Summary of the Bulletin of the International Seismological Centre

2019

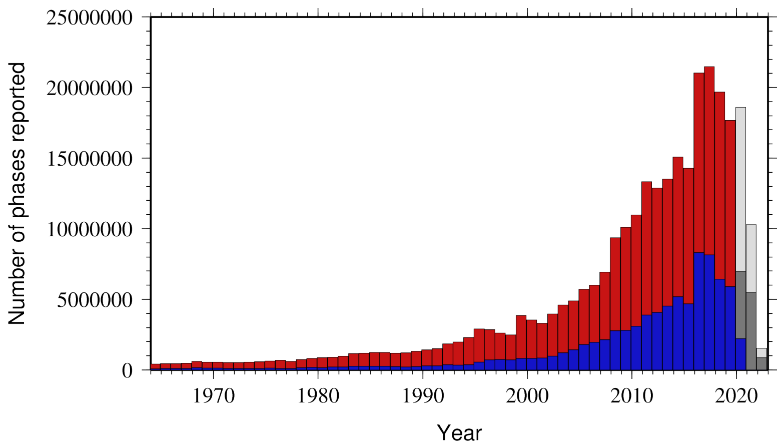
July – December

Volume 56 Issue II

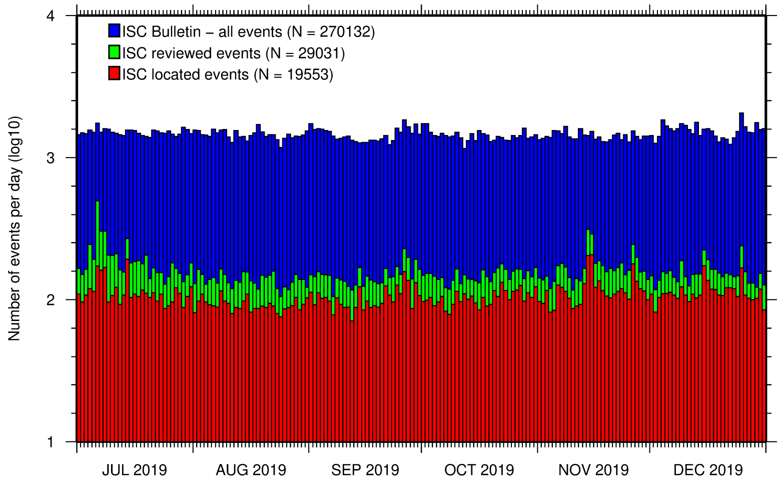
www.isc.ac.uk

ISSN 2309-236X

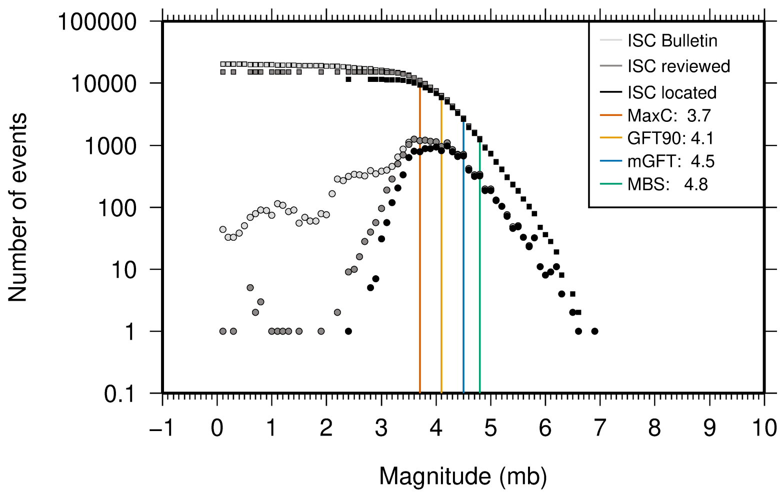
2022



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 6.3.



The number of events within the Bulletin for the current summary period. The vertical scale is logarithmic. See Section 7.1.



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 7.4.

Summary of the Bulletin of the International Seismological Centre

2019

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

Published by
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 FFB or ISF1 format:

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

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

Datafiles for the ISC data before the rebuild:

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

ftp://www.isc.ac.uk/pub/prerebuild/[isf|ffb]/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://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
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Thatcham
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ISSN 2309-236X

Printed and bound in Wales by Cambrian Printers.

Contents

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Preface

Dear Colleague,

This is the second 2019 issue of the Summary of the ISC Bulletin. The Bulletin remains the most fundamental reason for continued operations at the ISC. This issue of the Summary covers earthquakes and other seismic events that occurred during the period from July to December 2019. 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) available from the ISC website are now based on the ak135 velocity model and all ISC magnitudes (1964-present) are based on the latest robust procedures.

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)

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) (www.iaspei.org/projects/NMSOP.html).

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 130 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 50 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 EHB (*Engdahl et al.*, 1998) 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

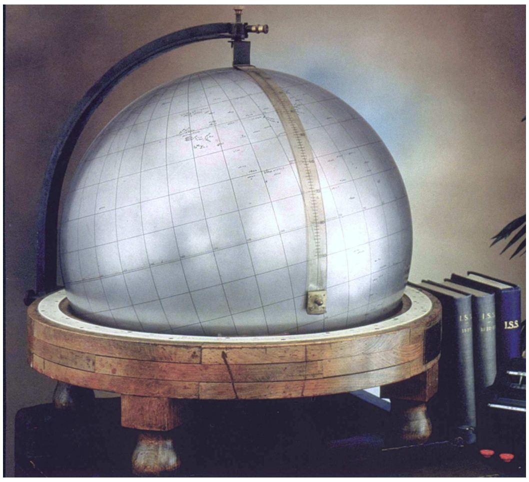


Figure 2.1: *The steel globe bearing positions of early seismic stations was used for locating positions of earthquakes for the International Seismological Summaries.*

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 almost 70, 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.

Throughout 2009-2011 a major internal reconstruction of the ISC building was undertaken to allow for more members of staff working in mainstream ISC operations as well as major development projects such as the CTBTO Link, ISC-GEM Catalogue and the ISC Bulletin Rebuild.

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

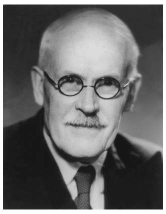
John Milne
Publisher of the Shide Cicular Reports on Earthquakes
1899-1913

Herbert Hall Turner

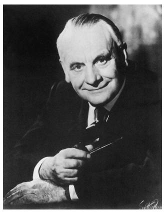
Seismological Bulletins of the BAAS

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

Article IV(a-b) of the ISC Working Statutes stipulates 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 with funding from its 70 Member Institutions and a four-year Grant Award EAR-1811737 from the US National Science Foundation.

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.

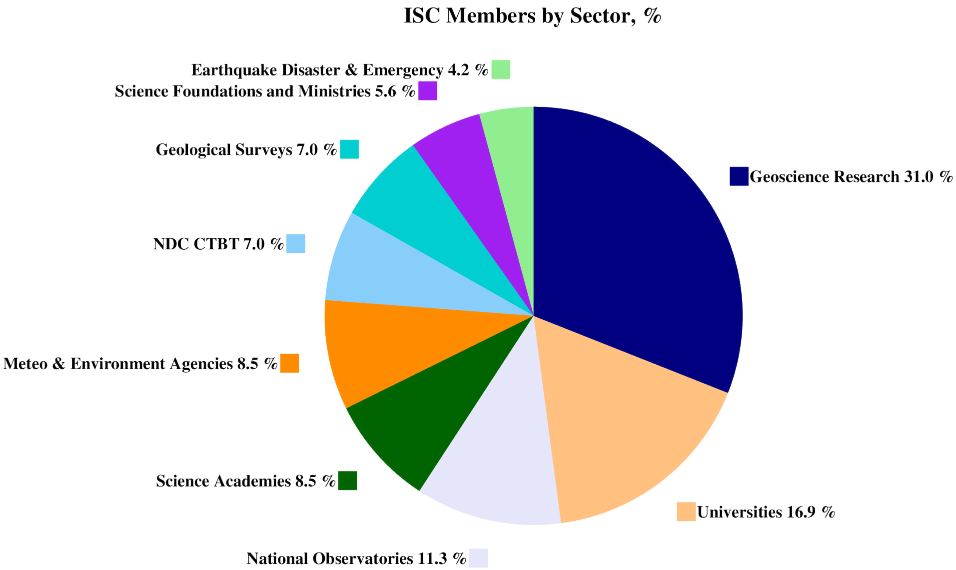


Figure 2.3: *Distribution of the ISC Member Institutions by sector in year 2013 as a percentage of total number of Members.*

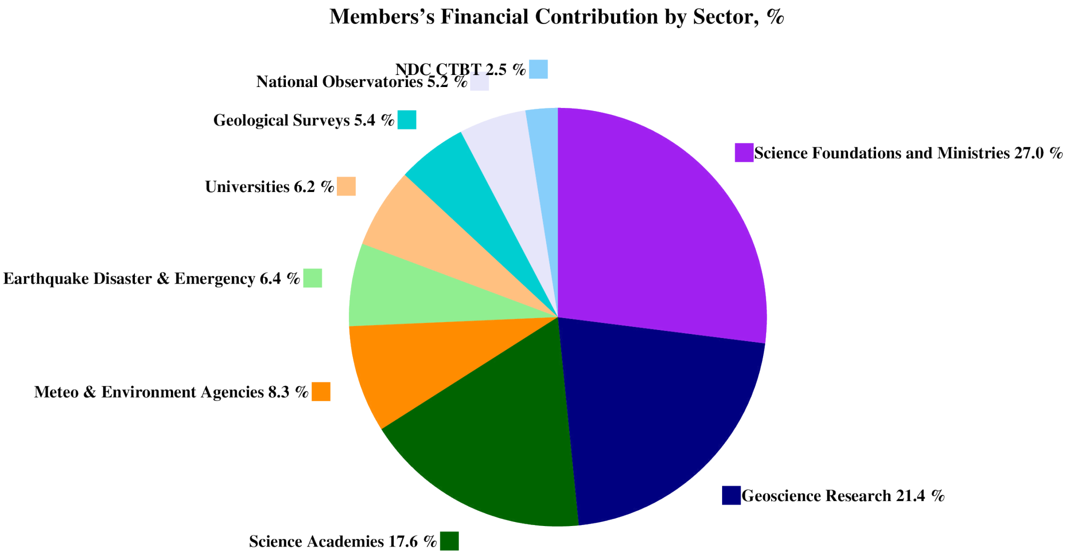


Figure 2.4: *Distribution of Member's financial contributions to the ISC by sector in year 2013 as a percentage of total annual Member contributions.*

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

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

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

Federal Ministry for Education, Science and Research
Austria

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

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

Seismological Observatory, Institute of Geosciences, University of Brasilia
Brazil
www.obsis.unb.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

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

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

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

Institute of Radiological and Nuclear Safety (IRSN), joint authority of the Ministries of Defense, the Environment, Industry, Research, and Health
France

Category: 1

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

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

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

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

Institute of Earth Physics and Space Science (EPSS), Hungarian Research Network (ELKH)
Hungary

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

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

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

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

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

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

Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE)
Mexico
resnom.cicese.mx
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 Centre for Earth Evolution and Dynamics (CEED), the University of Oslo
Norway

Category: 1

Stiftelsen NORSAR
Norway
www.norsar.no
Category: 2

The University of Bergen
Norway
www.uib.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

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: 1

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

Institute of Marine Sciences (ICM-CSIC)
Spain

Category: 1

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

AWE Blacknest
United Kingdom
www.blacknest.gov.uk
Category: 1

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

Incorporated Research Institutions for Seismology
U.S.A.
www.iris.edu
Category: 1

Alaska Earthquake Center (AEC), University of Alaska Fairbanks
U.S.A.

Category: 1

University of Utah Seismograph Stations (UUSS)
U.S.A.

Category: 1

The National Science Foundation of the United States. (Grant No. EAR-1811737)
U.S.A.
www.nsf.gov
Category: 9

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

National Earthquake Information Center, U.S. Geological Survey
U.S.A.
www.neic.usgs.gov
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, USGS (Award G18AP00035) and BGR.

2.5 Sponsoring Organisations

Article IV(c) of the ISC Working Statutes stipulates any commercial organisation with an interest in the objectives and/or output of the ISC may become an Associate Member of the ISC on payment of an Associate membership fee, but without entitlement to representation with a vote on the ISC's governing body.

REF TEK SYSTEMS INC. www.reftek.com

REF TEK designs and manufactures application specific, high-performance, battery-operated, field-portable geophysical data acquisition devices for the global market. With over 35 years of experience, REF TEK provides customers with complete turnkey solutions that include high resolution recorders, broadband sensors, state-of-the-art communications (V-SAT, GPRS, etc), installation, training, and continued customer support. Over 7,000 REF TEK instruments are currently being used globally for multiple applications. From portable earthquake monitoring to telemetry earthquake monitoring, earthquake aftershock recording to structural monitoring and more, REF TEK equipment is suitable for a wide variety of application needs.

GeoSIG swiss made to measure 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

泰德 TAIDE http://www.tai-de.com/en/

Zhuhai Taide Enterprise Co., Ltd. (Taide), a China based seismograph manufacturer, was set up in 1992. It is located in the city of Zhuhai, Guangdong Province, south-east China. The main products of Taide include data loggers, digitizers, all-band seismometers and accelerometers, intensity meters, magnetometers, strain meters, and software for earthquake related analysis. Over 80 professional engineers are employed at Taide, responsible for R&D, assembling and updating the hardware and software, and a team of 10 are engaged in stringent quality control and marketing.

In 2016, in collaboration with the Institute of Geophysics (China Earthquake Administration), Taide set up an Engineering Research Center for Earthquake Monitoring Techniques, aiming to improve the quality of earthquake observations. Taide-made instruments have been widely adapted by earthquake observation and monitoring networks, early warning systems, marine geophysical observation projects and deep borehole projects in China, as well as by seismograph networks in Indonesia, Nepal, Cuba, Pakistan and Kenya.

güralp http://www.guralp.com/

Güralp has been developing revolutionary force-feedback broadband seismic instrumentation for more than thirty years. Our sensors record seismic signals of all kinds, from teleseismic events occurring on the other side of the planet, to microseisms induced by unconventional hydrocarbon extraction. Our sophisticated digitisers record these signals with the highest resolution and accurate timing.

We supply individual instruments or complete seismic systems. Our services include field support such as installation and maintenance, to complete network and data management.

We design our instruments to meet increasingly complex requirements for deployment in the most challenging circumstances. As a result, you will find Güralp instruments gathering seismic data in the harshest of environments, from the Antarctic ice sheet; to boreholes 100s of metres deep; to the world's most active volcanoes and deepest ocean trenches.

SEISMOLOGY RESEARCH CENTRE http://src.com.au/

The Seismology Research Centre is an Australian earthquake observatory that began developing their own seismic recorders and data processing software in the late 1970s when digital recorders were uncommon. The Gecko is the SRC's 7th generation of seismic recorder, now available with a variety of integrated sensors to meet every monitoring requirement, including:

- Strong Motion Accelerographs
- 2Hz and 4.5Hz Blast Vibration Monitors
- Short Period 1Hz Seismographs

- Broadband 200s-1500Hz Optical Seismographs

Visit src.com.au/downloads/waves to grab a free copy of the SRC's MiniSEED waveform viewing and analysis software application, Waves.

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 5000 seismic units, 15000 acceleration transducers and 15000 geophysical exploration channels to thousands of professionals and researchers which are using our equipment with success. Providing low-cost instrumentation for developing countries is our main goal. We provided instruments from remote areas with radio telemetry to the Earth's depth such as a seismic array down to 285 meters in a borehole. Engineers use our systems to monitor historical monuments in Italy and in the middle east. Earthquake Early warning Systems in Italy and Turkey use our accelerometers and accelerographs. Our passion brings us to run our own seismic network including a small aperture seismic array in central Italy. 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. Visit our web site and download the free tools available at: www.sara.pg.it.

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 149 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

Instituto Nacional de Prevención Sísmica
Argentina
SJA

Universidad Nacional de La Plata
Argentina
LPA

National Survey of Seismic Protection
Armenia
NSSP

Curtin University
Australia
CUPWA

Geoscience Australia
Australia
AUST

Zentralanstalt für Meteorologie und Geodynamik (ZAMG)
Austria
VIE

International Data Centre, CTBTO
Austria
IDC

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
WBNET

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

Institute of Geophysics, Czech Academy of Sciences
Czech Republic
PRU

Korea Earthquake Administration
Democratic People's Republic of Korea
KEA

Geological Survey of Denmark and Greenland
Denmark
DNK

Universidad Autonoma de Santo Domingo
Dominican Republic
SDD

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

Institut de Physique du Globe de Paris
France
IPGP

EOST / RéNaSS
France
STR

Laboratoire de Géophysique/CEA
French Polynesia
PPT

Institute of Earth Sciences/ National Seismic Monitoring Center
Georgia
TIF

Seismological Observatory Berggießhübel, TU Bergakademie Freiberg
Germany
BRG

Alfred Wegener Institute for Polar and Marine Research
Germany
AWI

Geophysikalisches Observatorium Collm
Germany
CLL

Bundesanstalt für Geowissenschaften und Rohstoffe
Germany
BGR

Helmholtz Centre Potsdam GFZ German Research Centre For Geosciences
Germany
GFZ

National Observatory of Athens
Greece
ATH

Department of Geophysics, Aristotle University of Thessaloniki
Greece
THE

University of Patras, Department of Geology
Greece
UPSL

INSIVUMEH
Guatemala
GCG

Hong Kong Observatory
Hong Kong
HKC

Geodetic and Geophysical Reasearch Institute, Hungarian Academy of Sciences
Hungary
KRSZO

Icelandic Meteorological Office
Iceland
REY

National Geophysical Research Institute
India
HYB

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

Badan Meteorologi, Klimatologi dan Geofisika
Indonesia
DJA

Tehran University
Iran
TEH

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

Iraqi Meteorological and Seismology Organisation
Iraq
ISN

Dublin Institute for Advanced Studies
Ireland
DIAS

The Geophysical Institute of Israel
Israel
GII

Laboratory of Research on Experimental and Computational Seimology
Italy
RISSC

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

Istituto Nazionale di Geofisica e Vulcanologia
Italy
ROM

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

MedNet Regional Centroid - Moment Tensors
Italy
MED_RCMT

Jamaica Seismic Network
Jamaica
JSN

Japan Meteorological Agency
Japan
JMA

National Institute of Polar Research
Japan
SYO

National Research Institute for Earth Science and Disaster Resilience
Japan
NIED

Jordan Seismological Observatory
Jordan
JSO

National Nuclear Center
Kazakhstan
NNC

Seismological Experimental Methodological Expedition
Kazakhstan
SOME

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

Instituto de Geofísica de la UNAM
Mexico
MEX

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

Institute of Geophysics and Geology
Moldova
MOLD

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

Manila Observatory
Philippines
QCP

Philippine Institute of Volcanology and Seismology
Philippines
MAN

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

Institute of Geophysics, Polish Academy of Sciences
Poland
WAR

Sistema de Vigilância Sismológica dos Açores
Portugal
SVSA

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

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

Altai-Sayan Seismological Centre, GS SB RAS
Russia
ASRS

Geophysical Survey of Russian Academy of Sciences
Russia
MOS

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

Kamchatka Branch of the Geophysical Survey of the RAS
Russia
KRSC

Kola Regional Seismic Centre, GS RAS
Russia
KOLA

Sakhalin Experimental and Methodological Seismological Expedition, GS RAS
Russia
SKHL

Federal Center for Integrated Arctic Research
Russia
FCIAR

Yakutiya Regional Seismological Center, GS SB RAS
Russia
YARS

Baykal Regional Seismological Centre, GS SB RAS
Russia
BYKL

North Eastern Regional Seismological Centre, GS RAS
Russia
NERS

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

Institut Cartogràfic i Geològic de Catalunya
Spain
MRB

Instituto Geográfico Nacional
Spain
MDD

Real Instituto y Observatorio de la Armada
Spain
SFS

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	Disaster and Emergency Management Presidency Turkey AFAD
Kandilli Observatory and Research Institute Turkey ISK	IRIS Data Management Center U.S.A. IRIS	Red Sísmica de Puerto Rico U.S.A. RSPR
Texas Seismological Network, University of Texas at Austin U.S.A. TXNET	Pacific Northwest Seismic Network U.S.A. PNSN	National Earthquake Information Center U.S.A. NEIC
The Global CMT Project U.S.A. GCMT	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	

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

- Gary Job
- 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
- Zimbabwe

- 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

- Daniela Olaru
- Historical and Bibliographical Data Officer
- Romania/UK

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)
  (isc-mirror.iris.washington.edu/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.
- CD-ROMs/DVD-ROMs

  CDs/DVDs can be ordered from the ISC for any published volume (one per year), or for all back issues of the Bulletin (not including the latest volume). The data discs contain the Bulletin as a PDF, in IASPEI Seismic Format (ISF), and in Fixed Format Bulletin (FFB) format. An event catalogue is also included, together with the International Registry of seismic station codes.
- 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)
  (ftp://isc-mirror.iris.washington.edu)

Mirror service

A mirror of the ISC database, website and ftp site is available at IRIS DMC (isc-mirror.iris.washington.edu), which benefits from their high-speed internet connection, providing an alternative method of accessing the ISC Bulletin.

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:

4.1 The ISC Bulletin

International Seismological Centre (2022), 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 (2022), Summary of the Bulletin of the International Seismological Centre, July - December 2019, *56(II)*,https://doi.org/10.31905/QC1XQZ3T

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 (2022), IASPEI Reference Event (GT) List, https://doi.org/10.31905/32NSJF7V

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 (2022), ISC-GEM Earthquake Catalogue, https://doi.org/10.31905/d808b825, 2022.

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 (2022), 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

4.7 The ISC Event Bibliography

International Seismological Centre (2022), 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 (2022), International Seismograph Station Registry (IR), https://doi.org/10.31905/EL3FQQ40

4.9 Seismological Dataset Repository

International Seismological Centre (2022), 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, 2022.

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

Summary of Seismicity, July – December 2019

Regarding large seismic events, this Summary's time period was rather quiet with only three earthquakes larger than magnitude 7 (Tab. 5.1). The largest event was the shallow $M_W 7.2$ strike slip earthquake in Indonesia within the oceanic lithosphere of the Sunda plate (*USGS*, 2022) on 14 July (09:10:50.96 UTC, 0.6120°S, 128.0954°E, 14 km depth, 2130 stations (ISC)).

The most discussed earthquakes in the scientific community were the two largest events of the Ridgecrest sequence in California in July 2019 with currently 134 ($M_W 6.5$) and 163 entires ($M_W 7.0$) in the ISC Event Bibliography (*Di Giacomo et al.*, 2014; *International Seismological Centre*, 2022). 20 years after the previous larger earthquake in Southern California the Ridgecrest Sequence ruptured several unmapped intersecting orthogonal faults triggering shallow creep and an earthquake swarm in the close Garlock fault (*Ross et al.*, 2019; *Barnhart et al.*, 2019). The $M_w 6.5$ foreshock (2019/07/04 17:33:50.99 UTC, 35.6695°N, 117.5276°W, 12 km depth, 1961 stations (ISC)) occurred 34 hours before about 10 km away from the $M_W 7.0$ mainshock (2019/07/06 03:19:55.43 UTC, 35.7232°N, 117.6203°W, 9 km depth, 1771 stations (ISC)) with the rupture areas crossing each other: the largest structure ruptured by the main shock was a 55-km-long northwest-striking fault that is orthogonally cross-cut by a 15-km-long fault that was ruptured by the foreshock (*Ross et al.*, 2019). The main shock produced a slip of 5-9 m (*Ross et al.*, 2019; *Barnhart et al.*, 2019). These multifault ruptures are a significant challenge in regional seismic hazard assesment (*Ross et al.*, 2019).

Table 5.1: *Summary of the earthquakes of magnitude $M_W \geq 7$ between July and December 2019.*

Date	lat	lon	depth	Mw	Flinn-Engdahl Region
2019-07-14 09:10:50	-0.61	128.10	13	7.2	Halmahera
2019-11-14 16:17:42	1.56	126.33	48	7.1	Northern Molucca Sea
2019-07-06 03:19:55	35.72	-117.62	9	7.0	Central California

The number of events in this Bulletin Summary categorised by type are given in Table 5.2.

Figure 5.1 shows the number of moderate and large earthquakes in the second half of 2019. The distribution of the number of earthquakes should follow the Gutenberg-Richter law.

Figures 5.2 to 5.5 show the geographical distribution of moderate and large earthquakes in various magnitude ranges.

Table 5.2: Summary of events by type between July and December 2019.

felt earthquake	64
known earthquake	165256
known chemical explosion	8282
known induced event	3372
known landslide	6
known mine explosion	2632
known rockburst	790
known experimental explosion	175
suspected earthquake	77918
suspected chemical explosion	5862
suspected induced event	194
suspected mine explosion	5224
suspected rockburst	201
suspected experimental explosion	177
unknown	3
total	270156

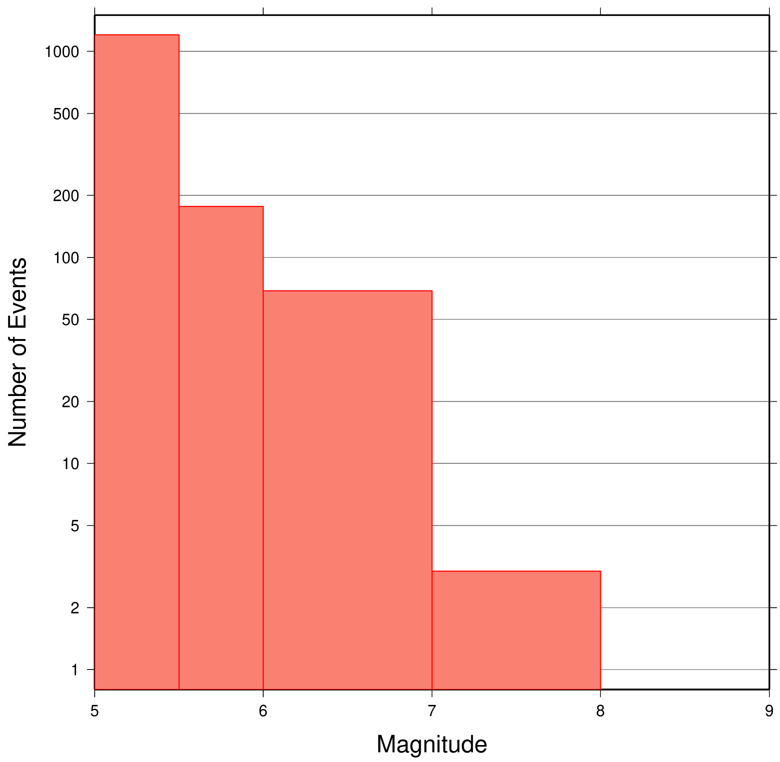


Figure 5.1: *Number of moderate and large earthquakes between July and December 2019. The non-uniform magnitude bias here correspond with the magnitude intervals used in Figures 5.2 to 5.5.*

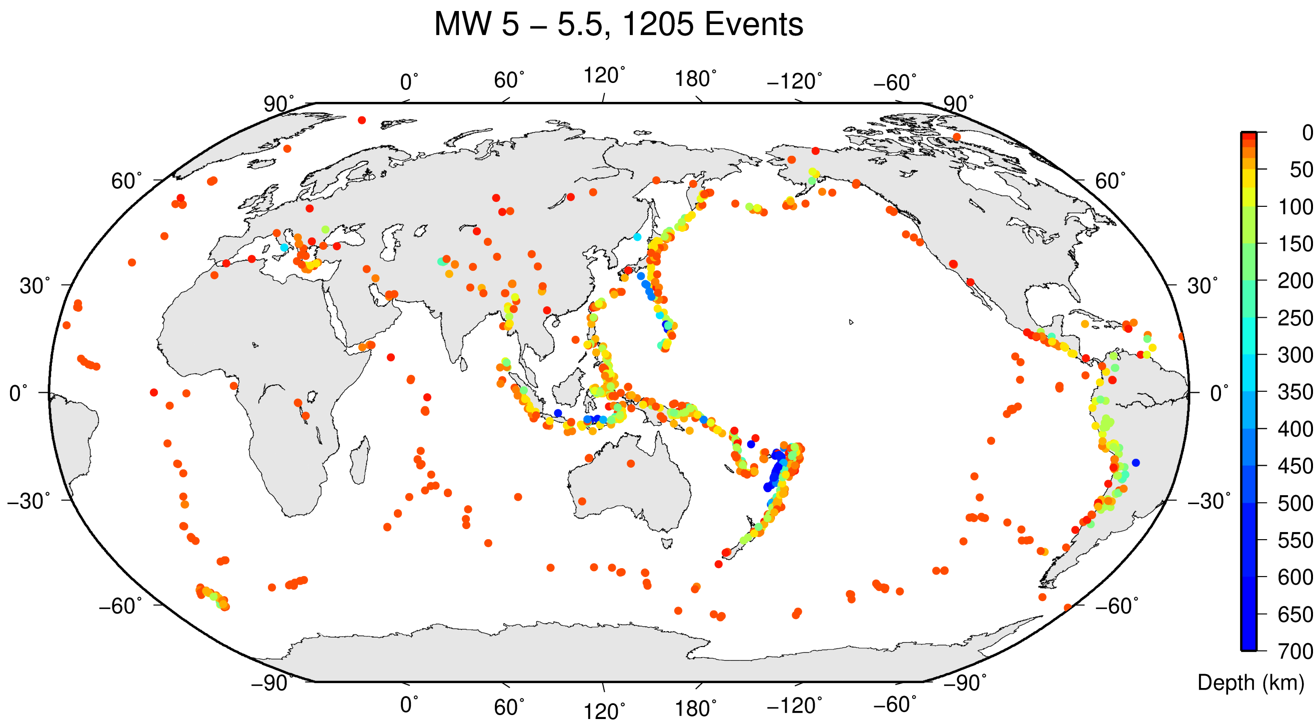


Figure 5.2: *Geographic distribution of magnitude 5-5.5 earthquakes between July and December 2019.*

