Summary of the Bulletin of the International Seismological Centre

2017

July – December

Volume 54 Issue II

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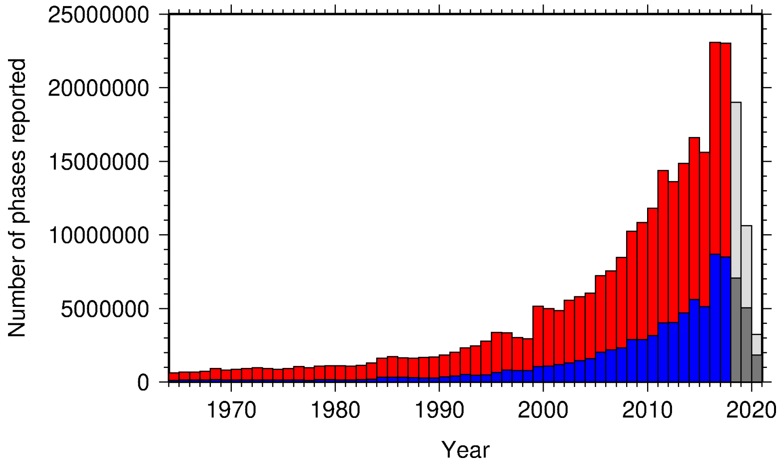
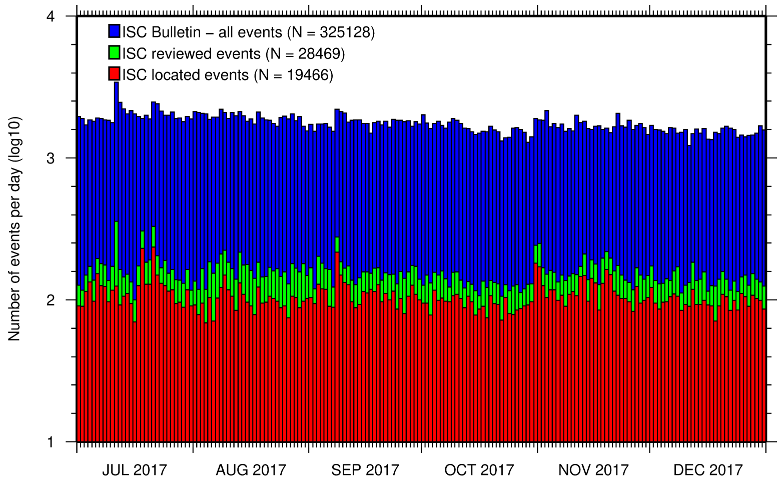
ISSN 2309-236X

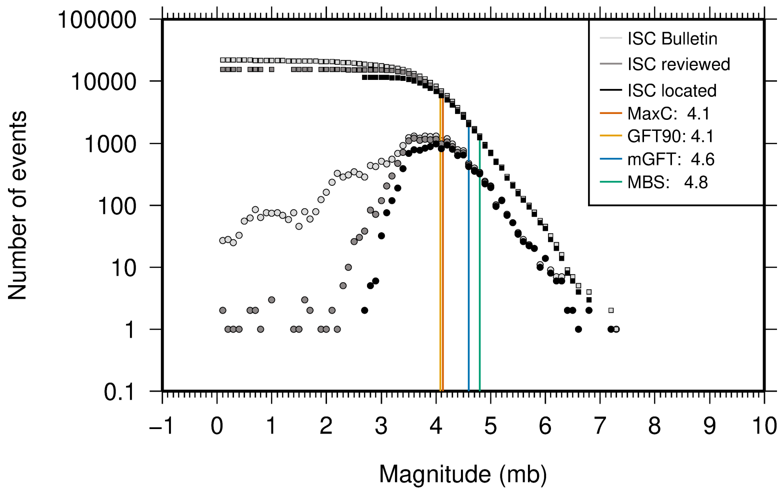
2020



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



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



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

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

Published by
International Seismological Centre

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/

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Pipers Lane
Thatcham
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United Kingdom
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Contents

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Preface

Dear Colleague,

This is the second 2017 issue of the Summary of the ISC Bulletin, which remains the most fundamental reason for continued operations at the ISC. This issue covers earthquakes and other seismic events that occurred during the period from July to December 2017. 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.

We continue publishing invited articles describing the history, current status and operational procedures at those networks that contribute data to the ISC. This time it is the turn for Chinese Seismic Network (CSN) run by China Earthquake Administration (CEA).

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 Data 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

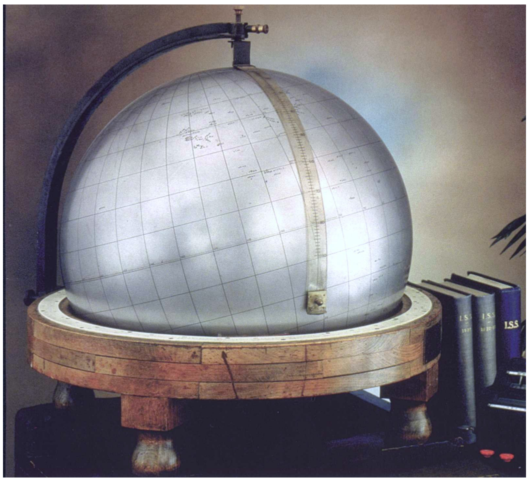


Figure 2.1: *The steel globe bearing positions of early seismic stations was used for locating positions of earthquakes for the International Seismological Summaries.*

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 60, 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

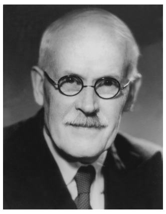
John Milne
Publisher of the Shide Cicular Reports on Earthquakes
1899-1913

Herbert Hall Turner

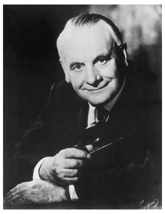
Seismological Bulletins of the BAAS

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 62 Member Institutions and a four-year Grant Award EAR-1417970 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.

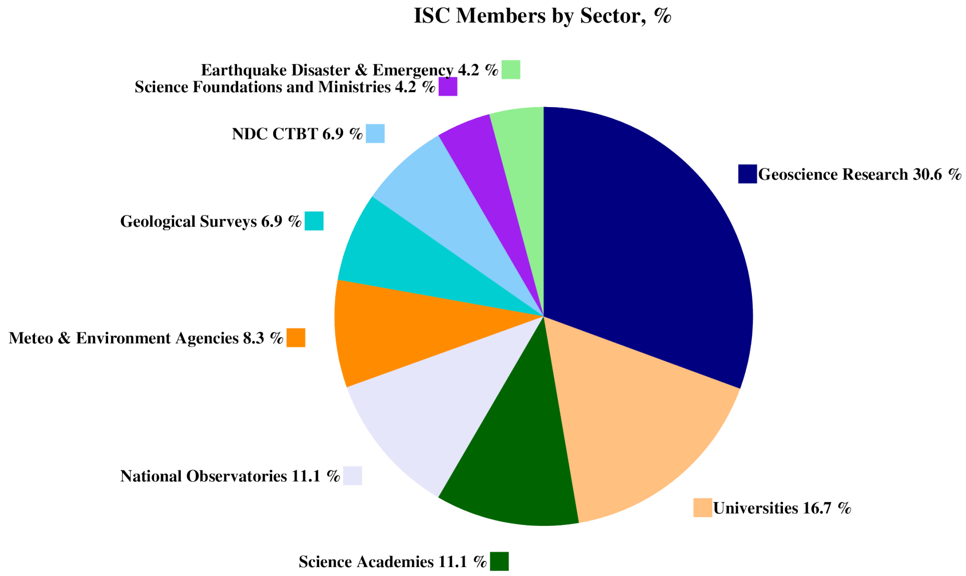


Figure 2.3: *Distribution of the ISC Member Institutions by sector in year 2013 as a percentage of total number of Members.*

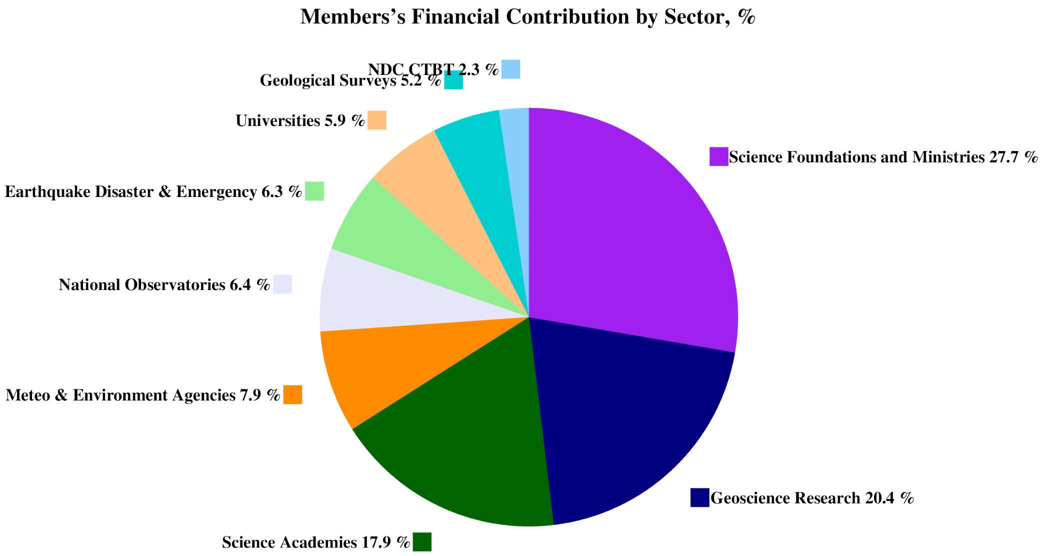


Figure 2.4: *Distribution of Member's financial contributions to the ISC by sector in year 2013 as a percentage of total annual Member contributions.*

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

Bundesministerium für Wissenschaft, Forschung und Wirtschaft (BMWFW)
Austria
www.bmbwk.gv.at
Category: 2

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

Belgian Science Policy Office (BELSPO)
Belgium

Category: 1

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

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

Observatorio Nacional
Brazil
www.on.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 National des Sciences de l'Univers
France
www.insu.cnrs.fr
Category: 4

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

Category: 1

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

The Hungarian Academy of Sciences
Hungary
www.mta.hu
Category: 1

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

National Geophysical Research Institute (NGRI), Council of Scientific and Industrial Research (CSIR)
India

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

The Geophysical Institute of Israel
Israel
www.gii.co.il
Category: 1

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

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

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

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

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

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

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

Royal Scientific Society
Jordan
www.rss.jo
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

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

Stiftelsen NORSAR
Norway
www.norsar.no
Category: 2

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

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

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

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

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

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

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

Institute of Earth Sciences Jaume Almera
Spain
www.ictja.csic.es
Category: 1

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

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

Uppsala Universitet
Sweden
www.uu.se
Category: 2

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

Alaska Earthquake Center (AEC), University of Alaska Fairbanks
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

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

Category: 1

Texas Seismological Network (TexNet), Bureau of Economic Geology, J.A. & 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

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

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.

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

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.

2.6 Data Contributing Agencies

In addition to its Members and Sponsors, the ISC owes its existence and successful long-term operations to its 147 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.

East African Network
EAF

The Institute of Seismology, Academy of Sciences of Albania
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

Geoscience Australia
Australia
AUST

Curtin University
Australia
CUPWA

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

Instituto Astronomico e Geofísico
Brazil
VAO

National Institute of Geophysics, Geology and Geography
Bulgaria
SOF

Seismological Observatory of Mount Cameroon
Cameroon
SOMC

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

University of Addis Ababa
Ethiopia
AAE

Seismological Observatory Skopje
FYR Macedonia
SKO

Institute of Seismology, University of Helsinki
Finland
HEL

Laboratoire de Détection et de Géophysique/CEA
France
LDG

EOST / RéNaSS
France
STR

Institut de Physique du Globe de Paris
France
IPGP

Laboratoire de Géophysique/CEA
French Polynesia
PPT

Institute of Earth Sciences/ National Seismic Monitoring Center
Georgia
TIF

Bundesanstalt für Geowissenschaften und Rohstoffe
Germany
BGR

Geophysikalisches Observatorium Collm
Germany
CLL

Alfred Wegener Institute for Polar and Marine Research
Germany
AWI

Seismological Observatory Berggießhübel, TU Bergakademie Freiberg
Germany
BRG

Department of Geophysics, Aristotle University of Thessaloniki
Greece
THE

National Observatory of Athens
Greece
ATH

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

National Geophysical Research Institute
India
HYB

Badan Meteorologi, Klimatologi dan Geofisika
Indonesia
DJA

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

Tehran University
Iran
TEH

Iraqi Meteorological and Seismology Organisation
Iraq
ISN

The Geophysical Institute of Israel
Israel
GII

MedNet Regional Centroid - Moment Tensors
Italy
MED_RCMT

Laboratory of Research on Experimental and Computational Seimology
Italy
RISSC

Istituto Nazionale di Geofisica e Vulcanologia
Italy
ROM

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

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

Station Géophysique de Lamto
Ivory Coast
LIC

Jamaica Seismic Network
Jamaica
JSN

National Research Institute for Earth Science and Disaster Prevention
Japan
NIED

Japan Meteorological Agency
Japan
JMA

Jordan Seismological Observatory
Jordan
JSO

Seismological Experimental Methodological Expedition
Kazakhstan
SOME

National Nuclear Center
Kazakhstan
NNC

Kyrgyz Seismic Network
Kyrgyzstan
KNET

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

Latvian Seismic Network
Latvia
LVSN

National Council for Scientific Research
Lebanon
GRAL

Geological Survey of Lithuania
Lithuania
LIT

Macao Meteorological and Geophysical Bureau
Macao, China
MCO

Antananarivo
Madagascar
TAN

Geological Survey Department Malawi
Malawi
GSDM

Malaysian Meteorological Service
Malaysia
KLM

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

Seismological Institute 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

Instituto Nicaraguense de Estudios Territoriales - INETER
Nicaragua
INET

Stiftelsen NORSAR
Norway
NAO

University of Bergen
Norway
BER

Sultan Qaboos University
Oman
OMAN

Micro Seismic Studies Programme, PINSTECH
Pakistan
MSSP

Universidad de Panama
Panama
UPA

Philippine Institute of Volcanology and Seismology
Philippines
MAN

Manila Observatory
Philippines
QCP

Institute of Geophysics, Polish Academy of Sciences
Poland
WAR

Instituto Dom Luiz, University of Lisbon
Portugal
IGIL

Sistema de Vigilância Sismológica dos Açores
Portugal
SVSA

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

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

Sakhalin Experimental and Methodological Seismological Expedition, GS RAS
Russia
SKHL

Kola Regional Seismic Centre, GS RAS
Russia
KOLA

Kamchatkan Experimental and Methodical Seismological Department, GS RAS
Russia
KRSC

Institute of Environmental Problems of the North, Russian Academy of Sciences
Russia
IEPN

North Eastern Regional Seismological Centre, GS RAS
Russia
NERS

Baykal Regional Seismological Centre, GS SB RAS
Russia
BYKL

Geophysical Survey of Russian Academy of Sciences
Russia
MOS

Altai-Sayan Seismological Centre, GS SB RAS
Russia
ASRS

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

Yakutiya Regional Seismological Center, GS SB RAS
Russia
YARS

Saudi Geological Survey
Saudi Arabia
SGS

Seismological Survey of Serbia
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

Sudan Seismic Network
Sudan
SSN

University of Uppsala
Sweden
UPP

Swiss Seismological Service (SED)
Switzerland
ZUR

The Seismic Research Centre
Trinidad and Tobago
TRN

Institut National de la Météorologie
Tunisia
TUN

Kandilli Observatory and Research Institute
Turkey
ISK

Disaster and Emergency Management Presidency
Turkey
AFAD

IRIS Data Management Center
U.S.A.
IRIS

National Earthquake Information Center
U.S.A.
NEIC

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

Pacific Northwest Seismic Network
U.S.A.
PNSN

The Global CMT Project
U.S.A.
GCMT

Subbotin Institute of Geophysics, National Academy of Sciences
Ukraine
SIGU

Dubai Seismic Network
United Arab Emirates
DSN

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

Geological Survey Department of Zambia
Zambia
LSZ

Goetz Observatory
Zimbabwe
BUL

2.7 ISC Staff

Listed below are the staff (and their country of origin) who were employed at the ISC at the time of this ISC Bulletin 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

- John Eve
- Data Collection Officer
- United Kingdom

- Domenico Di Giacomo
- Senior Seismologist
- Italy/UK

- Konstantinos Lentas
- Seismologist / Senior Developer
- Greece

- 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

- Charikleia Gkarlaouni
- Seismologist / Analyst
- Greece

- Peter Franek
- Seismologist / Analyst
- Slovakia

- Burak Sakarya
- Seismologist / Analyst
- Turkey

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

- Tom Garth
- Seismologist, PDRA, jointly with Department of Earth Sciences at University of Oxford
- United Kingdom

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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 (2020), 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 (currently: 1964-1990):

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`

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 (2020), Summary of the Bulletin of the International Seismological Centre, July - December 2016, *53(II)*,`https://doi.org/10.31905/V1QQWEBC`

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 (2020), 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 (2020), ISC-GEM Earthquake Catalogue, `https://doi.org/10.31905/d808b825`, 2020.

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 (2020), 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 (2020), 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 (2020), International Seismograph Station Registry (IR), https://doi.org/10.31905/EL3FQQ40

4.9 Seismological Dataset Repository

International Seismological Centre (2020), Seismological Dataset Repository, https://doi.org/10.31905/6TJZECEY

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

International Seismological Centre, Bulletin Disks 1-27 [CD-ROM], Internatl. Seismol. Cent., Thatcham, United Kingdom, 2020.

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

Operational Procedures of Contributing Agencies

5.1 China Earthquake Administration: Chinese Seismic Network

Guanghui Dai, Yanru An

China Earthquake Networks Center (CENC), China Earthquake Administration (CEA), Beijing, China

Guanghui Dai

Yanru An

The State Seismological Bureau (SSB) was established in China in 1971 and renamed China Earthquake Administration (CEA) in 1998. In 2018, the Ministry of Emergency Management of the People's Republic of China (PRC) was put in charge of CEA. As a government agency, CEA is mandated by the Law of the PRC on Protecting Against and Mitigating Earthquake Disasters to enforce earthquake administration in China. During the past 50 years, CEA has made great efforts on the construction of the Chinese Seismic Network (CSN) and on earthquake research to minimize earthquake disasters. In 2004, CEA authorized the China Earthquake Networks Center (CENC) to take charge of the CSN and earthquake monitoring. To meet the requirements of public concern and scientific research, CENC releases rapid earthquake notifications, archives seismic waveforms, provides seismic catalogues and phase reports. CENC provides data from 34 stations to the ISC (agency code BJI) on behalf of CEA.

5.1.1 Seismicity and Seismic Hazard

China and adjacent regions frequently suffer from severe earthquake disasters. As seen in Figure 5.1, strong earthquakes are prone to occur in the western part of the mainland, where the main driving force of tectonic deformation comes from the collision of the Indian and the Eurasian plates forming the Tibetan Plateau (*Zhang*, 2008). Another seismically active area is the Taiwan region which is located at the boundary between the Philippine Sea Plate to the East and the Eurasian Plate to the West.

Figure 5.1: *Epicentre distribution of earthquakes with M ≥ 5.0 in China and the border area from 1970 to 2019.*

Since the PRC was founded in 1949 it has been hit by several strong earthquakes, including the Tangshan 7.8 earthquake in 1976, the Jiji 7.6 earthquake in 1999, the Wenchuan 8.0 earthquake in 2008, the Yushu 7.1 earthquake in 2010, the Lushan 7.0 earthquake in 2013 and the Jiuzhaigou 7.0 earthquake in 2017. Huge casualties resulted from these events, as the Tangshan earthquake killed more than 240,000 people, and the Wenchuan earthquake led to nearly 70,000 deaths and 18,000 missing.

5.1.2 History and Outlook of CSN

In the 1950s, the first Chinese analogue seismic network consisting of 20 stations in the northern region was established by the Institute of Geophysics, Chinese Academy of Sciences, the predecessor of the Institute of Geophysics, SSB. With the data from this seismic network, moderate and strong earthquakes could be observed. Then in 1966, the first telemetric seismic network was constructed with 8 stations around Beijing and the station number was expanded to 21 after the Haicheng earthquake in 1975 (*Sun and Wu*, 2007). Since the establishment of SSB in 1971, the network construction, instrument design and production and data processing software have been greatly improved. From the 1980s, most seismic stations were equipped with domestic equipment and the data was transmitted by telemetry.

However, during the Tangshan earthquake in 1976, many stations were damaged due to the short epicentral distance, as a result the hypocentre location and magnitude could not be rapidly measured at the time. Therefore, in order to cope with these huge earthquakes, establishing a dense network throughout China has become an important task of SSB. With the funding of the Chinese government, more regional networks were established, and accelerometers were also installed besides the seismometers at some stations. Through China-U.S. cooperation, 11 stations of the China Digital Seismograph Network (CDSN) were deployed between 1983 and 1987. After about 20 years of development, the seismic observation technology and seismic network construction of CSN completed a comprehensive transformation from analogue to digital in the 2000s. Meanwhile, with the innovation and improvement of transmission technology, the data transmission method gradually shifted to satellite transmission, and nowadays depends on the IP network. In the year of 2007, 1021 seismographic stations distributed over 31 provinces realized real-time transmission to CENC. Based on the evolving network, CENC and 31 provincial centres coordinate to monitor seismic activities in China and strong earthquakes worldwide.

