%)
(PPPrev)	1	CLL (100%)
P4	1	SSNC (100%)
SSSmax	1	CLL (100%)
(pPSKS)	1	CLL (100%)
sPKKPdf	1	CLL (100%)
sSP	1	CLL (100%)
SKPPKPbc	1	CLL (100%)
PKPabd	1	PJWWP (100%)
IAMS_20	1	LJU (100%)
PKKSdf	1	CLL (100%)
(sSSS)	1	CLL (100%)
sSKKPbc	1	CLL (100%)
pSKKSac	1	CLL (100%)

Table 10.2: *(continued)*

Reported Phase	Total	Agencies reporting
(sSdif)	1	CLL (100%)
PKiKPd	1	PJWWP (100%)
pKPKdf	1	AWI (100%)
PPPPmax	1	CLL (100%)
sPPPP	1	CLL (100%)
XS	1	PRU (100%)
w-start	1	BRA (100%)
sSPP	1	CLL (100%)
PPPPrev	1	CLL (100%)
PnPn	1	INMG (100%)
(sPKPab)	1	CLL (100%)
(sSS)	1	CLL (100%)
PKSab	1	CLL (100%)
pScP	1	CLL (100%)
pP0	1	BER (100%)
PPP(2)	1	LPA (100%)
sSKKSac	1	CLL (100%)
sPSPSrev	1	CLL (100%)
AS	1	PRU (100%)

Table 10.3: Reporters of amplitude data

Agency	Number of reported amplitudes	Number of amplitudes in ISC located events	Number used for ISC mb	Number used for ISC MS
NEIC	980298	681846	227993	42282
IDC	576160	551897	129769	81245
ROM	504065	23325	0	0
AUST	292724	25286	10452	0
WEL	233100	25981	0	0
GFZ	215883	215029	87452	0
ATH	142751	16386	0	0
DJA	137764	105967	21712	0
MCSM	133435	100827	45879	0
MDD	116297	15542	0	0
AFAD	104999	12034	0	0
ISK	95561	17866	0	0
MOS	93370	90088	35424	9913
THE	93191	24561	0	0
RSNC	76901	24145	3968	0
BJI	76007	73402	18991	26555
NNC	73307	25908	76	0
VIE	59393	32694	11552	0
INMG	53600	28198	3191	0
SJA	42615	16621	0	0
SOME	38920	15882	2242	0
GUC	37850	9799	0	0
HEL	33941	1641	0	0
NOU	31921	31534	14336	0
TXNET	30458	730	0	0
SSNC	26311	3821	88	0
AWI	23189	8733	1793	0
DMN	16428	15362	0	0
JMA	15304	15200	0	0
PRU	14778	6201	213	3707
SVSA	13068	1196	463	0
PPT	13052	8437	456	0
TIR	12020	3792	328	0
LDG	11156	1361	0	0
TEH	10870	4880	0	0
PRE	9993	596	0	0
ZUR	9737	1364	0	0
NDI	8754	6746	1715	44
MRB	7897	240	0	0
BER	7735	2233	18	0
BUC	7713	2504	0	0
DNK	7536	3613	2639	15
OSPL	7309	2034	0	0
LJU	6893	639	6	2
SKHL	6804	2554	0	0
BKK	6179	4069	21	0

Table 10.3: *Continued.*

Agency	Number of reported amplitudes	Number of amplitudes in ISC located events	Number used for ISC mb	Number used for ISC MS
BYKL	6110	3911	0	0
ECX	6078	1303	0	0
KRSZO	5983	349	22	0
BELR	5969	3663	625	795
BGR	5530	5464	4005	0
CLL	5195	4955	348	1856
BGS	5091	3330	2607	460
PDG	4999	2567	0	0
NIC	4713	1329	0	0
KNET	3597	1362	0	0
YARS	3136	200	0	0
JSO	3120	1921	566	0
LVSN	3111	1669	6	892
BRG	3067	1632	0	0
ASGSR	2990	1379	0	0
BGSI	2688	573	0	0
UCC	2589	2415	1959	0
BRA	2557	1400	1094	0
IPEC	2349	560	0	0
NAO	2332	2288	1267	0
MIRAS	2293	72	0	0
WBNET	2188	24	0	0
SKO	2053	368	0	0
OTT	2024	100	0	0
SCB	1753	448	0	0
CFUSG	1354	1108	0	0
NERS	1207	207	0	0
MAN	1154	1050	0	0
KEA	911	538	0	75
IGIL	909	505	111	135
NAM	861	62	0	0
PLV	484	194	0	0
GCG	461	332	0	0
SIGU	423	334	0	0
ISN	399	389	0	0
THR	355	355	0	0
FCIAR	257	180	42	0
EAF	237	57	0	2
WAR	176	160	0	113
UPA	61	0	0	0
HYB	34	28	0	5
PJWWP	16	16	0	0