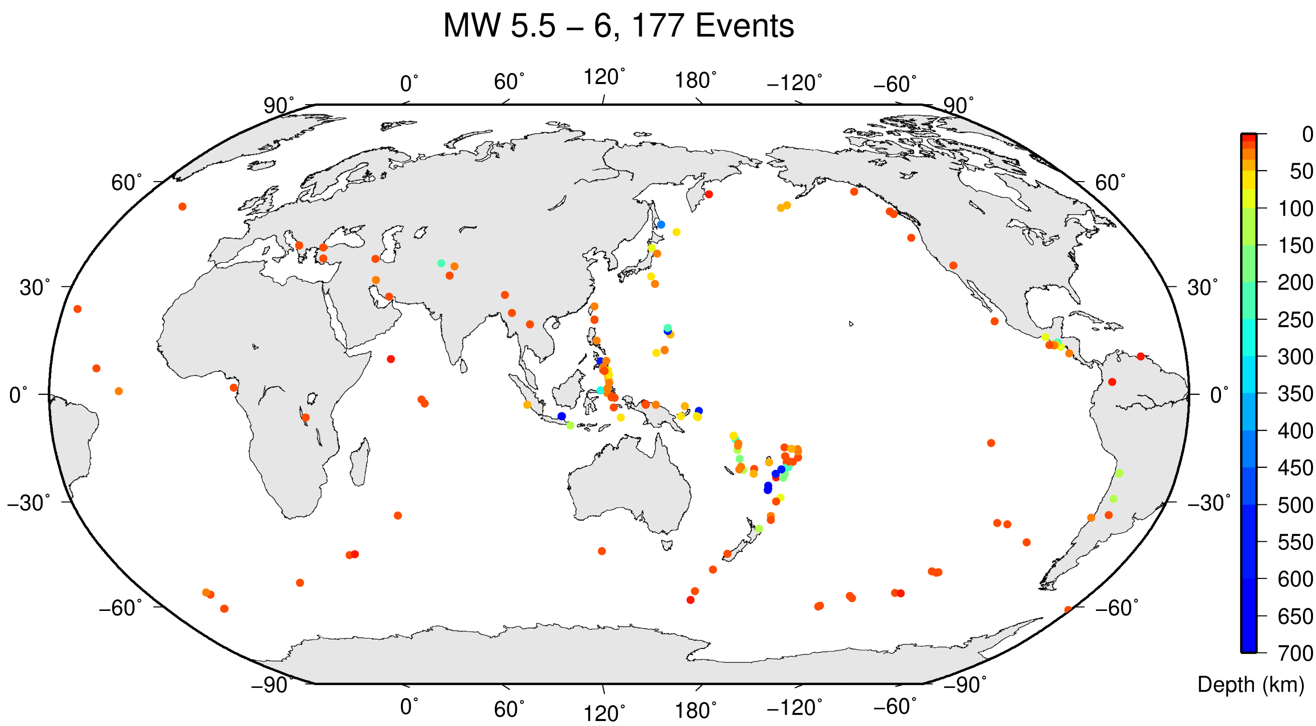


Figure 5.3: *Geographic distribution of magnitude 5.5-6 earthquakes between July and December 2019.*

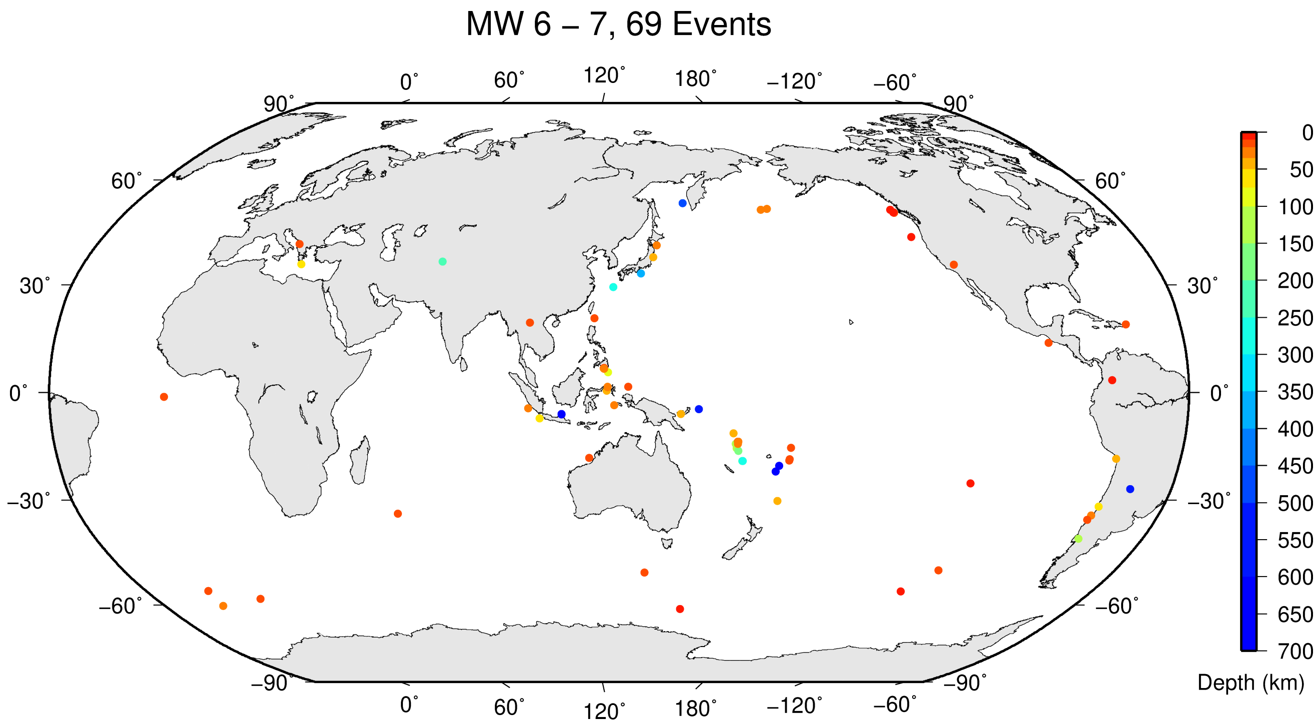


Figure 5.4: *Geographic distribution of magnitude 6-7 earthquakes between July and December 2019.*

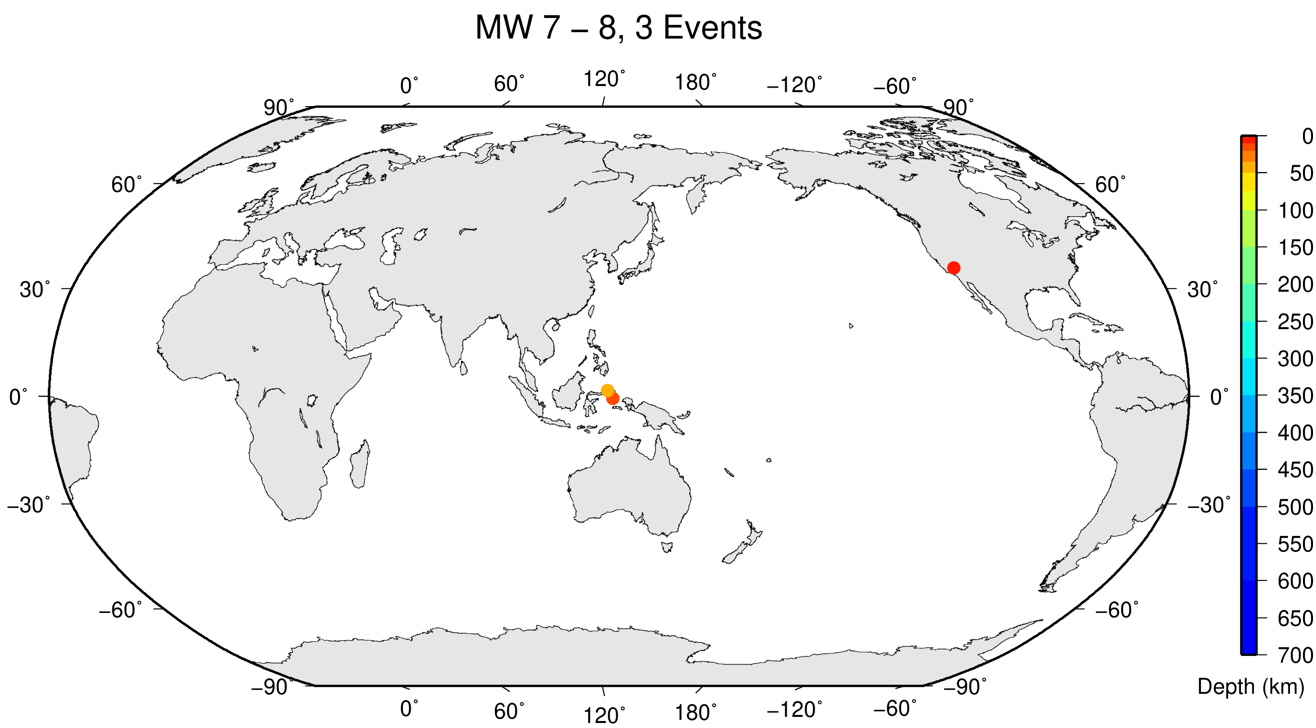


Figure 5.5: *Geographic distribution of magnitude 7-8 earthquakes between July and December 2019.*

References

Barnhart, W. D., G. P. Hayes and R. D. Gold (2019), The July 2019 Ridgecrest, California, earthquake sequence: Kinematics of slip and stressing in cross-fault ruptures, *Geophys. Res. Lett.*, *46*, 11859—11867, https://doi.org/10.1029/2019GL084741.

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6

Statistics of Collected Data

6.1 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.

6.2 Summary of Agency Reports to the ISC

A total of 149 agencies have reported data for July 2019 to December 2019. The parsing of these reports into the ISC database is summarised in Table 6.1.

Table 6.1: *Summary of the parsing of reports received by the ISC from a total of 149 agencies, containing data for this summary period.*

	Number of reports
Total collected	4717
Automatically parsed	2869
Manually parsed	1848

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 6.2, 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 6.1 and Figure 6.2.

Table 6.2: *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	1113	0	17625	0	4123
CRAAG	Algeria	D	144	0	1288	53	0
LPA	Argentina	D	0	0	0	212	0
SJA	Argentina	D	924	0	47198	27	13332
NSSP	Armenia	D	55	1	1116	0	0
AUST	Australia	D	1141	0	65582	0	59692
CUPWA	Australia	D	31	0	398	0	0
IDC	Austria	D	16920	1	564992	0	503513
VIE	Austria	D	4961	83	49017	978	49679
AZER	Azerbaijan	D	203	0	8638	0	0
UCC	Belgium	D	817	0	6982	24	1887
SCB	Bolivia	D	867	0	12702	0	1960
RHSSO	Bosnia and Herzegovina	D	837	8	10184	2893	0
BGSI	Botswana	D	551	0	6277	0	1524
OSUNB	Brazil	D	142	0	5514	0	0
VAO	Brazil	D	931	38	23108	0	0
SOF	Bulgaria	D	221	0	2835	2961	0
OTT	Canada	D	1469	16	47410	0	4221
PGC	Canada	I OTT	889	0	33498	0	0
GUC	Chile	D	3926	333	111772	7942	33533
BJI	China	D	1235	25	111686	32369	77698
ASIES	Chinese Taipei	D	0	34	0	0	0
TAP	Chinese Taipei	D	14954	0	707466	0	0
RSNC	Colombia	D	13677	45	236162	662	46996
UCR	Costa Rica	D	594	0	32727	0	6
ZAG	Croatia	D	0	0	0	47161	0
SSNC	Cuba	D	1124	0	23410	0	9044
NIC	Cyprus	D	345	0	11599	0	4808
IPEC	Czech Republic	D	538	4	4623	21913	2131
PRU	Czech Republic	D	4450	11	41525	189	9543
WBNET	Czech Republic	D	230	0	4477	22	4499
KEA	Democratic People's Republic of Korea	D	77	0	853	0	455
DNK	Denmark	D	2224	1745	31376	22743	7648
OSPL	Dominican Republic	D	1153	0	13920	0	4236
SDD	Dominican Republic	D	1747	0	35449	41	13388
IGQ	Ecuador	D	125	0	5614	0	0
HLW	Egypt	D	447	1	3520	6	0
SNET	El Salvador	D	1470	3	25185	10	897
EST	Estonia	I HEL	193	32	0	0	0
FIA0	Finland	I HEL	2	0	0	0	0
HEL	Finland	D	7235	973	182857	0	33019
CSEM	France	I BGR	2470	176	0	0	0
IPGP	France	D	0	139	0	0	0
LDG	France	D	2310	113	34395	0	15118

Table 6.2: *(continued)*

Agency	Country	Directly or indirectly reporting (D/I)	Hypocentres with associated phases	Hypocentres without associated phases	Associated phases	Unassociated phases	Amplitudes
STR	France	D	3179	2	70158	99	0
PPT	French Polynesia	D	1356	7	12633	55	12620
TIF	Georgia	D	0	89	0	1502	0
AWI	Germany	D	5104	1	22773	1402	10511
BGR	Germany	D	613	311	16978	31	4843
BNS	Germany	I BGR	4	18	0	0	0
BRG	Germany	D	0	0	0	11363	3868
BUG	Germany	I BGR	0	47	0	0	0
CLL	Germany	D	2	0	45	8244	2893
GDNRW	Germany	I BGR	1	5	0	0	0
GFZ	Germany	D	40	65	0	0	0
HLUG	Germany	I BGR	4	3	0	0	0
LEDBW	Germany	I BGR	54	5	0	0	0
ATH	Greece	D	8089	31	219708	0	61446
THE	Greece	D	2359	1	54077	3219	41898
UPSL	Greece	D	0	6	0	0	0
GCG	Guatemala	D	4445	61	46193	234	6982
HKC	Hong Kong	D	0	0	0	34	0
KRSZO	Hungary	D	552	324	9723	0	3571
REY	Iceland	D	34	0	1443	0	0
HYB	India	D	648	25	1809	0	244
NDI	India	D	757	565	28213	37	11546
DJA	Indonesia	D	6694	38	104547	0	102796
TEH	Iran	D	5990	0	49780	0	0
THR	Iran	D	111	0	2940	0	1391
ISN	Iraq	D	227	0	2149	0	644
DIAS	Ireland	D	0	0	0	720	0
GII	Israel	D	2168	0	45561	0	0
GEN	Italy	D	839	0	18122	24	0
MED_RCMT	Italy	D	0	188	0	0	0
RISSC	Italy	D	8	0	166	0	0
ROM	Italy	D	8901	112	786312	265866	525218
TRI	Italy	D	0	0	0	9572	0
JSN	Jamaica	D	196	6	608	0	0
JMA	Japan	D	86999	3793	573002	0	11342
NIED	Japan	D	0	573	0	0	0
SYO	Japan	D	0	0	0	1765	0
JSO	Jordan	D	119	0	1719	0	59
NNC	Kazakhstan	D	8303	28	77523	11	72617
SOME	Kazakhstan	D	4143	180	48072	0	37999
KNET	Kyrgyzstan	D	876	0	7283	0	2666
KRNET	Kyrgyzstan	D	2298	0	41082	0	0
LVSN	Latvia	D	145	0	2112	0	1346
GRAL	Lebanon	D	180	0	1747	794	0
LIT	Lithuania	D	572	515	4040	347	2
MCO	Macao, China	D	0	0	0	14	0
TAN	Madagascar	D	1093	0	11250	0	0
ECX	Mexico	D	725	0	18926	0	4141
MEX	Mexico	D	12412	91	224540	189	0
MOLD	Moldova	D	0	0	0	1874	931
PDG	Montenegro	D	1117	0	24621	9	12271
CNRM	Morocco	D	1530	1	17611	0	0
NAM	Namibia	D	40	0	588	6	186
DMN	Nepal	D	137	0	2413	0	1014
NOU	New Caledonia	D	3918	0	74333	0	2661
WEL	New Zealand	D	10107	44	314797	22606	238983
CATAC	Nicaragua	D	2193	0	79693	14	0
SKO	North Macedonia	D	690	0	10609	1956	1978
BER	Norway	D	2167	1569	41452	5731	9400
NAO	Norway	D	2169	651	5006	0	2067
OMAN	Oman	D	624	0	31565	0	0
UPA	Panama	D	911	3	19844	9	1201
ARE	Peru	I RSNC	1	0	0	0	0
MAN	Philippines	D	0	43	0	0	0
QCP	Philippines	D	0	0	0	287	0
PJWWP	Poland	D	140	0	296	0	23

Table 6.2: *(continued)*

Agency	Country	Directly or indirectly reporting (D/I)	Hypocentres with associated phases	Hypocentres without associated phases	Associated phases	Unassociated phases	Amplitudes
WAR	Poland	D	0	0	0	7164	368
IGIL	Portugal	D	824	0	3664	0	1137
INMG	Portugal	D	1815	0	89205	19985	46320
SVSA	Portugal	D	1569	0	54284	15115	43990
BELR	Republic of Belarus	D	0	0	0	21660	7216
CFUSG	Republic of Crimea	D	65	0	1262	434	1007
KMA	Republic of Korea	D	14	0	281	0	0
BUC	Romania	D	797	40	19312	74753	8239
ASRS	Russia	D	148	3564	5109	0	1866
BYKL	Russia	D	68	0	9310	0	3183
DRS	Russia	I MOS	191	160	0	0	0
FCIAR	Russia	D	148	0	1299	789	471
IDG	Russia	I MOS	0	8	0	0	0
KOLA	Russia	D	1615	133	15351	26	0
KRSC	Russia	D	665	0	21720	0	0
MIRAS	Russia	D	42	7	1385	0	616
MOS	Russia	D	2846	4053	306874	1	103993
NERS	Russia	D	100	0	2184	0	986
NORS	Russia	I MOS	12	156	0	0	0
SKHL	Russia	D	1057	1066	21773	2	9442
VKMS	Russia	I MOS	0	21	0	0	0
YARS	Russia	D	509	45	5220	0	3844
SGS	Saudi Arabia	D	3048	0	46446	56	0
BEO	Serbia	D	1595	13	40536	0	0
BRA	Slovakia	D	0	0	0	18872	0
LJU	Slovenia	D	1699	30	17907	3561	6522
PRE	South Africa	D	1719	0	41434	449	13776
MDD	Spain	D	3478	5	84522	0	22907
MRB	Spain	D	569	0	15994	203	7105
SFS	Spain	D	1355	0	23799	38	0
UPP	Sweden	D	3223	1518	38342	0	0
ZUR	Switzerland	D	1402	1	36136	0	21816
BKK	Thailand	D	335	12	2031	0	3013
TRN	Trinidad and Tobago	D	1178	7	17803	27417	0
TUN	Tunisia	D	34	0	194	0	0
AFAD	Turkey	D	11044	1	273531	1	96034
ISK	Turkey	D	8502	0	134156	1478	74577
AEIC	U.S.A.	I NDI	2145	1247	79636	0	0
ANF	U.S.A.	I IRIS	291	807	0	0	0
BUT	U.S.A.	I NEIC	0	68	2008	0	0
GCMT	U.S.A.	D	0	2420	0	0	0
HVO	U.S.A.	I NEIC	261	24	17457	0	0
IRIS	U.S.A.	D	1980	807	276366	0	0
LDO	U.S.A.	I NEIC	0	19	152	0	0
NCEDC	U.S.A.	I NEIC	78	2	10145	0	0
NEIC	U.S.A.	D	17311	10151	1709597	0	898427
PAS	U.S.A.	I NEIC	940	2	73037	0	0
PMR	U.S.A.	I IRIS	13	0	0	0	0
PNSN	U.S.A.	D	0	119	0	0	0
REN	U.S.A.	I NEIC	52	16	2234	0	0
RSPR	U.S.A.	D	3969	1334	75179	0	0
SEA	U.S.A.	I NEIC	44	8	3212	0	0
SLM	U.S.A.	I NEIC	1	61	1767	0	0
TXNET	U.S.A.	D	3810	54	54626	1131	24621
UUSS	U.S.A.	I NEIC	62	8	1451	0	0
MCSM	Ukraine	D	839	125	16281	0	7890
SIGU	Ukraine	D	29	31	846	0	400
DSN	United Arab Emirates	D	527	0	6984	0	0
BGS	United Kingdom	D	285	22	8026	0	3322
ISC-PPSM	United Kingdom	D	0	99	0	0	0
ISU	Uzbekistan	D	629	0	4060	46	0

Table 6.2: *(continued)*

Agency	Country	Directly or indirectly reporting (D/I)	Hypocentres with associated phases	Hypocentres without associated phases	Associated phases	Unassociated phases	Amplitudes
FUNV	Venezuela	D	862	0	7315	0	0
PLV	Viet Nam	D	53	6	720	0	348
BUL	Zimbabwe	D	185	0	1520	69	0

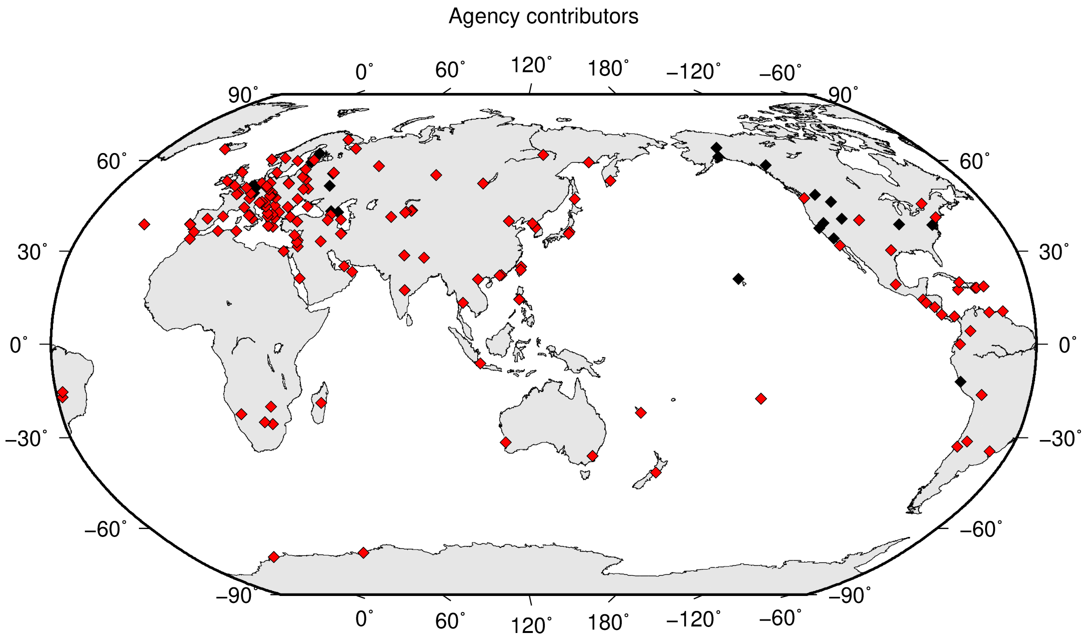


Figure 6.1: *Map of agencies that have contributed data to the ISC for this summary period. Agencies that have reported directly to the ISC are shown in red. Those that have reported indirectly (via another agency) are shown in black. Any new or renewed agencies, since the last six-month period, are shown by a star. Each agency is listed in Table 6.2.*

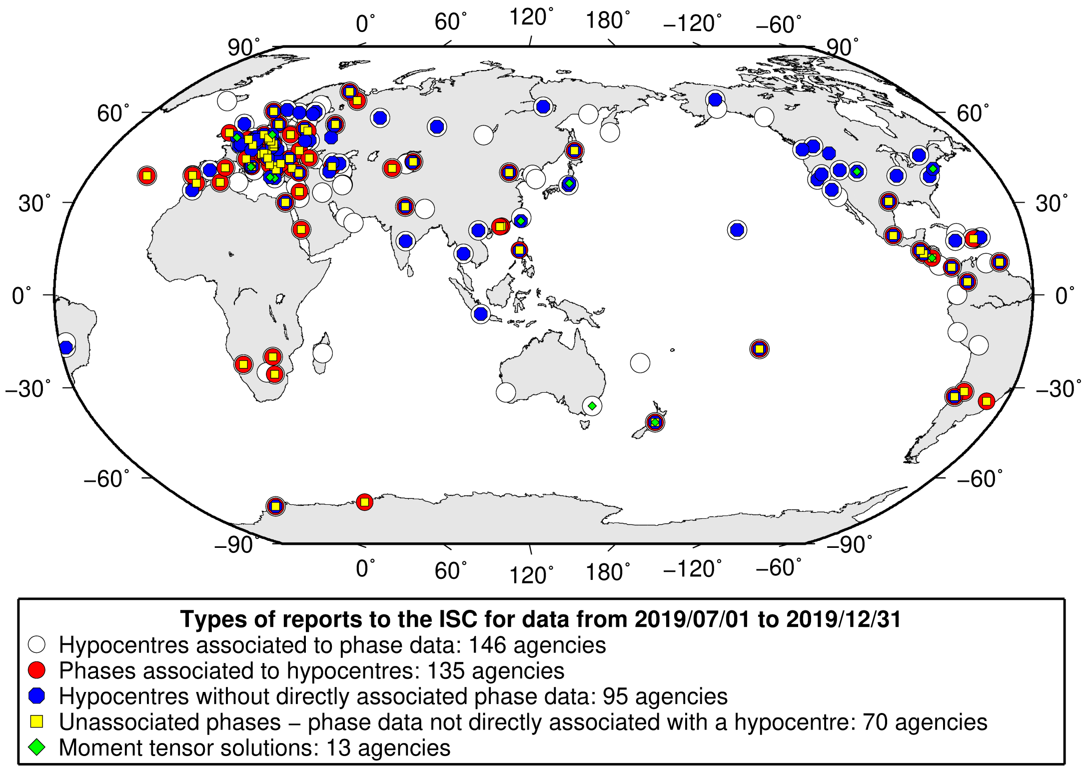


Figure 6.2: *Map of the different data types reported by agencies to the ISC. A full list of the data types reported by each agency is shown in Table 6.2.*

6.3 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 6.3.

The reports with phase data are summarised in Table 6.3. 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 6.4.

The ISC encourages the reporting of phase arrival times together with amplitude and period measurements whenever feasible. Figure 6.5 shows the percentage of events for which phase arrival times from each station are accompanied with amplitude and period measurements.

Figure 6.6 indicates the number of amplitude and period measurement for each station.

Together with the increase in the number of phases (Figure 6.3), 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 6.7. This increase can also be seen on the maps for stations reported each decade in Figure 6.8.

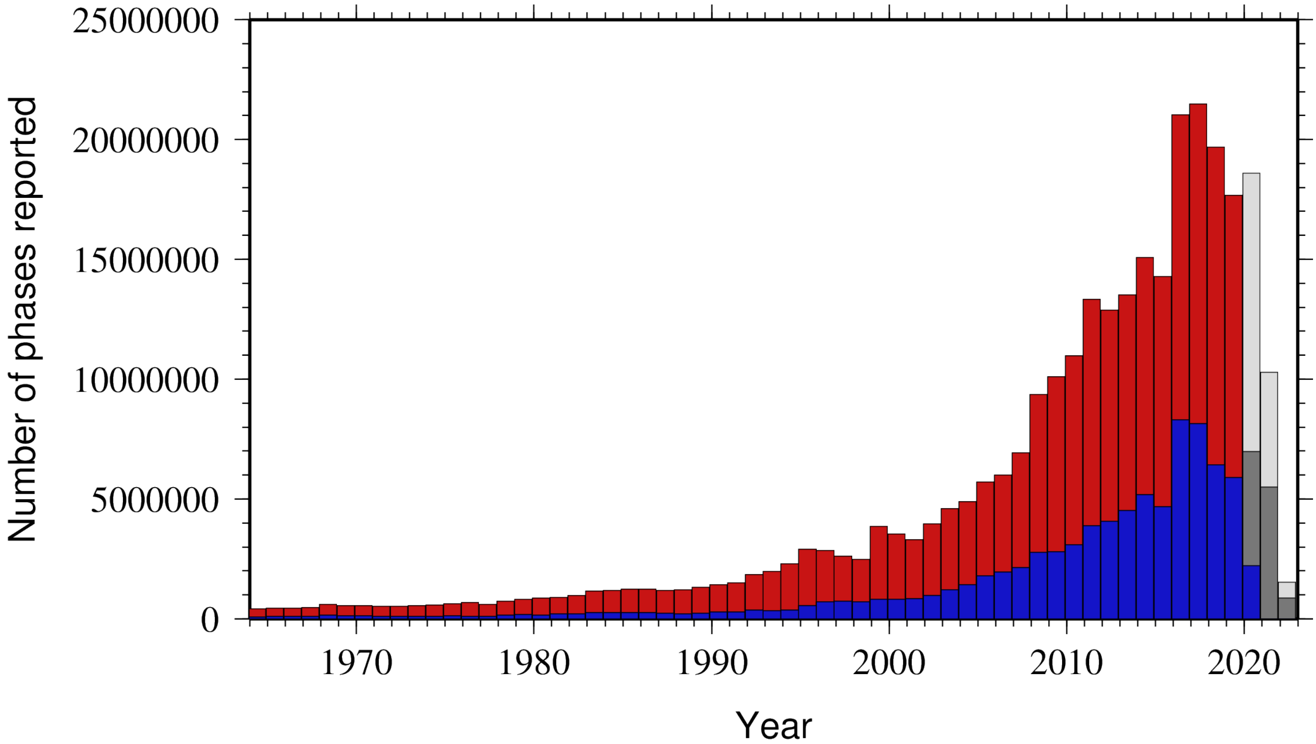


Figure 6.3: *Histogram showing the number of phases (red) and number of amplitudes (blue) collected by the ISC for events each year since 1964. The data in grey covers the current period where data are still being collected before the ISC review takes place and is accurate at the time of publication.*

Table 6.3: *Summary of reports containing phase arrival observations.*

Reports with phase arrivals	4197
Reports with phase arrivals including amplitudes	3633
Reports with only phase arrivals (no hypocentres reported)	177
Total phase arrivals received	9515116
Total phase arrival-times received	8784889
Number of duplicate phase arrival-times	711438 (8.1%)
Number of amplitudes received	3436774
Stations reporting phase arrivals	9828
Stations reporting phase arrivals with amplitude data	5572
Max number of stations per report	2292