When the Wenchuan earthquake occurred in 2008, it took only 12 minutes to release the rapid earthquake notification which is an important reference for earthquake emergency rescue. However, CEA was still unable to prevent huge casualties and decided to explore earthquake early warning and intensity rapid notification. Finally, in the year of 2018, the implementation of the National Earthquake Intensity Rapid notification and Early Warning Project began, and CENC was appointed as the legal entity by CEA. It is estimated that by 2022, the CSN will have 15,391 stations (Figure 5.2), including 1,928 seismographic stations, 3114 strong motion stations and 10349 intensity instrument stations with the aim of saving more lives in earthquake disasters.

The chronological list below summarises the development of CSN.

1950s	The first analogue seismic network consisting of 20 stations equipped with 51 seismometers in northern China was established to monitor moderate and strong earthquakes.
Early 1960s	The elementary seismic network with 12 stations equipped with SK seismometers all over China was built, and the station number was increased to 26 in the mid to late 1960s.
1966	The first telemetric seismic network consisting of 8 stations around Beijing was constructed after the occurrence of Xingtai 7.2 earthquake, and the station number was expanded to 21 after the Haicheng 7.3 earthquake in 1975.
1980s	The elementary seismic network was renewed, and the station number was expanded to 86, including 27 class I stations mainly equipped with SK or DK-1 seismometers and 59 class II stations mainly equipped with DD-1 seismometers.
1982-1985	Another 5 telemetric regional seismic networks were built.
1985-1995	More than 10 wireless-transferred local seismic networks were built.
1983-1987	Through China-U.S. cooperation, 11 stations of the China Digital Seismograph Network (CDSN) were deployed.
1996-2000	The elementary seismic network and 21 provincial seismic networks were undergoing digital transformation. The basic seismic network was renamed the National Digital

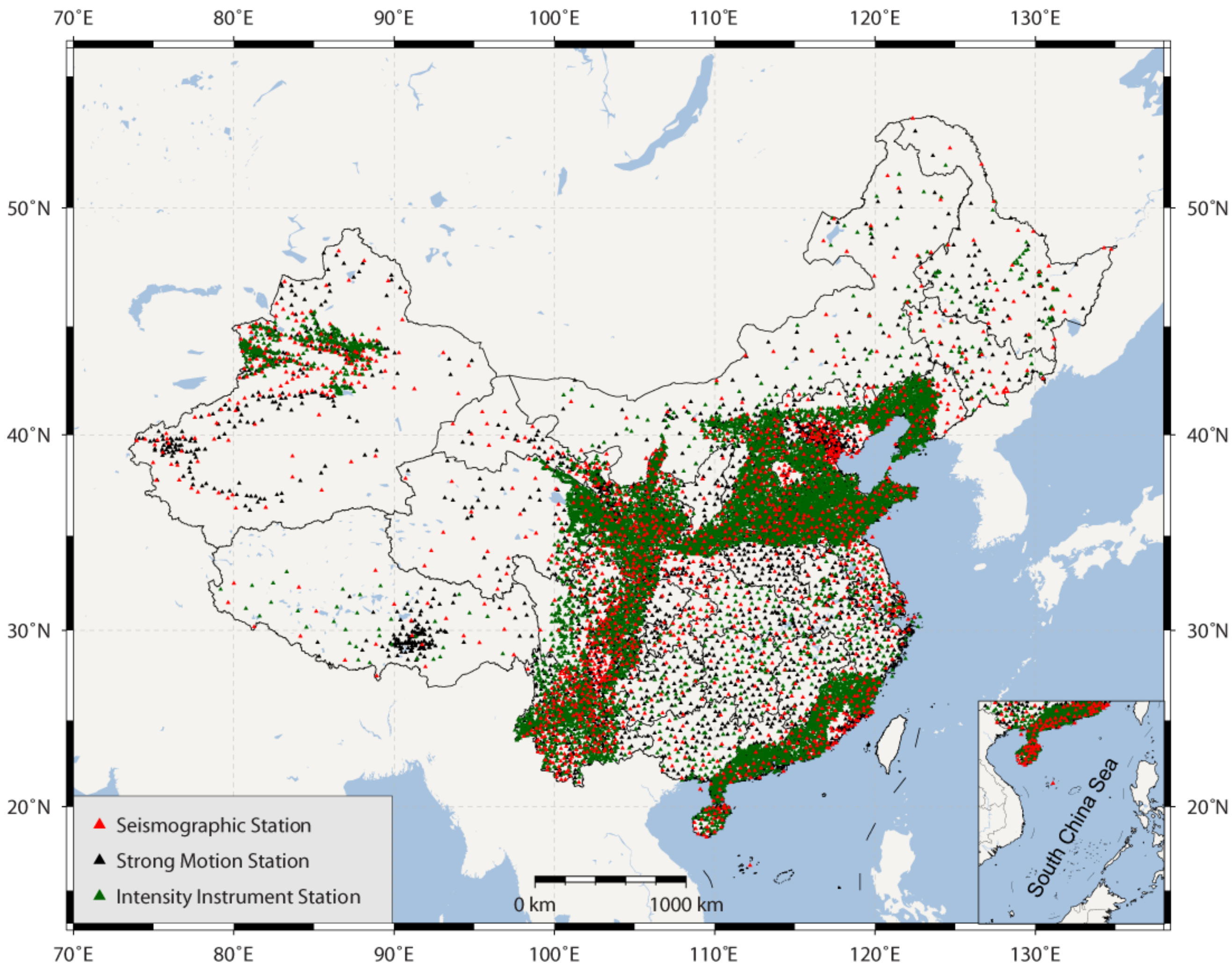

Figure 5.2: *Outlook of CSN in 2022.*

Seismic Network, of which 48 digital stations were equipped with broadband or ultra-broadband seismometers and 24-bit data acquisition units. The data was transmitted to the network centre via satellite.

1998-2001 The Capital Area Seismic Network of 107 stations was built, including broadband seismometers or borehole short period seismometers and 24-bit data acquisition units. Data is transmitted to the network centre through a DDN network.

2001-2007 1025 seismographic stations were updated or newly built. The data is transferred in real-time through the IP network. 148 national stations were equipped with ultra-broadband seismometers and 2g accelerometers, while 821 regional stations, 33 volcanic stations and 19 small aperture array stations were installed, mainly with broadband seismometers.

1154 free-field strong motion stations were newly built or updated, and 2g accelerometers and 12 structural seismic response observation arrays were installed. The stored event data was transmitted in non-real time through telephone lines.

A working system coordinated by CENC, 31 provincial centres and 107 national stations was established.

2011-2016 Very-broadband seismometers were installed in 18 national seismic stations, and broadband seismometers were installed in 68 regional seismic stations.

76 non-real-time strong motion stations and 160 real-time stations with 2g accelerometers were built.

2015-2018 1010 intensity instrument stations were built to carry out rapid intensity reports and earthquake early warning tests.

2018-2022 15391 stations are being upgraded or newly built for the project of rapid intensity reports and earthquake early warning, including 1928 seismographic stations, 3114 strong motion stations, and 10349 intensity instrument stations.

5.1.3 Current Status

The CSN is composed of the seismographic network, the strong motion network and the intensity instrument network, with 4082 stations in total (Figure 5.3). The seismographic network is distributed all over mainland China, while the other two networks are located around earthquake hazard zones. All stations are maintained by the 31 provincial centres in their jurisdiction under the management of CENC.

The Seismographic Network

The seismographic network has 1107 seismographic stations, including 166 national stations and 941 regional stations (Figure 5.4). National stations are mainly equipped with 120 s ultra-broadband seismometers (some stations with 360 s very-broadband seismometers) which are used to monitor global seismicity. Regional stations are mainly installed with 60s broadband seismometers for monitoring regional seismic activities. The density of stations in different regions is related to the degree of economic development and population density, so station distribution in eastern China is denser than in the west.

The real-time waveform data with a sampling rate of 100 Hz is transmitted to CENC via the provincial centres through a SDH network. At the same time, each provincial network centre receives waveform data from neighbouring provinces from CENC.

The Strong Motion Network

The strong motion network consists of 1965 strong motion stations with accelerometers (2g) installed to monitor the acceleration in the near field and serve for the estimation of intensity and engineering seismology (Figure 5.5). After an earthquake has occurred event waveform data sampled at 200 Hz for all the stations is stored in the data acquisition unit and then collected through a dedicated telephone line. Only 393 sites transmit the real-time data with a sampling rate of 100 Hz via the provincial network centre to CENC. Meanwhile, the real-time data is shared with the neighbouring provincial centres. Next year, about 786 non-real-time sites will be upgraded to real-time mode.

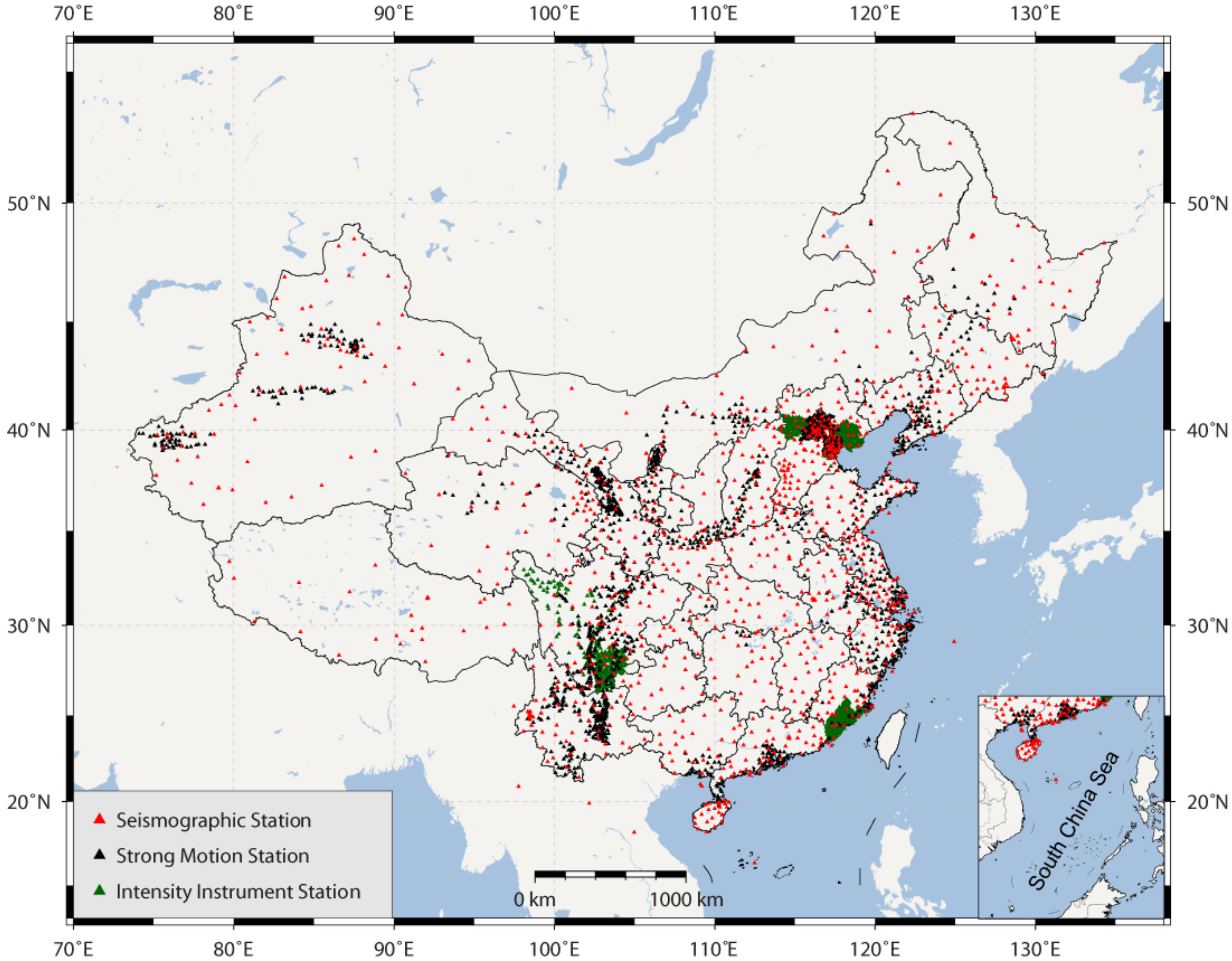

Figure 5.3: *Current status of CSN*

The Intensity Instrument Network

The intensity instrument network is composed of 1010 stations equipped with intensity meters. These stations are distributed in parts of six provinces, Beijing, Tianjin, Hebei, Sichuan, Yunnan and Fujiang (Figure 5.6). Combined with seismographic stations and strong motion stations, the intensity instrument stations are used for the rapid intensity reports and earthquake early warning testing. The continuous waveform with a sampling rate of 100Hz is transmitted via the provincial network centres in real time to CENC, and shared by the adjacent provincial centres.

Data Sharing With Other Organisations

To improve the capacity of monitoring strong earthquakes in China's border areas and worldwide, CENC shares near real-time seismic data from 99 stations from the Global Seismic Network (GSN). In addition, CENC and Korea Meteorological Administration (KMA) both share data from five stations with each other in near real time via the Internet. When a global earthquake above magnitude 5.0 occurs, CENC will send event waveform data from 20 national stations to the IRIS FTP server.

Figure 5.4: *Distribution of the Seismographic Network.*

5.1.4 Routine Data Analysis

In order to meet different requirements, e.g. public concern, rescue, forecast and research, the routine data analysis of CSN is organized in two modes: rapid analysis and precise analysis. The publication timeline is summarised in Table 5.1.

Rapid Analysis

Rapid analysis provides the rapid reports for emergency relief after an earthquake. In order to release information immediately and accurately, the rapid analysis is coordinated by CENC and 31 provincial centres. In the end, CENC releases the rapid reports.

Automatic Processing - Automatic Rapid Report (ARR)

After the Wenchuan 8.0 earthquake, CEA began to implement the automatic processing system. Three automatic systems have been developed successively and have their own specialities in handling small, medium and large earthquakes. Receiving seismic data in real time, the automatic processing systems

Figure 5.5: *Distribution of the Strong Motion Network*

Time after earthquake	**Title**	**Output**
Within 2-3 minutes if in China and adjacent areas, 7-15 minutes if in other regions abroad	Automatic rapid report (ARR)	Earthquake catalogue (Origin time, latitude, longitude, depth, magnitude, event type and place name)
Within 8-15 minutes if in China and adjacent areas, 30 minutes if in other regions abroad	Formal rapid report (FRR)	Earthquake catalogue (Origin time, latitude, longitude, depth, magnitude, event type and place name)
Within 2 days worldwide	Preliminary uniform report (PUR)	Earthquake catalogue and phase report (arrival-time, amplitude, period) of most CSN stations
Within 1 month worldwide	Final uniform report (FUR)	Earthquake catalogue and phase report (arrival-time, amplitude, period) of all CSN stations

Table 5.1: *Publication timeline of routine data analysis.*

Figure 5.6: *Distribution of Intensity Instrument Network*

detect and locate events according to the preset magnitude threshold. In order to reduce the possibility of earthquake mislocation, the results of the three systems are weighted average to produce the ARR. At present, the ARR will be released within 2-3 minutes for events M≥3.0 in China and adjacent area, and within 7-15 minutes for events M≥5.0 in other regions abroad.

Manual Processing - Formal Rapid Report (FRR)

The manual processing system will immediately issue a warning after detecting an event that exceeds the preset trigger threshold. Based on the automatic location result, the staff will check the accuracy of the phase arrival time and reduce the azimuthal gap to get a better location result. Then, more stations are used to calculate the magnitude, and the FRR is prepared to be released.

During this process, the provincial centres are only responsible for handling events in their own provinces and neighbouring areas, while CENC is dealing with global earthquakes and releases FRR final results. All information is shared among the provincial centres and CENC via the exchange platform. For events M≥3.0 in China and surrounding areas, FRR will be released within 8-15 minutes, and for events M≥5.0 in other regions abroad, FRR will be released within 30 minutes.

Precise Analysis

In contrast to the rapid analysis, the precise analysis will take more time but will be more complete and accurate. All the identified seismic events should be located and finally presented in the form of an earthquake catalogue and seismic phase report. Due to the heavy workload, the precise analysis is implemented by CENC, 31 provincial centres and the national stations together. Finally, CENC compiles and publishes the preliminary uniform report daily and the final uniform report monthly. These catalogues and seismic phase reports are widely used for disaster relief, earthquake forecasting and scientific research. In addition, CENC is trying to provide the focal mechanism, Mw, stress drop, Q factor, corner frequency and other additional parameters for events M≥3.0 in China.

Daily Processing - Preliminary Uniform Report (PUR)

Every day, 31 provincial centres analyse the data from all stations in the jurisdiction and neighbouring regions of the previous day, then submit the catalogues and phase reports to CENC. Later, CENC will process all the data to form the PUR. For this CENC will relocate events M≥4.0 in China and M≥5.0 worldwide as well as merge the provincial results for events M<4.0 in China. If the catalogues from two or more provinces are significantly different for the same event, CENC will relocate it and confirm the final results. The PUR is to give earthquake forecasters and scientific researchers a quick and precise result for analysing the development trend of earthquakes. It is possible that not all events and phases are included in PUR, especially for some events that are too small to be analysed.

Monthly Processing - Final Uniform Report (FUR)

As the final bulletin, the FUR is widely used in earthquake forecasting and scientific research. It lags one month behind real-time and is jointly accomplished by CENC, 31 provincial centres and 107 manned national stations. For global events M≥4.0 the period, amplitude and arrival time of all identifiable phases recorded by national stations are sent to CENC weekly. Then, CENC will associate these phases to locate events and generate the national network bulletin including the magnitude types M_L, M_S, M_{S7}, m_B and m_b. On the basis of the PUR, 31 provincial centres review the continuous waveform again to modify or supplement phases to ensure that all identifiable events are involved accurately, even events recorded by a single station. In the end, CENC compiles results from all sources to output the FUR using the rules similar for the PUR. The earthquake distribution from the FUR of CSN in 2009-2019 is presented in Figure 5.7 which is showing that the majority of the Earth's earthquakes occur along plate boundaries.

5.1.5 Methodology

Determination of Hypocentres

A hypocentre is constrained by the arrival-time of P phase and S phase. In order to determine the accurate location, data from any station with a large arrival time residual will not be used for calculation. For deep focus earthquakes, the depth phases, such as pP and sP will be taken into account in determining

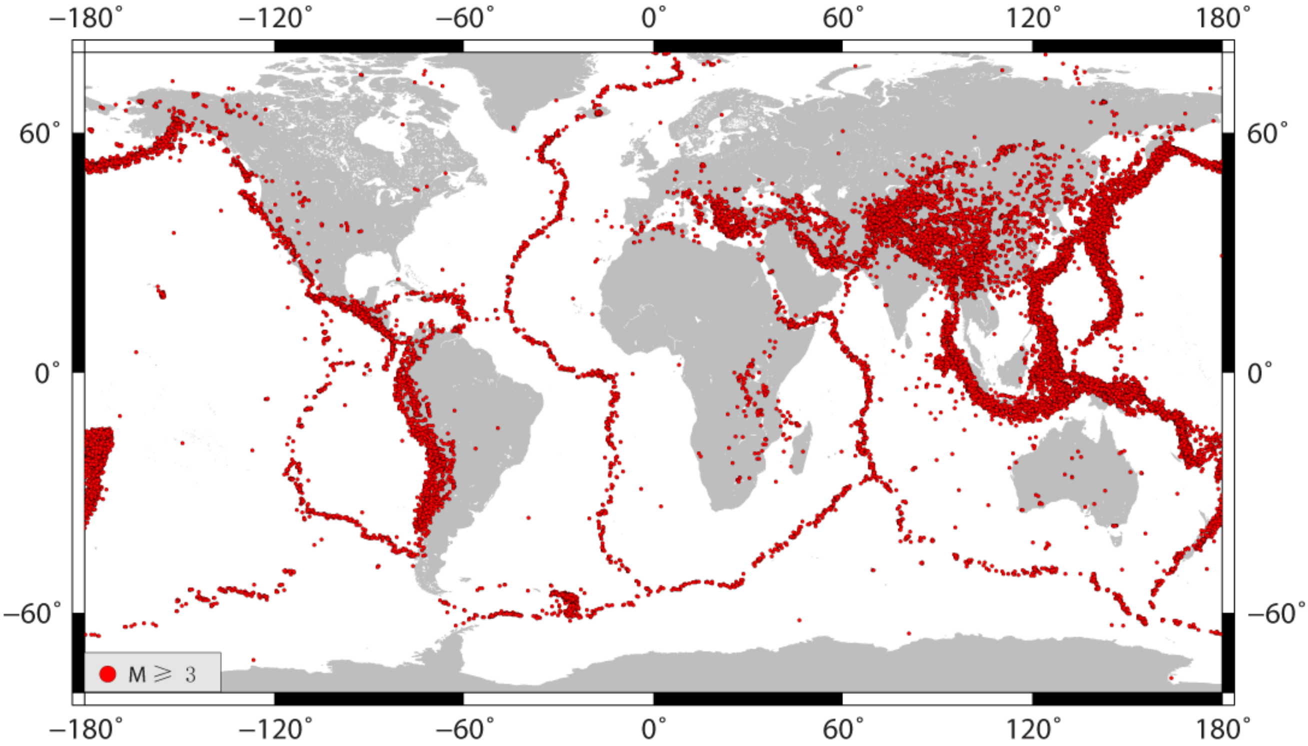

Figure 5.7: *Earthquake distribution from FUR of CSN in 2009-2019.*

the focal depth.