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Glossary of ISC Terminology

- ADSL

  An acronym for Agency.Deployment.Station.Location, a method of describing a seismic station. Allowing station coordinates to be distinguished by many more parameters.

- Agency/ISC data contributor

  An academic or government institute, seismological organisation or company, geological/meteorological survey, station operator or author that reports or contributed data in the past to the ISC or one of its predecessors. Agencies may contribute data to the ISC directly, or indirectly through other ISC data contributors.

- Agency code

  A unique, maximum eight-character code for a data reporting agency (e.g. NEIC, GFZ, BUD) or author (e.g. ISC, ISC-EHB, IASPEI). Often the agency code is the commonly used acronym of the reporting institute.

- Arrival

  A phase pick at a station is characterised by a phase name and an arrival time.

- Associated phase

  Associated phase arrival or amplitude measurements represent a collection of observations belonging to (i.e. generated by) an event. The complete set of observations are associated to the prime hypocentre.

- Azimuthal gap/Secondary azimuthal gap

  The azimuthal gap for an event is defined as the largest angle between two stations with defining phases when the stations are ordered by their event-to-station azimuths. The secondary azimuthal gap is the largest azimuthal gap a single station closes.

- BAAS

  Seismological bulletins published by the British Association for the Advancement of Science (1913-1917) under the leadership of H.H. Turner. These bulletins are the predecessors of the ISS Bulletins and include reports from stations distributed worldwide.

- Bulletin

  An ordered list of event hypocentres, uncertainties, focal mechanisms, network magnitudes, as well as phase arrival and amplitude observations associated to each event. An event bulletin may list all the reported hypocentres for an event. The convention in the ISC Bulletin is that the preferred (prime) hypocentre appears last in the list of reported hypocentres for an event.

- Catalogue

  An ordered list of event hypocentres, uncertainties and magnitudes. An event catalogue typically lists only the preferred (prime) hypocentres and network magnitudes.

- CoSOI/IASPEI

  Commission on Seismological Observation and Interpretation, a commission of IASPEI that prepares and discusses international standards and procedures in seismological observation and interpretation.

- Defining/Non-defining phase

  A defining phase is used in the location of the event (time-defining) or in the calculation of the network magnitude (magnitude-defining). Non-defining phases are not used in the calculations because they suffer from large residuals or could not be identified.

- Direct/Indirect report

  A data report sent (e-mailed) directly to the ISC, or indirectly through another ISC data contributor.

- Duplicates

  Nearly identical phase arrival time data reported by one or more agencies for the same station. Duplicates may be created by agencies reporting observations from other agencies, or several agencies independently analysing the waveforms from the same station.

- Event

  A natural (e.g. earthquake, landslide, asteroid impact) or anthropogenic (e.g. explosion) phenomenon that generates seismic waves and its source can be identified by an event location algorithm.

- Grouping

  The ISC algorithm that organises reported hypocentres into groups of events. Phases associated to any of the reported hypocentres will also be associated to the preferred (prime) hypocentre. The grouping algorithm also attempts to associate phases that were reported without an accompanying hypocentre to events.

- Ground Truth

  An event with a hypocentre known to certain accuracy at a high confidence level. For instance, GT0 stands for events with exactly known location, depth and origin time (typically explosions); GT5 stands for events with their epicentre known to 5 km accuracy at the 95% confidence level, while their depth and origin time may be known with less accuracy.

- Ground Truth database

  On behalf of IASPEI, the ISC hosts and maintains the IASPEI Reference Event List, a bulletin of ground truth events.

- IASPEI

  International Association of Seismology and Physics of the Earth Interior, www.iaspei.org.