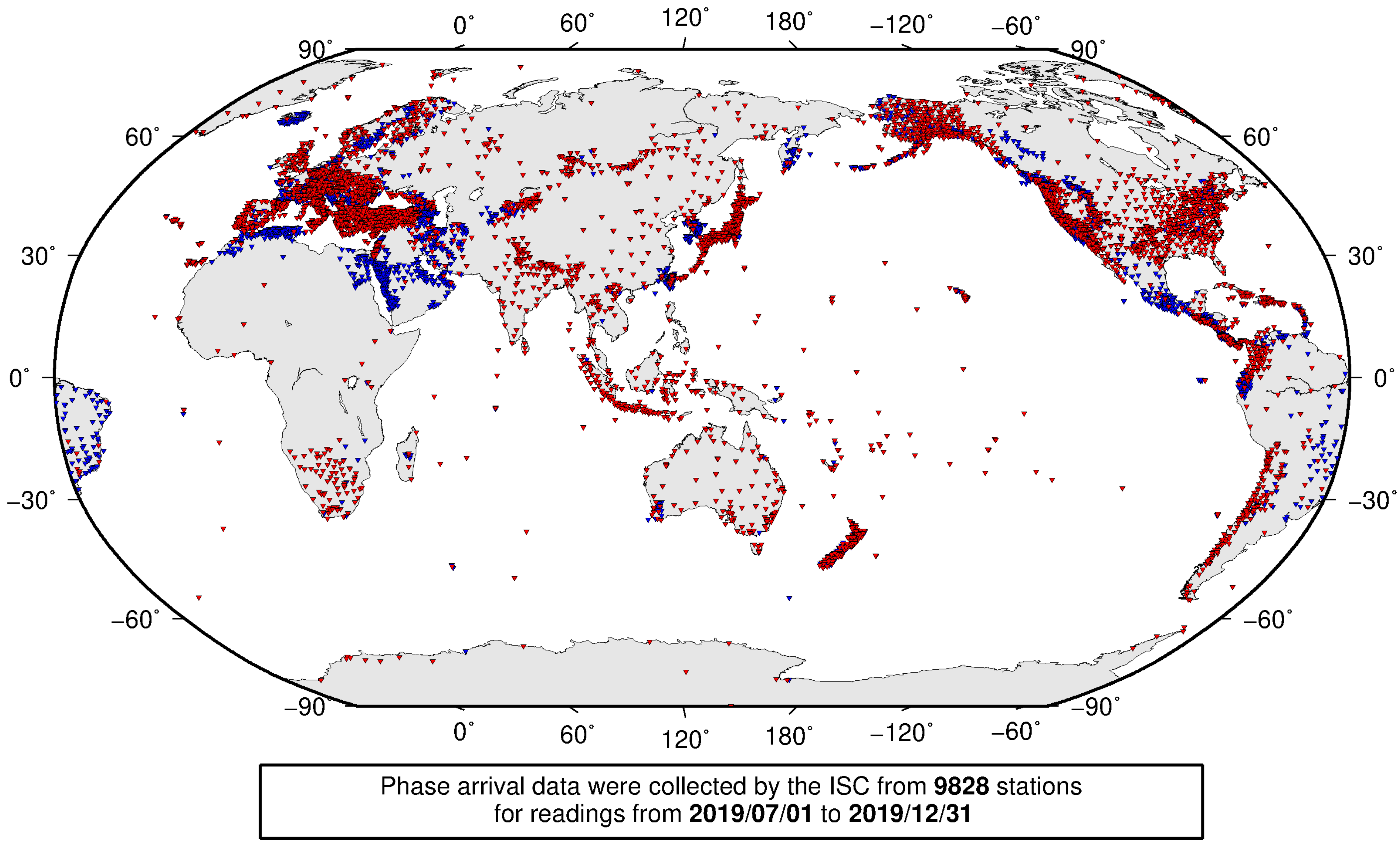


Figure 6.4: *Stations contributing phase data to the ISC for readings from July 2019 to the end of December 2019. Stations in blue provided phase arrival times only; stations in red provided both phase arrival times and amplitude data.*

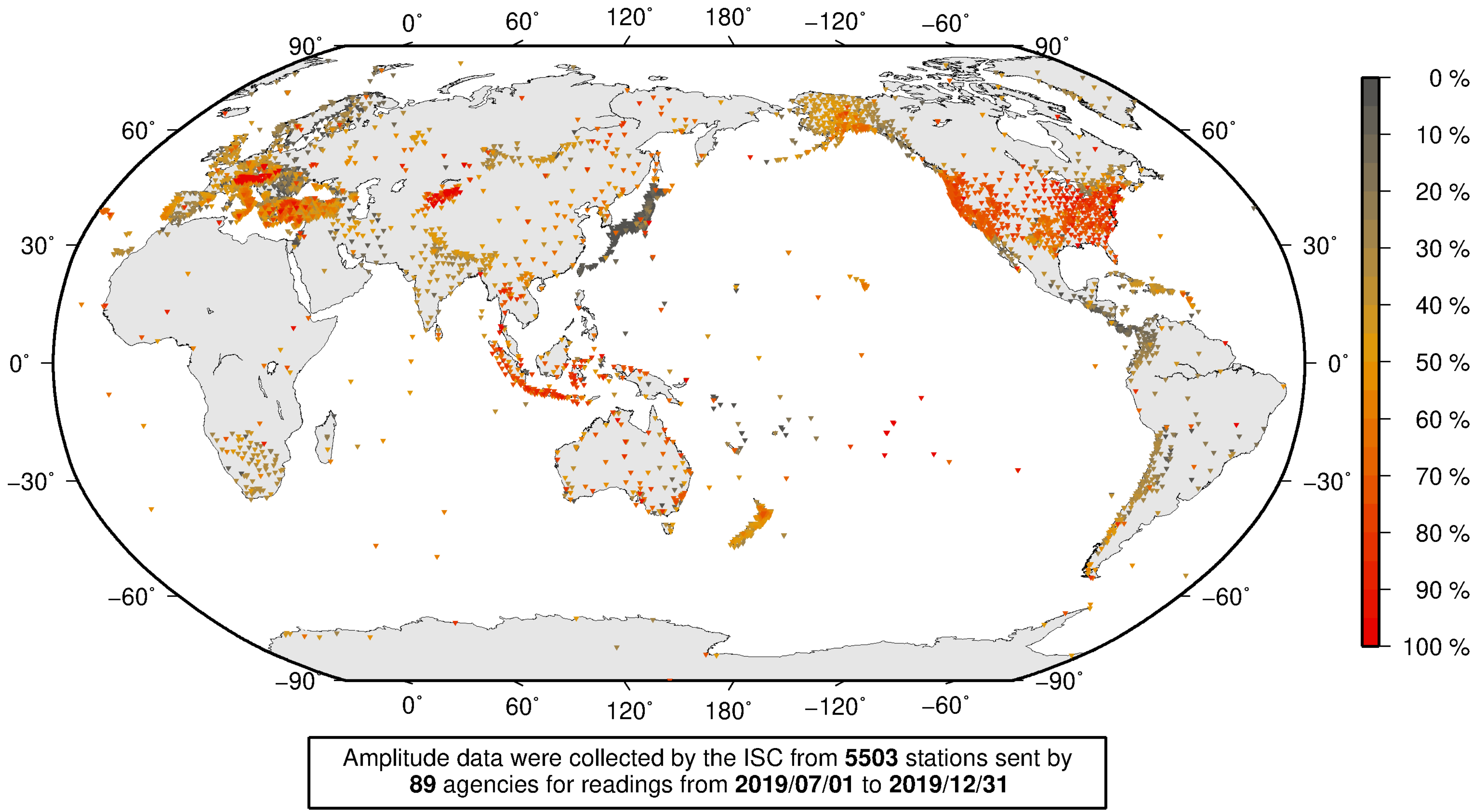


Figure 6.5: *Percentage of events for which phase arrival times from each station are accompanied with amplitude and period measurements.*

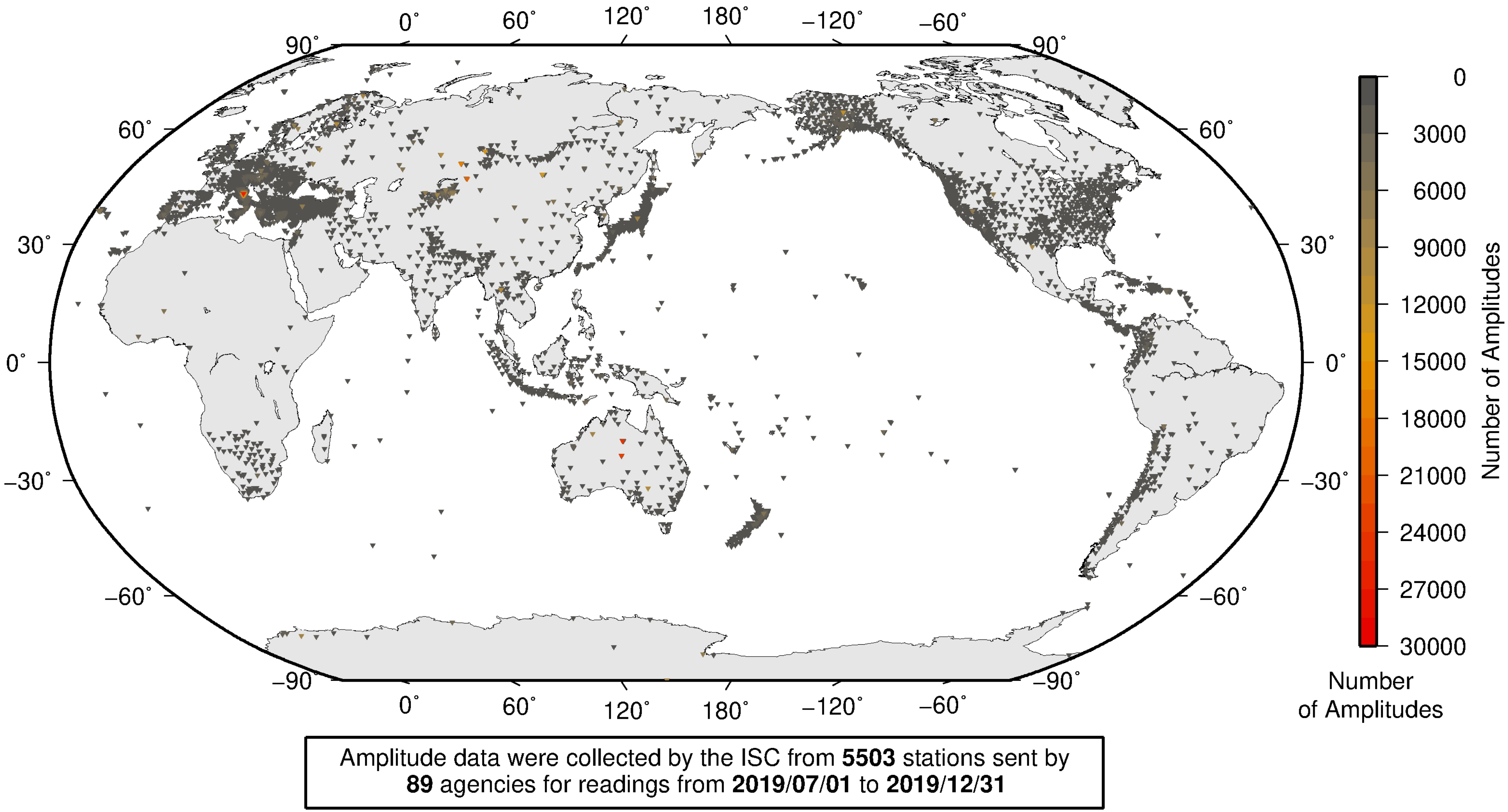


Figure 6.6: *Number of amplitude and period measurements for each station.*

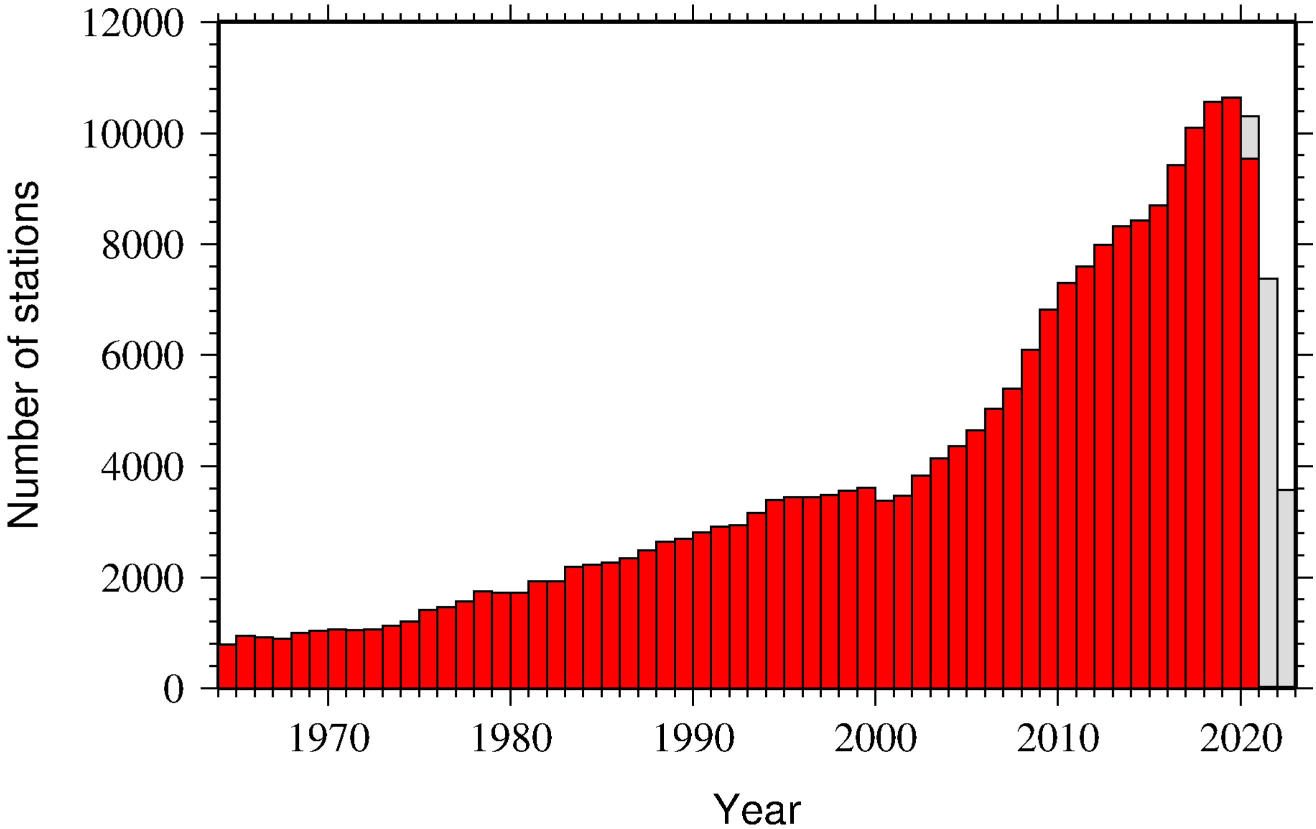
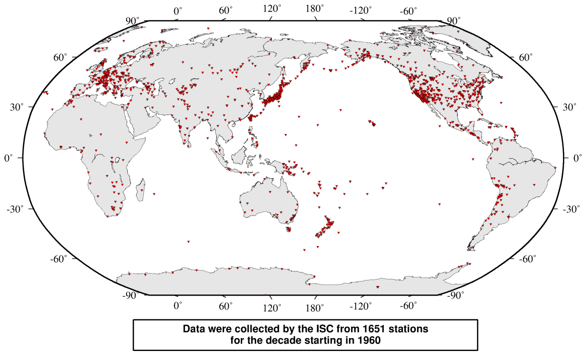
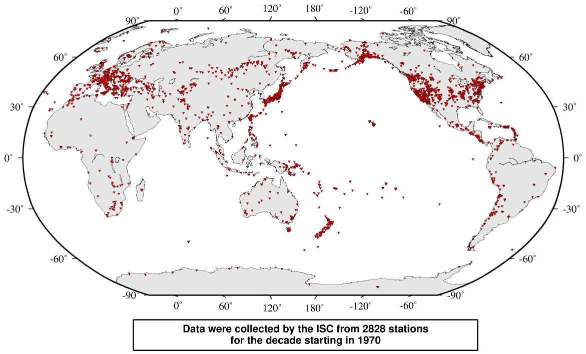


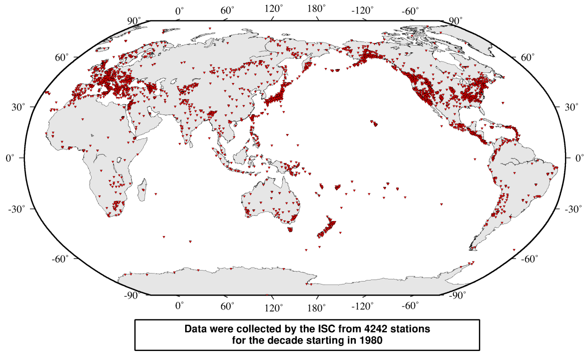
Figure 6.7: *Histogram showing the number of stations reporting to the ISC each year since 1964. The data in grey covers the current period where station information is still being collected before the ISC review of events takes place and is accurate at the time of publication.*



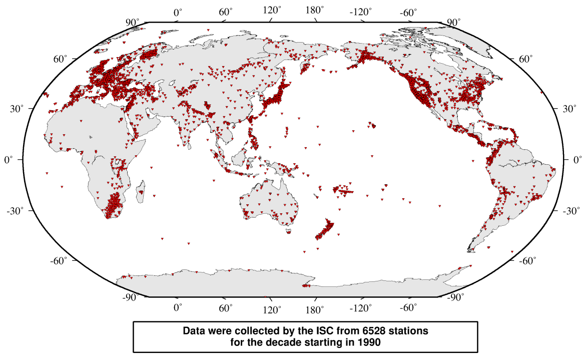
(a)



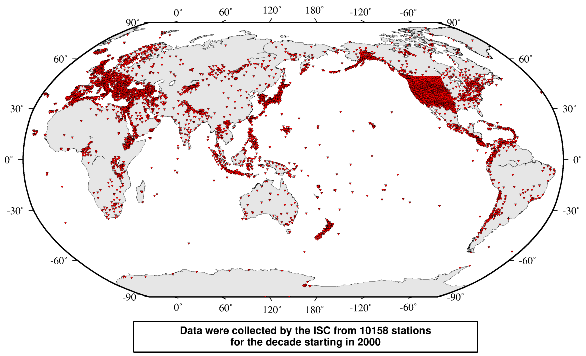
(b)



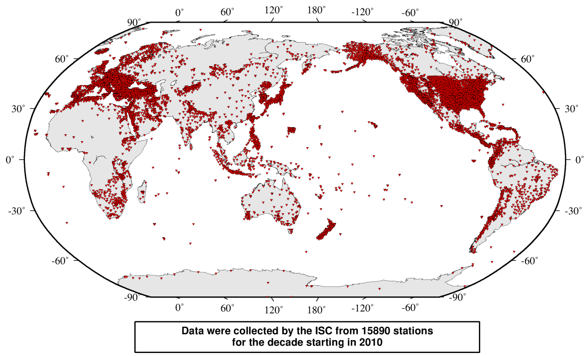
(c)



(d)



(e)



(f)

Figure 6.8: *Maps showing the stations reported to the ISC for each decade since 1960. Note that the last map covers a shorter time period.*

6.4 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 6.4. The number of hypocentres collected by the ISC has also increased significantly since 1964, as shown in Figure 6.9. A map of all hypocentres reported to the ISC for this summary period is shown in Figure 6.10. 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 6.4: *Summary of the reports containing hypocentres.*

Reports with hypocentres	4471
Reports of hypocentres only (no phase readings)	451
Total hypocentres received	388941
Number of duplicate hypocentres	13852 (3.6%)
Agencies determining hypocentres	161

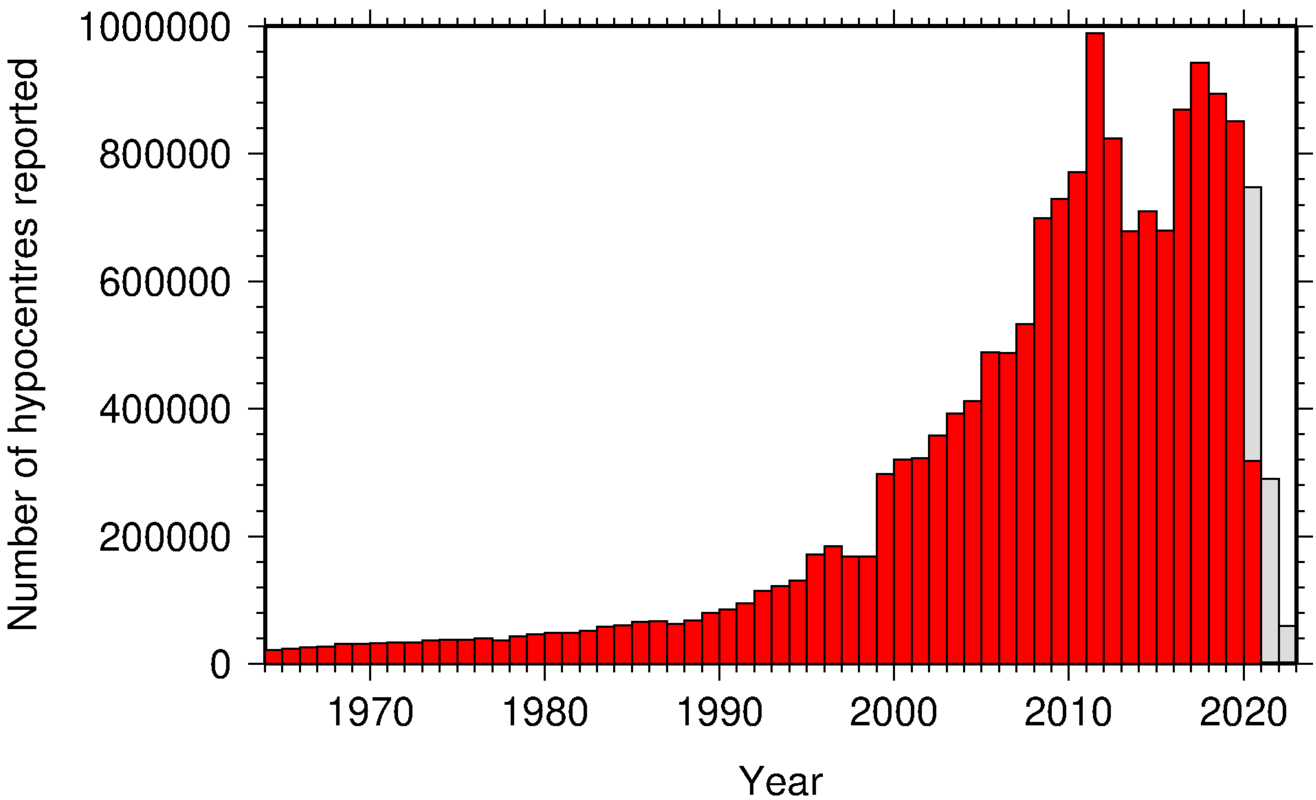


Figure 6.9: *Histogram showing the number of hypocentres collected by the ISC for events each year since 1964. For each event, multiple hypocentres may be reported.*

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 409247 hypocentres (including ISC) were grouped into 279641 events, the largest of these having 53 hypocentres in one event. The total number of events

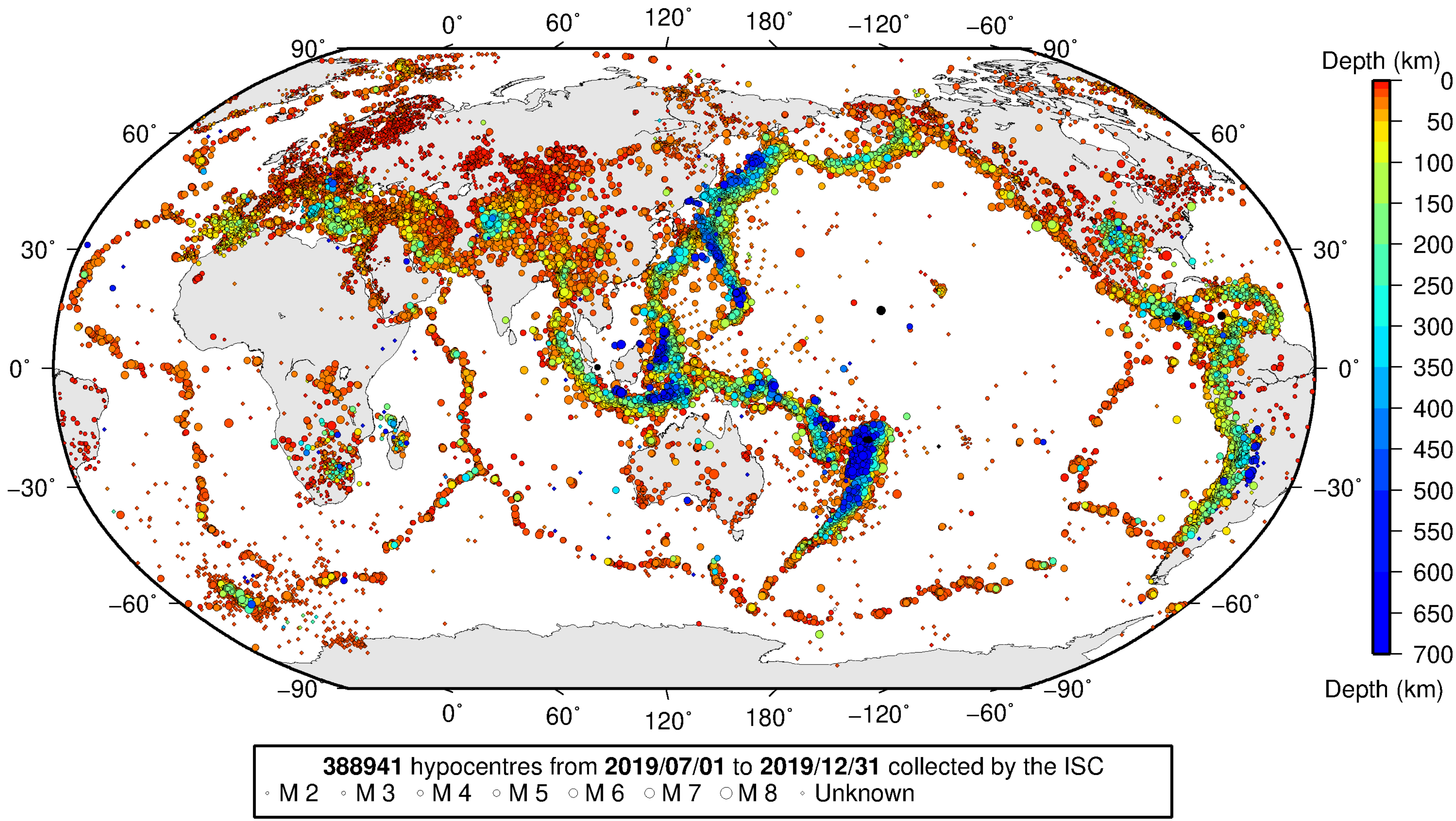


Figure 6.10: *Map of all hypocentres collected by the ISC. The scatter shows the large variation of the multiple hypocentres that are reported for each event. The magnitude corresponds with the reported network magnitude. If more than one network magnitude type was reported, preference was given to values of* M_W*,* M_S*,* m_b *and* M_L *respectively. Compare with Figure 7.2*

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 the January to June 2019 Bulletin Summary. Figure 7.2 on page 60 shows a map of all prime hypocentres.

6.5 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 6.5 provides an overview of the complexity of reported network magnitudes reported for seismic events during the summary period.

Table 6.5: *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	209153	42804	525
Average number of magnitude estimates per event	1.4	3.1	22.6
Average number of magnitudes (by the same agency) per event	1.2	1.9	3.1
Average number of magnitude types per event	1.3	2.5	10.4
Number of magnitude types	27	39	36

Table 6.6 gives the basic description, main features and scientific paper references for the most commonly reported magnitude types.

Table 6.6: *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 6.6: *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 6.6: *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 6.7 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 6.7: *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	15582	WEL (9512), MOS (3604), CATAC (2064), BKK (309), PRU (70), INMG (15), KRSZO (8), OTT (2), TAN (1)
MB	136	NAO (112), SCB (23), SSNC (1)
mb	23591	IDC (15415), NEIC (6920), NNC (3880), KRNET (2297), VIE (1996), DJA (1855), MOS (1676), BJI (1031), RSNC (530), NOU (418), VAO (319), AUST (231), BGR (200), OMAN (167), CATAC (157), MDD (115), NAO (105), MCSM (100), IASPEI (71), CFUSG (54), BKK (45), MAN (42), INMG (26), DSN (20), SIGU (19), THE (19), SFS (16), OSUNB (14), NDI (14), THR (9), ANF (8), BGS (8), YARS (5), PDG (4), ROM (4), DNK (4), PMR (3), CRAAG (2), SCB (2), PPT (2), IGIL (2), BER (1), AZER (1)
mB	2188	BJI (998), DJA (935), WEL (241), RSNC (235), CATAC (120), BKK (33), OSUNB (7), NOU (7), SFS (1)
mb(Pn)	185	BER (185)
mB_BB	12	BGR (12)
mb_Lg	3809	MDD (3342), NEIC (460), OTT (14)
mBc	5	RSNC (5)

Table 6.7: *Continued.*

Magnitude type	Events	Agencies reporting magnitude type (number of values)
mbR	70	VAO (70)
mbtmp	16781	IDC (16781)
Mc	40	KRSC (40)
MD	12091	RSPR (4088), LDG (1724), SDD (1716), GCG (1376), TRN (1178), SSNC (926), ECX (536), GII (527), PDG (302), JMA (299), TIR (241), HLW (238), SOF (204), GRAL (180), UPA (130), JSN (120), ROM (110), PNSN (104), MEX (88), SLM (61), JSO (59), CFUSG (49), BUG (47), STR (34), TUN (33), SNET (15), HVO (10), NCEDC (9), DNK (8), SIGU (6), UUSS (6), LJU (1), SEA (1)
Mi	2	PMR (2)
Mjma	221	BKK (211), RSNC (6), JSO (2), WEL (1), DJA (1)
ML	124284	TAP (14954), RSNC (13158), AFAD (10739), WEL (8988), IDC (8927), ROM (8562), ISK (8501), ATH (8041), HEL (7284), NEIC (6205), GUC (4113), UPP (3978), SGS (3037), VIE (3020), INMG (2845), AEIC (2735), SFS (2134), LDG (1753), SDD (1717), PRE (1703), BEO (1592), KOLA (1528), SNET (1469), BER (1402), DNK (1398), LJU (1279), OSPL (1151), TIR (1081), PDG (1068), CNRM (1026), GCG (1009), SSNC (923), SCB (849), SJA (837), RHSSO (837), PAS (783), GEN (771), ANF (731), BUC (701), TXNET (677), SKO (667), KRSC (664), ECX (655), AUST (645), PGC (602), MRB (568), IPEC (537), YARS (517), IGIL (503), TAN (458), HLW (447), KRSZO (366), NIC (345), UPA (345), BGSI (288), NDI (279), HVO (274), OMAN (273), DSN (247), NAO (247), WBNET (230), ISN (226), BKK (215), AZER (203), KNET (198), BGR (159), BJI (143), LVSN (142), UCC (135), BGS (119), CRAAG (97), THR (94), NOU (87), JSO (76), BUT (70), PPT (70), REN (69), SEA (69), UUSS (64), PLV (52), NCEDC (49), BUG (47), MAN (43), MIRAS (42), DMN (40), KEA (35), BNS (22), RSPR (21), CUPWA (21), ASIES (20), LDO (19), OTT (19), RISSC (7), VAO (5), NAM (4), SIGU (2), MEX (2), UCR (1), PMR (1), CLL (1), CATAC (1), DJA (1), THE (1), HYB (1), FIA0 (1)
MLh	3588	THE (2329), ZUR (1110), ASRS (145), RSNC (4)
MLSn	280	PGC (281)
MLv	25190	WEL (9607), DJA (5876), STR (3147), RSNC (2129), CATAC (2107), SFS (1096), NOU (1026), BKK (318), JSO (158), MCSM (113), IGQ (96), KRSZO (8), OSUNB (8), ASRS (3), OTT (2), PPT (1)
MN	560	OTT (560)
mpv	4170	NNC (4170)
MPVA	215	MOS (202), NORS (168)
mR	87	OSUNB (87)

Table 6.7: *Continued.*

Magnitude type	Events	Agencies reporting magnitude type (number of values)
MS	7338	IDC (7176), BJI (818), MOS (444), BGR (129), NSSP (56), VIE (50), MAN (42), SOME (39), IASPEI (37), OMAN (15), INMG (14), DSN (2), IGIL (2), DNK (2), BGS (2), GUC (1), SSNC (1), YARS (1)
Ms(BB)	8	RSNC (8)
Ms7	815	BJI (815)
Ms_20	177	NEIC (177)
MsBB	1	OTT (1)
MSH	1	CFUSG (1)
MV	86553	JMA (86553)
MW	7549	SDD (1628), GCMT (1210), FUNV (845), SJA (836), NIED (573), UPA (521), UCR (507), PGC (292), AFAD (288), SSNC (286), NDI (274), BER (197), GCG (195), SCB (134), IPGP (131), MED_RCMT (94), JMA (84), GFZ (56), DJA (55), WEL (39), ASIES (34), ATH (26), ROM (21), RSNC (18), INMG (11), UPSL (6), IEC (6), GUC (5), PLV (4), MEX (2), AUST (2), OSUNB (2), DNK (1)
Mw(mB)	374	WEL (228), CATAC (114), BKK (31), SFS (1)
Mwb	189	NEIC (189)
MwMwp	47	CATAC (38), BKK (5), AUST (4)
Mwp	249	DJA (172), CATAC (40), RSNC (23), OMAN (10), BKK (5), THE (4), AUST (4), ROM (2)
Mwr	536	NEIC (278), PAS (159), GUC (116), SLM (41), NCEDC (22), OTT (14), VIE (1)
Mws	538	GII (538)
Mww	651	NEIC (651), GUC (15)

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 6.1). 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 6.1: *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)

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 6.2.