Different centres are using different location methods. In CENC, a self-made gird search method is used in FRR and PUR, and the Geiger's method (*Geiger*, 1910; *Bormann*, 2012) is used in FUR. In the provincial centres, there are several methods to be used in different situations. For example, the simplex algorithm (*Nelder and Mead*, 1965) is always used for locating shallow earthquakes, while the Hyposat algorithm (*Schweitzer*, 2001) is used for the moderate-deep focal earthquakes and the Locsat algorithm (*Bratt and Bache*, 1988) for earthquakes that occurred on the brim or outside of the network. Similarly, the choices of velocity models are also different. In CENC, AK135 and IASP91 models are used for FRR, PUR and FUR, while each provincial centres are using regional models.

Calculation of Magnitudes

In the provincial centres, M_L, M_S and m_b are calculated. In CENC M_L, M_S and m_b are determined for FRR and PUR, and all magnitudes(M_L, M_S, M_{S7}, m_b and m_B) are presented in FUR. Each type of magnitude is the mean of the magnitudes of all the stations involved in the calculation.

M_L

For local and regional earthquakes the magnitude M_L is given according to the following formula (*Bormann et al.*, 2007)

$$M_L = \log A_\mu + R(\Delta) \qquad \text{for } 0 \text{ km} < \Delta < 1000 \text{ km},$$

where A_μ is the arithmetical mean value of the maximum S-wave amplitude of two horizontal components in µm. $R(\Delta)$ is the calibration function of epicentral distance. The broadband velocity record should be simulated to the short period displacement record of a DD-1 or WA seismometer before the magnitude is calculated.

M_S and M_{S7}

For regional and remote earthquakes, magnitude M_S and M_{S7} are given according to the following formulas (*Bormann et al.*, 2007)

$$M_S = \log\left(\frac{A}{T}\right)_{max} + 1.66\log(\Delta) + 3.5 \qquad \text{for } 1^\circ < \Delta < 130^\circ,$$

where A is the vector average of maximum displacement of surface wave of two horizontal components in µm, T is the period in seconds and Δ is the epicentral distance in degrees. The broadband velocity record should be simulated to the medium long period displacement record of a SK seismometer before the magnitude is calculated.

$$M_{S7} = \log\left(\frac{A}{T}\right)_{max} + \delta_{763}(\Delta) \qquad \text{for } 3^\circ < \Delta < 177^\circ,$$

where A is the maximum displacement of surface wave of the vertical component in µm, T is the corresponding period of the maximum displacement in seconds, and $\delta_{763}(\Delta)$ is the calibration function of epicentral distance. The broadband velocity record should be simulated to the long period displacement record of a model 763 seismometer before the magnitude is calculated.

m_B and m_b

For all earthquakes, magnitudes m_B and m_b are given according to the following formula (*Bormann et al.*, 2007)

$$m_B \text{ or } m_b = \log\left(\frac{A}{T}\right)_{max} + Q(\Delta, h),$$

where A is the maximum displacement of the P wave of the vertical components in µm, T is the corresponding period of maximum displacement in seconds and $Q(\Delta, h)$ is the calibration function of epicentral distance and focal depth.

For m_b it should be noted that the broadband velocity record must be simulated to the short period displacement record of a DD-1 or WA seismometer and the maximum displacement should be measured within 5 seconds after the P wave arrival. For m_B the broadband velocity record should be simulated to the medium long period displacement record of a SK seismometer and the maximum displacement should be measured within 20 seconds (for large earthquakes it should be extended to 60 seconds) after the P wave arrival.

5.1.6 Data Availability

All the output of CSN is to serve the public, government and scientific research. Therefore, there are many convenient ways to get the reports and seismic data. After an earthquake has occurred, the ARR and FRR will be quickly released through SMS messages, microblog (`https://weibo.com/ceic?refer_` flag=100808&is_all=1), apps and a data-share website (http://data.earthquake.cn/). When the PUR, FUR and seismic data are ready for publication, they will be available on the same data-share website above. An exciting feature of the current rapid report service is its capability to reach hundreds of millions of users within one minute.

5.1.7 Acknowledgements

We would like to thank Dr. Dmitry A. Storchak for suggesting we write this article, which is a great vehicle to introduce CSN to the world. We also thank colleagues for useful comments including Professor Liu Jie, Professor Zhao Zhonghe from CENC, Professor Liu Ruifeng from Institute of Geophysics, CEA. Thanks to Dr. Kathrin Lieser for the careful review. Finally we would like to express our deep thanks to all the staff who work hard for CSN. All the figures were generated using the Generic Mapping Tools (*Wessel and Smith*, 1998).

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6

Summary of Seismicity, July – December 2017

Between July and December 2017 five earthquakes with magnitudes $M_W \geq 7$ occurred (Tab. 6.2). The largest was the M_W 8.2 Tehuantepec event in Mexico in September (2017/09/08 04:49:18.66 UTC, 14.9411°N, 93.8817°W, 51.1 km depth, 3639 stations (ISC)). Rather than being a thrust event rupturing the plate interface, as is typical for large events in a subduction zone, this event was caused by normal faulting within the slab at intermediate depths. Studies show that the event likely broke through the entire lithosphere of the subducting slab due to downdip slab pull (*Ye et al.*, 2017; *Suárez et al.*, 2019; *Melgar et al.*, 2018a). 11 days later Mexico was struck by another large intermediate depth earthquake that was caused by normal faulting within the slab (2017/09/19 18:14:37.41 UTC, 18.4324°N, 98.5344°W, 49.8 km depth, 3504 stations (ISC)). This event occurred 600 km further to the north west of the epicentre of the previous event and only 120 km away from Mexico City where it caused substantial damage (e.g *Melgar et al.*, 2018b). Although both events occurred only 11 days apart, within a few of hundred kilometres and as a result of normal faulting within the subducting slab there is no indication that the 8 September Tehuantepec earthquake triggered the 19 September event (*Segou and Parsons*, 2018).

The event with the most entries (53 entries at publication date) in the ISC Event Bibliography (*Di Giacomo et al.*, 2020; *International Seismological Centre*, 2020) was the M_W 6.5 Jiuzhaigou earthquake on 8 August (2017/08/08 13:19:49.77 UTC, 33.1985°N, 103.8756°E, 8.8 km depth, 2669 stations (ISC)). The shallow strike-slip event occurred about 250 km to the north of the 2008 M7.9 Wenchuan event that led to nearly 70,000 deaths and 18,000 people missing (see Chapter 5 of this issue: *Dai and An*, 2020). The close spatial proximity of both strong events raises the question of whether the Wenchuang event played any role in triggering the Jiuzhaigou event of 2017 (e.g.. *Liu et al.*, 2019; *Jia et al.*, 2018; *Li, Bürgmann and Zhao*, 2020).

On 3 September 2017 the DPRK conducted its sixth and thus-far strongest underground nuclear weapons test with a magnitude of *mb* 6.3 that was detected on stations around the globe (2017/09/03 03:30:00.88 UTC, 41.3199°N, 129.0491°E, 0 km depth, 2944 stations (ISC)). It was followed by a collapse event about 8.5 minutes later (2017/09/03 03:38:32.08 UTC, 41.3436°N, 129.0155°E, 0 km depth, 30 stations (ISC)).

The number of events in this Bulletin Summary categorised by type are given in Table 6.1.

Figure 6.1 shows the number of moderate and large earthquakes in the second half of 2017. The distribution of the number of earthquakes should follow the Gutenberg-Richter law.

Figures 6.2 to 6.6 show the geographical distribution of moderate and large earthquakes in various magnitude ranges.

Table 6.1: *Summary of events by type between July and December 2017.*

felt earthquake	171
known earthquake	271789
known chemical explosion	4870
known induced event	2675
known mine explosion	1514
known rockburst	645
known experimental explosion	173
suspected collapse	1
suspected earthquake	32970
suspected chemical explosion	4500
suspected induced event	3
suspected mine explosion	5709
suspected nuclear explosion	1
suspected rockburst	106
unknown	2
total	325129

Table 6.2: *Summary of the earthquakes of magnitude Mw ≥ 7 between July and December 2017.*

Date	lat	lon	depth	Mw	Flinn-Engdahl Region
2017-09-08 04:49:18	14.94	-93.88	51	8.2	Near coast of Chiapas
2017-07-17 23:34:14	54.41	168.70	8	7.8	Komandorsky Islands region
2017-11-12 18:18:17	34.87	45.88	20	7.4	Iran-Iraq border region
2017-09-19 18:14:37	18.43	-98.53	49	7.2	Central Mexico
2017-11-19 22:43:29	-21.37	168.74	13	7.0	Loyalty Islands

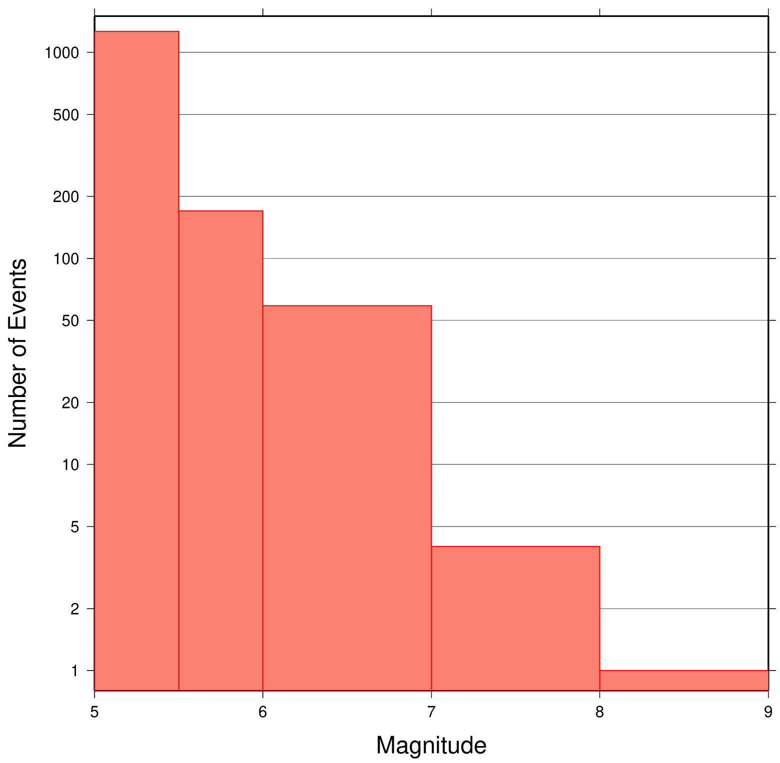

Figure 6.1: *Number of moderate and large earthquakes between July and December 2017. The non-uniform magnitude bias here correspond with the magnitude intervals used in Figures 6.2 to 6.6.*

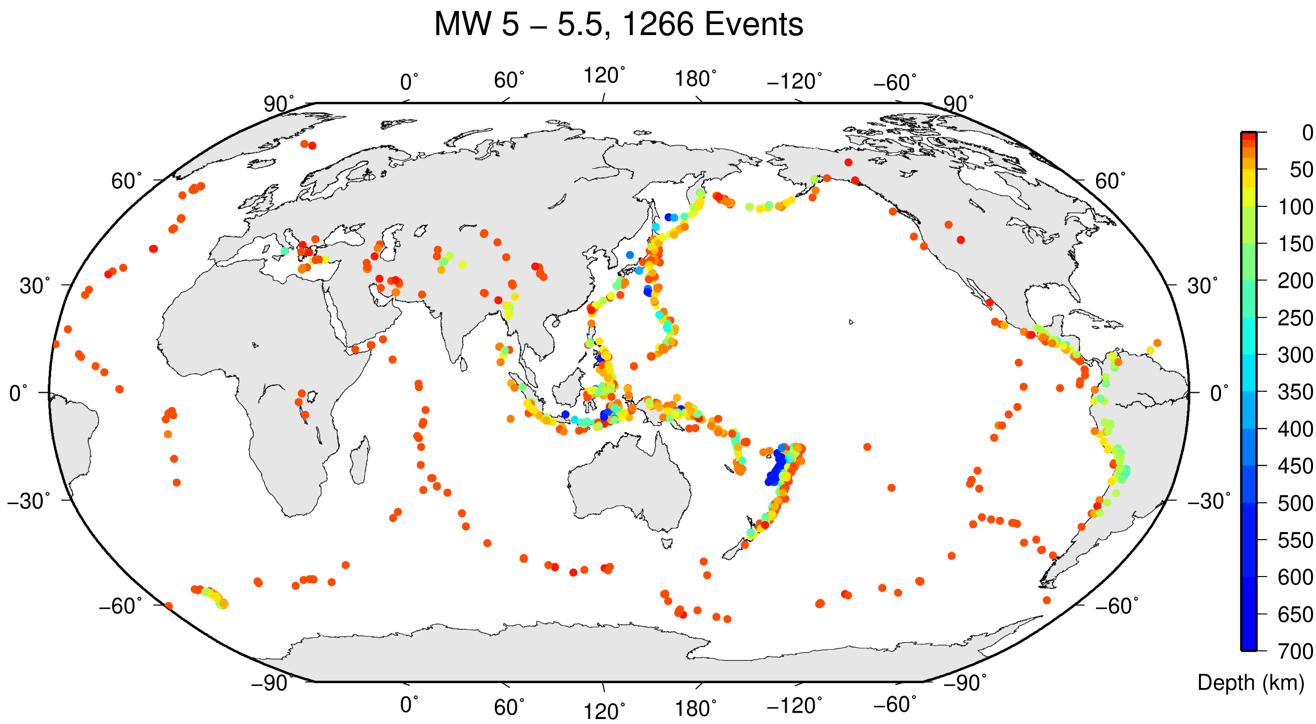

Figure 6.2: *Geographic distribution of magnitude 5-5.5 earthquakes between July and December 2017.*

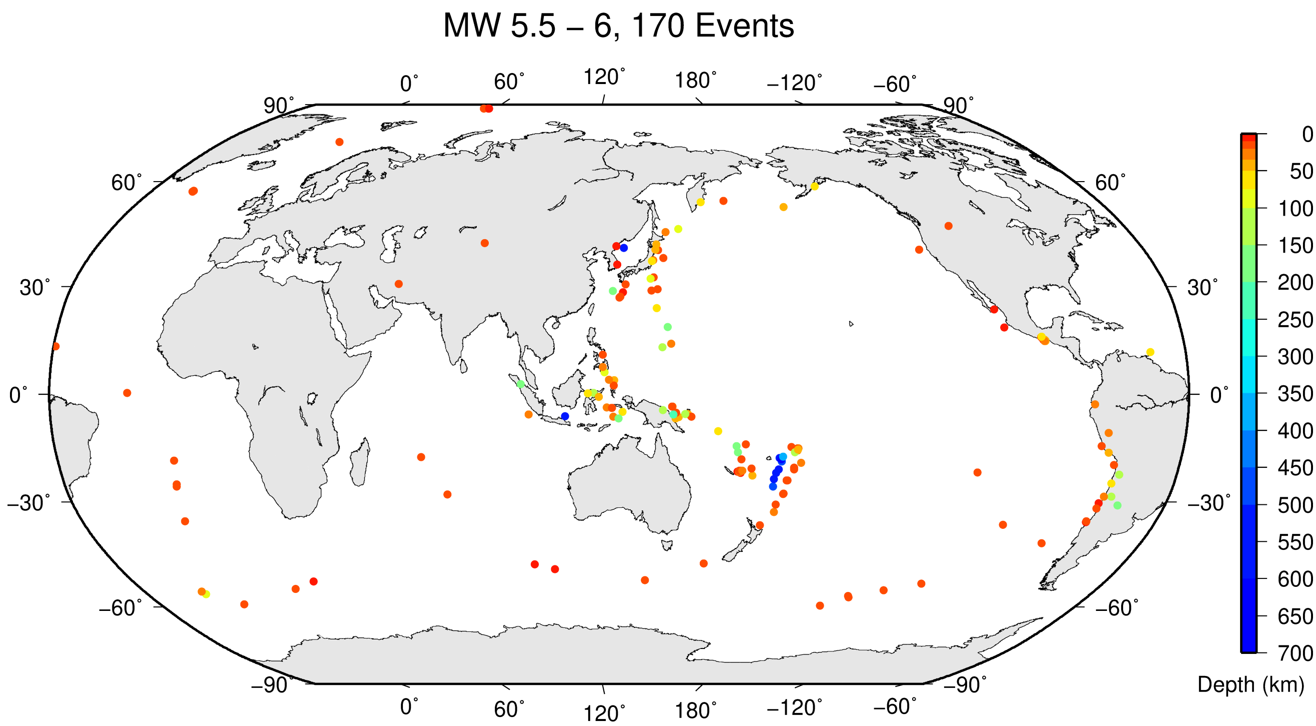

Figure 6.3: *Geographic distribution of magnitude 5.5-6 earthquakes between July and December 2017.*

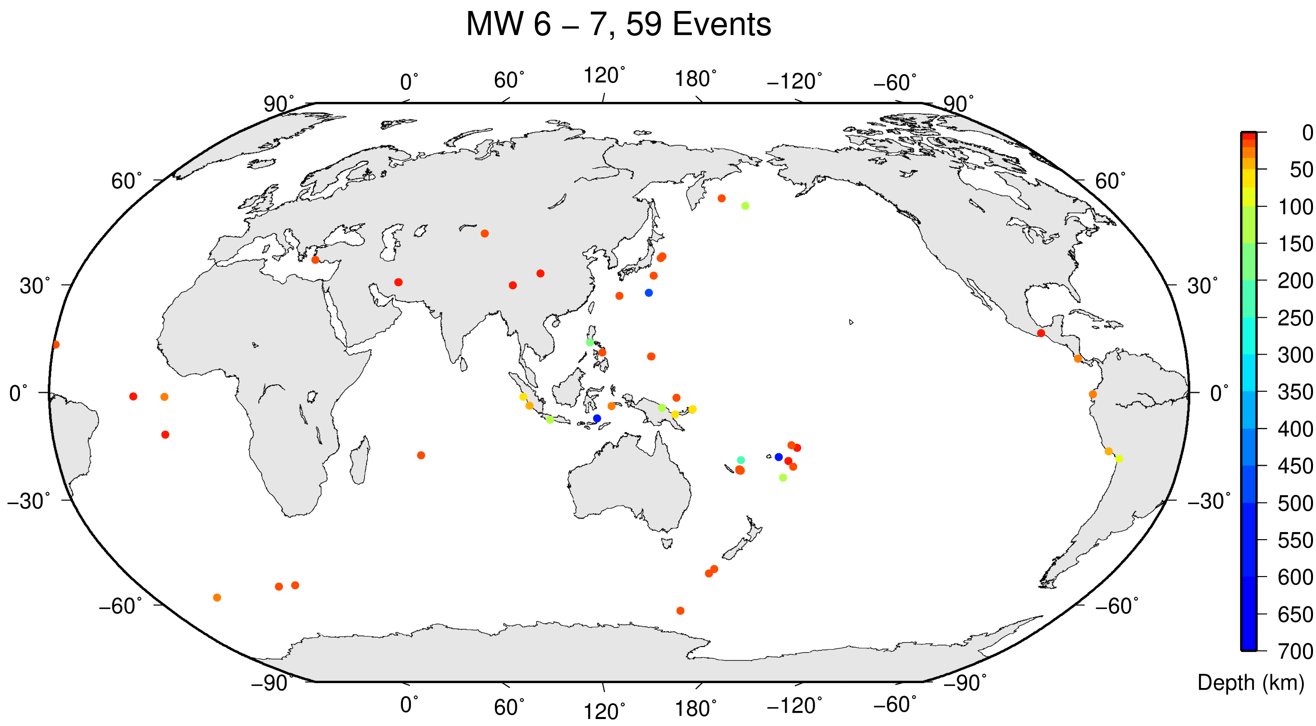

Figure 6.4: *Geographic distribution of magnitude 6-7 earthquakes between July and December 2017.*

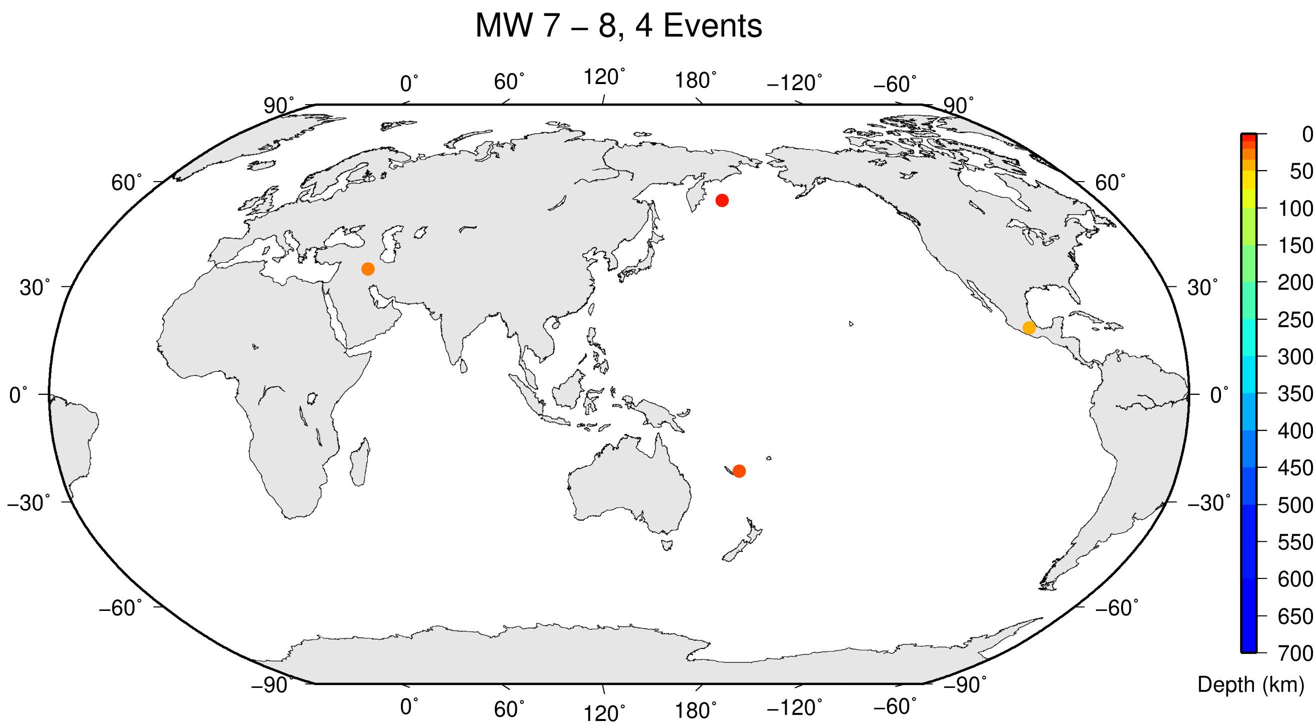

Figure 6.5: *Geographic distribution of magnitude 7-8 earthquakes between July and December 2017.*