- International Registry of Seismograph Stations (IR)

  Registry of seismographic stations, jointly run by the ISC and the World Data Center for Seismology, Denver (NEIC). The registry provides and maintains unique five-letter codes for stations participating in the international parametric and waveform data exchange.

- ISC Bulletin

  The comprehensive bulletin of the seismicity of the Earth stored in the ISC database and accessible through the ISC website. The bulletin contains both natural and anthropogenic events. Currently the ISC Bulletin spans more than 60 years (1960-to date) and it is constantly extended by adding both recent and past data. Eventually the ISC Bulletin will contain all instrumentally recorded events since 1900.

- ISC Governing Council

  According to the ISC Bye-laws: The Governing Council of the ISC is the forum of the Formal Representatives of all Members of the ISC.

- ISC-located events

  A subset of the events selected for ISC review are located by the ISC. The rules for selecting an event for location are described in Section 10.1.3 of Volume 58 Issue I of the ISC Summary; ISC-located events are denoted by the author ISC.

- ISC Member

  An academic or government institute, seismological organisation or company, geological/meteorological survey, station operator, national/international scientific organisation that contribute to the ISC budget by paying membership fees. ISC members have voting rights in the ISC Governing Council.

- ISC-PPSM

  ISC-PPSM (ISC - Probabilistic Point Source Model) is a catalogue of probabilistic point source models, comprising an earthquake depth, moment tensor and source time function, calculated at the ISC to address shallow moderate magnitude earthquake depths and monet tensor uncertainties, as well as adding new constraints on earthquake source time functions.

- ISC-reviewed events

  A subset of the events reported to the ISC are selected for ISC analyst review. These events may or may not be located by the ISC. The rules for selecting an event for review are described in Section 10.1.3 of Volume 58 Issue I of the ISC Summary. Non-reviewed events are explicitly marked in the ISC Bulletin by the comment following the prime hypocentre "Event not reviewed by the ISC".

- ISF

  International Seismic Format (www.isc.ac.uk/standards/isf). A standard bulletin format approved by IASPEI. The ISC Bulletin is presented in this format at the ISC website.

- ISS

  International Seismological Summary (1918-1963). These bulletins are the predecessors of the ISC Bulletin and represent the major source of instrumental seismological data before the digital era. The ISS contains regionally and teleseismically recorded events from several hundreds of globally distributed stations.

- Network magnitude

  The event magnitude reported by an agency or computed by the ISC locator. An agency can report several network magnitudes for the same event and also several values for the same magnitude type. The network magnitude obtained with the ISC locator is defined as the median of station magnitudes of the same magnitude type.

- Phase

  A maximum eight-character code for a seismic, infrasonic, or hydroacoustic phase. During the ISC processing, reported phases are mapped to standard IASPEI phase names. Amplitude measurements are identified by specific phase names to facilitate the computation of body-wave and surface-wave magnitudes.

- Prime hypocentre

  The preferred hypocentre solution for an event from a list of hypocentres reported by various agencies or calculated by the ISC.

- Reading

  Parametric data that are associated to a single event and reported by a single agency from a single station. A reading typically includes one or more phase names, arrival time and/or amplitude/period measurements.

- Report/Data report

  All data that are reported to the ISC are parsed and stored in the ISC database. These may include event bulletins, focal mechanisms, moment tensor solutions, macroseismic descriptions and other event comments, as well as phase arrival data that are not associated to events. Every single report sent to the ISC can be traced back in the ISC database via its unique report identifier.

- Shide Circulars

  Collections of station reports for large earthquakes occurring in the period 1899-1912. These reports were compiled through the efforts of J. Milne. The reports are mainly for stations of the British Empire equipped with Milne seismographs. After Milne's death, the Shide Circulars were replaced by the Seismological Bulletins of the BAAS.

- Station code

  A unique, maximum five-character code for a seismic station.