Listing 6.2: *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 6.11 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.

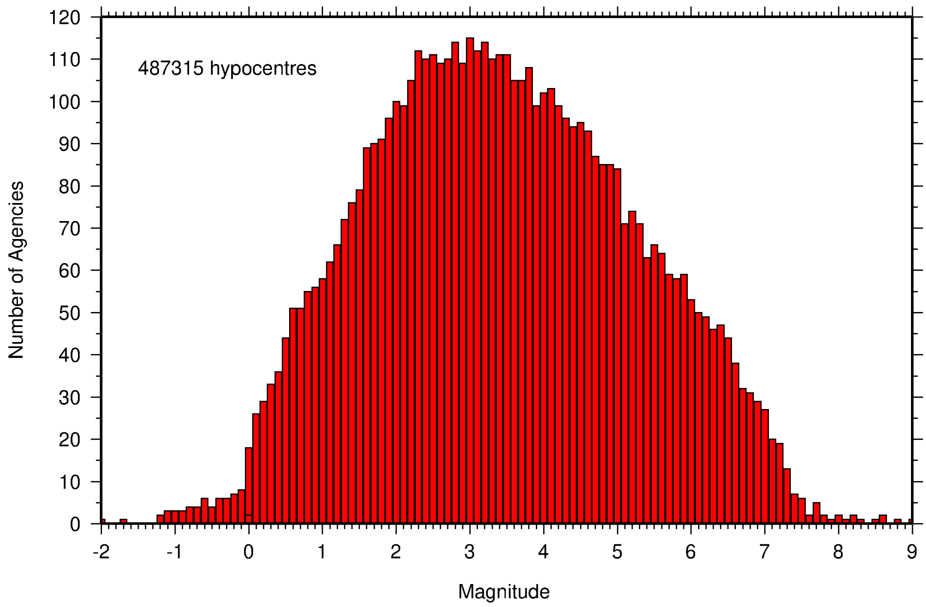


Figure 6.11: *Histogram showing the number of agencies that reported network magnitude values. All magnitude types are included.*

6.6 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 6.8. A histogram showing all moment tensor solutions collected throughout the ISC history is shown in Figure 6.12. 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 6.8: *Summary of reports containing moment tensor solutions.*

Reports with Moment Tensors	402
Total moment tensors received	20276
Agencies reporting moment tensors	13

The number of moment tensors for this summary period, reported by each agency, is shown in Table 6.9. The moment tensor solutions are plotted in Figure 6.13.

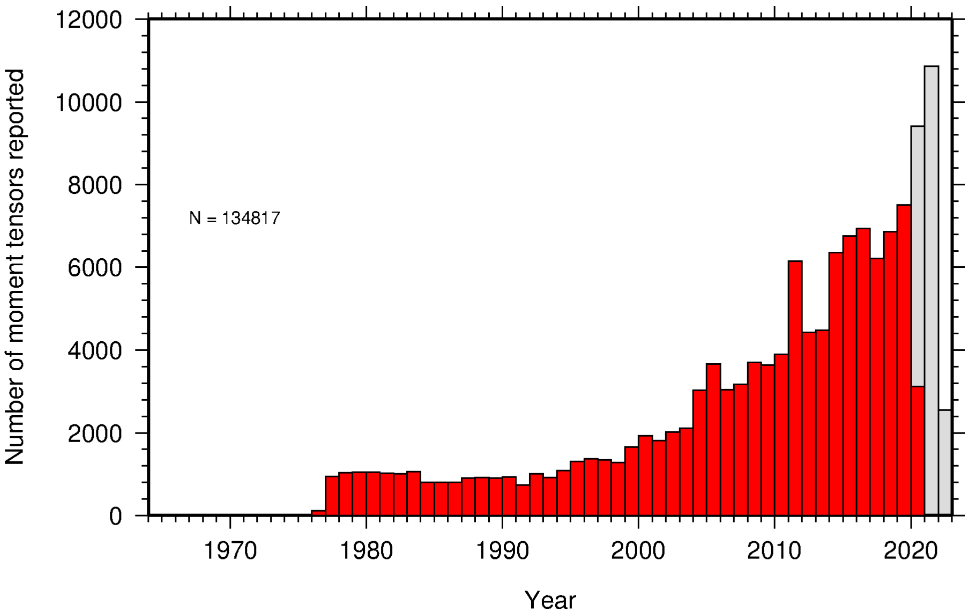
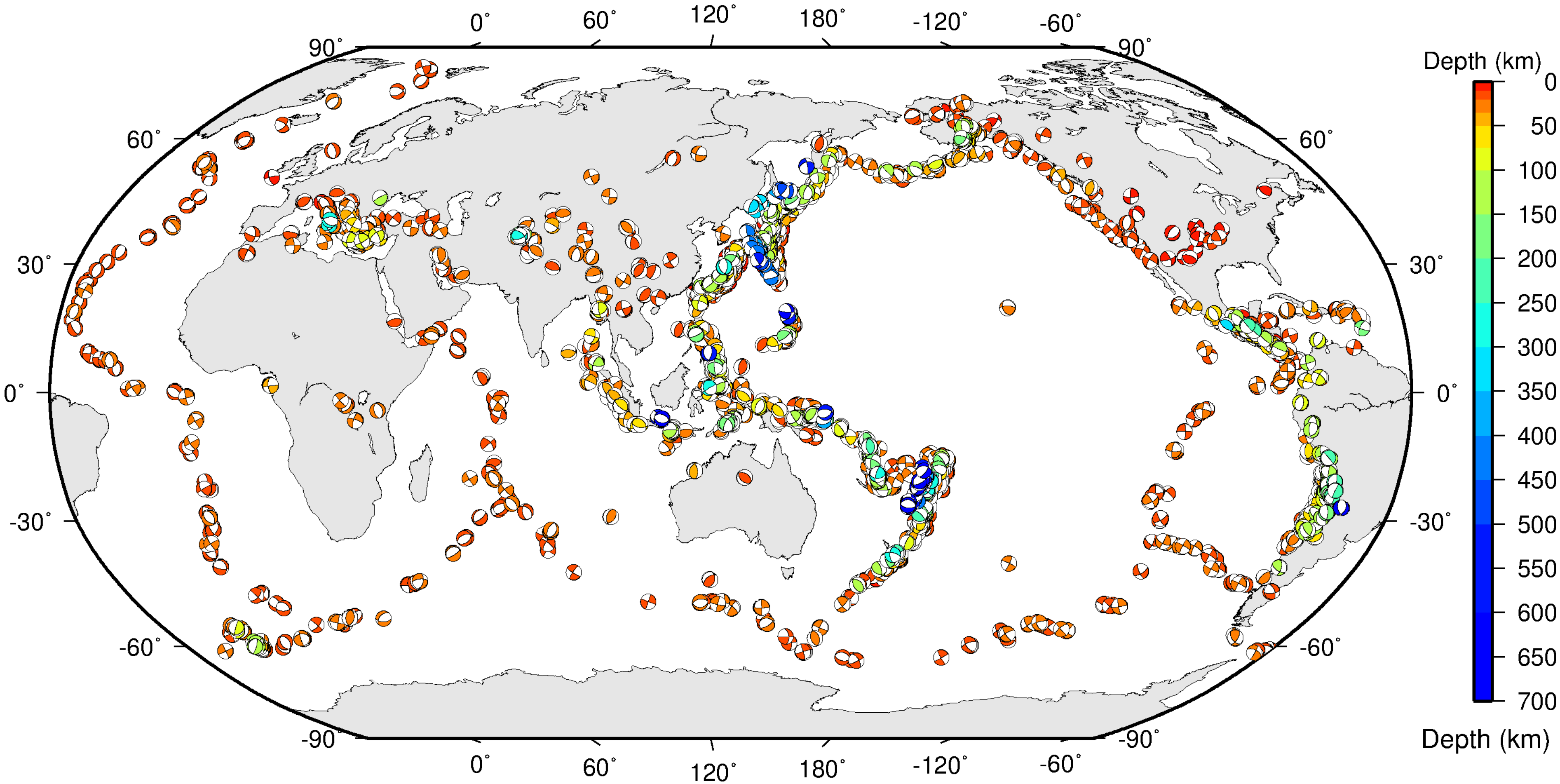


Figure 6.12: *Histogram showing the number of moment tensors reported to the ISC since 1964. The regions in grey represent data that are still being actively collected.*



ISC Bulletin: **3777** focal mechanism solutions for **2177** events from **2019/07/01** to **2019/12/31**

Figure 6.13: *Map of all moment tensor solutions in the ISC Bulletin for this summary period.*

Table 6.9: Summary of moment tensor solutions in the ISC Bulletin reported by each agency.

Agency	Number of moment tensor solutions		Agency	Number of moment tensor solutions
GCMT	1210		ATH	26
NEIC	1132		ASIES	20
ISC	1082		ROM	20
NIED	573		ECX	14
CATAC	502		IEC	12
TAN	392		GCG	6
IPGP	262		UPSL	6
PNSN	104		MOS	4
ISC-PPSM	99		AUST	2
MED_RCMT	94		BER	1
GFZ	54		BGS	1
UPA	52		SJA	1
WEL	39		NAM	1
UCR	39			

6.7 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 6.14. In Figure 6.15 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.

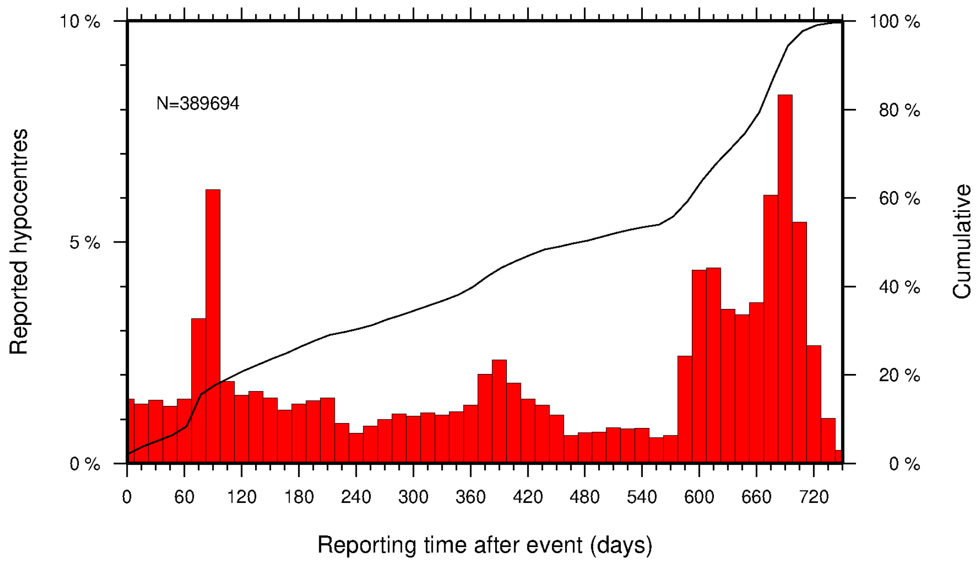


Figure 6.14: *Histogram showing the timing of final reports of the hypocentres (total of N) to the ISC. The cumulative frequency is shown by the solid line.*

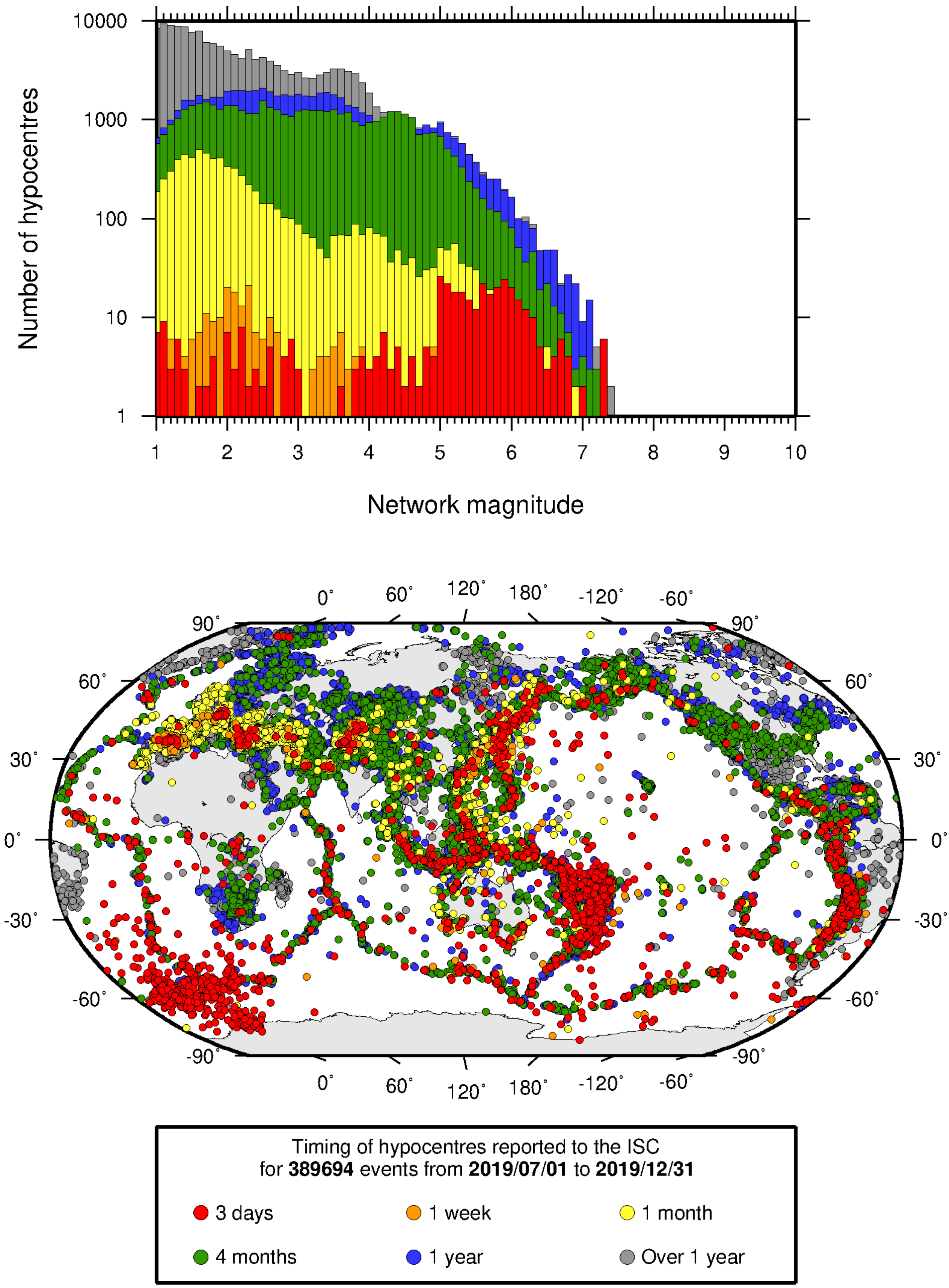


Figure 6.15: *Timing of hypocentres reported to the ISC. The colours show the time after the origin time that the corresponding hypocentre was reported. The histogram shows the distribution with magnitude. If more than one network magnitude was reported, preference was given to a value of M_W followed 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.*

7

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.

7.1 Events

The ISC Bulletin had 270156 reported events in the summary period between July and December 2019. Some 90% (243238) of the events were identified as earthquakes, the rest (26918) were of anthropogenic origin (including mining and other chemical explosions, rockbursts and induced events) or of unknown origin. As discussed in Section 10.1.3 of the January to June 2019 Bulletin Summary. In this summary period 10% 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 the January to June 2019 Bulletin Summary.

Of the 9848150 reported phase observations, 36% are associated to ISC-reviewed events, and 33% 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 about one-fifth of the events in any given month is reviewed although the number of phases associated to reviewed events has increased nearly exponentially in the past decades.

Figure 7.1 shows the daily number of events throughout the summary period. Figure 7.2 shows the locations of the events in the ISC Bulletin; the locations of ISC-reviewed and ISC-located events are shown in Figures 7.3 and 7.4, respectively.

Figure 7.5 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 7.6 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 the January to June 2019 Bulletin 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

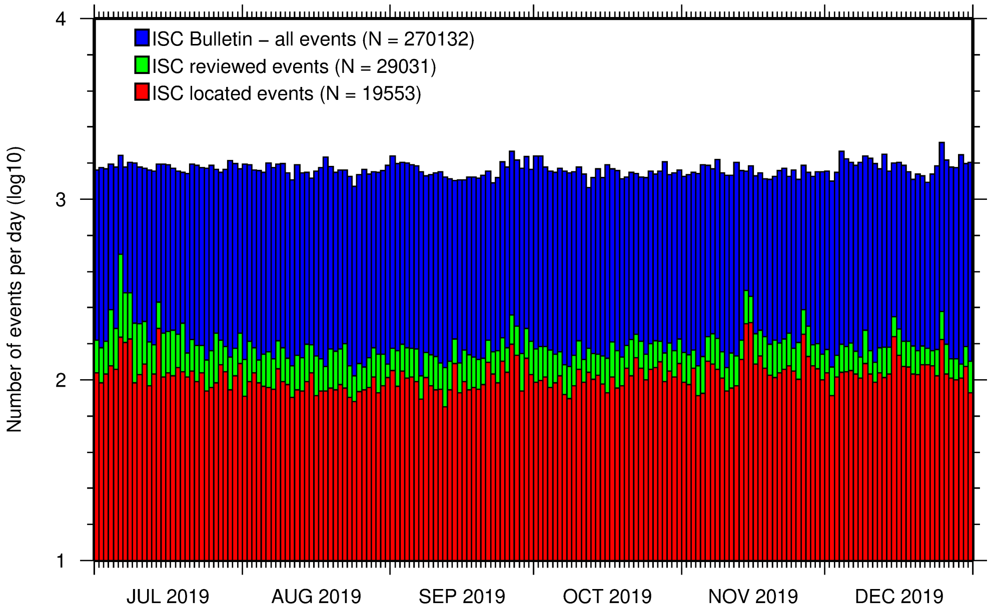


Figure 7.1: *Histogram showing the number of events in the ISC Bulletin for the current summary period. The vertical scale is logarithmic.*

phases are reported.

Figure 7.7 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 the January to June 2019 Bulletin Summary). During the ISC review editors are inclined to accept the depth obtained from the default depth grid, but they typically change the depth of those solutions that have a nominal (10 or 35 km) depth. When doing so, they usually fix the depth 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 7.8 illustrates that the secondary azimuthal gap is indeed generally smaller for ISC-located events than that for all events in the ISC Bulletin. Figure 7.9 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 7.10 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 7.11 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.

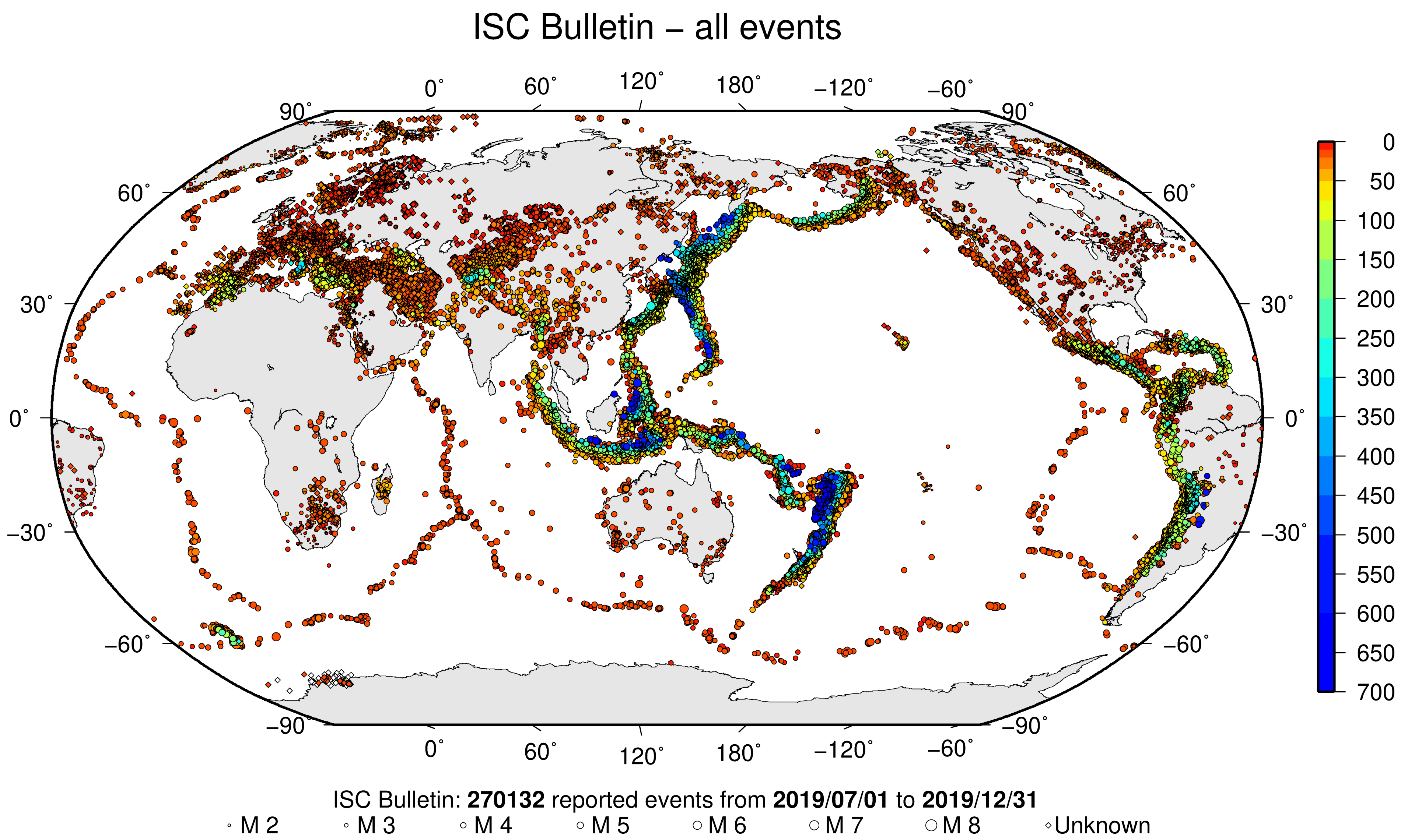


Figure 7.2: *Map of all events in the ISC Bulletin. Prime hypocentre locations are shown. Compare with Figure 6.10.*

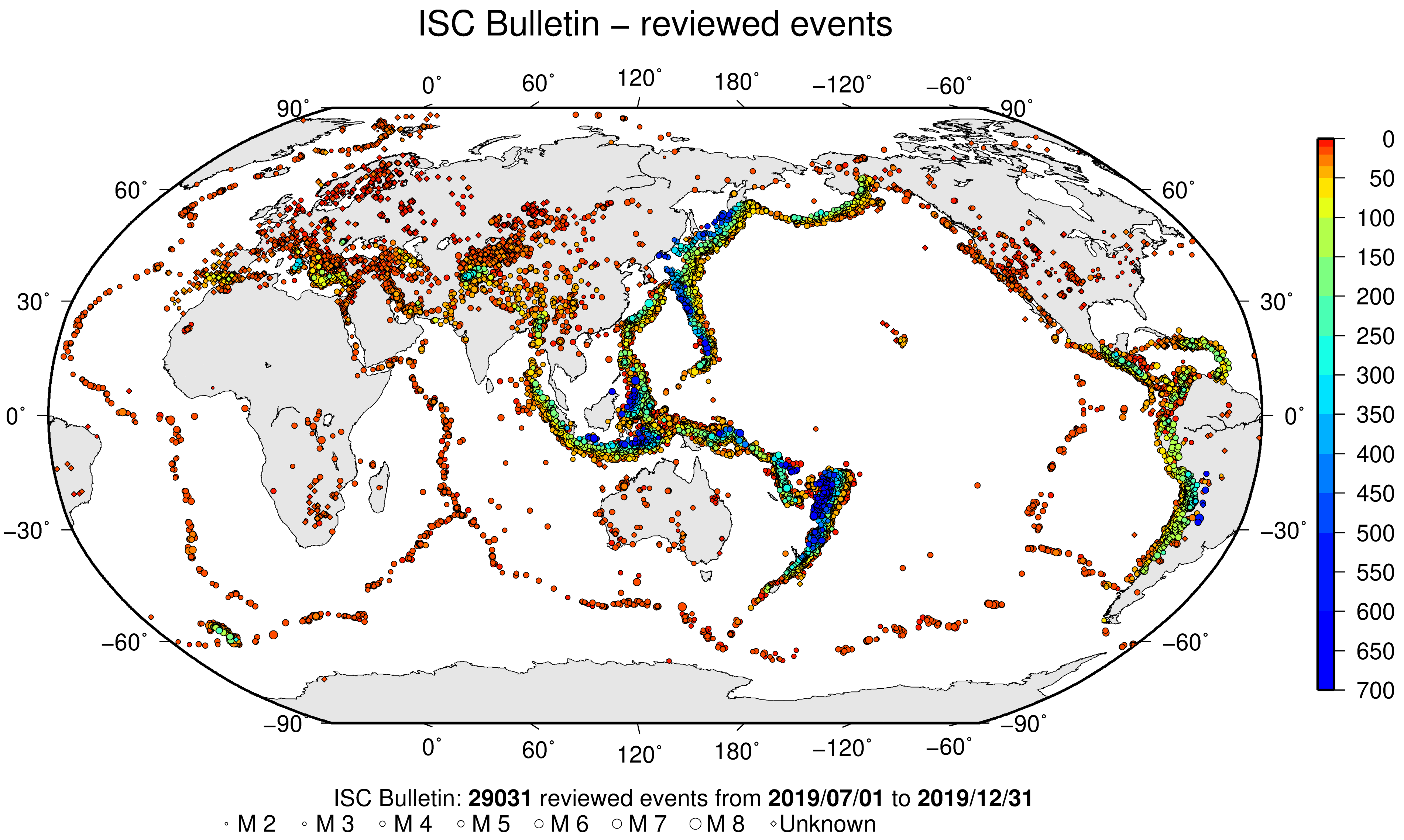


Figure 7.3: *Map of all events reviewed by the ISC for this time period. Prime hypocentre locations are shown.*

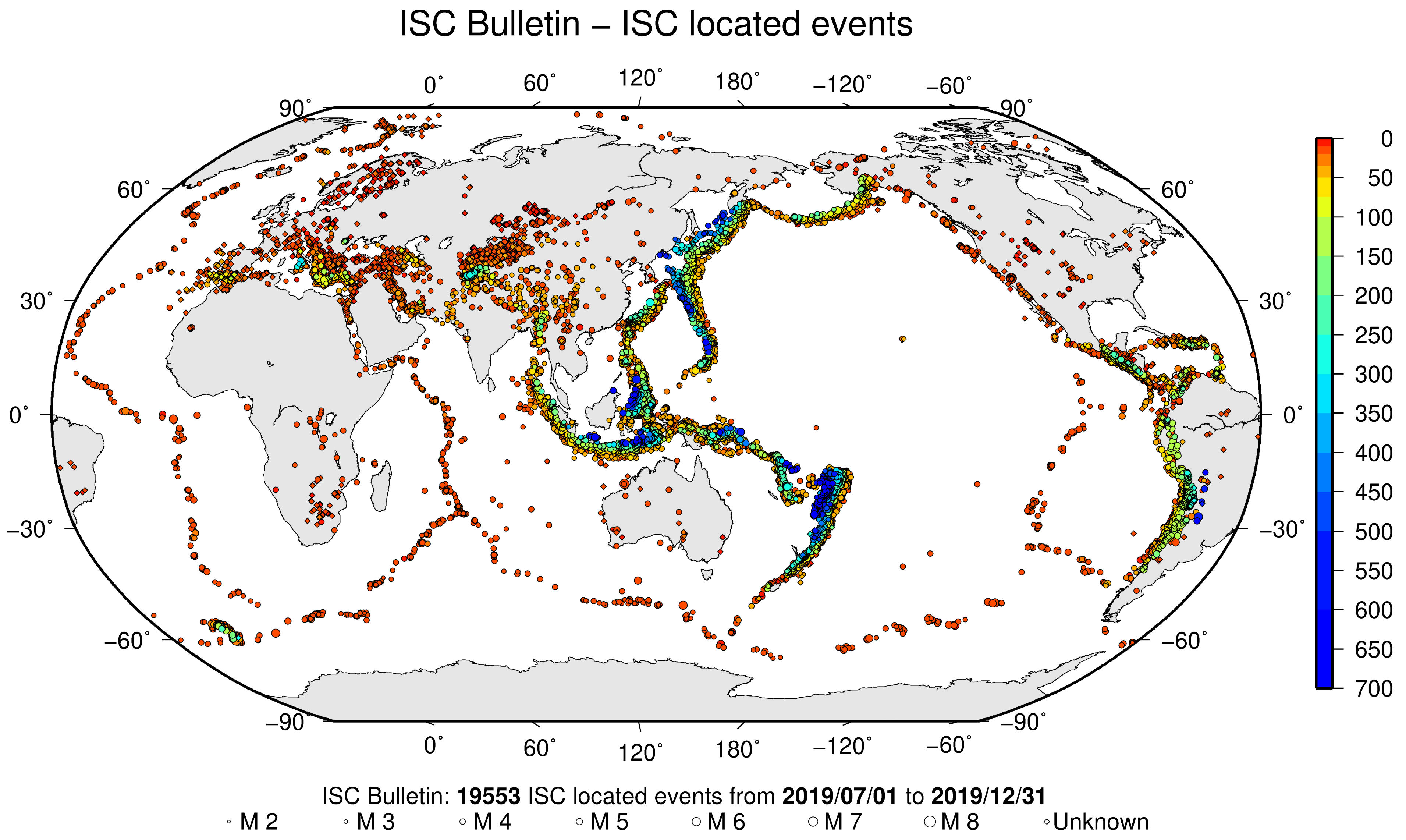


Figure 7.4: *Map of all events located by the ISC for this time period. ISC determined hypocentre locations are shown.*