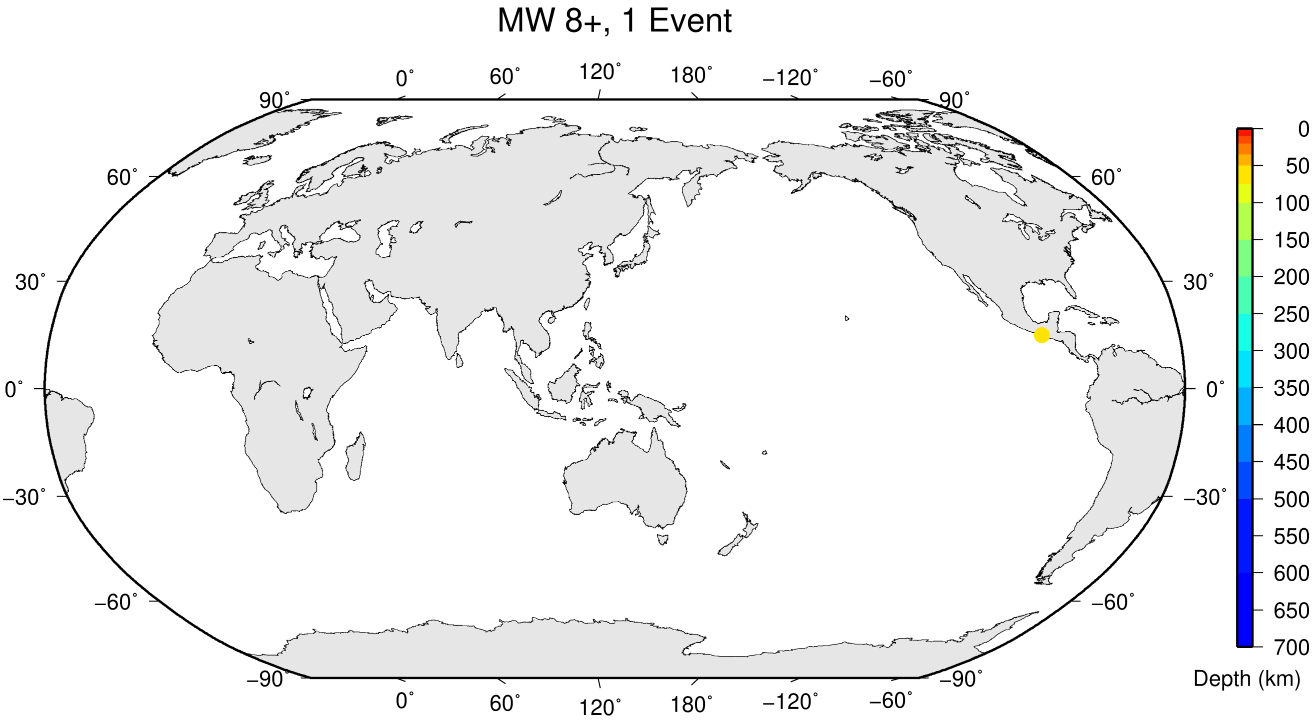

Figure 6.6: *Geographic distribution of magnitude 8+ earthquakes between July and December 2017.*

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7

Statistics of Collected Data

7.1 Introduction

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

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

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

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

7.2 Summary of Agency Reports to the ISC

A total of 147 agencies have reported data for July 2017 to December 2017. The parsing of these reports into the ISC database is summarised in Table 7.1.

Table 7.1: *Summary of the parsing of reports received by the ISC from a total of 147 agencies, containing data for this summary period.*

	Number of reports
Total collected	3906
Automatically parsed	2654
Manually parsed	1252

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

- Bulletin, hypocentres with associated phase arrival observations.

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

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

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

Agency	Country	Directly or indirectly reporting (D/I)	Hypocentres with associated phases	Hypocentres without associated phases	Associated phases	Unassociated phases	Amplitudes
TIR	Albania	D	334	2	4977	41	935
CRAAG	Algeria	D	176	0	1140	72	0
LPA	Argentina	D	0	0	0	639	0
SJA	Argentina	D	956	2	42937	0	11283
NSSP	Armenia	D	55	1	716	0	0
AUST	Australia	D	1492	253	24960	0	0
CUPWA	Australia	D	70	0	1096	0	0
IDC	Austria	D	17258	1	556469	0	513590
VIE	Austria	D	4825	124	47132	1537	48001
AZER	Azerbaijan	D	245	0	8923	0	0
UCC	Belgium	D	1382	0	9125	33	2267
LPZ	**Bolivia**	**I ECX**	**41**	**0**	**0**	**0**	**0**
SCB	Bolivia	D	790	0	12637	0	1860
RHSSO	Bosnia and Herzegovina	D	1007	0	20204	7825	0
VAO	Brazil	D	1242	39	38264	0	0
SOF	Bulgaria	D	139	0	1001	2342	0
SOMC	Cameroon	D	0	0	0	20	0
OTT	Canada	D	2214	152	64834	0	4288
PGC	Canada	I OTT	1416	0	47258	0	0
GUC	Chile	D	4194	334	131425	12580	37983
BJI	China	D	1058	0	108587	47462	80030
ASIES	Chinese Taipei	D	0	132	0	0	0
TAP	Chinese Taipei	D	17926	0	791912	0	0
RSNC	Colombia	D	8731	0	203250	25380	61766
ICE	Costa Rica	I UCR	0	1	0	0	0
UCR	Costa Rica	D	508	3	25780	0	0
ZAG	Croatia	D	0	0	0	49531	0
SSNC	Cuba	D	636	1	9514	0	3683
NIC	Cyprus	D	354	0	10999	0	5747
IPEC	Czech Republic	D	509	0	3299	23112	1488
PRU	Czech Republic	D	5284	37	48449	476	12926
WBNET	Czech Republic	D	1254	0	26741	0	26575
KEA	Democratic People's Republic of Korea	D	141	0	1899	0	943
DNK	Denmark	D	2337	1399	28778	22190	8500
OSPL	Dominican Republic	D	584	0	6200	0	1819
SDD	Dominican Republic	D	476	0	12867	12	5879
IGQ	Ecuador	D	0	57	3965	0	0
HLW	Egypt	D	534	0	3843	0	0
SNET	El Salvador	D	1315	5	22704	69	2591
EST	Estonia	I HEL	277	21	0	0	0
AAE	Ethiopia	D	221	0	1855	600	172
SKO	FYR Macedonia	D	3078	0	38781	3021	6412
FIA0	Finland	I HEL	6	0	0	0	0

Table 7.2: *(continued)*

Agency	Country	Directly or indirectly reporting (D/I)	Hypocentres with associated phases	Hypocentres without associated phases	Associated phases	Unassociated phases	Amplitudes
HEL	Finland	D	7955	747	195071	0	35046
CSEM	France	I AWI	2591	496	0	0	0
IPGP	France	D	0	104	0	0	0
LDG	France	D	3916	106	62675	0	26498
STR	France	D	4151	0	92411	0	0
PPT	French Polynesia	D	1278	2	9648	296	9899
TIF	Georgia	D	0	481	0	6549	0
AWI	Germany	D	4094	1	18234	2846	9324
BGR	Germany	D	715	262	19316	0	6066
BNS	Germany	I BGR	2	26	0	0	0
BRG	Germany	D	0	0	0	10822	5603
BUG	Germany	I BGR	4	24	0	0	0
CLL	Germany	D	59	0	1254	9844	3754
GDNRW	Germany	I BGR	1	9	0	0	0
GFZ	Germany	I PRE	62	3	0	0	0
HLUG	**Germany**	**I BGR**	**5**	**2**	**0**	**0**	**0**
LEDBW	Germany	I BGR	20	11	0	0	0
ATH	Greece	D	6719	22	188097	0	64729
THE	Greece	D	5635	0	105144	5809	31804
GCG	Guatemala	D	618	0	4165	0	0
HKC	Hong Kong	D	0	0	0	26	0
KRSZO	Hungary	D	337	190	7721	0	3426
REY	Iceland	D	67	0	3201	0	0
HYB	India	D	526	11	1173	0	158
NDI	India	D	433	336	11462	269	2990
DJA	Indonesia	D	4576	54	63640	0	80820
TEH	Iran	D	3171	0	49690	0	0
THR	Iran	D	45	0	1331	0	381
ISN	Iraq	D	376	0	3417	8	1223
GII	Israel	D	476	0	9869	0	0
GEN	Italy	D	955	0	20213	0	0
MED_RCMT	Italy	D	0	128	0	0	0
RISSC	Italy	D	8	0	110	0	0
ROM	Italy	D	14236	76	1229258	394614	829055
TRI	Italy	D	0	0	0	9363	0
LIC	Ivory Coast	D	415	0	1245	0	1244
JSN	Jamaica	D	106	0	505	11	0
JMA	Japan	D	126189	6485	774445	0	15682
NIED	Japan	D	0	667	0	0	0
JSO	Jordan	D	250	1	3223	0	0
NNC	Kazakhstan	D	9150	0	108481	0	101958
SOME	Kazakhstan	D	6775	116	83106	0	75441
KNET	Kyrgyzstan	D	990	0	8627	0	3012
KRNET	Kyrgyzstan	D	2134	0	43604	0	0
LVSN	Latvia	D	251	0	4115	0	2360
GRAL	Lebanon	D	298	0	2547	567	0
LIT	Lithuania	D	450	446	3787	2094	29
MCO	Macao, China	D	0	0	0	48	0
TAN	Madagascar	D	0	0	0	145	0
GSDM	Malawi	D	0	0	0	80	0
KLM	Malaysia	D	88	0	251	0	0
ECX	Mexico	D	1097	0	28199	0	5634
MEX	Mexico	D	18902	619	335412	18	0
MOLD	Moldova	D	0	0	0	1341	670
PDG	Montenegro	D	391	0	7663	0	3715
CNRM	Morocco	D	2453	0	25613	0	0
NAM	Namibia	D	58	0	184	0	0
DMN	Nepal	D	1409	3	13300	0	11142
NOU	New Caledonia	D	5344	16	80079	0	2854
WEL	New Zealand	D	7116	49	253543	135	221142
CATAC	Nicaragua	D	3655	1	130291	0	50577
INET	Nicaragua	D	41	1	514	0	55
BER	Norway	D	2458	1759	46917	5282	11109
NAO	Norway	D	2555	931	5496	0	2360
OMAN	Oman	D	546	0	26589	0	0
MSSP	Pakistan	D	0	0	0	507	0
UPA	Panama	D	905	0	14186	0	409

Table 7.2: (continued)

Agency	Country	Directly or indirectly reporting (D/I)	Hypocentres with associated phases	Hypocentres without associated phases	Associated phases	Unassociated phases	Amplitudes
MAN	Philippines	D	0	2211	0	44770	6586
QCP	**Philippines**	**D**	**0**	**0**	**0**	**45**	**0**
WAR	Poland	D	0	0	0	7837	450
IGIL	Portugal	D	759	0	3380	0	1114
INMG	Portugal	D	1551	0	48023	1942	15993
PDA	**Portugal**	**I SVSA**	**1**	**0**	**0**	**0**	**0**
SVSA	Portugal	D	858	0	17979	4170	7990
BELR	Republic of Belarus	D	0	0	0	23353	7798
CFUSG	Republic of Crimea	D	25	2	656	241	512
KMA	Republic of Korea	D	131	0	2049	0	0
BUC	Romania	D	717	32	16199	52898	5808
ASRS	Russia	D	84	0	2906	0	1043
BYKL	Russia	D	55	0	6595	0	2249
DRS	Russia	I MOS	201	162	0	0	0
IEPN	Russia	D	125	0	1245	4991	1772
KOLA	Russia	D	518	0	4734	0	0
KRSC	Russia	D	1034	0	31039	0	0
MIRAS	Russia	D	100	0	2380	0	1150
MOS	Russia	D	2060	315	312528	0	109322
NERS	Russia	D	20	0	566	0	266
NORS	Russia	I MOS	17	152	0	0	0
SKHL	Russia	D	910	909	18839	0	8671
YARS	Russia	D	349	0	4209	0	3184
SGS	Saudi Arabia	D	18	0	267	0	0
BEO	Serbia	D	1443	0	26986	0	11
BRA	Slovakia	D	0	0	0	21390	0
LJU	Slovenia	D	1351	402	18376	4123	6774
PRE	South Africa	D	1046	0	29250	0	9860
MDD	Spain	D	2897	1	66783	0	18624
MRB	Spain	D	463	0	11076	0	4393
SFS	Spain	D	1389	0	23456	0	0
SSN	Sudan	D	96	0	398	0	4
UPP	Sweden	D	2037	1340	22433	0	0
ZUR	Switzerland	D	829	1	12751	0	8098
TRN	Trinidad and Tobago	D	0	1294	0	28598	0
TUN	Tunisia	D	58	1	248	0	0
AFAD	Turkey	D	18964	0	370340	0	131799
ISK	Turkey	D	21346	0	316640	5421	180154
AEIC	U.S.A.	I NEIC	1114	947	73101	0	0
ANF	U.S.A.	I IRIS	286	1572	0	0	0
BUT	U.S.A.	I NEIC	0	164	712	0	0
GCMT	U.S.A.	D	0	2190	0	0	0
HVO	U.S.A.	I NEIC	205	5	9973	0	0
IRIS	U.S.A.	D	3774	1572	410425	0	0
LDO	U.S.A.	I NEIC	11	5	219	0	0
NCEDC	U.S.A.	I IRIS	142	22	13282	0	0
NEIC	U.S.A.	D	15994	8736	1541634	0	785766
PAS	U.S.A.	I NEIC	68	1	9895	0	0
PNSN	U.S.A.	D	0	175	0	0	0
REN	U.S.A.	I IRIS	66	30	2252	0	0
RSPR	U.S.A.	D	1065	410	17066	0	0
SCEDC	U.S.A.	I IRIS	2	0	0	0	0
SEA	U.S.A.	I NEIC	58	8	3893	0	0
SLM	U.S.A.	I NEIC	41	1	1511	0	0
TUL	U.S.A.	I NEIC	438	0	0	0	0
UUSS	U.S.A.	I NEIC	71	592	8623	0	0
SIGU	Ukraine	D	56	39	1373	0	400
DSN	United Arab Emirates	D	516	0	6000	0	0
BGS	United Kingdom	D	295	21	8858	15	3638
EAF	Unknown	D	1846	2	15531	5411	381
ISU	Uzbekistan	D	403	0	4241	0	0
CAR	Venezuela	I NEIC	0	7	0	0	0

Table 7.2: *(continued)*

Agency	Country	Directly or indirectly reporting (D/I)	Hypocentres with associated phases	Hypocentres without associated phases	Associated phases	Unassociated phases	Amplitudes
FUNV	Venezuela	D	356	0	5690	0	0
PLV	Viet Nam	D	4	3	27	0	11
LSZ	Zambia	D	102	0	335	13	5
BUL	Zimbabwe	D	635	2	5290	97	0

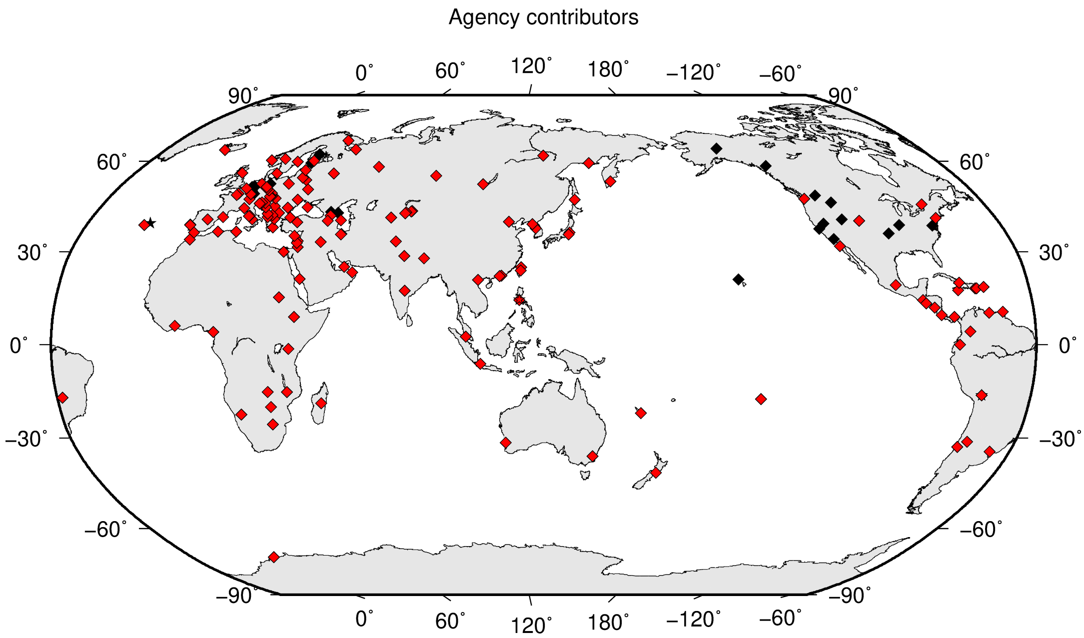


Figure 7.1: *Map of agencies that have contributed data to the ISC for this summary period. Agencies that have reported directly to the ISC are shown in red. Those that have reported indirectly (via another agency) are shown in black. Any new or renewed agencies, since the last six-month period, are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

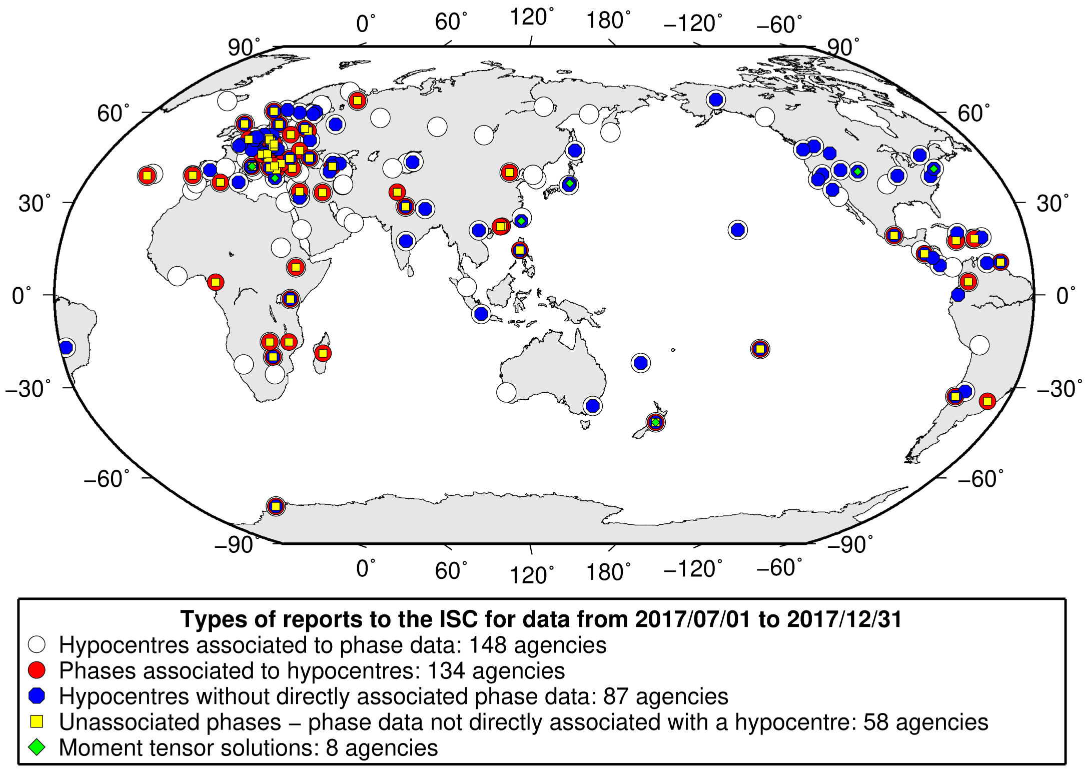


Figure 7.2: *Map of the different data types reported by agencies to the ISC. A full list of the data types reported by each agency is shown in Table 7.2.*