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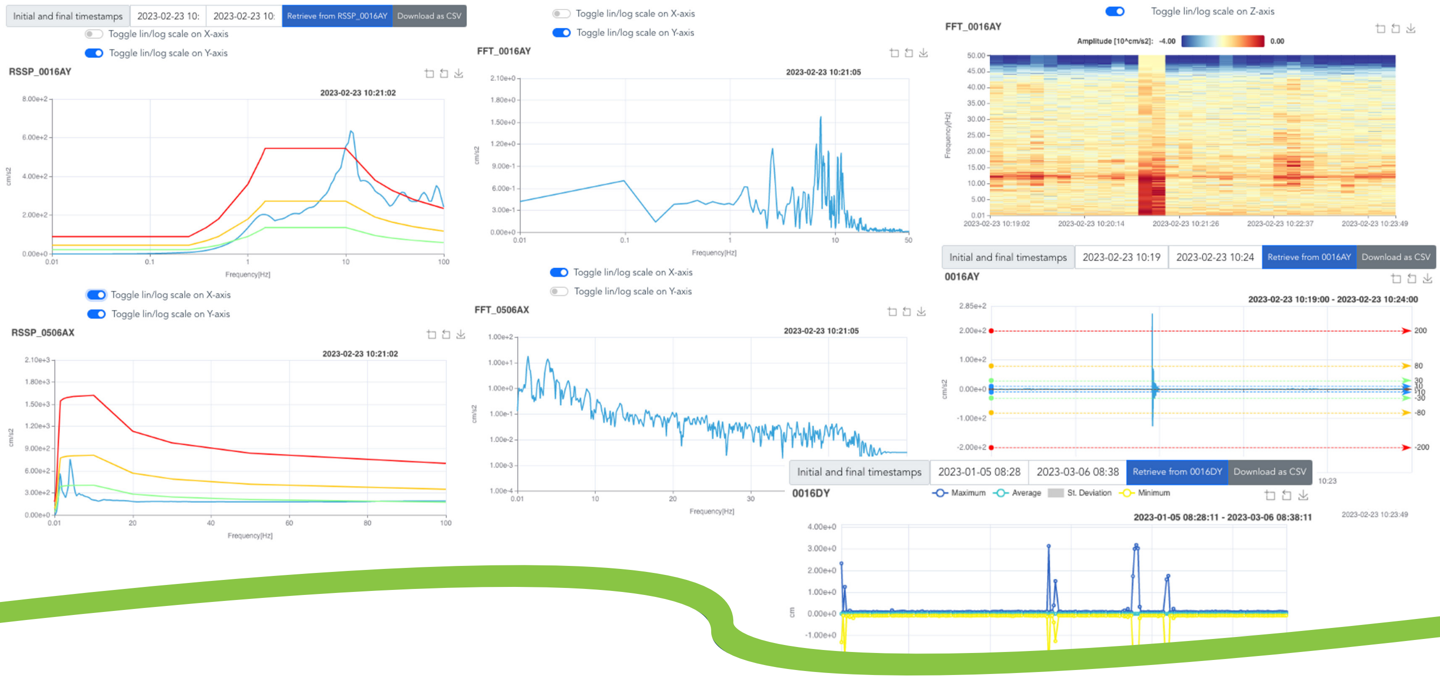

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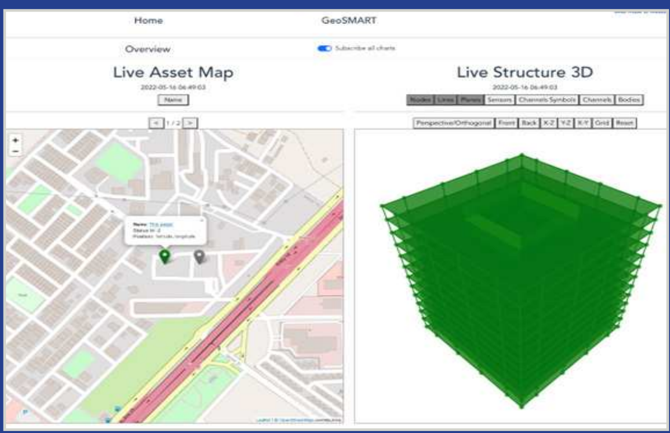

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What is a hybrid seismometer?

Typically, the output of seismic instruments is proportional either to the velocity or the acceleration of ground motions. Seismometers with velocity outputs are mostly used for measuring weak motions like seismic waves stemming from earthquakes at regional or teleseismic distances. On the other hand, instruments with acceleration output record strong motions and are commonly called accelerometers.

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