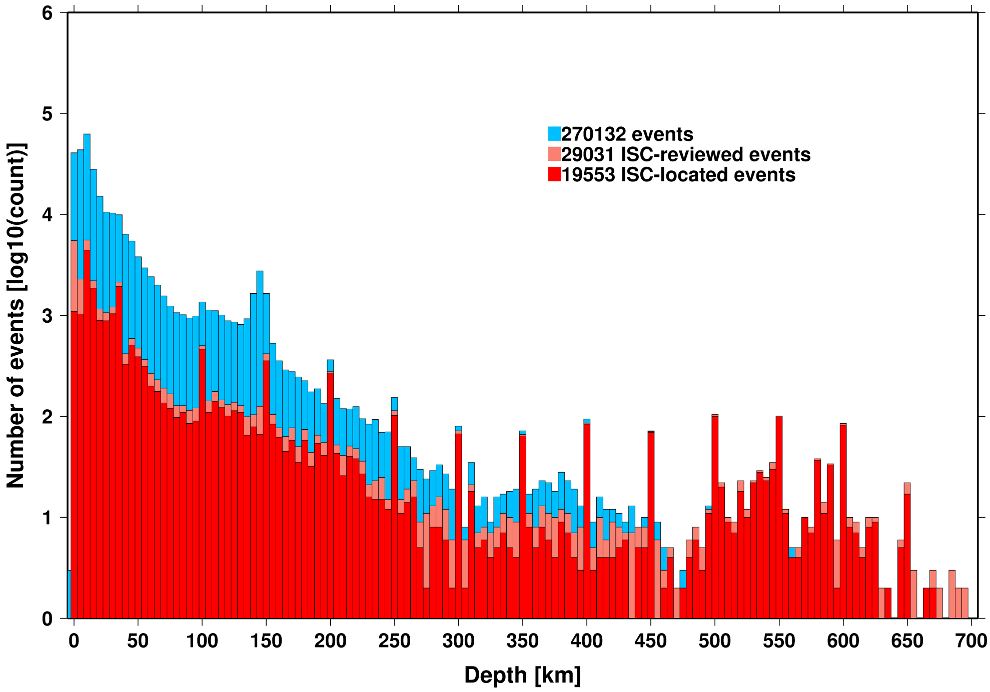


Figure 7.5: *Distribution of event depths in the ISC Bulletin (blue) and for the ISC-reviewed (pink) and the ISC-located (red) events during the summary period. All ISC-located events are reviewed, but not all reviewed events are located by the ISC. The vertical scale is logarithmic.*

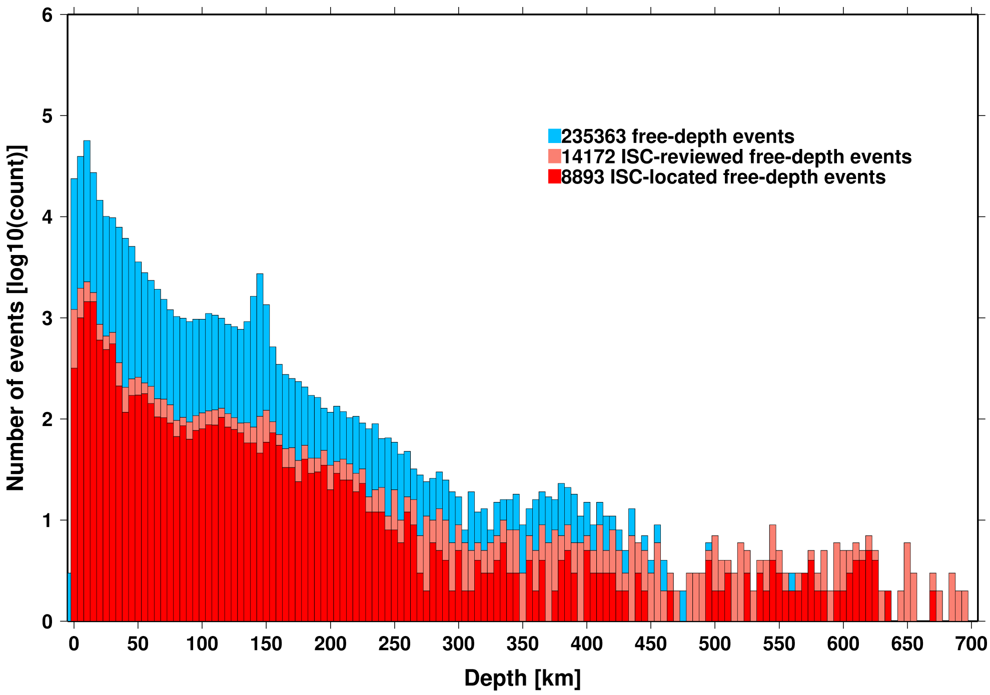


Figure 7.6: *Hypocentral depth distribution of events where the prime hypocentres are reported/located with a free-depth solution in the ISC Bulletin. The vertical scale is logarithmic.*

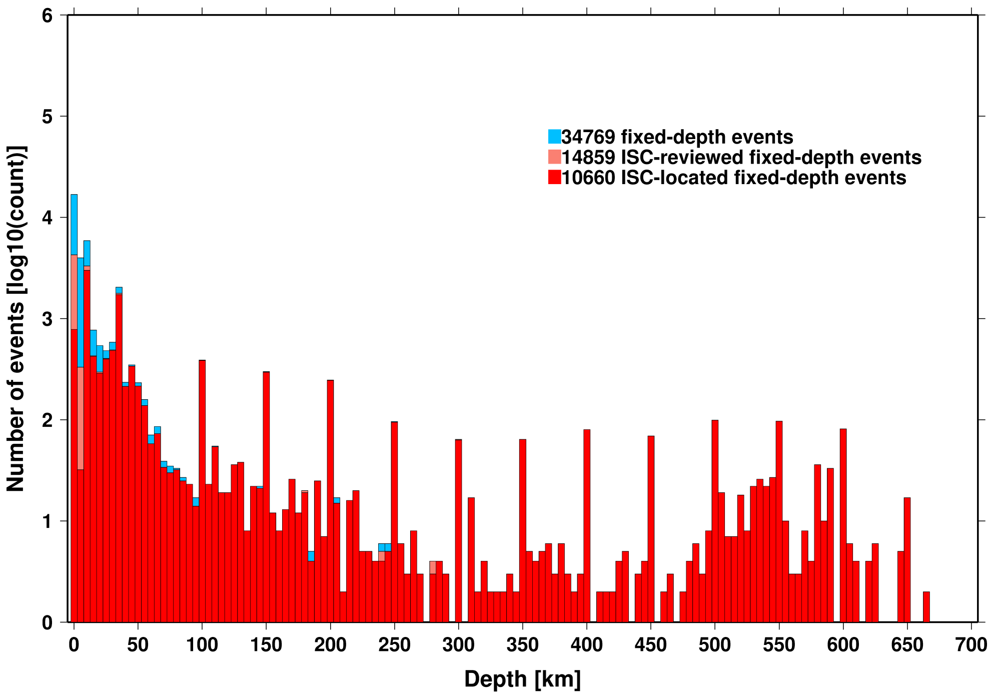


Figure 7.7: *Hypocentral depth distribution of events where the prime hypocentres are reported/located with a fixed-depth solution in the ISC Bulletin. The vertical scale is logarithmic.*

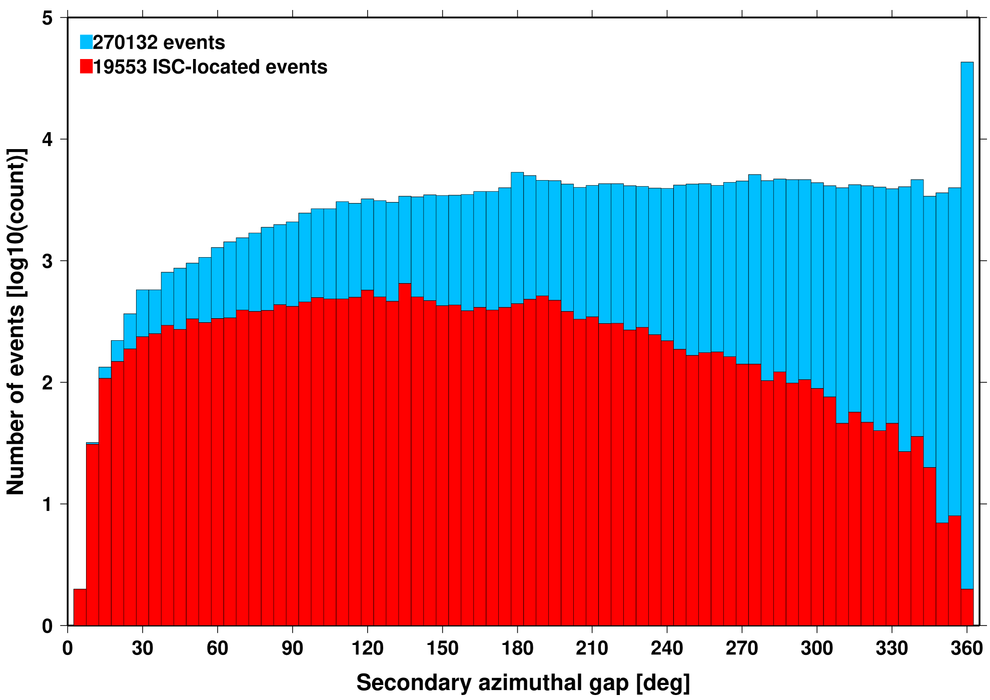


Figure 7.8: *Distribution of secondary azimuthal gap for events in the ISC Bulletin (blue) and those selected for ISC location (red). The vertical scale is logarithmic.*

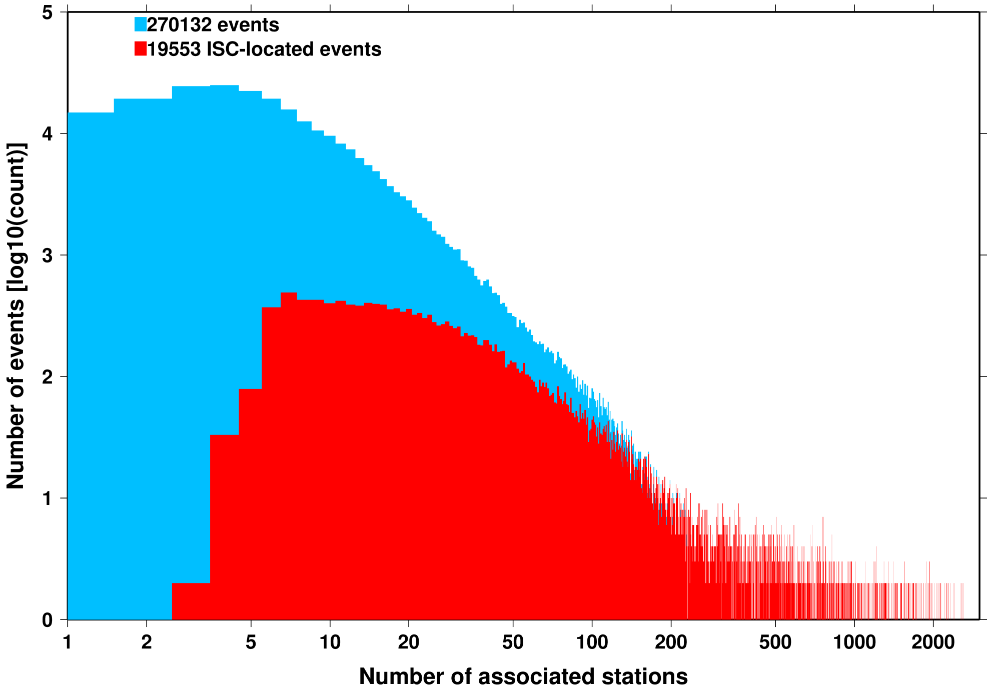


Figure 7.9: *Distribution of the number of associated stations for events in the ISC Bulletin (blue) and those selected for ISC location (red). The vertical scale is logarithmic.*

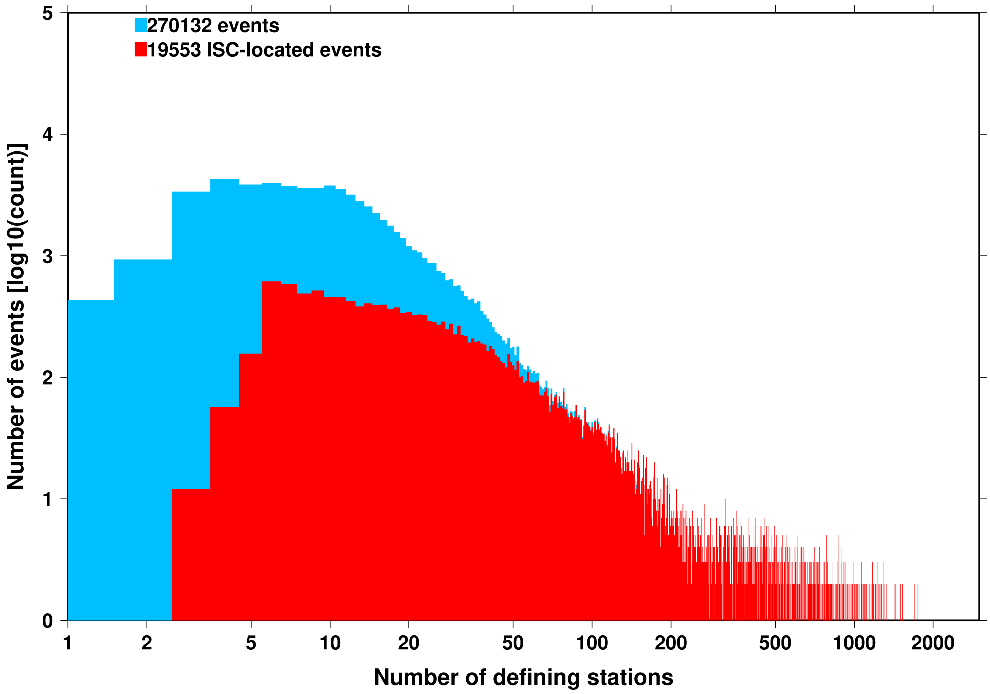


Figure 7.10: *Distribution of the number of defining stations for events in the ISC Bulletin (blue) and those selected for ISC location (red). The vertical scale is logarithmic.*

Nevertheless, half of the events are characterised by an error ellipse with an area less than 184 km^2, 90% of the events have an error ellipse area less than 1281 km^2, and 95% of the events have an error ellipse area less than 2279 km^2.

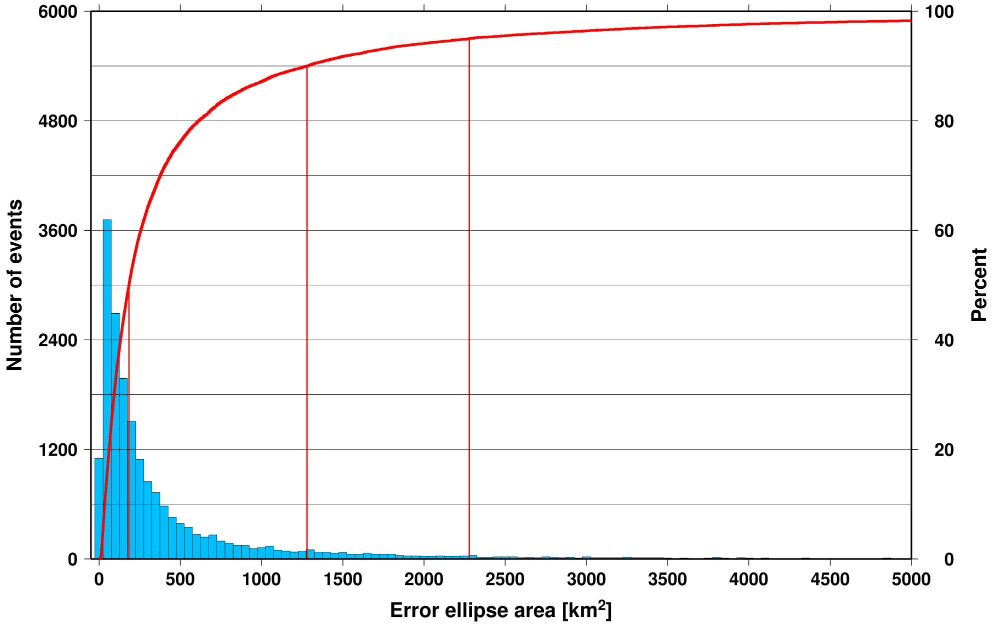


Figure 7.11: *Distribution of the area of the 90% confidence error ellipse of the ISC-located events. Vertical red lines indicate the 50th, 90th and 95th percentile values.*

Figure 7.12 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.

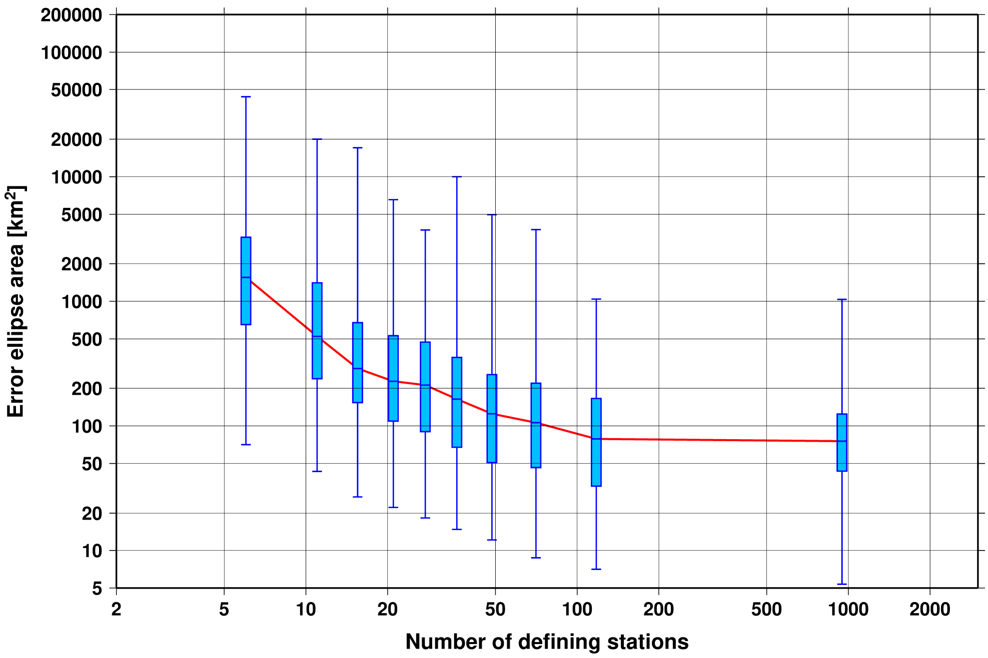


Figure 7.12: *Box-and-whisker plot of the area of the 90% confidence error ellipse of the ISC-located events as a function of the number of defining stations. Each box represents one-tenth-worth of the total number of data. The red line indicates the median 90% confidence error ellipse area.*

7.2 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 7.13. Phase types and their total number in the ISC Bulletin is shown in the Appendix, Table 9.2. A summary of phase types is indicated in Figure 7.14.

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 7.15, the number of defining phases is shown in a histogram over the summary period. Each defining phase is listed in Table 7.1, 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 7.16. Figure 7.17 shows travel times of seismic waves. The distribution of residuals for these defining phases is shown for the top five phases in Figures 7.18 through 7.22.

Table 7.1: *Numbers of 'time defining' phases (N) within the ISC Bulletin for 19553 ISC located events.*

Phase	Number of 'defining' phases	Number of events	Max per event	Median per event
P	897538	12768	2033	15
Pn	611760	17838	827	17
Sn	198258	15136	219	7
Pb	94088	8282	157	7
Pg	68249	6439	181	6
Sb	61080	7745	125	5
Sg	54133	5978	172	6
S	49174	3571	522	3
PKPdf	44326	3969	562	2
PKiKP	29185	2978	437	2
PKPbc	21778	3172	199	2
PKPab	14663	2352	218	2
PcP	12422	3433	104	2

Table 7.1: *(continued)*

Phase	Number of 'defining' phases	Number of events	Max per event	Median per event
pP	8249	1259	152	3
PP	7977	1011	148	2
Pdif	7947	944	320	2
SS	4391	1053	42	2
ScP	3657	1028	80	2
SKSac	3282	478	153	2
sP	3204	1028	85	2
PKKPbc	2173	390	69	3
pwP	1197	476	28	2
SnSn	984	564	10	1
PnPn	945	497	16	1
pPKPdf	883	270	48	1
ScS	844	286	32	1
SKPbc	844	309	30	2
sS	776	404	23	1
P'P'df	633	185	22	2
SKiKP	538	269	27	1
PKKPab	504	219	26	1
PKKPdf	487	197	20	2
pPKPab	359	137	25	1
pPKPbc	316	170	22	1
PS	272	131	32	1
SKPab	212	115	17	1
sPKPdf	199	111	20	1
sPKPab	181	57	33	1
SKSdf	157	76	52	1
PcS	154	104	7	1
SKPdf	123	70	6	1
SKKSac	112	80	5	1
PnS	108	87	3	1
P'P'bc	98	65	4	1
Sdif	93	69	5	1
pS	90	80	2	1
sPKPbc	88	62	7	1
SP	79	33	14	1
SKKPbc	79	31	16	1
pPdif	64	26	13	1
pPKiKP	58	26	9	1
PKSdf	43	25	6	1
P'P'ab	24	15	5	1
SKKSdf	19	16	4	1
SKKPdf	18	8	6	1
SPn	16	15	2	1
SKKPab	15	7	4	1
sPdif	10	6	5	1
sPKiKP	10	10	1	1
PbPb	8	7	2	1
SbSb	5	5	1	1
sPn	5	4	2	1
SgSg	2	2	1	1
PKSbc	1	1	1	1
sSKSac	1	1	1	1
PgPg	1	1	1	1

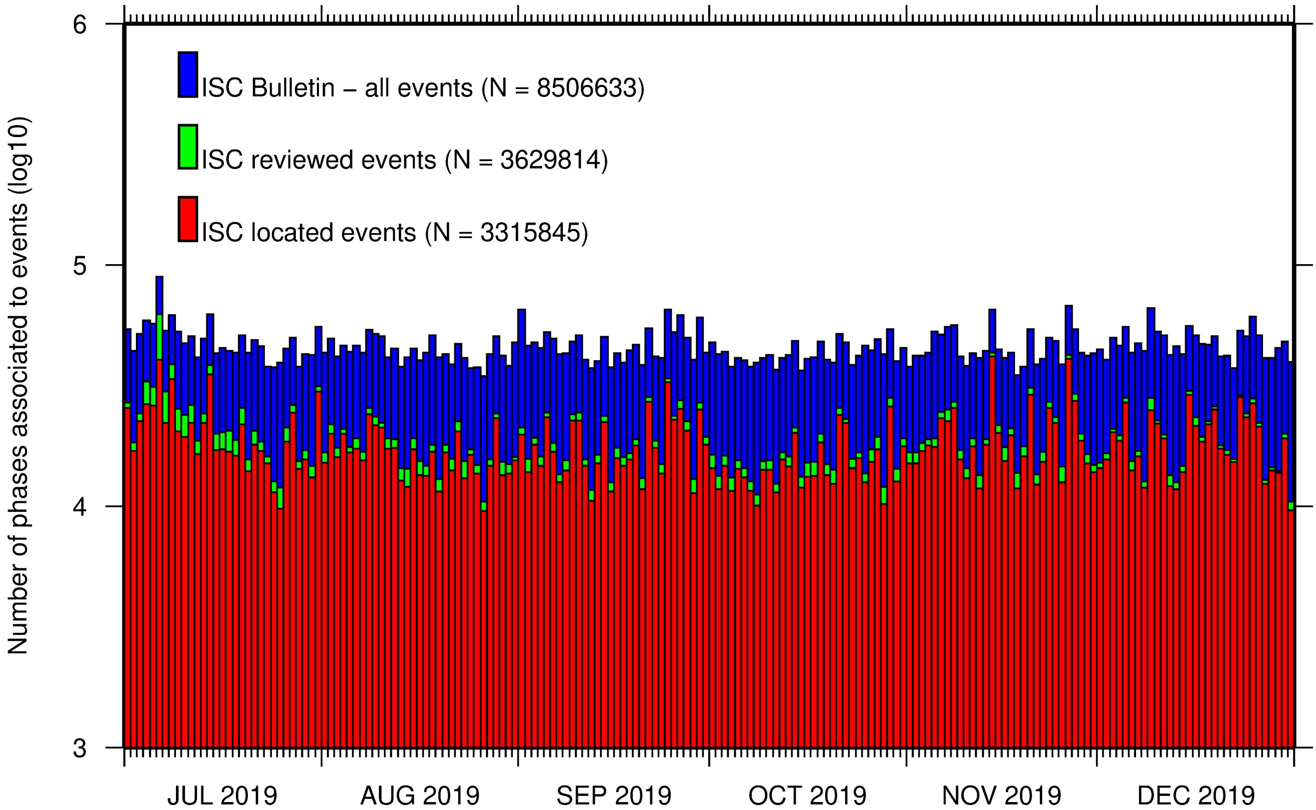


Figure 7.13: *Histogram showing the number of phases (N) that the ISC has associated to events within the ISC Bulletin for the current summary period.*

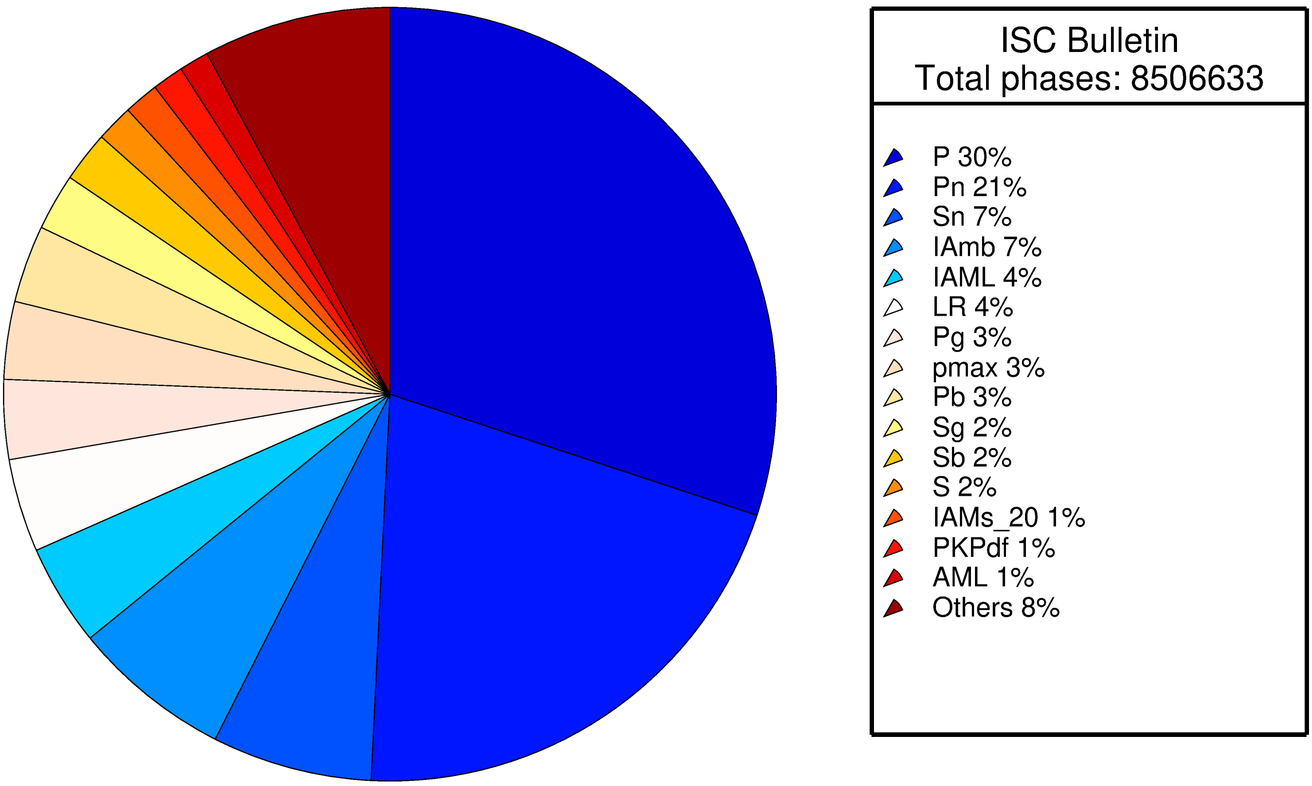


Figure 7.14: *Pie chart showing the fraction of various phase types in the ISC Bulletin for this summary period.*