7.3 Arrival Observations

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

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

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

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

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

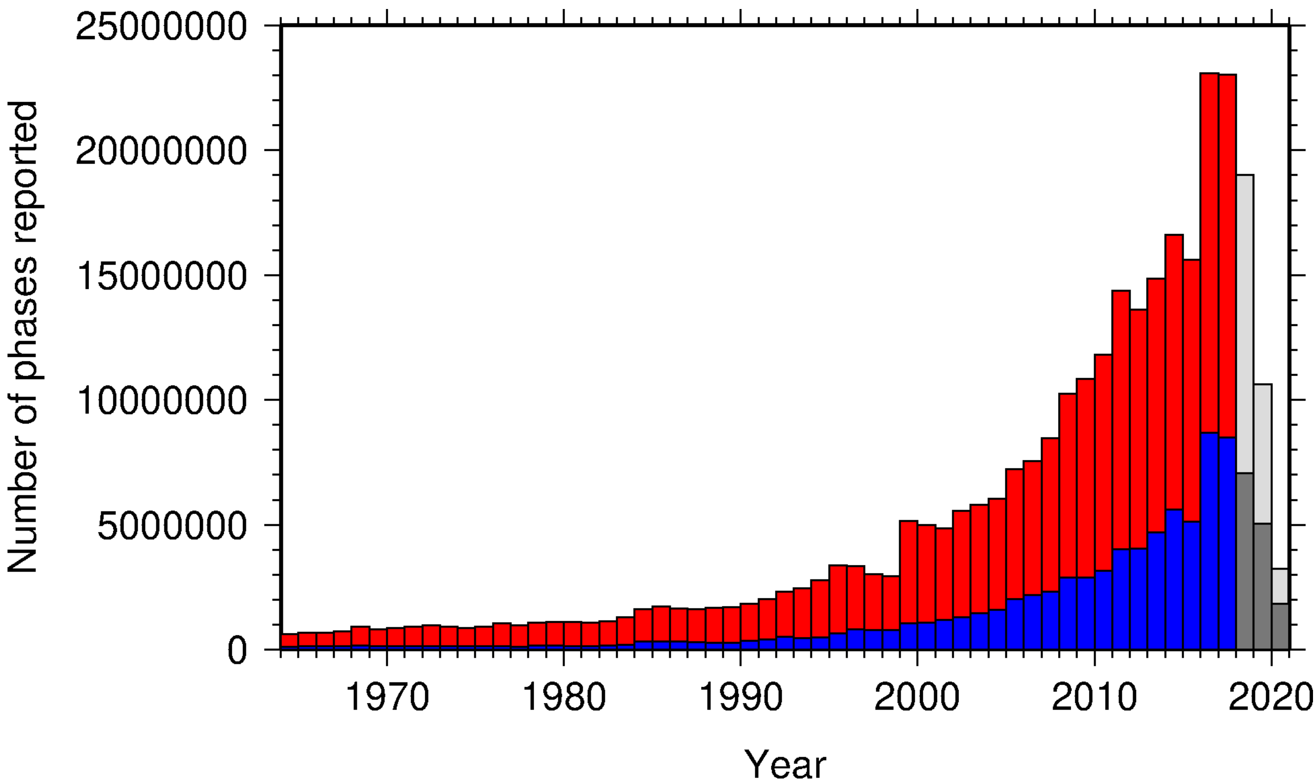


Figure 7.3: *Histogram showing the number of phases (red) and number of amplitudes (blue) collected by the ISC for events each year since 1964. The data in grey covers the current period where data are still being collected before the ISC review takes place and is accurate at the time of publication.*

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

Reports with phase arrivals	3697
Reports with phase arrivals including amplitudes	2034
Reports with only phase arrivals (no hypocentres reported)	226
Total phase arrivals received	10497572
Total phase arrival-times received	9465743
Number of duplicate phase arrival-times	762971 (8.1%)
Number of amplitudes received	3732141
Stations reporting phase arrivals	9226
Stations reporting phase arrivals with amplitude data	5311
Max number of stations per report	2403

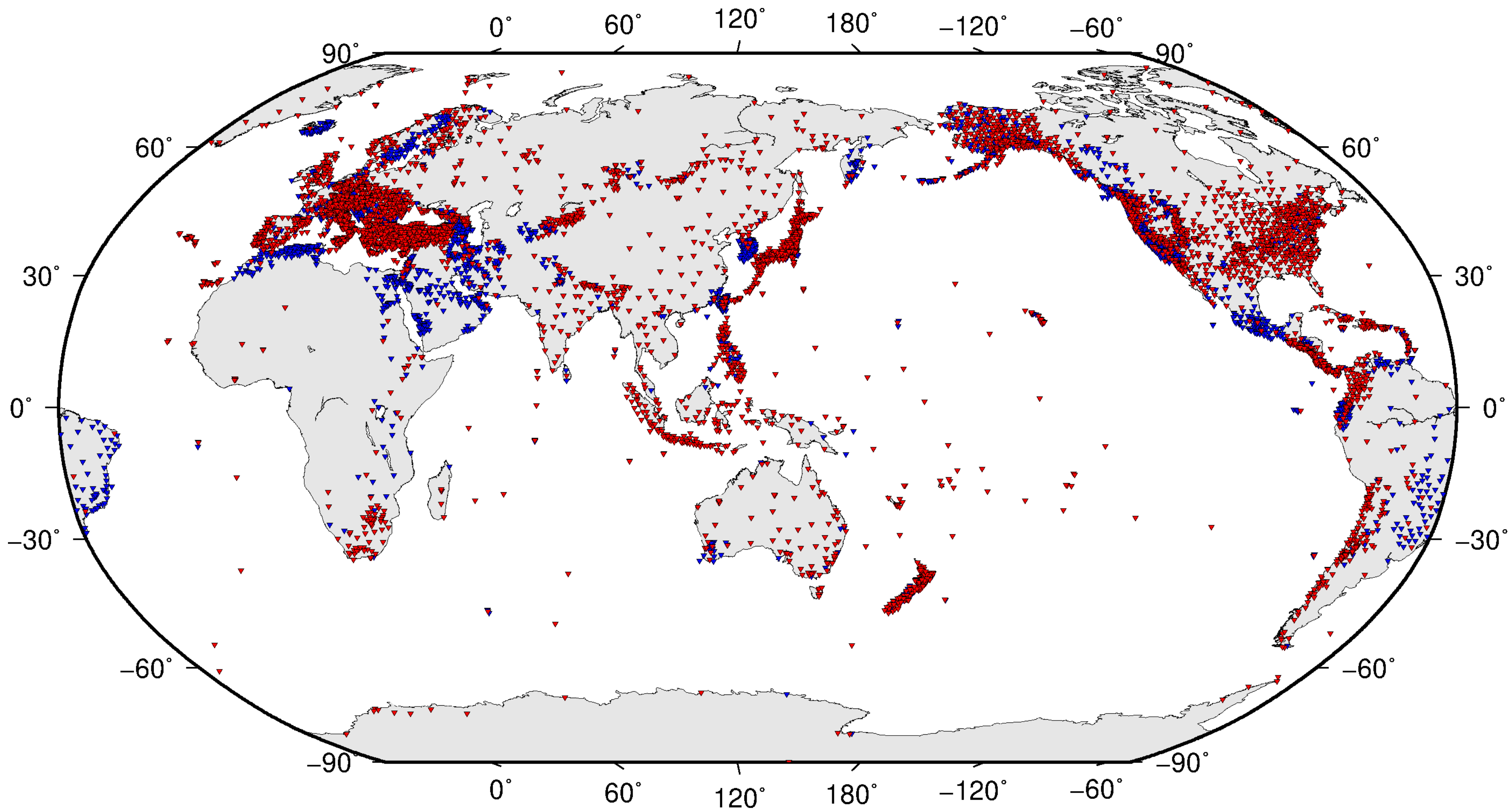


Figure 7.4: *Stations contributing phase data to the ISC for readings from July 2017 to the end of December 2017. Stations in blue provided phase arrival times only; stations in red provided both phase arrival times and amplitude data.*

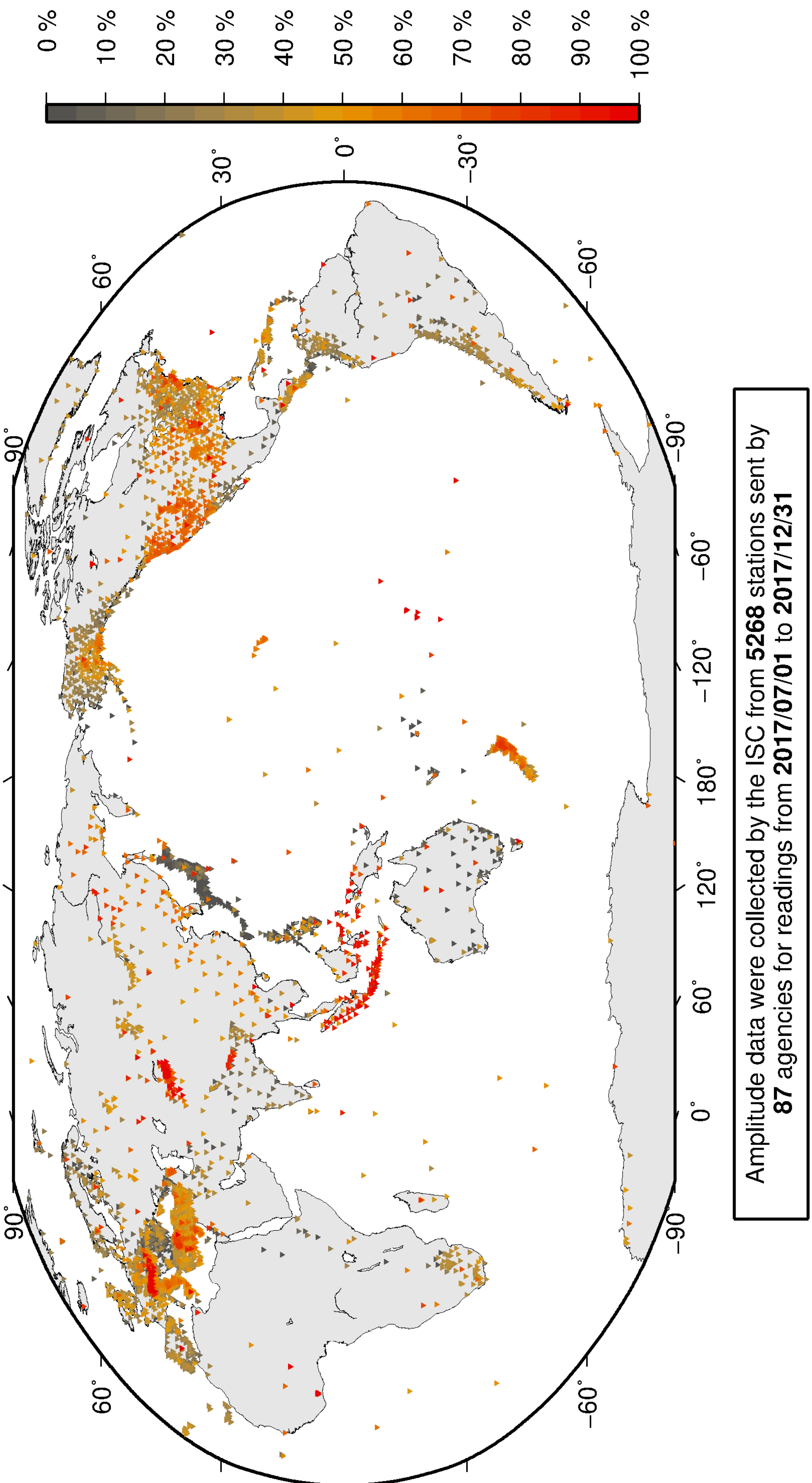


Figure 7.5: *Percentage of events for which phase arrival times from each station are accompanied with amplitude and period measurements.*

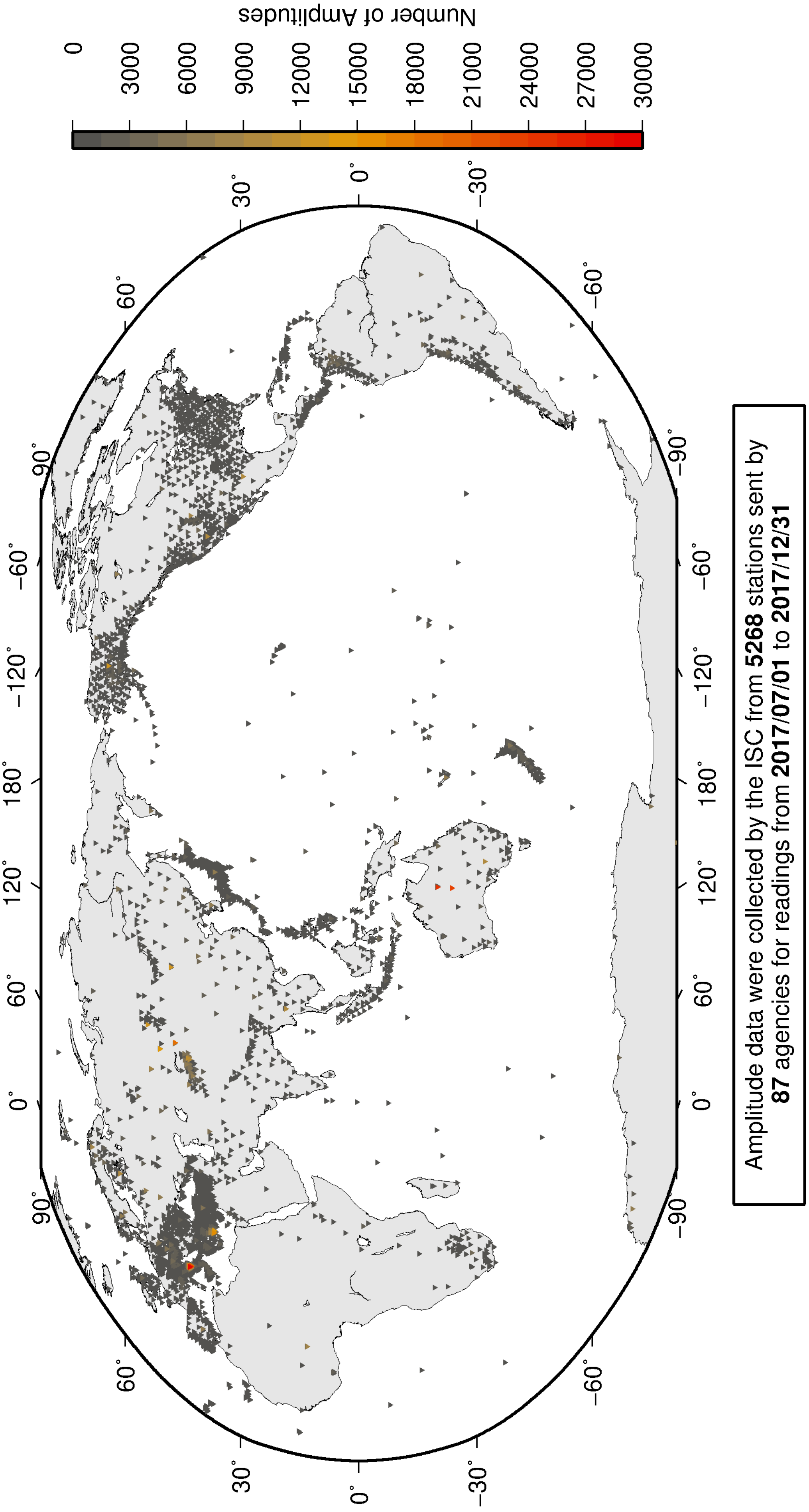


Figure 7.6: *Number of amplitude and period measurements for each station.*

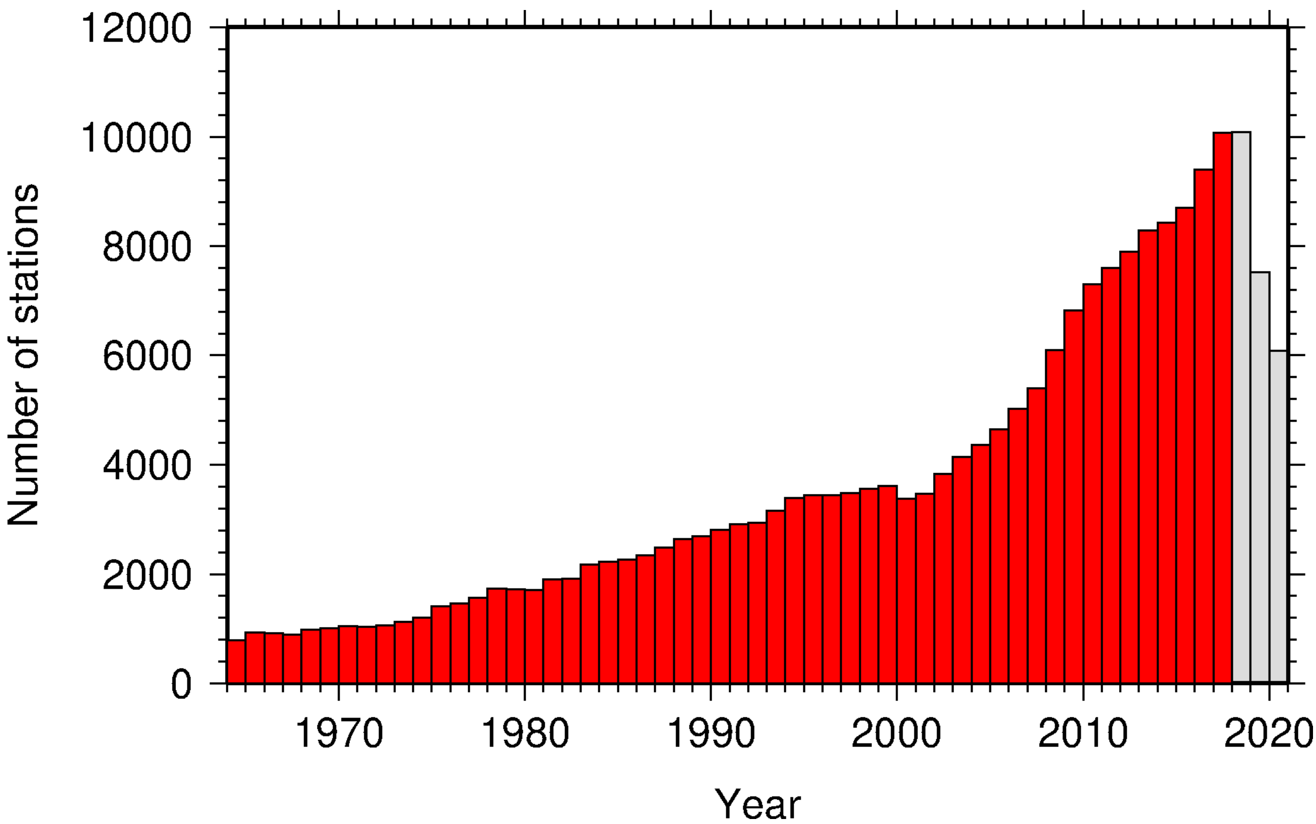


Figure 7.7: *Histogram showing the number of stations reporting to the ISC each year since 1964. The data in grey covers the current period where station information is still being collected before the ISC review of events takes place and is accurate at the time of publication.*

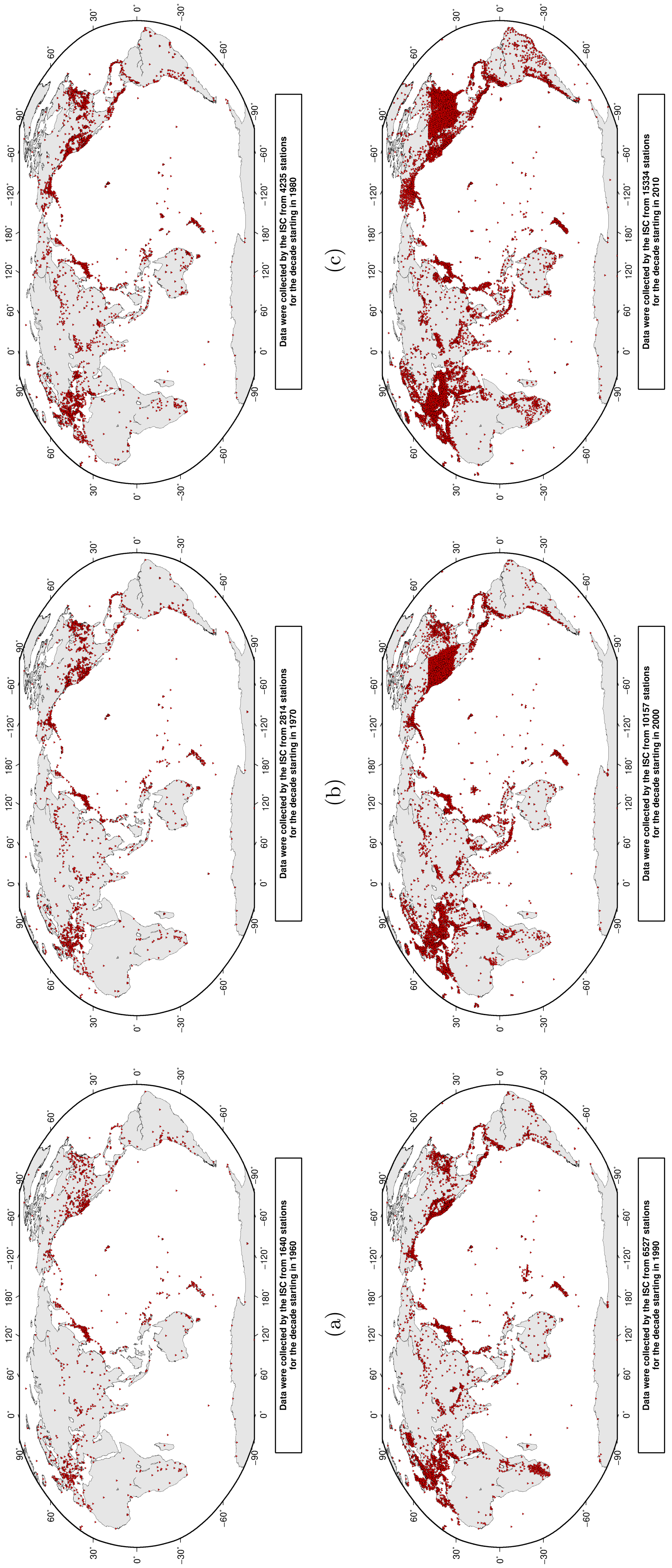


Figure 7.8: *Maps showing the stations reported to the ISC for each decade since 1960. Note that the last map covers a shorter time period.*