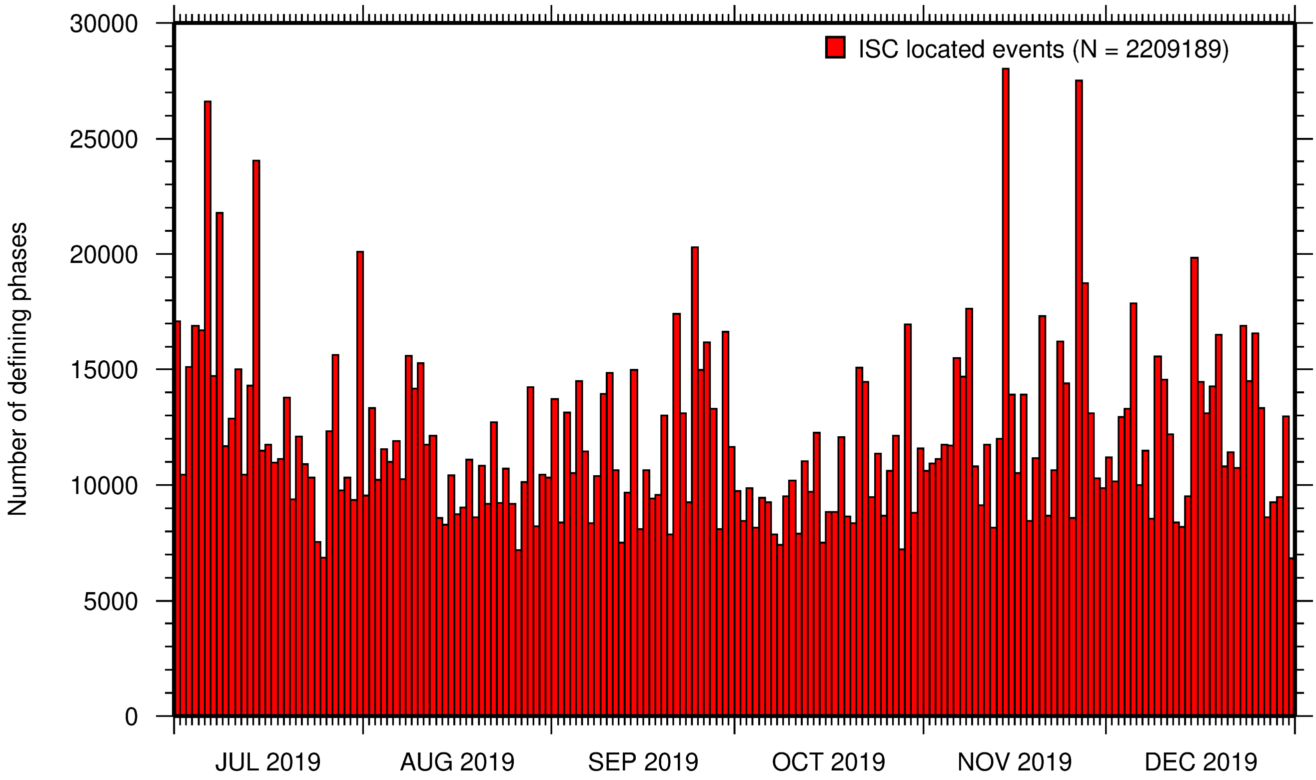


Figure 7.15: *Histogram showing the number of defining phases in the ISC Bulletin, for events located by the ISC.*

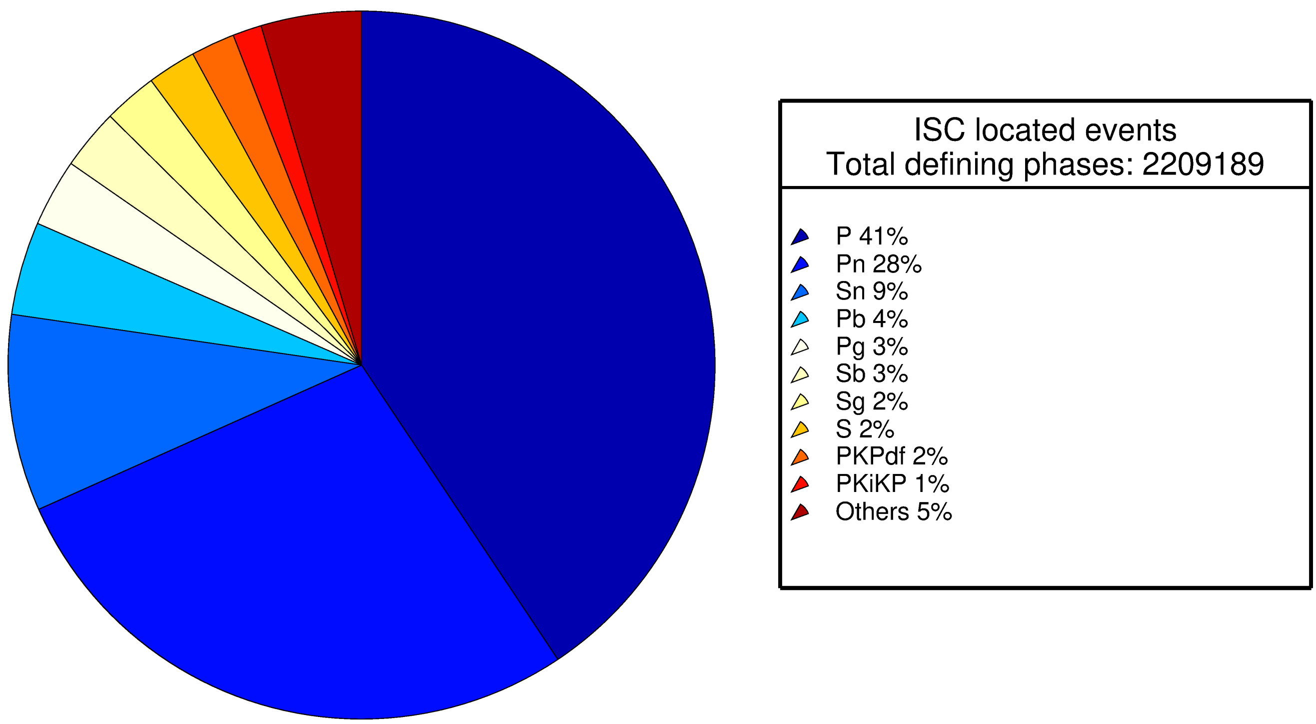


Figure 7.16: *Pie chart showing the defining phases in the ISC Bulletin, for events located by the ISC. A complete list of defining phases is shown in Table 7.1.*

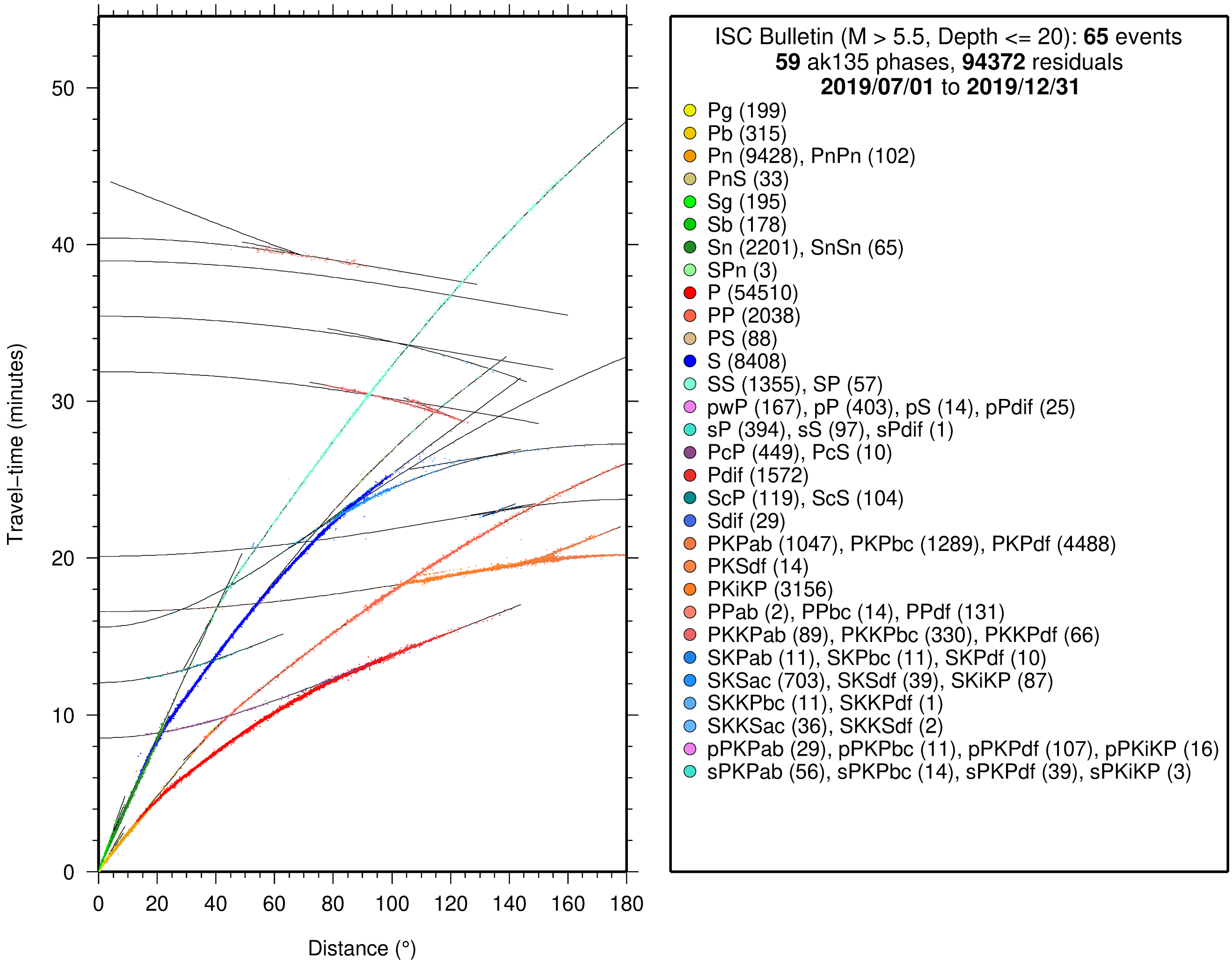


Figure 7.17: *Distribution of travel-time observations in the ISC Bulletin for events with M > 5.5 and depth less than 20 km. The travel-time observations are shown relative to a 0 km source and compared with the theoretical ak135 travel-time curves (solid lines). The legend lists the number of each phase plotted.*

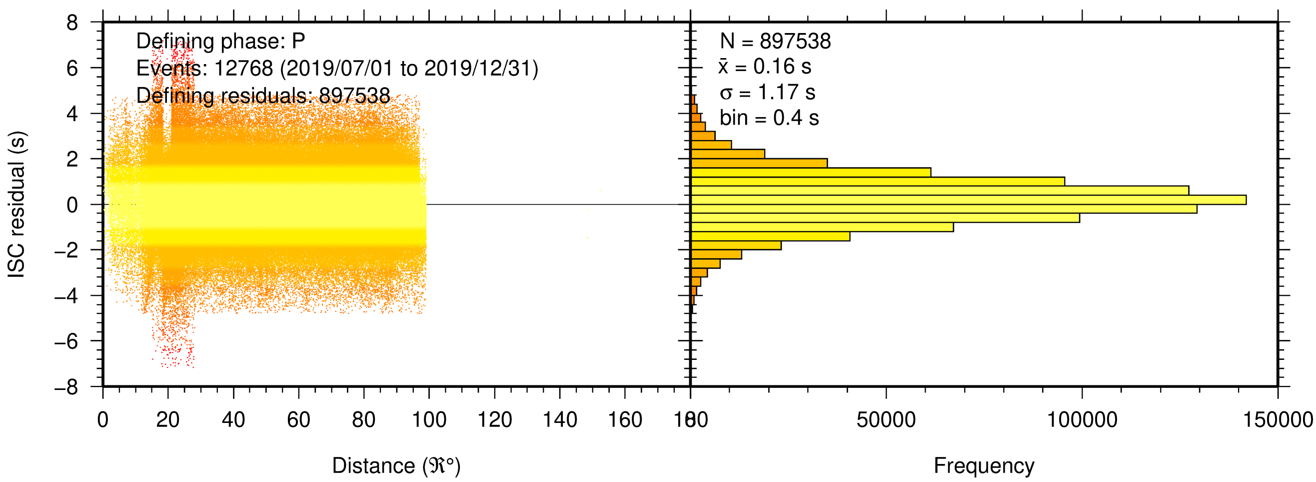


Figure 7.18: *Distribution of travel-time residuals for the defining P phases used in the computation of ISC located events in the Bulletin.*

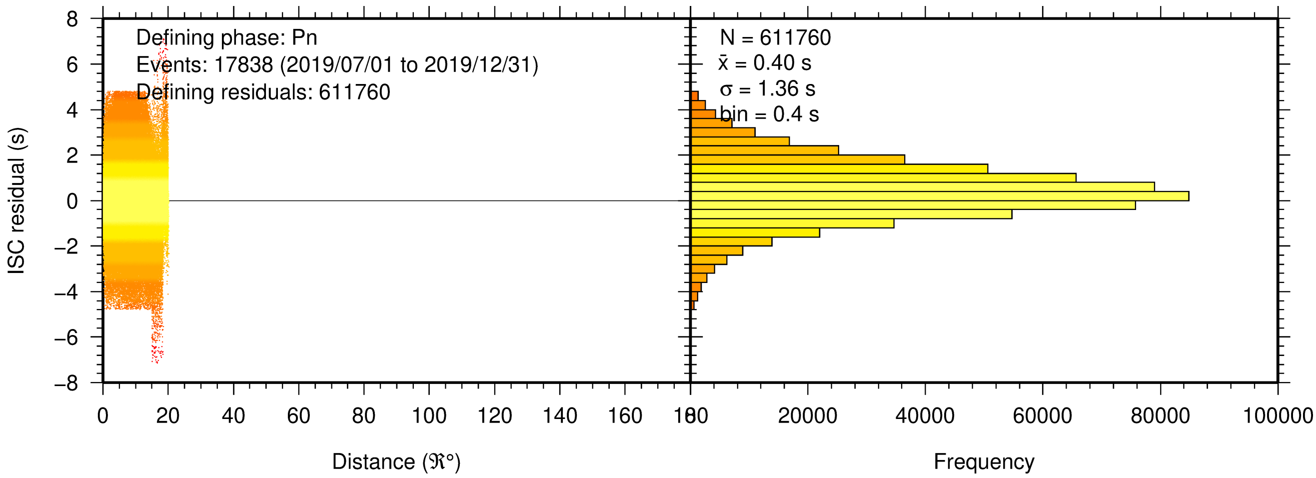


Figure 7.19: *Distribution of travel-time residuals for the defining Pn phases used in the computation of ISC located events in the Bulletin.*

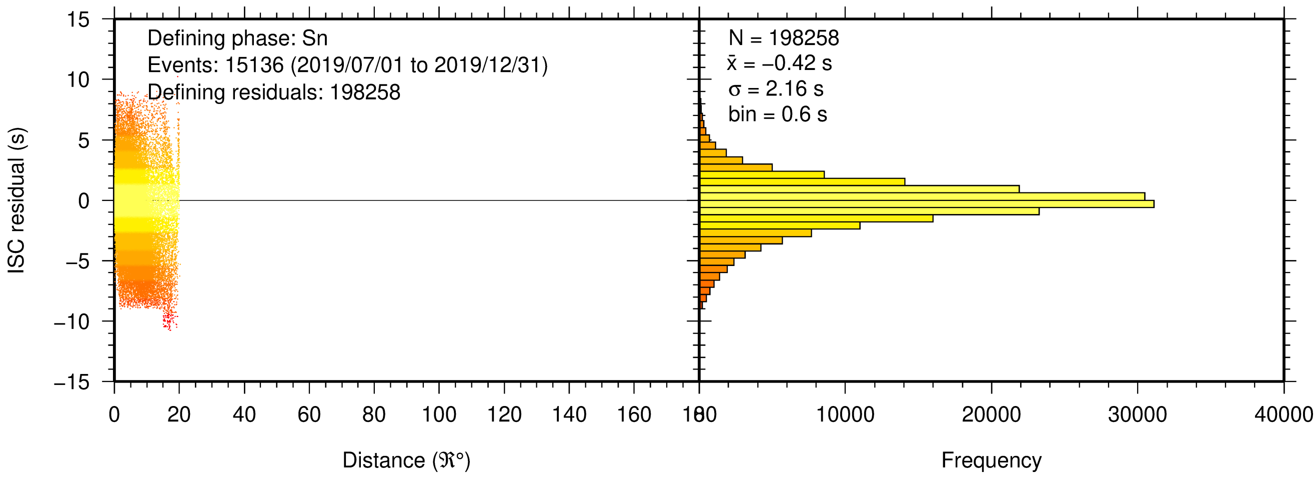


Figure 7.20: *Distribution of travel-time residuals for the defining Sn phases used in the computation of ISC located events in the Bulletin.*

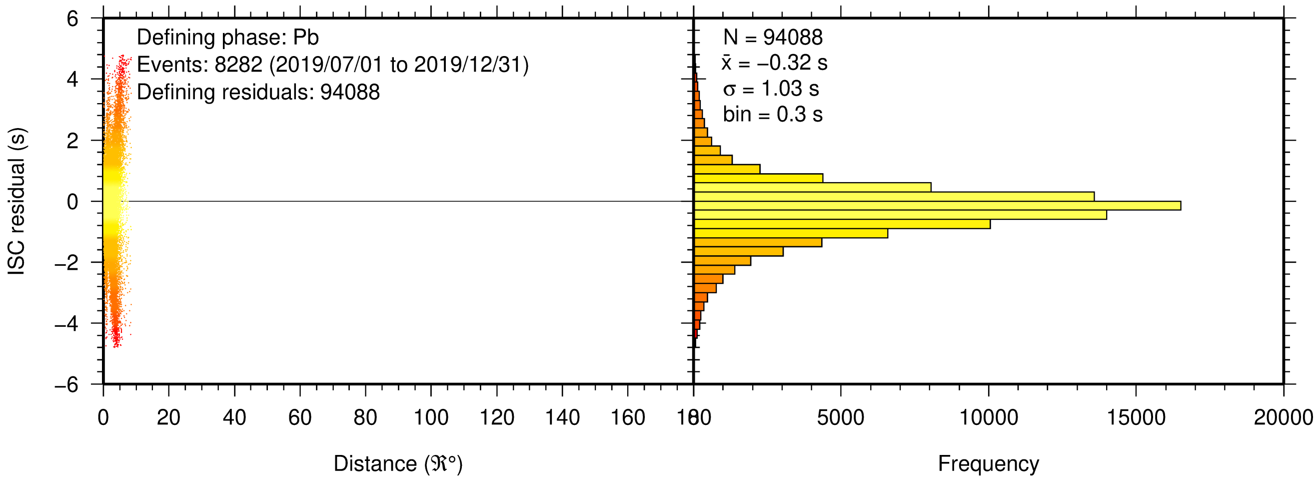


Figure 7.21: *Distribution of travel-time residuals for the defining Pb phases used in the computation of ISC located events in the Bulletin.*

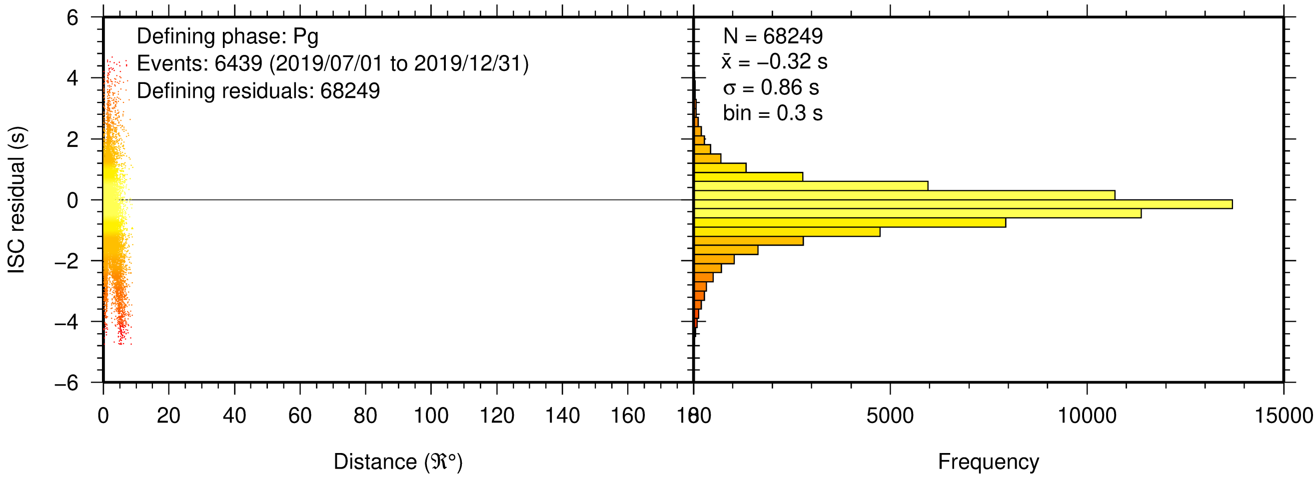


Figure 7.22: *Distribution of travel-time residuals for the defining Pg phases used in the computation of ISC located events in the Bulletin.*

7.3 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 3436774 (see Section 6.3). 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 the January to June 2019 Bulletin 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 7.2 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 7.2: *Summary of the amplitude-period data used by the ISC Locator to compute MS and mb.*

	MS	mb
Number of amplitude-period data	156916	456063
Number of readings	138296	452265
Percentage of readings in the ISC located events with qualifying data for magnitude computation	16.6	43.5
Number of station magnitudes	134439	419026
Number of network magnitudes	3312	11553

A small percentage of the readings with qualifying data for MS and mb calculation have more than one amplitude-period pair. Notably, only 17% of the readings for the ISC located (shallow) events included qualifying data for MS computation, whereas for mb the percentage is much higher at 44%. This is due to the seismological practice of reporting agencies. Agencies contributing systematic reports of amplitude and period data are listed in Appendix Table 9.3. Obviously the ISC Bulletin would benefit if more agencies included surface wave amplitude-period data in their reports.

Figure 7.23 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.

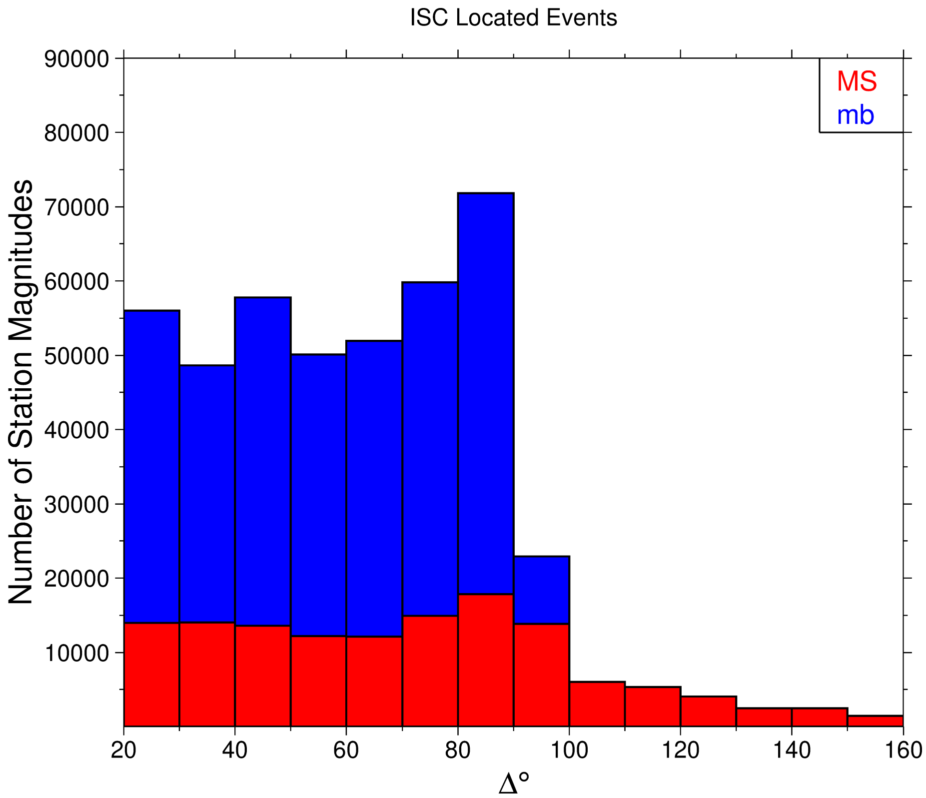


Figure 7.23: *Distribution of the number of station magnitudes computed by the ISC Locator for mb (blue) and MS (red) versus distance.*

Finally, Figure 7.24 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 but with a general tendency of having more stations contributing to the network magnitude.

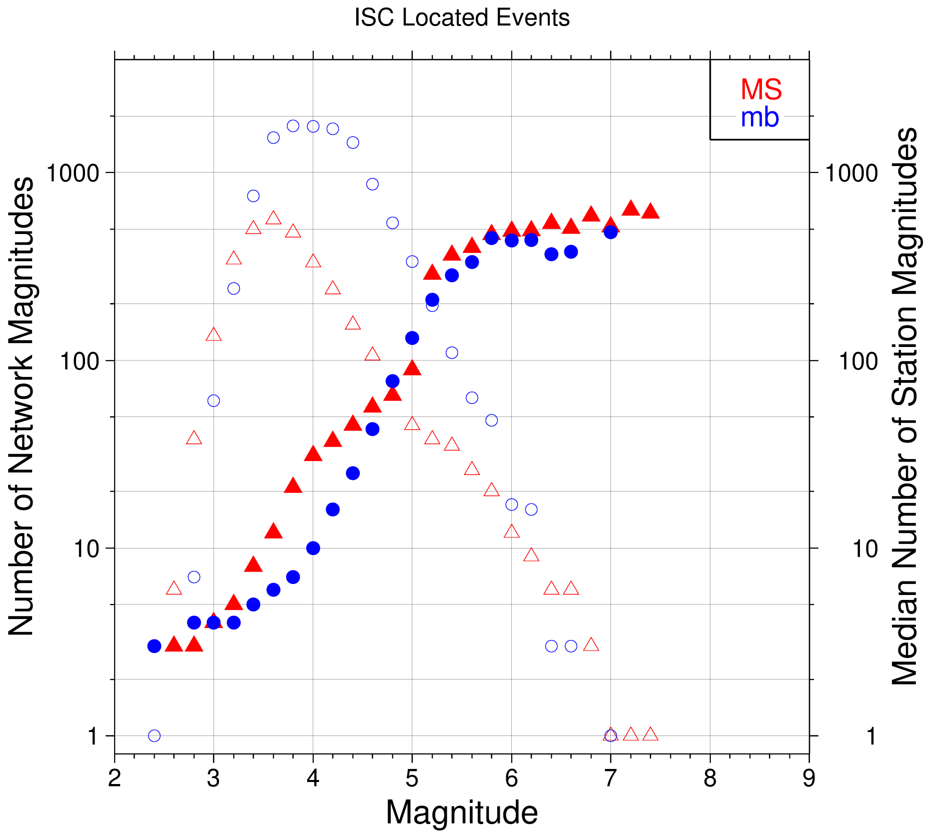


Figure 7.24: *Number of network magnitudes (open symbols) and median number of stations magnitudes (filled symbols). Blue circles refer to mb and red triangles to MS. The width of the magnitude interval* δM *is 0.2, and each symbol includes data with magnitude in* $M \pm \delta M/2$.

7.4 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 7.25. How M_C varies for the ISC Bulletin over the years is shown in Figure 7.26. 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.

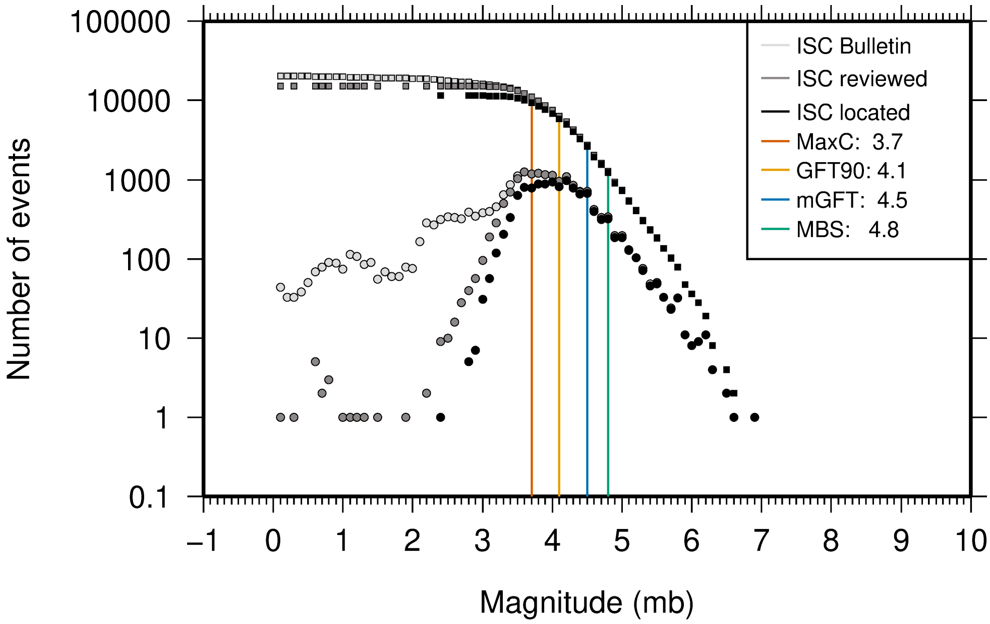


Figure 7.25: Frequency and cumulative frequency magnitude distribution for all events in the ISC Bulletin, ISC reviewed events and events located by the ISC. The magnitude of completeness (M_C) is shown for the ISC Bulletin. Note: only events with values of mb are represented in the figure.

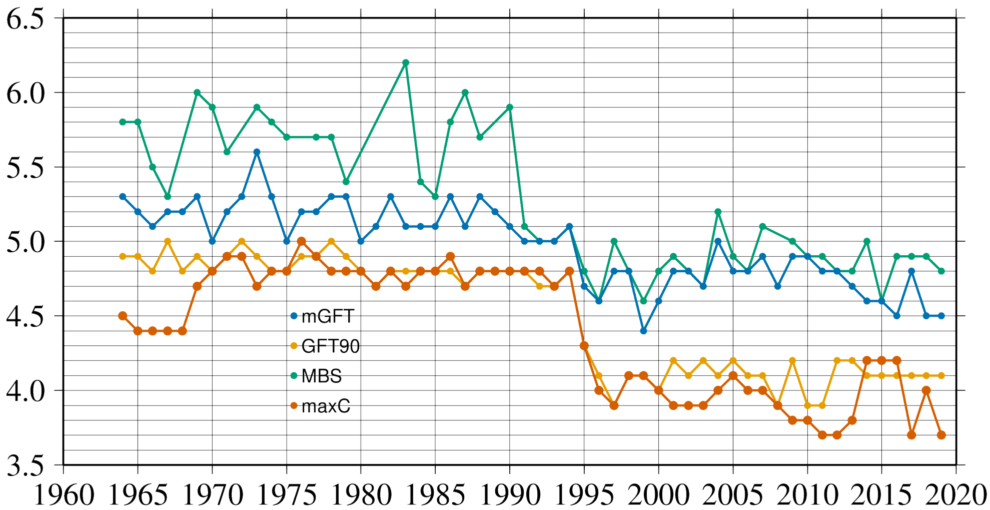


Figure 7.26: Variation of magnitude of completeness (M_C) for each year in the ISC Bulletin. Note: M_C is calculated only using those events with values of mb.

7.5 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 7.27, 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 7.28 and 7.29, 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 7.30 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 7.31, 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. For the MS comparisons between ISC and NEIC a similar but smaller effect is observed for $MS < 4.5$, whereas a good scaling is generally observed for the MS comparisons between ISC and IDC.

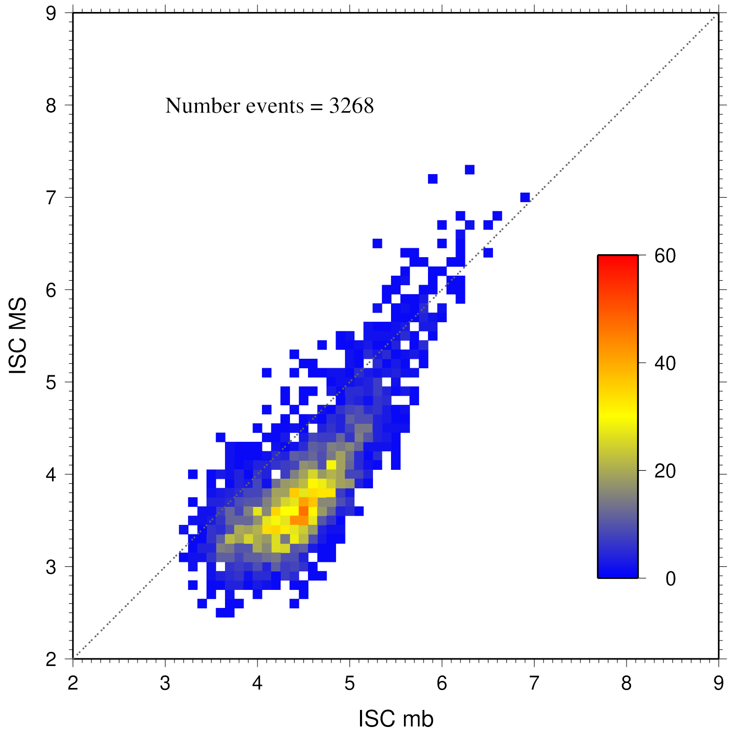


Figure 7.27: *Comparison of ISC values of MS with mb for common event pairs.*

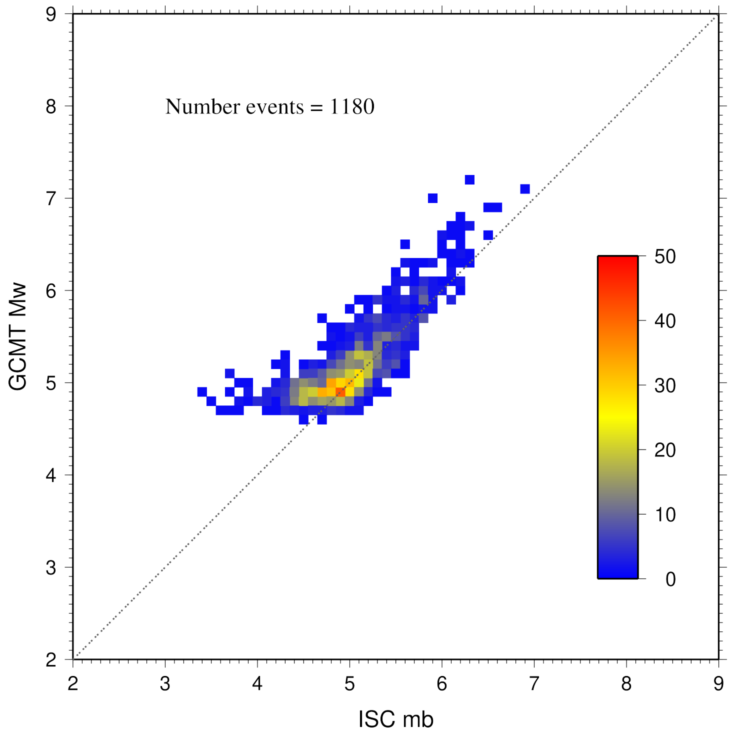


Figure 7.28: *Comparison of ISC values of mb with GCMT M_W for common event pairs.*

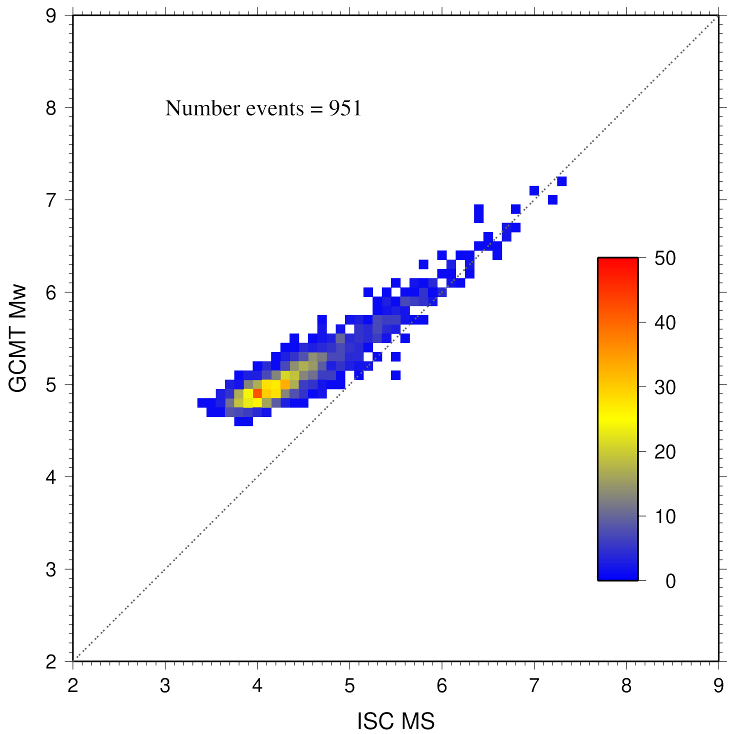
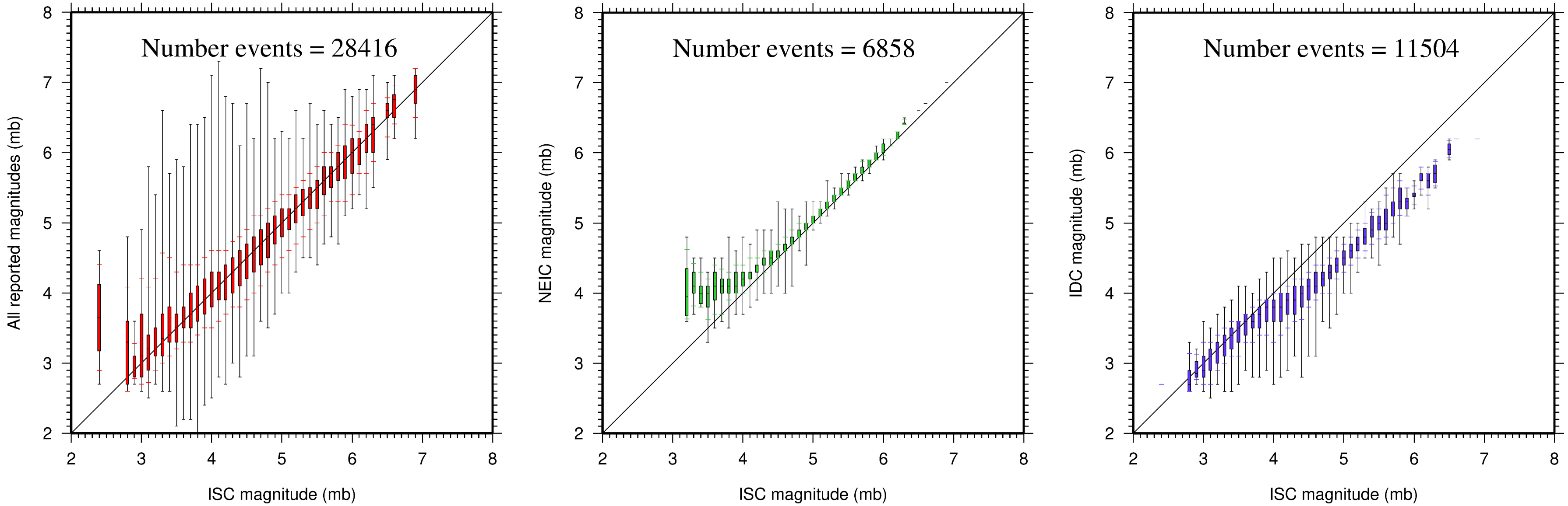
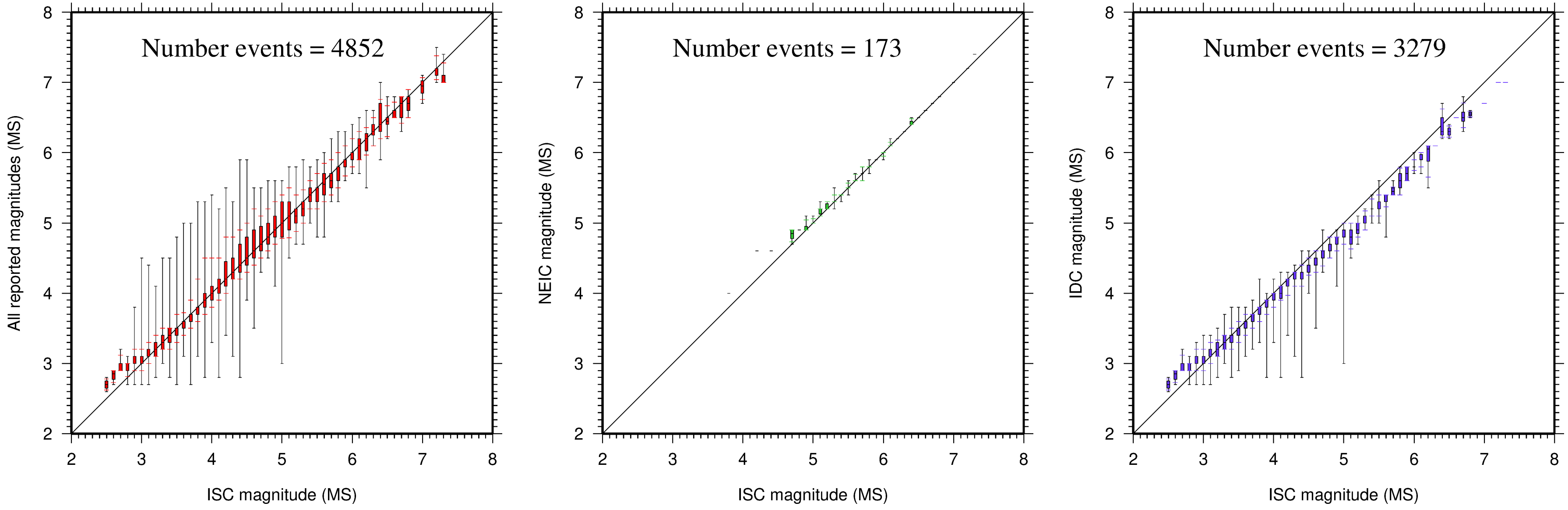


Figure 7.29: *Comparison of ISC values of MS with GCMT M_W for common event pairs.*



(a) (b) (c)

Figure 7.30: *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 7.31: *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.*

8

The Leading Data Contributors

For the current six-month period, 149 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 8.1),
- reported data that helped quite considerably to improve the quality of the ISC locations or magnitude determinations (see Section 8.2),
- 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 8.3).

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.

8.1 The Largest Data Contributors

We acknowledge the contribution of IDC, NEIC, MOS, BJI, GCMT, DJA, PPT and a few others (Figure 8.1) 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, TAP, RSNC, AFAD, 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, Chinese Taipei, 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 8.2). For small magnitude events, these are local agencies in charge of monitoring local and regional seismicity. For moderate to large events, contributions of IDC, USArray, NEIC, MOS are especially acknowledged. Notably, three agencies (IDC, NEIC 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.

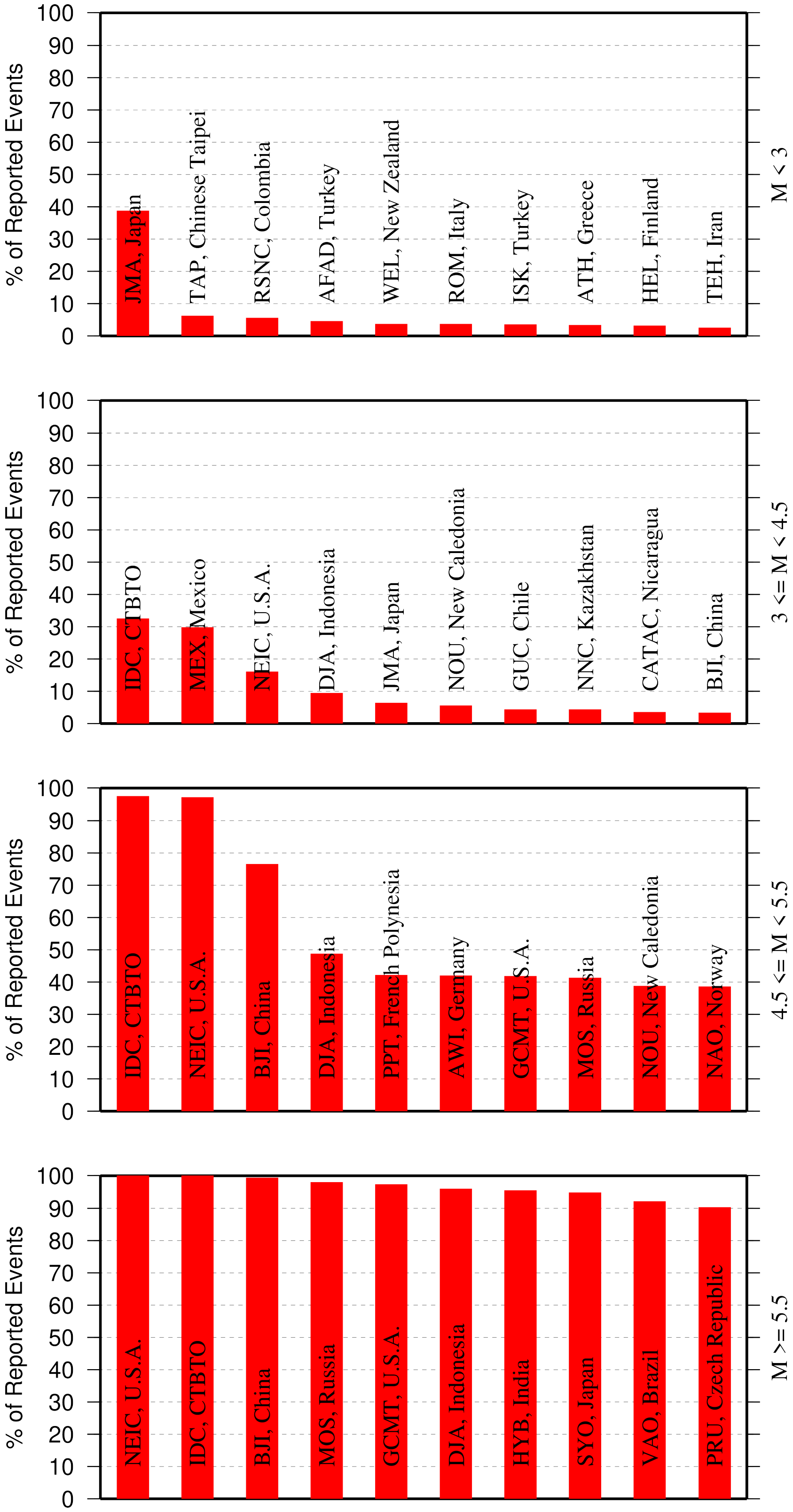


Figure 8.1: *Frequency of events in the ISC Bulletin for which an agency reported at least one item of data: a moment tensor, a hypocentre, a station arrival time or an amplitude. The top ten agencies are shown for four magnitude intervals.*

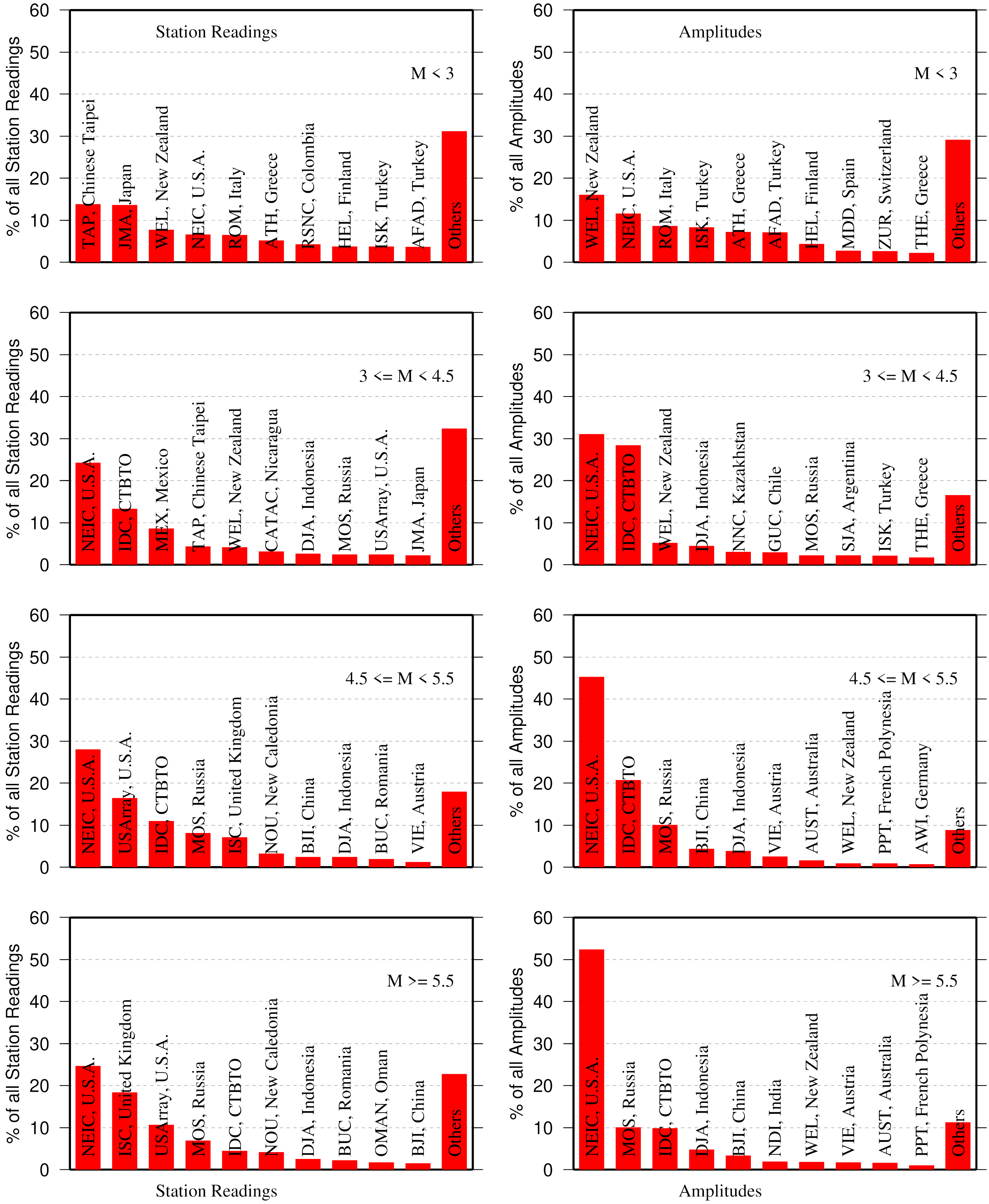


Figure 8.2: *Contributions of station arrival time readings (left) and amplitudes (right) of agencies to the ISC Bulletin. Top ten agencies are shown for four magnitude intervals.*

8.2 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 8.3). 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 45% 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, NAO, MOS, AWI, PPT, VIE, NOU, CLL 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 8.4). 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.

Another important long-term task that the ISC performs is to compute the most definitive values of

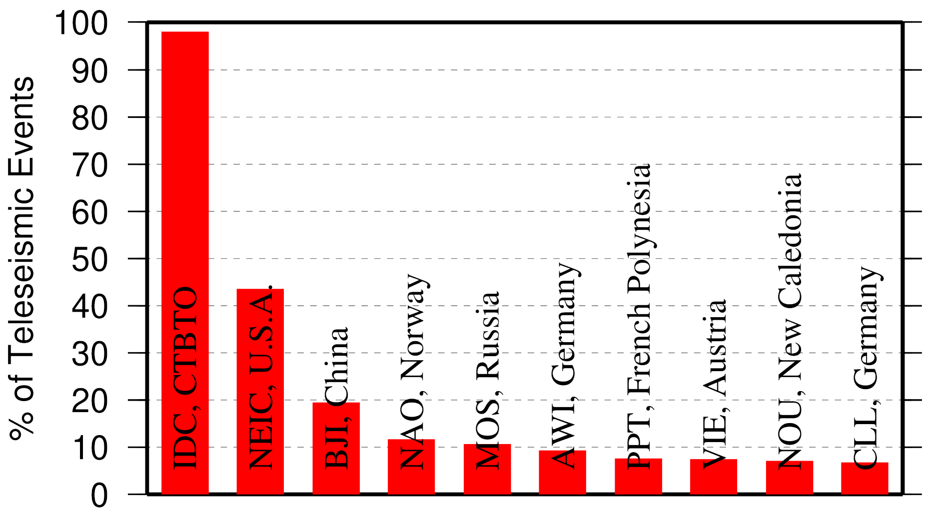


Figure 8.3: *Top ten agencies that reported teleseismic phase arrivals for a large portion of ISC events.*

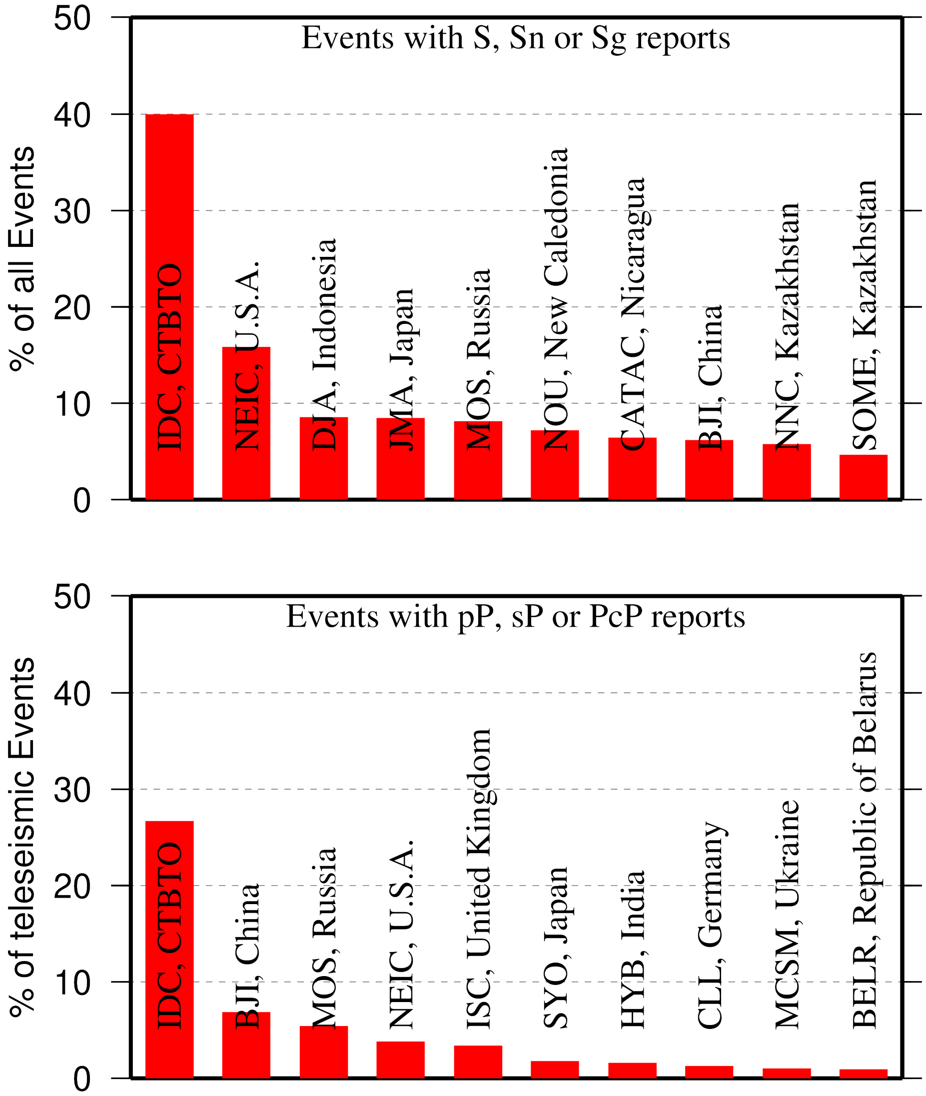


Figure 8.4: *Top ten agencies that reported secondary phases important for an accurate epicentre location (top) and focal depth determination (bottom).*

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 7.5.

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, MOS, PRU, CLL, NAO and a few other agencies (Figure 8.5) are also responsible for the majority of the amplitude and period reports that contribute towards the ISC magnitudes.

The ISC only recently started to determine source mechanisms in addition to those reported by other agencies. For moment tensor magnitudes we rely on reports from other agencies (Figure 8.6).

Among other event parameters the ISC Bulletin also contains information on event type. We cannot

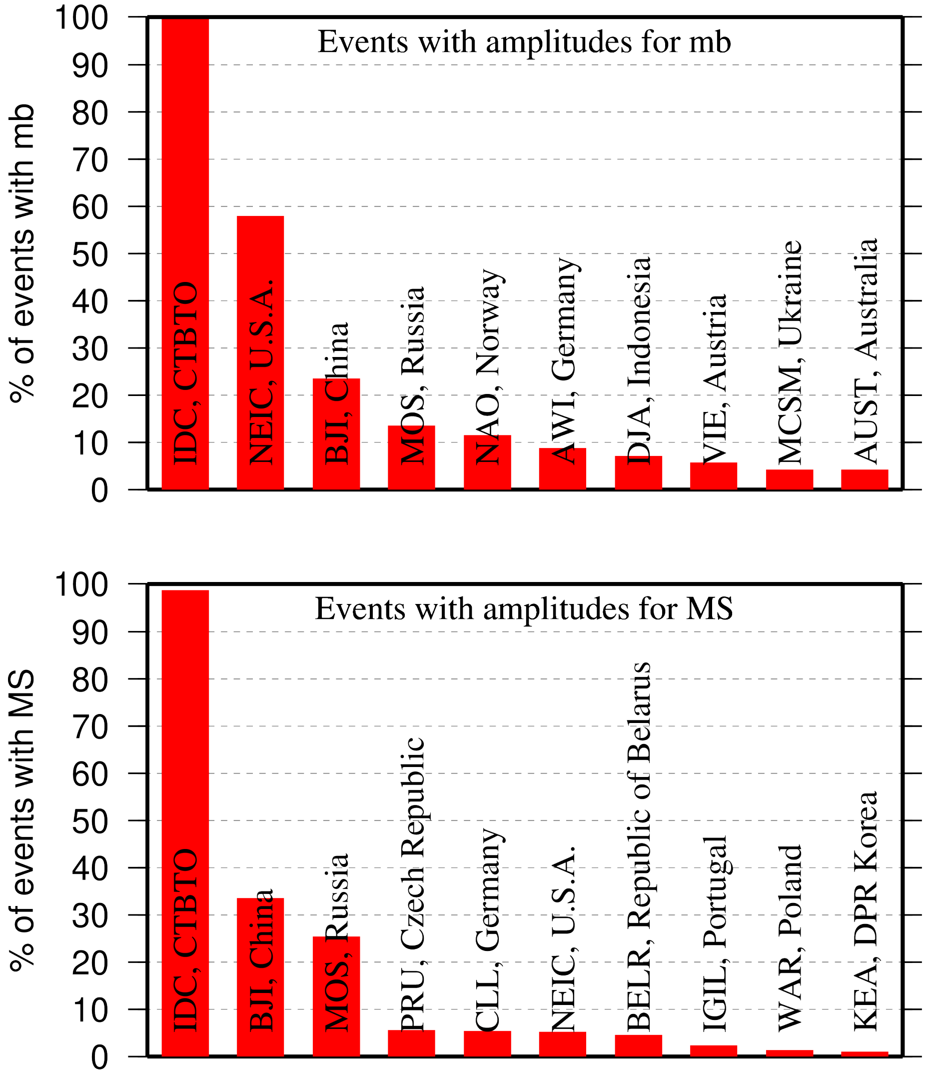


Figure 8.5: *Agencies that report defining body (top) and surface (bottom) wave amplitudes and periods for the largest fraction of those ISC Bulletin events with MS/mb determinations.*

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 8.7 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 8.8 provide such information for the majority of all felt or damaging events in the ISC Bulletin.