7.4 Hypocentres Collected

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

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

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

Reports with hypocentres	3680
Reports of hypocentres only (no phase readings)	209
Total hypocentres received	446307
Number of duplicate hypocentres	11349 (2.5%)
Agencies determining hypocentres	161

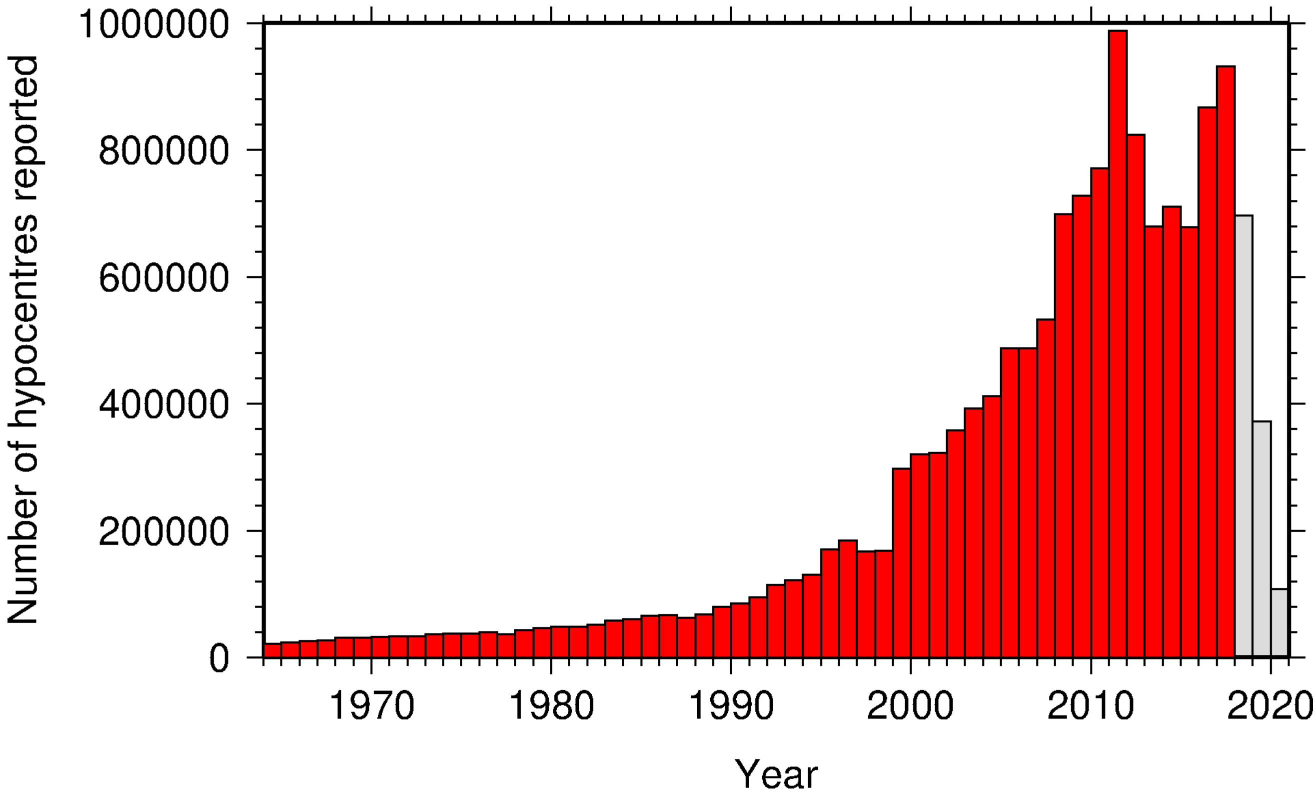


Figure 7.9: *Histogram showing the number of hypocentres collected by the ISC for events each year since 1964. For each event, multiple hypocentres may be reported.*

All the hypocentres that are reported to the ISC are automatically grouped into events, which form the basis of the ISC Bulletin. For this summary period 467250 hypocentres (including ISC) were grouped into 332050 events, the largest of these having 59 hypocentres in one event. The total number of events

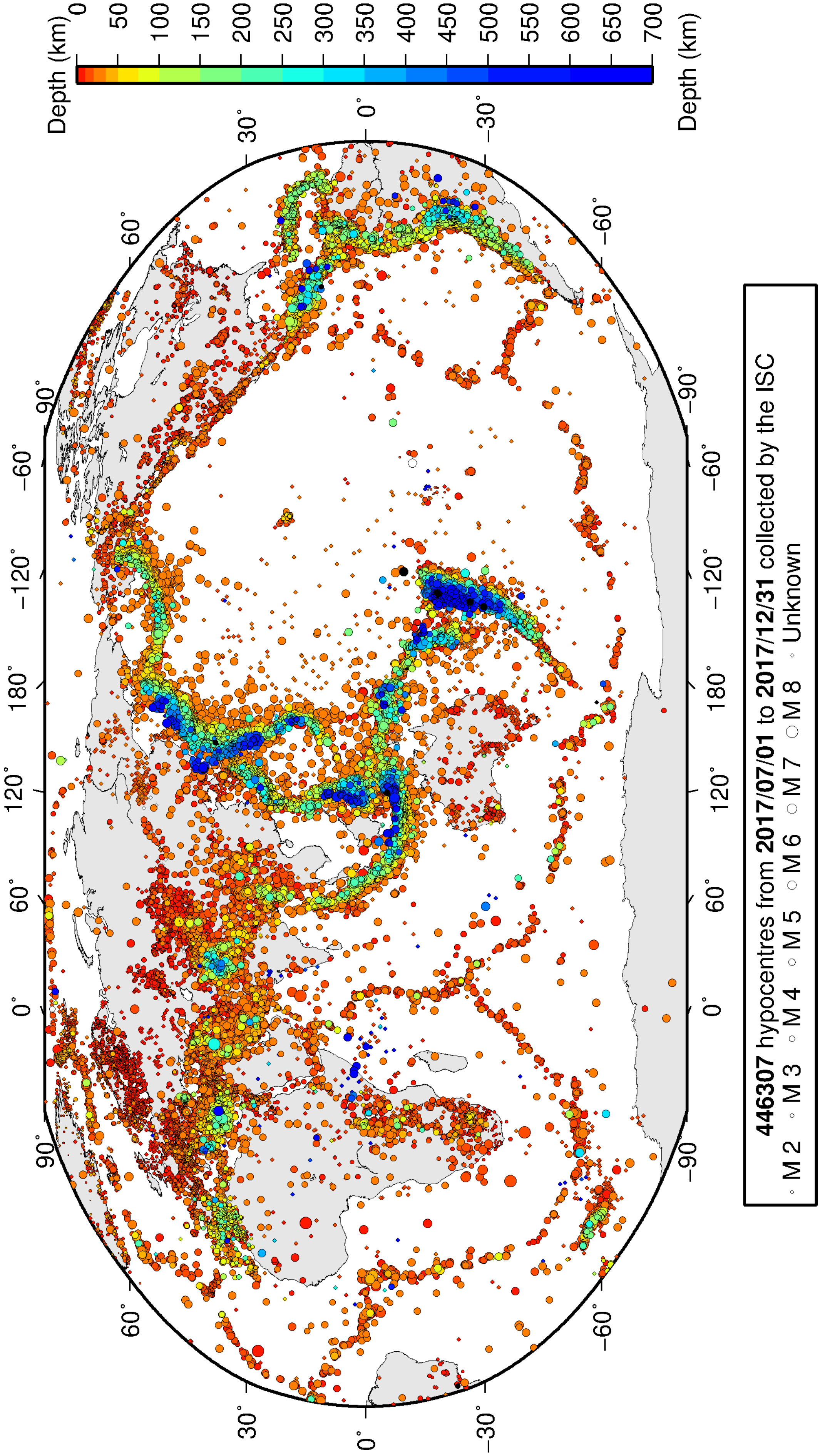


Figure 7.10: *Map of all hypocentres collected by the ISC. The scatter shows the large variation of the multiple hypocentres that are reported for each event. The magnitude corresponds with the reported network magnitude. If more than one network magnitude type was reported, preference was given to values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

shown here is the result of an automatic grouping algorithm, and will differ from the total events in the published ISC Bulletin, where both the number of events and the number of hypocentre estimates will have changed due to further analysis. The process of grouping is detailed in Section 11.1.3 of the January to June Bulletin Summary. Figure 8.2 on page 73 shows a map of all prime hypocentres.

7.5 Collection of Network Magnitude Data

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

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

	M<3.0	3.0≤M<5.0	M≥5.0
Number of seismic events	255448	50436	458
Average number of magnitude estimates per event	1.3	2.7	19.6
Average number of magnitudes (by the same agency) per event	1.1	1.7	2.7
Average number of magnitude types per event	1.1	2.1	9.4
Number of magnitude types	27	35	27

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

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

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

Table 7.6: *continued*

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

Table 7.6: *continued*

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

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

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

Magnitude type	Events	Agencies reporting magnitude type (number of values)
M	6686	WEL (6632), PRU (33), TRN (14), RSPR (4), KRSZO (3)
MB	192	CATAC (196)
mb	25430	IDC (15567), NEIC (7135), NNC (4776), MAN (2178), KRNET (2134), VIE (1718), MOS (1566), DJA (1200), BJI (824), VAO (440), NOU (410), BGR (251), CATAC (228), OMAN (210), NAO (203), MDD (130), IASPEI (84), DSN (51), GII (32), SIGU (29), NDI (28), SFS (18), DMN (8), PGC (8), PRE (5), PDG (5), DNK (4), IGIL (3), CFUSG (3), THR (2), STR (1), GUC (1), ROM (1), BER (1), RSPR (1), CRAAG (1), BGS (1), CSEM (1)
mB	1422	BJI (860), DJA (607), WEL (149), BER (1)
mb(Pn)	354	BER (354)
mB_BB	34	BGR (34)
mb_Lg	3475	MDD (2748), NEIC (715), OTT (26)
mbR	127	VAO (127)
mbtmp	17040	IDC (17040)
Mc	37	KRSC (28), DNK (6), RSNC (3)
MC	291	EAF (263), AFAD (28)

Table 7.7: *Continued.*

Magnitude type	Events	Agencies reporting magnitude type (number of values)
MD	11223	LDG (3232), TRN (1239), RSPR (1186), ECX (994), MEX (614), GCG (609), SSNC (609), HLW (499), ROM (460), SDD (460), EAF (444), JMA (332), GRAL (298), TIR (268), UPA (175), PNSN (151), SOF (137), GII (113), LSZ (89), JSN (69), PDG (69), TUN (54), SLM (41), BUG (26), HVO (16), NCEDC (12), NAM (11), SNET (8), ISK (6), INET (4), UUSS (3), PLV (3), OSPL (2)
ML	141696	ISK (21334), AFAD (18572), TAP (17926), ROM (13700), IDC (9585), RSNC (8713), HEL (8180), ATH (6696), WEL (6228), THE (5625), GUC (4407), NEIC (4115), CATAC (3630), TEH (3169), LDG (3168), UPP (2898), SKO (2854), VIE (2767), MAN (2199), AEIC (2058), SFS (2001), INMG (1803), ANF (1753), CNRM (1674), BER (1592), BEO (1440), PGC (1422), DNK (1346), SNET (1329), LJU (1314), WBNET (1248), ECX (1050), KRSC (1031), RHSSO (1007), PRE (987), SJA (915), GEN (872), SCB (787), BUC (734), UUSS (659), SSNC (598), OSPL (584), IPEC (507), IGIL (493), KOLA (486), MRB (463), TUL (438), SDD (436), HLW (421), ISN (375), NIC (354), PDG (349), KRSZO (287), TIR (278), LVSN (249), NAO (235), DSN (234), KNET (211), UPA (207), OMAN (203), HVO (193), NDI (174), BUT (164), CRAAG (149), BGS (134), OTT (134), ASIES (132), BGR (131), BJI (103), MIRAS (100), UCC (90), PPT (68), SEA (66), KEA (64), NCEDC (64), PAS (60), REN (56), NOU (48), THR (41), CUPWA (39), CLL (38), BNS (28), BUG (28), INET (21), SGS (18), DMN (17), LDO (15), RISSC (7), EAF (7), FIA0 (6), AAE (6), PLV (4), VAO (4), ASRS (3), MEX (3), LSZ (2), MDD (1), CSEM (1)
MLh	834	ZUR (754), ASRS (80)
MLSn	273	PGC (273)
MLv	17592	WEL (6648), STR (4149), DJA (3770), NOU (2418), SFS (1080), KRSZO (30)
Mm	389	GII (389)
MN	451	OTT (451)
mpv	5160	NNC (5160)
MPVA	248	MOS (231), NORS (168)
MS	9998	IDC (7821), MAN (2200), BJI (697), MOS (413), BGR (168), OMAN (72), NSSP (56), IASPEI (37), SOME (34), VIE (22), DNK (8), DSN (6), AAE (5), BER (4), IGIL (4), UPA (1), EAF (1), NDI (1), AFAD (1), SSNC (1), GUC (1)
Ms7	697	BJI (697)
Ms_20	222	NEIC (222)
MV	123351	JMA (123351)

Table 7.7: *Continued.*

Magnitude type	Events	Agencies reporting magnitude type (number of values)
MW	5654	GCMT (1095), SJA (908), NIED (667), UPA (646), UCR (421), SCB (355), SSNC (348), AFAD (348), FUNV (347), PGC (295), RSNC (204), SDD (165), ASIES (132), IPGP (100), JMA (98), DJA (76), MED_RCMT (64), WEL (48), NDI (30), INET (29), ROM (26), ATH (19), MEX (12), INMG (5), AAE (3), BER (3), GFZ (1), CATAC (1), NEIC (1), GUC (1)
mw	1	BUC (1)
Mw(mB)	129	WEL (129)
Mwb	177	NEIC (177)
Mwc	10	NEIC (10)
Mwp	125	DJA (108), OMAN (16), ROM (1)
Mwr	495	NEIC (370), GUC (85), NCEDC (30), SLM (29), OTT (20), REN (15), PAS (9), CAR (7), VIE (2)
Mww	465	NEIC (465), GUC (10)

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

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

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

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

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

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

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

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

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

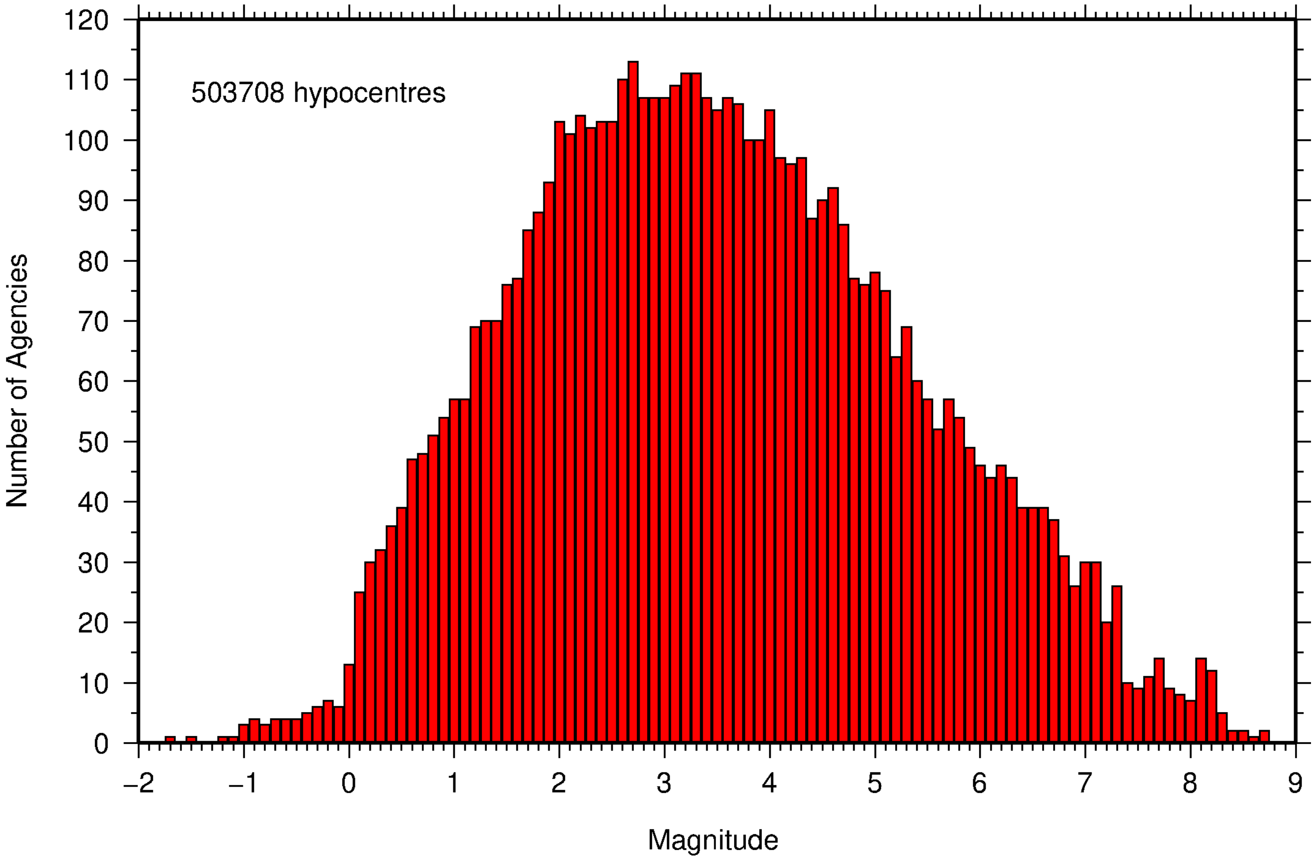


Figure 7.11: *Histogram showing the number of agencies that reported network magnitude values. All magnitude types are included.*

7.6 Moment Tensor Solutions

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

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

Reports with Moment Tensors	108
Total moment tensors received	18652
Agencies reporting moment tensors	8

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

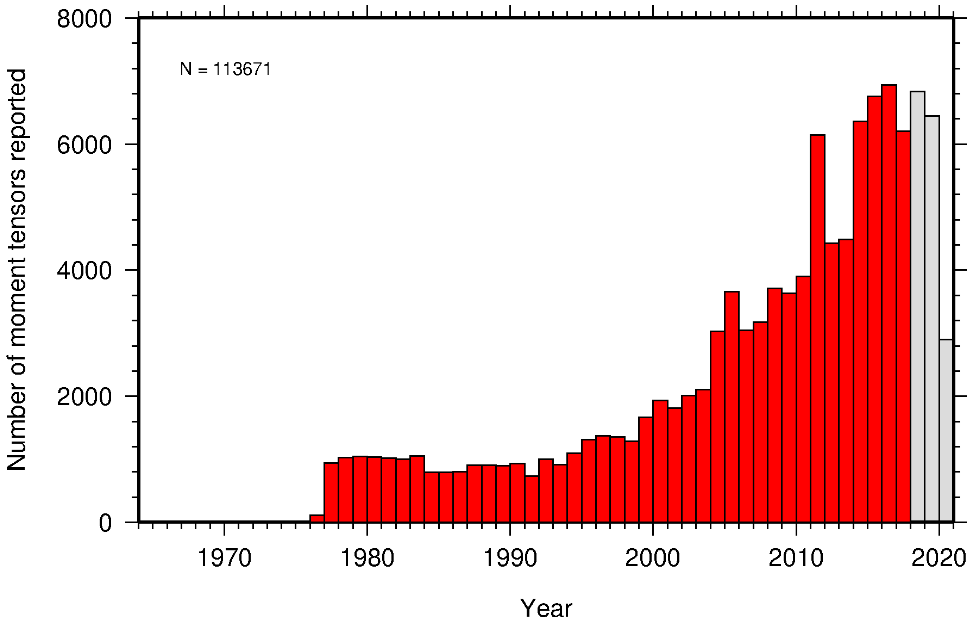


Figure 7.12: *Histogram showing the number of moment tensors reported to the ISC since 1964. The regions in grey represent data that are still being actively collected.*