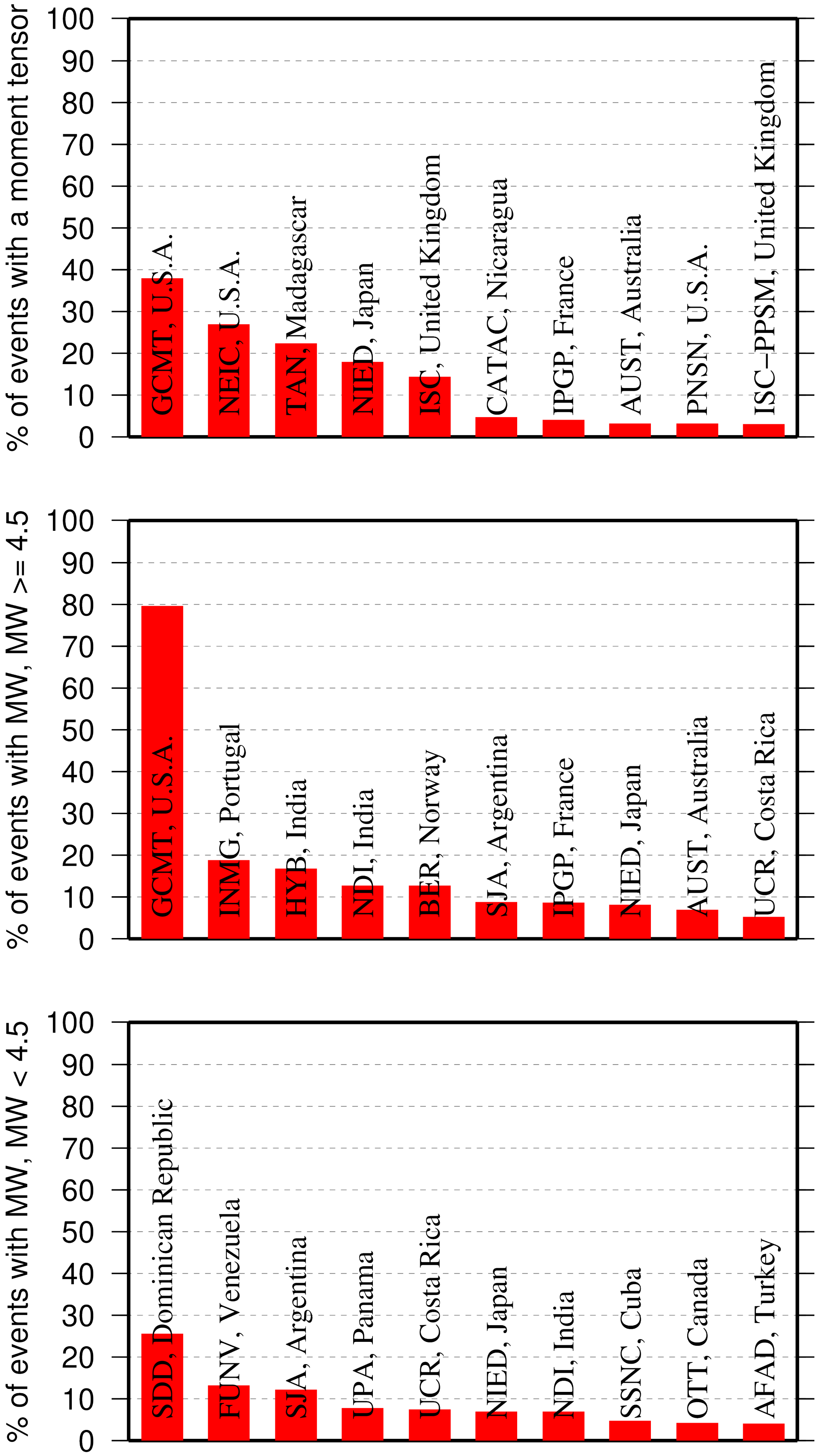


Figure 8.6: *Top ten agencies that most frequently report determinations of seismic moment tensor (top) and moment magnitude (middle/bottom for M greater/smaller than 4.5); notably, the ISC's recent dedicated effort of determination of source mechanisms based on automated picking of first arrival polarities, currently makes it the 4th largest contributor of such data.*

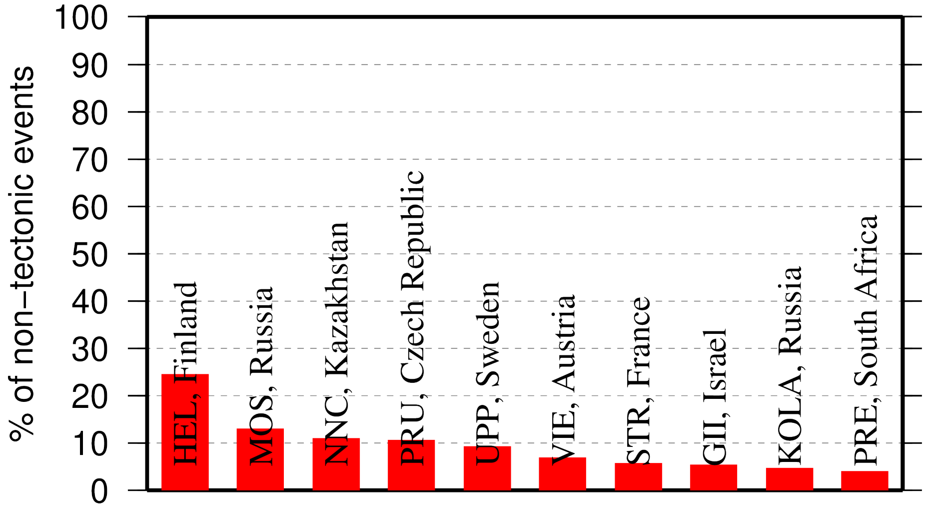


Figure 8.7: *Top ten agencies that most frequently report non-tectonic seismic events to the ISC.*

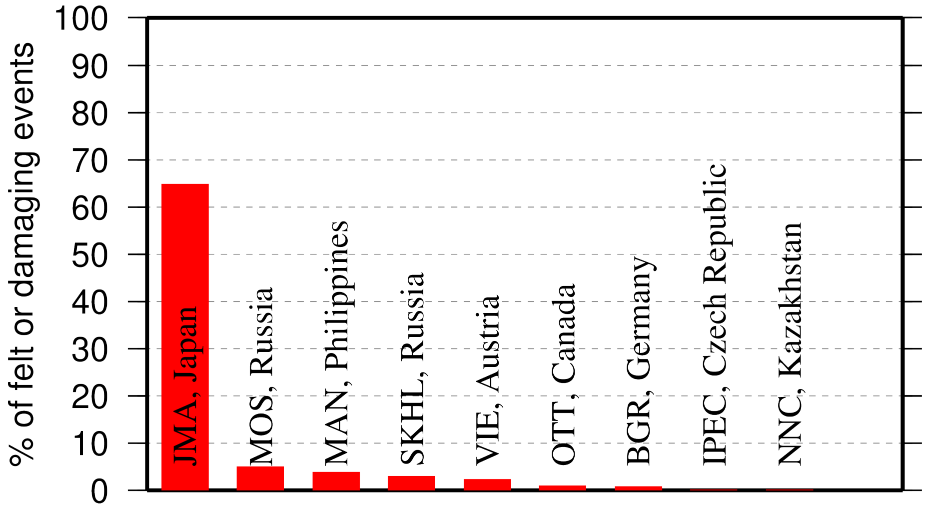


Figure 8.8: *Top ten agencies that most frequently report macroseismic information to the ISC.*

8.3 The Most Consistent and Punctual Contributors

During this six-month period, 41 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 8.1 lists all agencies that have been helpful to the ISC in this respect during the six-month period.

Table 8.1: *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)
ZUR	Switzerland	11
WEL	New Zealand	16
ATH	Greece	24
IDC	Austria	29
KNET	Kyrgyzstan	31
IGIL	Portugal	32
LDG	France	33
ECX	Mexico	37
BUC	Romania	40
ISN	Iraq	40
MDD	Spain	46
PPT	French Polynesia	59
AUST	Australia	65
NAO	Norway	72
ISK	Turkey	95
NEIC	U.S.A.	100
AFAD	Turkey	114
TIR	Albania	117
BJI	China	133
TEH	Iran	135
BGS	United Kingdom	135
BGSI	Botswana	145
KEA	Democratic People's Republic of Korea	147
INMG	Portugal	161
OMAN	Oman	164
MRB	Spain	207
UPP	Sweden	211
SSNC	Cuba	211
RHSSO	Bosnia and Herzegovina	227
ASRS	Russia	232
IPEC	Czech Republic	236
SVSA	Portugal	259
FUNV	Venezuela	287
NERS	Russia	288
BYKL	Russia	294
NDI	India	294
UCC	Belgium	309
NAM	Namibia	319
SOME	Kazakhstan	344
DSN	United Arab Emirates	365
LIT	Lithuania	365

9

Appendix

9.1 Tables

Table 9.1: *Listing of all 391 agencies that have directly reported to the ISC. The 149 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
ASIES	**Institute of Earth Sciences, Academia Sinica, Chinese Taipei**
ASL	Albuquerque Seismological Laboratory, USA
ASM	University of Asmara, Eritrea
ASRS	**Altai-Sayan Seismological Centre, GS SB RAS, Russia**
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**
BGSI	**Botswana Geoscience Institute, Botswana**

Table 9.1: *Continued.*

Agency Code	Agency Name
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**
CMWS	Laboratory of Seismic Monitoring of Caucasus Mineral Water Region, GSRAS, Russia
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**
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
DNK	**Geological Survey of Denmark and Greenland**, **Denmark**

Table 9.1: Continued.

Agency Code	Agency Name
DRS	Dagestan Branch, Geophysical Survey, Russian Academy of Sciences, Russia
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 9.1: *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
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
ISC	**International Seismological Centre**, **United Kingdom**

Table 9.1: *Continued.*

Agency Code	Agency Name
ISC-PPSM	**International Seismological Centre Probabilistic Point Source Model**, **United Kingdom**
ISK	**Kandilli Observatory and 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**
KNET	**Kyrgyz Seismic Network**, **Kyrgyzstan**
KOLA	**Kola Regional Seismic Centre, GS RAS**, **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
LIS	Instituto de Meteorologia, Portugal
LIT	**Geological Survey of Lithuania**, **Lithuania**
LJU	**Slovenian Environment Agency**, **Slovenia**
LPA	**Universidad Nacional de La Plata**, **Argentina**

Table 9.1: Continued.

Agency Code	Agency Name
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**
NEIC	**National Earthquake Information Center**, **USA**
NEIS	National Earthquake Information Service, USA
NERS	**North Eastern Regional Seismological Centre, 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**
NORS	North Ossetia (Alania) Branch, Geophysical Survey, Russian Academy of Sciences, Russia
NOU	**IRD Centre de Nouméa**, **New Caledonia**
NSSC	National Syrian Seismological Center, Syria
NSSP	**National Survey of Seismic Protection**, **Armenia**
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

Table 9.1: Continued.

Agency Code	Agency Name
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**
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
SAPSE	Southern Alps Passive Seismic Experiment, New Zealand

Table 9.1: Continued.

Agency Code	Agency Name
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
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
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

Table 9.1: Continued.

Agency Code	Agency Name
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**
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

Table 9.1: Continued.

Agency Code	Agency Name
VAO	**Instituto Astronomico e Geofísico**, **Brazil**
VIE	**Zentralanstalt für Meteorologie und Geodynamik (ZAMG)**, **Austria**
VKMS	Lab. of Seismic Monitoring, Voronezh region, GSRAS & Voronezh State University, Russia
VLA	Vladivostok Seismological Station, 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
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 9.2: *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	3825854	
S	1850220	TAP (18%), JMA (15%)
IAML	643121	NEIC (51%), AFAD (15%)
NULL	638266	NEIC (36%), IDC (26%), AEIC (12%), PAS (11%)
AML	537013	ROM (98%)
IAmb	463570	NEIC (97%)
Pg	314117	ISK (18%), STR (11%)
Pn	274956	NEIC (32%), ISK (18%)
Sg	234932	STR (12%), ISK (11%)
LR	137238	IDC (65%), BJI (29%)
pmax	115327	MOS (69%), BJI (31%)
IAMs_20	101142	NEIC (97%)
Sn	85476	IDC (12%)
SG	72686	HEL (58%), PRU (22%)
PG	66571	HEL (60%), PRU (16%), IPEC (12%)
PKP	37832	IDC (38%), VIE (15%)
Lg	33845	NNC (63%), IDC (20%)
PN	31518	MOS (41%), HEL (35%)
MSG	27409	HEL (100%)
T	25367	IDC (99%)
SN	22143	HEL (80%), OTT (11%)
IVmb_Lg	21557	MDD (100%)
IAmb_Lg	19787	NEIC (100%)
MLR	15435	MOS (100%)
pP	14972	BJI (37%), IDC (20%), VIE (11%)
PKPbc	14385	IDC (68%)
PKIKP	14131	MOS (99%)
SB	13248	HEL (100%)
PcP	12901	IDC (63%)
smax	12872	MOS (44%), HEL (43%), BJI (13%)
A	11852	SKHL (52%), JMA (48%)
PP	11810	BJI (23%), IDC (19%), BELR (16%)
PB	10460	HEL (100%)
SS	9782	MOS (35%), BJI (20%), BELR (20%), PPT (12%)
PKPdf	7685	NEIC (42%), INMG (18%)
sP	6150	BJI (71%)
Sb	5790	IRIS (96%)
PKPab	5153	IDC (52%), INMG (17%)
PKiKP	4898	IDC (31%), VIE (26%), IRIS (18%)
x	4630	BRG (48%), CLL (26%), PRU (12%)
SPECP	4516	AFAD (100%)
Trac	4220	OTT (100%)
AMS	4210	PRU (83%)
PPP	3929	MOS (55%), BELR (40%)
Amp	3868	BRG (100%)
AMB	3758	SKHL (85%), BJI (15%)
ScP	3594	IDC (77%), BJI (12%)
LRM	3437	BELR (89%), MOLD (11%)
SSS	3208	BELR (52%), MOS (40%)
LG	2649	BRA (80%), OTT (20%)
PKP2	2641	MOS (99%)
*PP	2639	MOS (100%)
Pb	2617	IRIS (90%)
LQ	2364	BELR (54%), PPT (34%)
PKKPbc	2293	IDC (93%)
Pdiff	2161	IRIS (39%), IDC (25%), VIE (22%)
PKhKP	1758	IDC (100%)
sS	1703	BJI (76%), BELR (15%)
I	1699	IDC (99%)
pPKP	1662	VIE (39%), IDC (25%), BJI (11%)
Smax	1600	BYKL (100%)
SKS	1445	BJI (35%), BELR (33%), PRU (14%)
IVmb_VC	1350	MDD (100%)
L	1285	BGR (42%), WAR (28%), MOLD (27%)
AMP	1252	UPA (96%)
Pmax	1251	BYKL (95%)
AMd	1001	TIR (100%)
SKPbc	1001	IDC (92%)
X	971	JMA (92%)
PS	910	MOS (43%), BELR (25%), CLL (15%)

Table 9.2: *(continued)*

Reported Phase	Total	Agencies reporting
PKKP	907	VIE (43%), IDC (41%)
IVmB_BB	857	BER (78%), HYB (16%)
PKPPKP	814	IDC (98%)
Pdif	809	BER (28%), BJI (17%), NEIC (14%), INMG (13%), CLL (11%)
PKHKP	796	MOS (100%)
Sgmax	784	NERS (100%)
IVMs_BB	773	BER (84%), HYB (12%)
Sm	721	CFUSG (86%), SIGU (14%)
ScS	717	BJI (73%)
SKP	693	IDC (38%), VIE (19%), BELR (13%), PRU (11%)
SKSac	650	BER (43%), AWI (29%), CLL (11%)
PDIFF	523	PRU (45%), BRA (31%), IPEC (22%)
END	513	ROM (100%)
*SS	488	MOS (100%)
pPKPbc	453	IDC (64%), BGR (27%)
*SP	435	MOS (100%)
SP	408	MOS (30%), BER (27%), PRU (11%)
PKPAB	383	PRU (100%)
pPKiKP	375	VIE (70%), BELR (17%)
Pm	369	CFUSG (74%), SIGU (26%)
max	367	BYKL (100%)
SKKS	362	BJI (46%), BELR (39%)
PKPDF	339	PRU (100%)
tx	330	INMG (98%)
SmS	329	BGR (84%), ZUR (16%)
PKKPab	325	IDC (95%)
PmP	268	BGR (72%), ZUR (28%)
pPKPdf	268	NEIC (44%), BER (11%)
PKP2bc	264	IDC (100%)
PnA	238	THR (100%)
sPKP	236	BJI (76%), BELR (20%)
Pgmax	214	NERS (100%)
PPS	200	CLL (70%), MOS (16%)
P3KPbc	200	IDC (100%)
SKKPbc	178	IDC (98%)
pPKPab	177	BGR (38%), IDC (30%), CLL (27%)
Lm	173	CLL (100%)
PcS	166	BJI (86%)
PKS	150	BELR (63%), BJI (31%)
pPdiff	148	VIE (45%), SYO (35%)
SKKP	142	VIE (42%), BELR (28%), IDC (20%)
SKPdf	132	CLL (42%), BGR (23%), BER (17%)
LmV	132	CLL (100%)
SSSS	126	CLL (100%)
p	125	ROM (99%)
AmB	119	KEA (100%)
PKPpre	119	NEIC (60%), PRU (32%)
SKPab	94	IDC (96%)
P4KPbc	77	IDC (100%)
LmH	70	CLL (100%)
SKKSac	70	CLL (64%), HYB (31%)
Rg	67	IDC (67%), BRG (16%), NNC (12%)
Sdif	66	CLL (73%), BELR (12%)
Pif	60	BRG (100%)
Px	59	CLL (100%)
m	57	SIGU (100%)
r	57	BRG (100%)
P'P'	56	VIE (93%)
H	56	IDC (100%)
PKP2ab	55	IDC (100%)
Pn_2	55	ATH (100%)
sPP	47	CLL (98%)
PKP1	47	PPT (89%), LDG (11%)
sPKiKP	46	BELR (67%), HYB (22%)
PCP	46	IPEC (26%), NAO (22%), PRU (20%), MOS (20%), LPA (13%)
PKPf	46	BRG (100%)
SKSdf	44	HYB (80%)
PPPP	41	CLL (100%)
LQM	41	MOLD (100%)
Lmax	40	CLL (100%)
PSKS	39	CLL (100%)

Table 9.2: *(continued)*

Reported Phase	Total	Agencies reporting
pPP	39	CLL (67%), LPA (26%)
sSKS	37	BELR (100%)
IAML_BB	36	THR (100%)
Sgm	34	CFUSG (100%)
SgSg	29	BYKL (100%)
E	28	YARS (61%), ZAG (36%)
PKKPdf	27	CLL (52%), AWI (44%)
PKPmax	24	CLL (100%)
LgM	24	MOLD (100%)
P3KP	24	IDC (100%)
IVmBBB	24	BER (92%)
PKKS	24	BELR (96%)
rx	24	SKHL (54%), INMG (38%)
sSS	24	CLL (96%)
PgPg	24	BYKL (100%)
PKSdf	23	CLL (57%), BER (39%)
pPcP	22	IDC (91%)
sPdiff	22	BGR (55%), SYO (41%)
pPdif	20	CLL (45%), INMG (30%), BELR (25%)
PKPb	19	BRG (100%)
(PKiKP)	19	CLL (100%)
PKPlp	19	CLL (100%)
PKPdif	19	CLL (79%), LJU (16%)
Sif	17	BRG (100%)
PgA	16	THR (100%)
sPKPab	15	AWI (67%), CLL (13%), HYB (13%)
MPN	15	HEL (100%)
Snm	14	CFUSG (100%)
SCS	14	IPEC (50%), LPA (50%)
(PP)	14	CLL (100%)
(pP)	13	CLL (100%)
SKIKS	13	LPA (100%)
PnPn	13	SYO (92%)
MSN	13	HEL (69%), BER (31%)
Plp	13	CLL (100%)
(SS)	12	CLL (100%)
PKPPKPdf	12	CLL (100%)
sPKPdf	12	SYO (50%), CLL (33%), HYB (17%)
SDIFF	12	LPA (58%), BRA (42%)
sPdif	12	CLL (75%), BELR (25%)
SKIKP	11	LPA (100%)
PKIKS	11	LPA (100%)
SKSa	11	BRG (100%)
AMPG	11	NAM (100%)
P'P'df	11	AWI (91%)
IVMsBB	10	BER (100%)
(sP)	10	CLL (100%)
PM2	10	MOLD (100%)
PM1	10	MOLD (100%)
Pgm	9	CFUSG (100%)
PPlp	9	CLL (100%)
sPPP	9	CLL (100%)
(PKPab)	9	CLL (100%)
(Pg)	9	CLL (100%)
SDIF	9	PRU (100%)
M	9	MOLD (56%), LJU (44%)
PPPrev	8	CLL (100%)
SPP	8	CLL (75%), BELR (12%), MOS (12%)
PSP	8	LPA (100%)
P*	8	BGR (62%), MOS (38%)
SKiKP	8	IDC (75%), HYB (25%)
PKDdf	7	INMG (100%)
sPKPbc	7	HYB (43%), CLL (29%), LJU (14%), SYO (14%)
sSSS	7	CLL (100%)
XS	7	PRU (100%)
PPmax	7	CLL (100%)
(Pn)	7	CLL (100%)
sSdif	7	CLL (86%), BELR (14%)
(PPS)	6	CLL (100%)
(SSS)	6	CLL (100%)
AP	6	MOS (100%)

Table 9.2: (continued)

Reported Phase	Total	Agencies reporting
sPPS	6	CLL (100%)
sPS	5	CLL (100%)
(Sn)	5	CLL (100%)
pPif	5	BRG (100%)
Sx	5	CLL (100%)
(Sg)	5	CLL (100%)
SKSP	5	CLL (80%), MOLD (20%)
(PKPdf)	5	CLL (100%)
del	5	KNET (80%), PGC (20%)
sSSSS	5	CLL (100%)
pPS	5	CLL (100%)
PKKSbc	5	CLL (80%), HYB (20%)
(SSSS)	5	CLL (100%)
PKSbc	5	CLL (100%)
pPPS	4	CLL (100%)
SCP	4	IPEC (100%)
R2	4	CLL (100%)
sSP	4	CLL (100%)
SKKSa	4	BRG (100%)
PKPc	4	PJWWP (100%)
LV	4	CLL (100%)
SKKSdf	4	CLL (75%), HYB (25%)
(PKPbc)	4	CLL (100%)
PKSd	4	BER (100%)
Pg_3	4	ATH (100%)
Sdiff	4	LJU (75%), BGR (25%)
P(2)	4	CLL (100%)
pSKSac	4	CLL (100%)
Pn_3	4	ATH (100%)
(PcP)	4	CLL (100%)
PPPPrev	3	CLL (100%)
ATSG	3	OSPL (100%)
(PS)	3	CLL (100%)
pPn	3	SYO (100%)
PKPM1	3	MOLD (100%)
ATPG	3	OSPL (100%)
PSPS	3	CLL (100%)
ASSG	3	OSPL (100%)
ASPG	3	OSPL (100%)
Pnm	3	CFUSG (100%)
pPKKPbc	3	CLL (100%)
pS	3	BELR (33%), HYB (33%), CLL (33%)
(PKPdif)	3	CLL (100%)
P4KP	3	IDC (100%)
(SKPdf)	3	CLL (100%)
PKPM	3	MOLD (100%)
sPSKS	2	CLL (100%)
PKPbc(2)	2	CLL (100%)
?	2	PPT (100%)
(pPKPab)	2	CLL (100%)
SnSn	2	KRSZO (100%)
pPPP	2	CLL (100%)
pSdiff	2	CLL (50%), LJU (50%)
PsP	2	MOLD (100%)
sPKKPbc	2	CLL (100%)
pPKSdf	2	CLL (100%)
(PKPm)	2	CLL (100%)
BAZ	2	DNK (100%)
PSPSrev	2	CLL (100%)
LH	2	CLL (100%)
PKPab(2)	2	CLL (100%)
XM	2	MOLD (100%)
P5KP	2	NAO (100%)
PM	2	MOLD (100%)
sPKKPdf	2	CLL (100%)
Li	2	MOLD (100%)
(sPP)	2	CLL (100%)
AMSN	2	SJA (100%)
pPKIKP	2	IPEC (100%)
sSKKSac	2	CLL (100%)
SSPrev	2	CLL (100%)

Table 9.2: (continued)

Reported Phase	Total	Agencies reporting
SKSSKSac	2	CLL (100%)
(SKKSac)	2	CLL (100%)
PKPM2	2	MOLD (100%)
sSKSac	2	CLL (100%)
S*	2	BJI (50%), BGR (50%)
PSS	2	CLL (100%)
sPif	2	BRG (100%)
sPSS	2	CLL (100%)
SKKPdf	2	CLL (100%)
sSKSdf	2	CLL (100%)
(PPP)	1	CLL (100%)
(Sdif)	1	CLL (100%)
SKSSKS	1	BRG (100%)
sPKPab2	1	CLL (100%)
SA	1	SJA (100%)
h	1	KRSC (100%)
Z	1	MEX (100%)
PzP	1	SYO (100%)
SKPf	1	BRG (100%)
pSKPbc	1	CLL (100%)
pScS	1	CLL (100%)
(sPPP)	1	CLL (100%)
pSKKPbc	1	CLL (100%)
(pPKiKP)	1	CLL (100%)
SKKPab	1	IDC (100%)
pScP	1	CLL (100%)
(pPKPdf)	1	CLL (100%)
SS(2)	1	LPA (100%)
PKPabmax	1	CLL (100%)
Pn_1	1	ATH (100%)
pPKKPdf	1	CLL (100%)
PKPbcmax	1	CLL (100%)
Pdif(2)	1	CLL (100%)
PP(2)	1	CLL (100%)
PPPPmax	1	CLL (100%)
RG	1	HEL (100%)
Pg_2	1	ATH (100%)
(ScS)	1	CLL (100%)
PSSrev	1	CLL (100%)
PSPZ	1	MOS (100%)
QP	1	MOLD (100%)
PKPg	1	NAO (100%)
sPcP	1	CLL (100%)
sPKSbc	1	CLL (100%)
PSmax	1	CLL (100%)
APKP	1	MOLD (100%)
SKKSacr	1	CLL (100%)
PKPM3	1	MOLD (100%)
Pn_0	1	ATH (100%)
pPLPab	1	SYO (100%)
LRN	1	MOLD (100%)
(PPPrev)	1	CLL (100%)
SH	1	SYO (100%)
(PKP)	1	CLL (100%)
Odiff	1	SYO (100%)
sPn	1	SYO (100%)
Sdifmax	1	CLL (100%)
PKPdf(2)	1	CLL (100%)
pPdifF	1	SYO (100%)
sSif	1	BRG (100%)
UPdiff	1	SYO (100%)
OcO	1	SYO (100%)
sPKPf	1	BRG (100%)
(PSPS)	1	CLL (100%)
SKPa	1	NAO (100%)
PKBdf	1	INMG (100%)
pSKPdf	1	CLL (100%)
SSP	1	CLL (100%)
SSrev	1	CLL (100%)
pPKPab2	1	CLL (100%)
pPPPP	1	CLL (100%)

Table 9.2: *(continued)*

Reported Phase	Total	Agencies reporting
(sPKiKP)	1	CLL (100%)
AMb	1	LVSN (100%)
Sg_3	1	ATH (100%)
AMPN	1	SJA (100%)
pPKPf	1	BRG (100%)
PKSab	1	CLL (100%)
PKPbcd	1	PJWWP (100%)
sPmax	1	CLL (100%)
(sSKSac)	1	CLL (100%)
sSKPbc	1	CLL (100%)
Pg_0	1	ATH (100%)
P9	1	SNET (100%)
SKSacmax	1	CLL (100%)
pPmax	1	CLL (100%)
(PPPP)	1	CLL (100%)
SKSp	1	BRA (100%)
SKPlp	1	CLL (100%)
SKPPKPbc	1	CLL (100%)
s	1	MEX (100%)
SKPPKPdf	1	CLL (100%)
PKPdfc	1	PJWWP (100%)
(pPdif)	1	CLL (100%)
(sSSS)	1	CLL (100%)
(SKSac)	1	CLL (100%)
pPKSbc	1	CLL (100%)
pSKKSac	1	CLL (100%)
PDIF	1	MOLD (100%)
SKPM	1	MOLD (100%)
PPSmax	1	CLL (100%)
sSPP	1	CLL (100%)
(SPP)	1	CLL (100%)
Pnd	1	PJWWP (100%)

Table 9.3: 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	898519	299660	199666	46896
ROM	525218	21494	0	0
IDC	503489	473249	123631	66145
WEL	238983	32382	0	0
MOS	103993	99327	47359	10719
DJA	102796	62172	10402	0
AFAD	96034	7604	0	0
BJI	77698	74715	22394	26001
ISK	74577	13627	0	0
NNC	72617	26979	71	0
ATH	61446	7218	0	0
AUST	59692	11852	7999	0
VIE	49679	28365	8508	0
RSNC	46996	12746	1840	0
INMG	46320	16788	3213	0
SVSA	43990	1087	174	0
THE	41898	14650	0	0
SOME	37999	13499	2705	0
GUC	33533	7275	0	0
HEL	33019	1857	0	0
TXNET	24621	354	0	0
MDD	22907	3873	0	0
ZUR	21816	1441	0	0
LDG	15118	2411	0	0
PRE	13776	1147	0	0
SDD	13388	4811	0	0
SJA	13332	12349	0	0
PPT	12617	11768	676	0
PDG	12271	6276	0	0
NDI	11546	9112	2993	389
JMA	11342	11288	0	0
AWI	10511	6422	2345	0
PRU	9543	4413	0	1837
SKHL	9442	4263	0	0
BER	9400	3179	348	79
SSNC	9044	1896	0	3
BUC	8239	2524	0	0
MCSM	7890	7818	3435	0
DNK	7648	3411	2622	47
BELR	7216	2218	347	356
MRB	7105	176	0	0
GCG	6982	1976	0	0
LJU	6522	237	0	0
BGR	4843	4509	3246	0
NIC	4808	2785	0	0
WBNET	4499	22	0	0

Table 9.3: Continued.

Agency	Number of reported amplitudes	Number of amplitudes in ISC located events	Number used for ISC mb	Number used for ISC MS
OSPL	4236	1918	0	0
OTT	4221	204	0	0
ECX	4141	390	0	0
TIR	4123	1843	0	0
BRG	3868	1079	0	0
YARS	3844	101	2	0
KRSZO	3571	415	0	0
BGS	3322	1987	1165	590
BYKL	3183	1760	0	0
BKK	3013	1136	13	0
CLL	2893	1732	293	279
KNET	2666	1172	0	0
NOU	2661	2561	1724	0
IPEC	2131	389	0	0
NAO	2067	2017	1332	0
SKO	1978	1004	0	0
SCB	1960	214	0	0
UCC	1887	1777	1445	0
ASRS	1866	1018	0	0
BGSI	1524	508	0	0
THR	1391	1270	0	0
LVSN	1346	445	0	0
UPA	1201	232	0	0
IGIL	1137	613	106	190
DMN	1014	828	0	0
CFUSG	1007	833	0	0
NERS	986	393	0	0
MOLD	931	675	119	0
SNET	897	268	0	0
ISN	644	582	0	0
MIRAS	616	66	0	0
FCIAR	471	186	10	0
KEA	455	291	0	85
SIGU	400	254	0	0
WAR	368	335	0	248
PLV	348	91	0	0
HYB	244	240	1	3
NAM	186	26	0	0
JSO	59	54	0	0
PJWWP	23	23	0	0
UCR	6	6	0	0
LIT	2	1	0	0

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Glossary of ISC Terminology

- 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 50 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 Working Statutes the Governing Council is the governing body of the ISC, comprising one representative for each ISC Member.

- 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 the January to June 2019 Bulletin 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-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 the January to June 2019 Bulletin 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 six-character code for a station. The ISC Bulletin contains data exclusively from stations registered in the International Registry of Seismograph Stations.

11

Acknowledgements

We are grateful to the developers of the Generic Mapping Tools (GMT) suite of software (Wessel et al., 2019) that was extensively used for producing the figures.

Finally, we thank the ISC Member Institutions, Data Contributors, Funding Agencies (including NSF Award EAR-1811737) and Sponsors for supporting the long-term operation of the ISC.

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