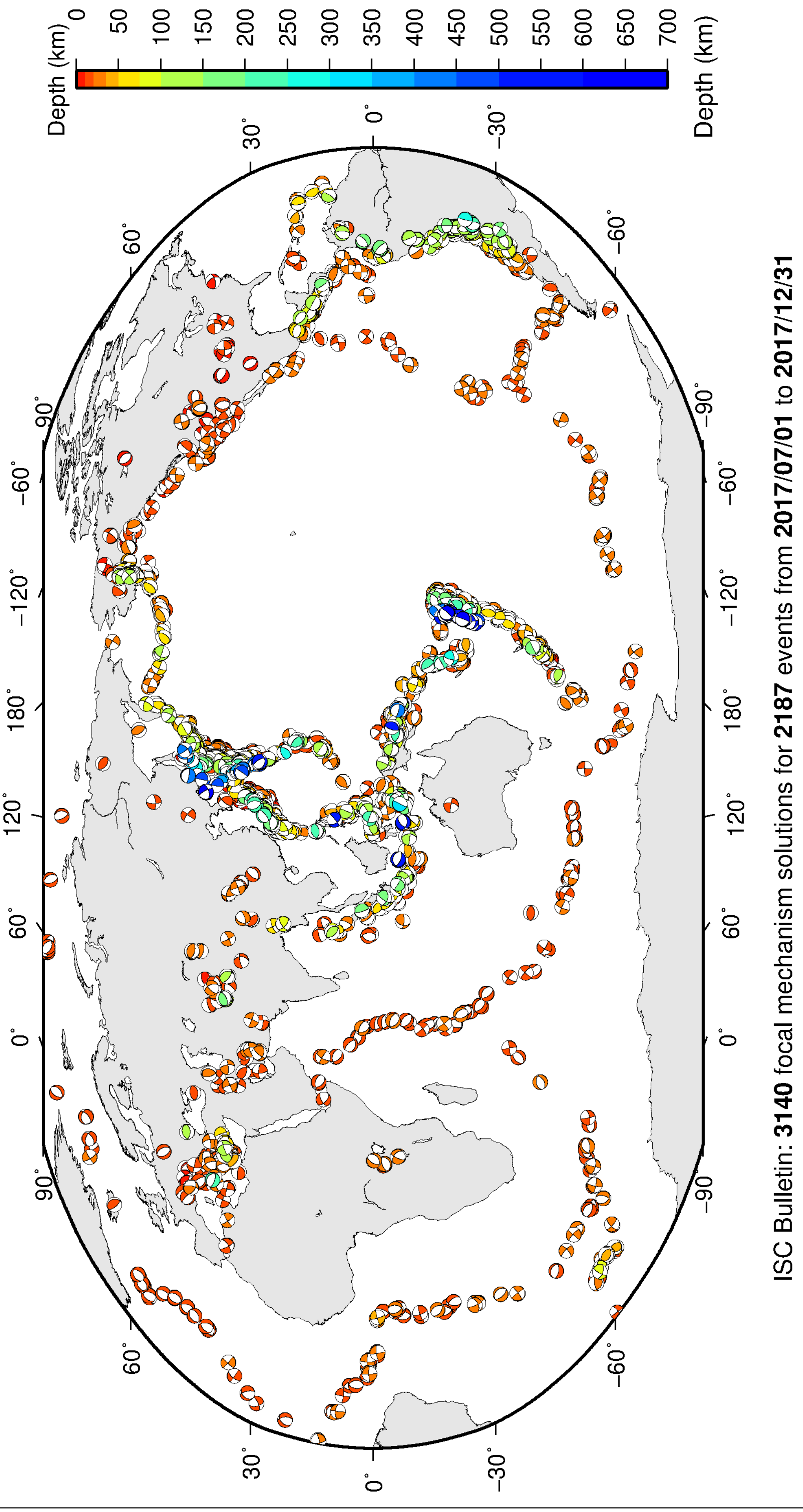


Figure 7.13: *Map of all moment tensor solutions in the ISC Bulletin for this summary period.*

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

Agency	Number of moment tensor solutions
ISC	1388
GCMT	1095
NEIC	1087
NIED	667
IPGP	200
PNSN	151
ASIES	132
MED_RCMT	64
RSNC	63
WEL	48
ROM	28
SDD	26
ECX	20
ATH	19
UPA	16
MOS	10
PRE	9
UCR	6
OSPL	2
MEX	1

7.7 Timing of Data Collection

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

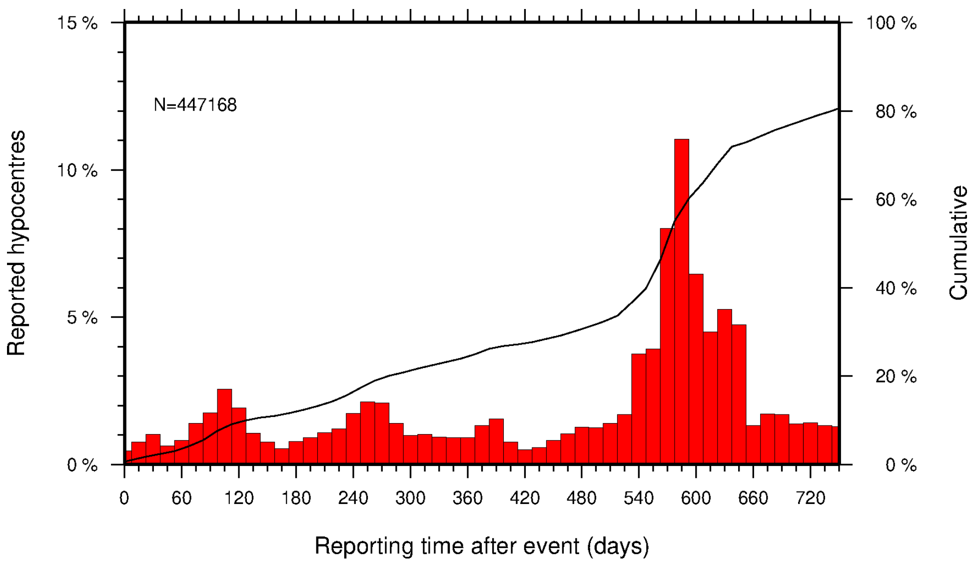
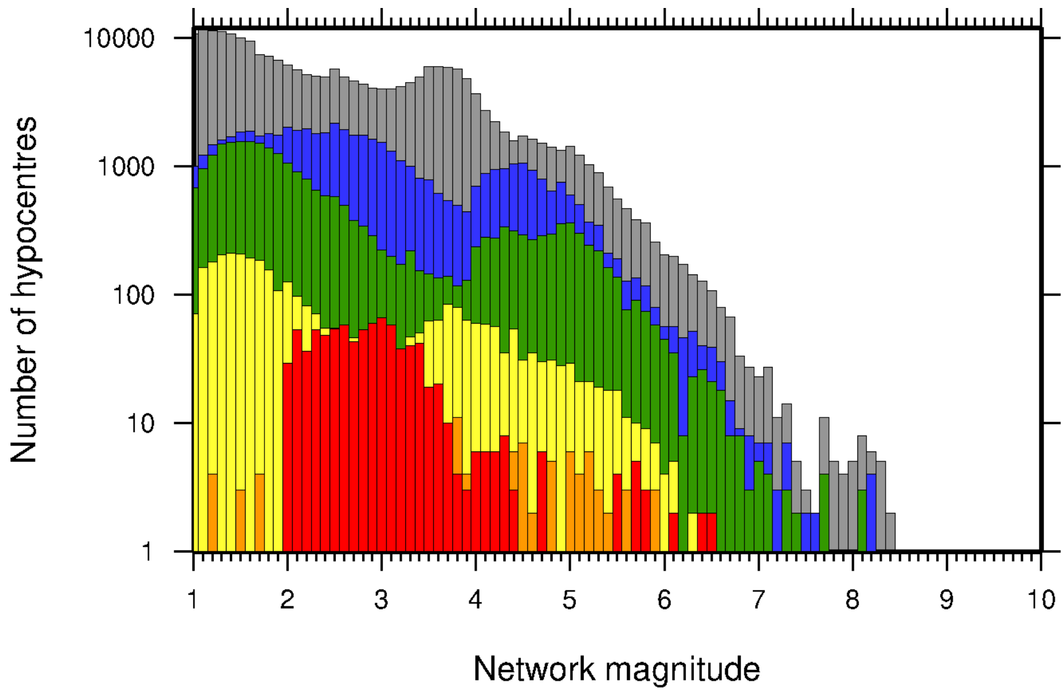


Figure 7.14: *Histogram showing the timing of final reports of the hypocentres (total of N) to the ISC. The cumulative frequency is shown by the solid line.*



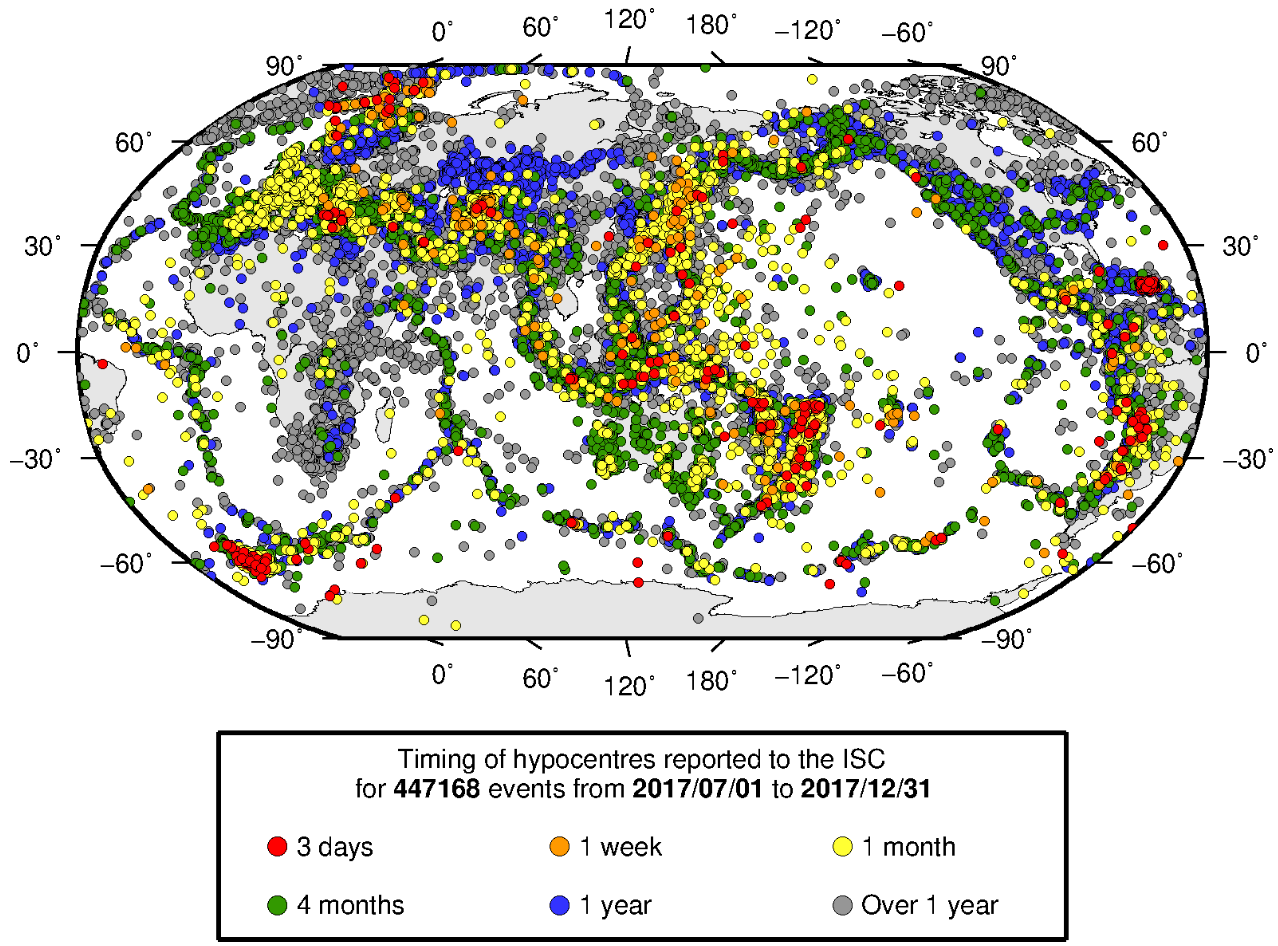


Figure 7.15: *Timing of hypocentres reported to the ISC. The colours show the time after the origin time that the corresponding hypocentre was reported. The histogram shows the distribution with magnitude. If more than one network magnitude was reported, preference was given to a value of M_W followed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

8

Overview of the ISC Bulletin

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

8.1 Events

The ISC Bulletin had 325149 reported events in the summary period between July and December 2017. Some 93% (304950) of the events were identified as earthquakes, the rest (20199) were of anthropogenic origin (including mining and other chemical explosions, rockbursts and induced events) or of unknown origin. In this summary period 8% of the events were reviewed and 5% 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 11.1.3 of the January to June Bulletin Summary.

Of the 10746078 reported phase observations, 35% 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 8.1 shows the daily number of events throughout the summary period. Figure 8.2 shows the locations of the events in the ISC Bulletin; the locations of ISC-reviewed and ISC-located events are shown in Figures 8.3 and 8.4, respectively.

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

Figure 8.6 shows the depth distribution of free-depth solutions in the ISC Bulletin. The depth of a hypocentre reported to the ISC is assumed to be determined as a free parameter, unless it is explicitly labelled as a fixed-depth solution. On the other hand, as described in Section as described in Section 11.1.4 of the January to June 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 phases are reported.

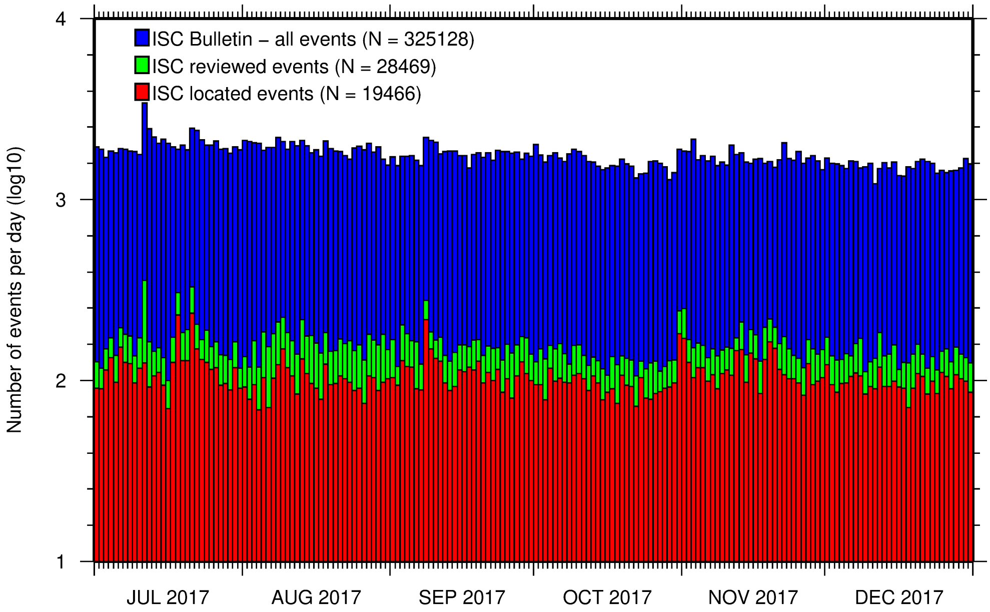


Figure 8.1: *Histogram showing the number of events in the ISC Bulletin for the current summary period. The vertical scale is logarithmic.*

Figure 8.7 shows the depth distribution of fixed-depth solutions in the ISC Bulletin. Except for a fraction of events whose depth is fixed to a shallow depth, this set comprises mostly ISC-located events. If there is no resolution for depth in the data, the ISC locator fixes the depth to a value obtained from the ISC default depth grid file, or if no default depth exists for that location, to a nominal default depth assigned to each Flinn-Engdahl region (see details in Section 11.1.4 of the January to June 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 8.8 illustrates that the secondary azimuthal gap is indeed generally smaller for ISC-located events than that for all events in the ISC Bulletin. Figure 8.9 shows the distribution of the number of associated stations. For large events the number of associated stations is usually larger for ISC-located events than for any of the reported event bulletins. On the other hand, events with just a few reporting stations are rarely selected for ISC location. The same is true for the number of defining stations (stations with at least one defining phase that were used in the location). Figure 8.10 indicates that because the reported observations from multiple agencies are associated to the prime, large ISC-located events typically have a larger number of defining stations than any of the reported event bulletins.

The formal uncertainty estimates are also typically smaller for ISC-located events. Figure 8.11 shows the distribution of the area of the 90% confidence error ellipse for ISC-located events during the summary period. The distribution suffers from a long tail indicating a few poorly constrained event locations. Nevertheless, half of the events are characterised by an error ellipse with an area less than 180 km^2, 90% of the events have an error ellipse area less than 1200 km^2, and 95% of the events have an error ellipse

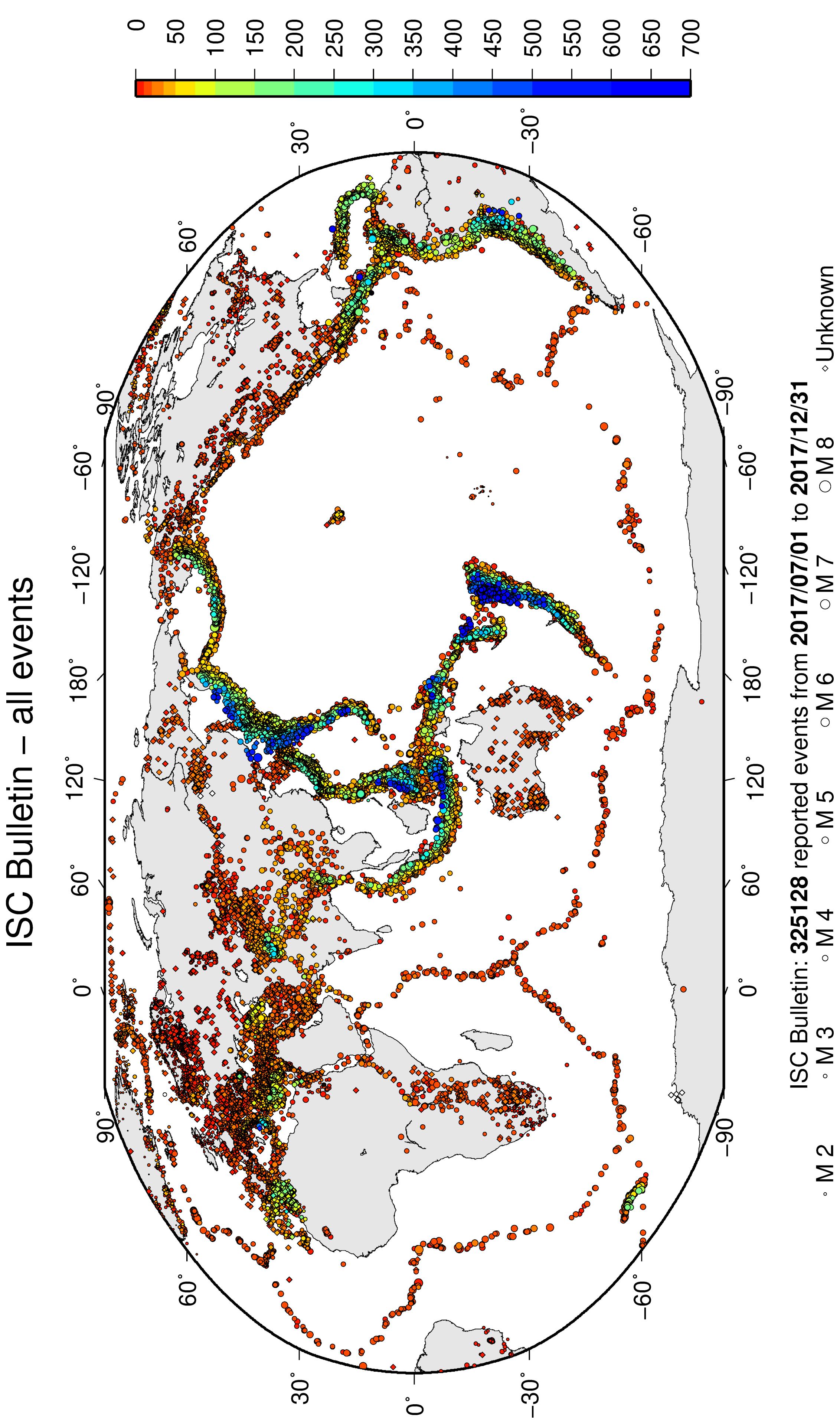


Figure 8.2: *Map of all events in the ISC Bulletin. Prime hypocentre locations are shown. Compare with Figure 7.10.*

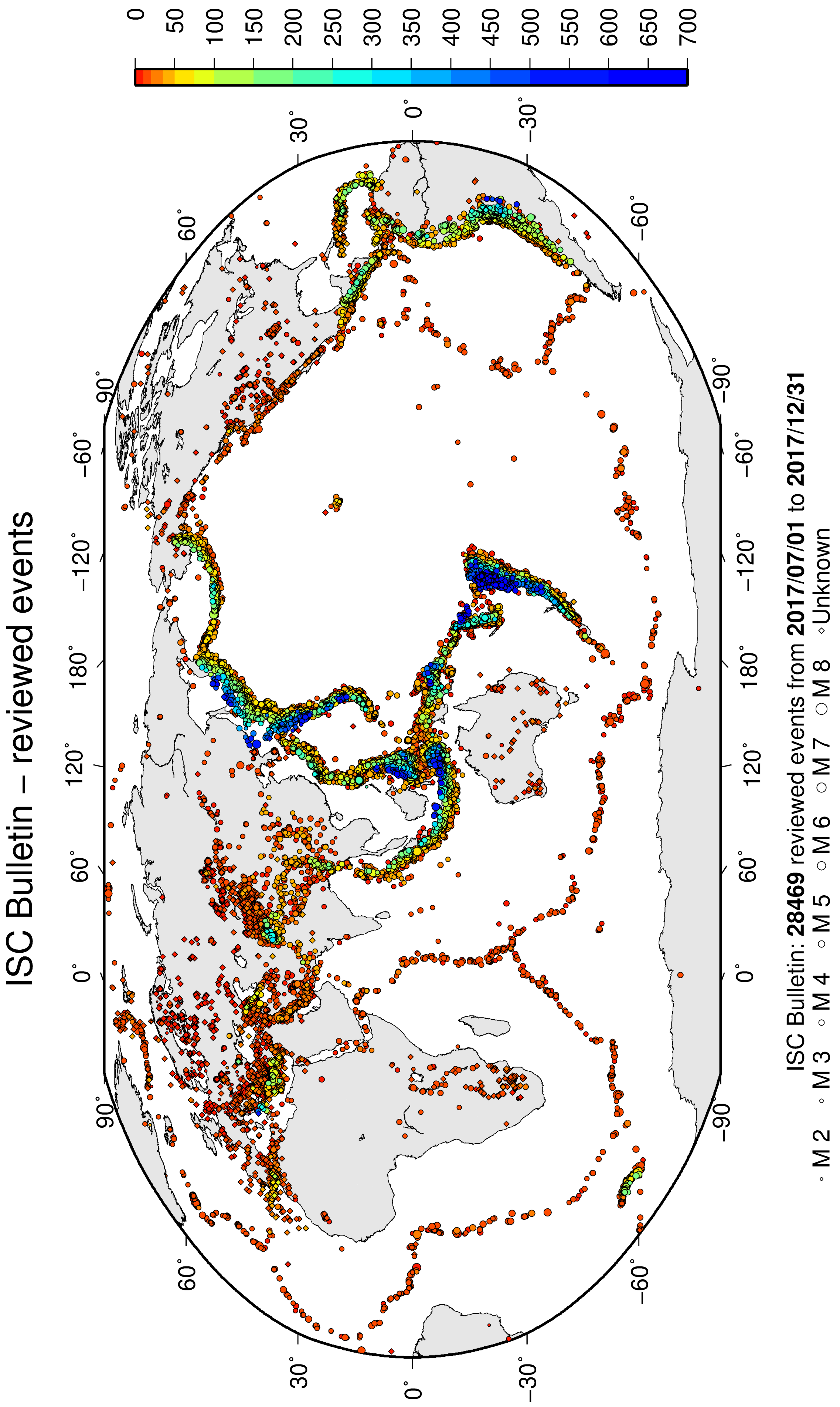


Figure 8.3: *Map of all events reviewed by the ISC for this time period. Prime hypocentre locations are shown.*

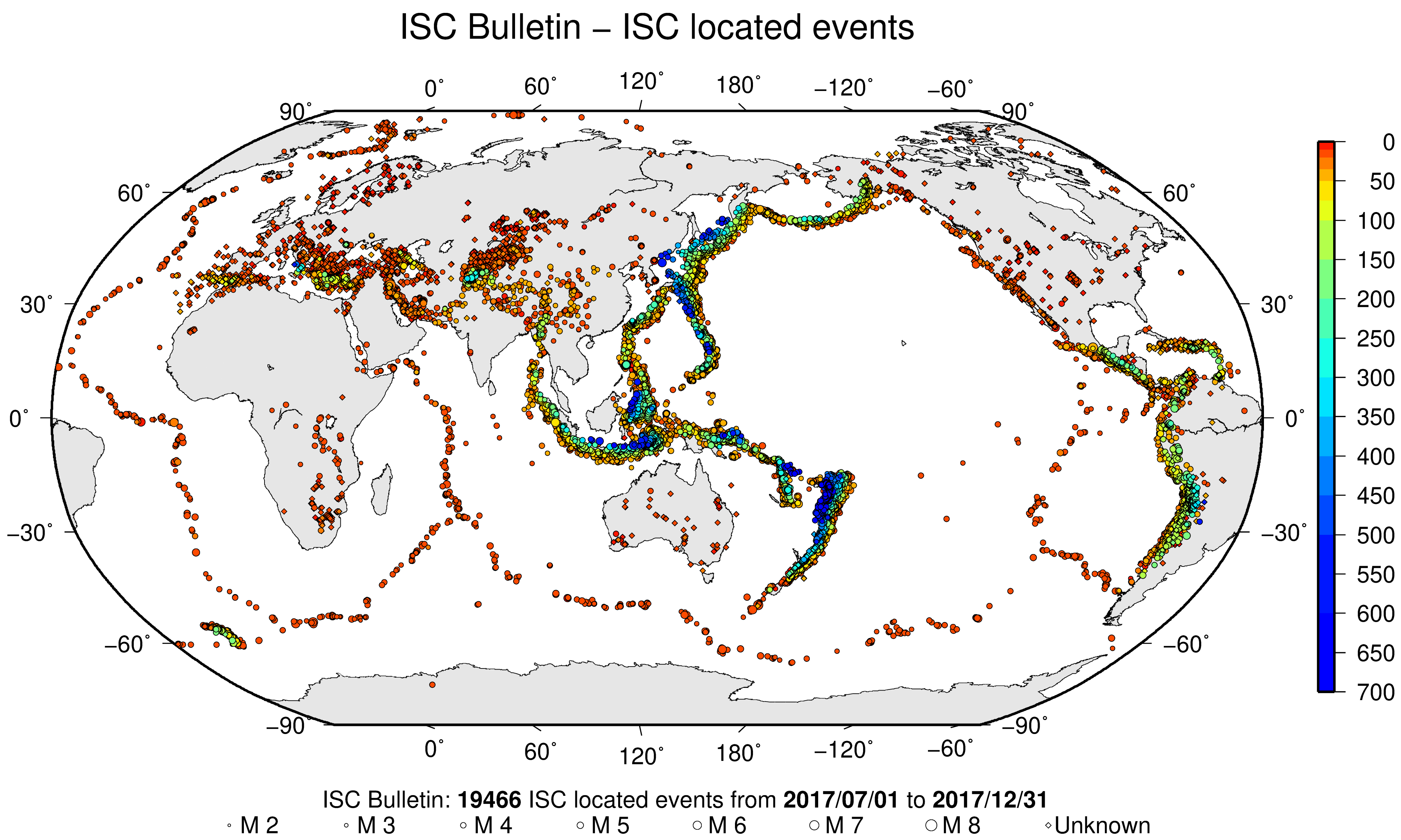


Figure 8.4: *Map of all events located by the ISC for this time period. ISC determined hypocentre locations are shown.*

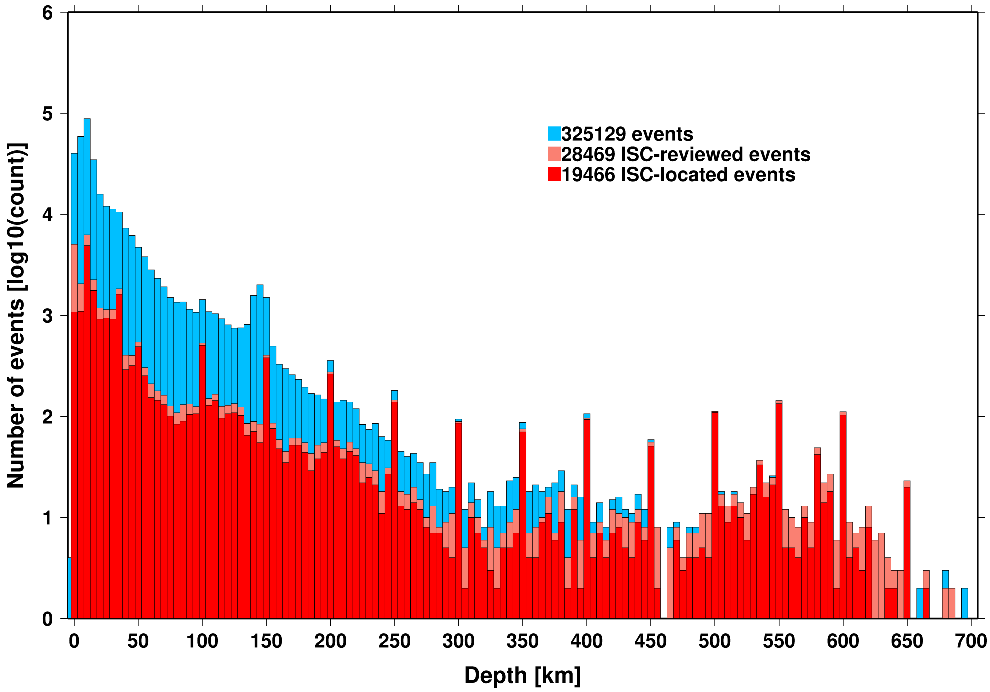


Figure 8.5: *Distribution of event depths in the ISC Bulletin (blue) and for the ISC-reviewed (pink) and the ISC-located (red) events during the summary period. All ISC-located events are reviewed, but not all reviewed events are located by the ISC. The vertical scale is logarithmic.*

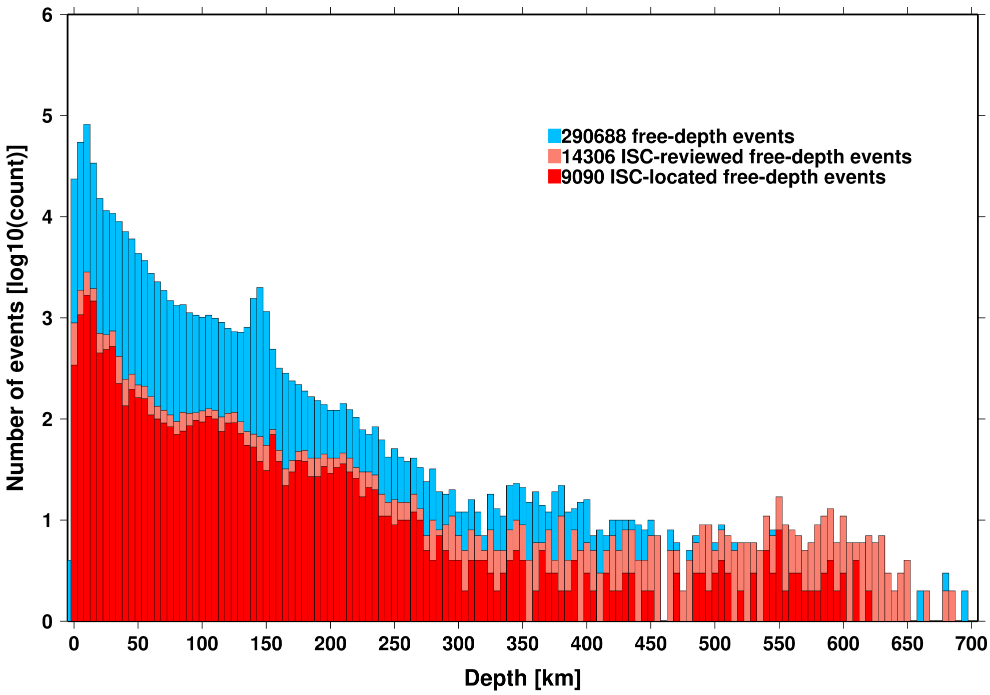


Figure 8.6: *Hypocentral depth distribution of events where the prime hypocentres are reported/located with a free-depth solution in the ISC Bulletin. The vertical scale is logarithmic.*

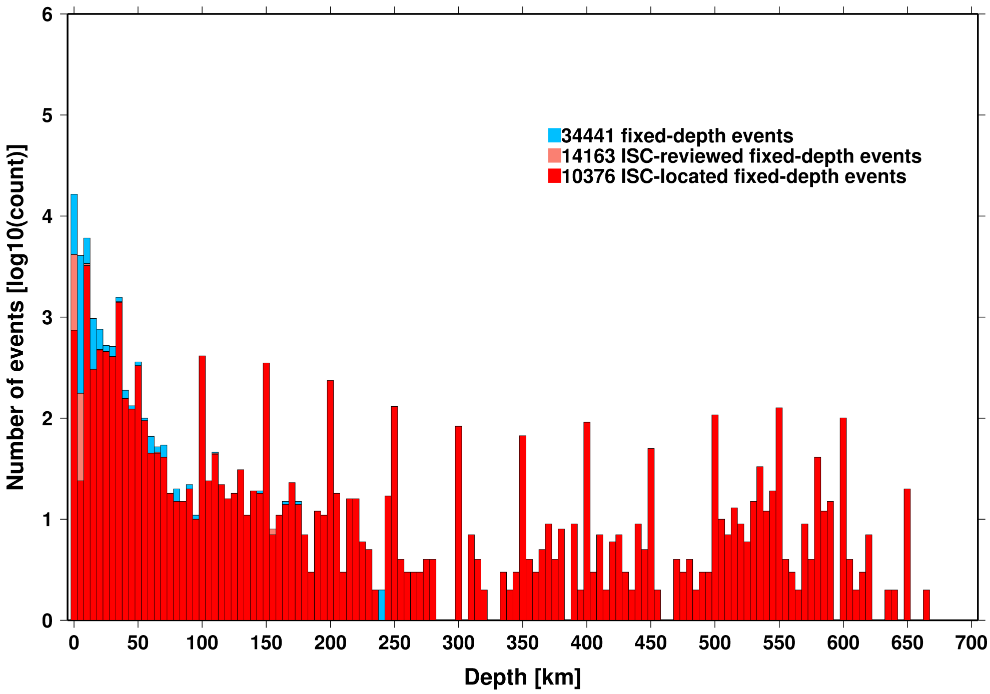


Figure 8.7: *Hypocentral depth distribution of events where the prime hypocentres are reported/located with a fixed-depth solution in the ISC Bulletin. The vertical scale is logarithmic.*

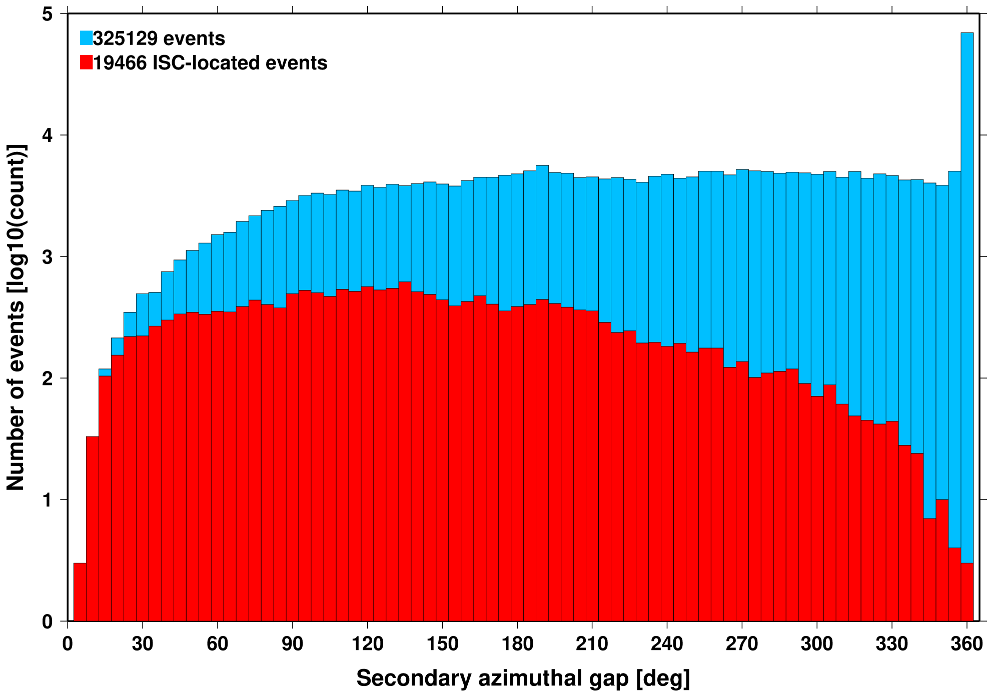


Figure 8.8: *Distribution of secondary azimuthal gap for events in the ISC Bulletin (blue) and those selected for ISC location (red). The vertical scale is logarithmic.*

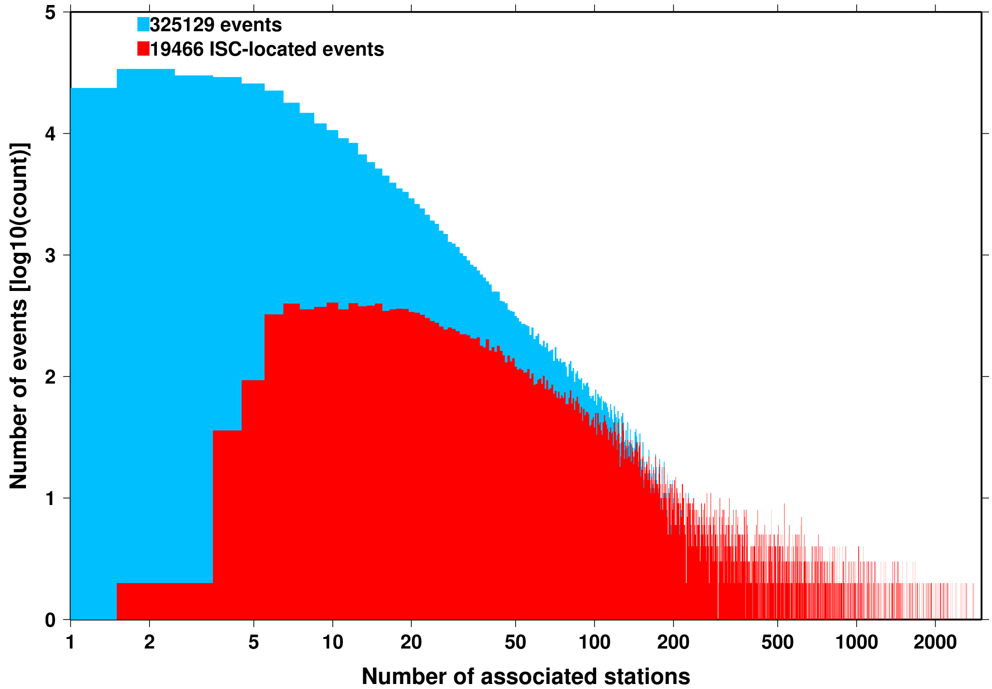


Figure 8.9: *Distribution of the number of associated stations for events in the ISC Bulletin (blue) and those selected for ISC location (red). The vertical scale is logarithmic.*

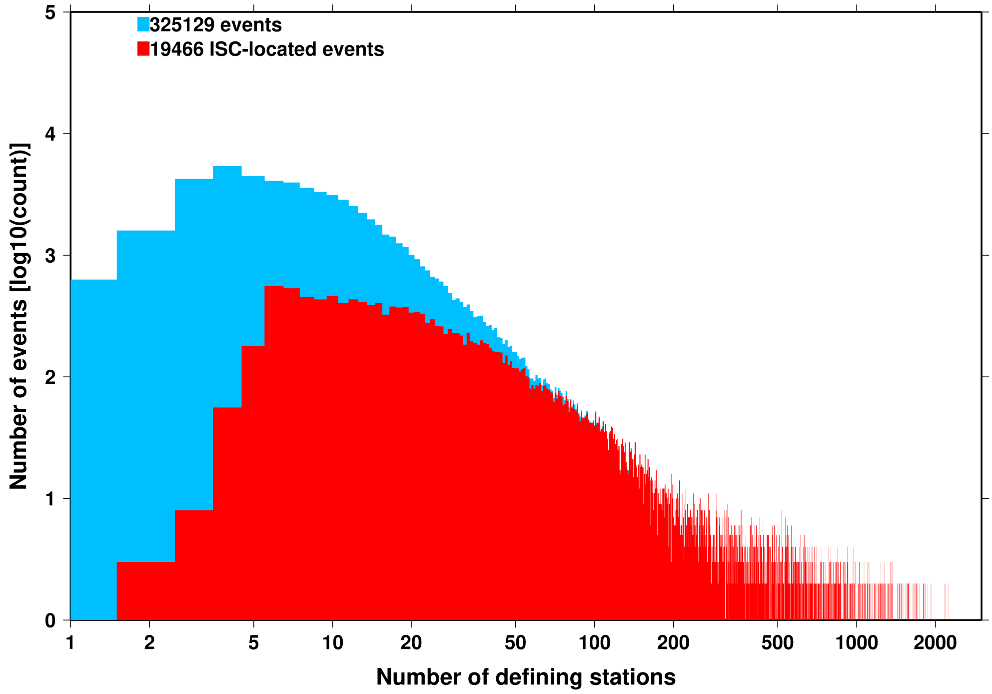


Figure 8.10: *Distribution of the number of defining stations for events in the ISC Bulletin (blue) and those selected for ISC location (red). The vertical scale is logarithmic.*

area less than 2210 km^2.

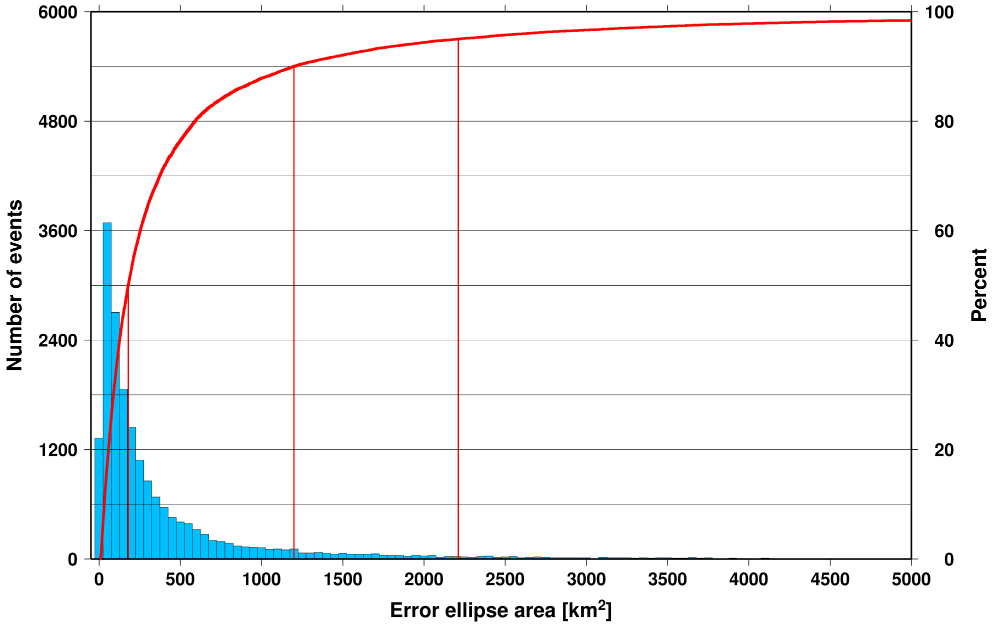


Figure 8.11: *Distribution of the area of the 90% confidence error ellipse of the ISC-located events. Vertical red lines indicate the 50th, 90th and 95th percentile values.*

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

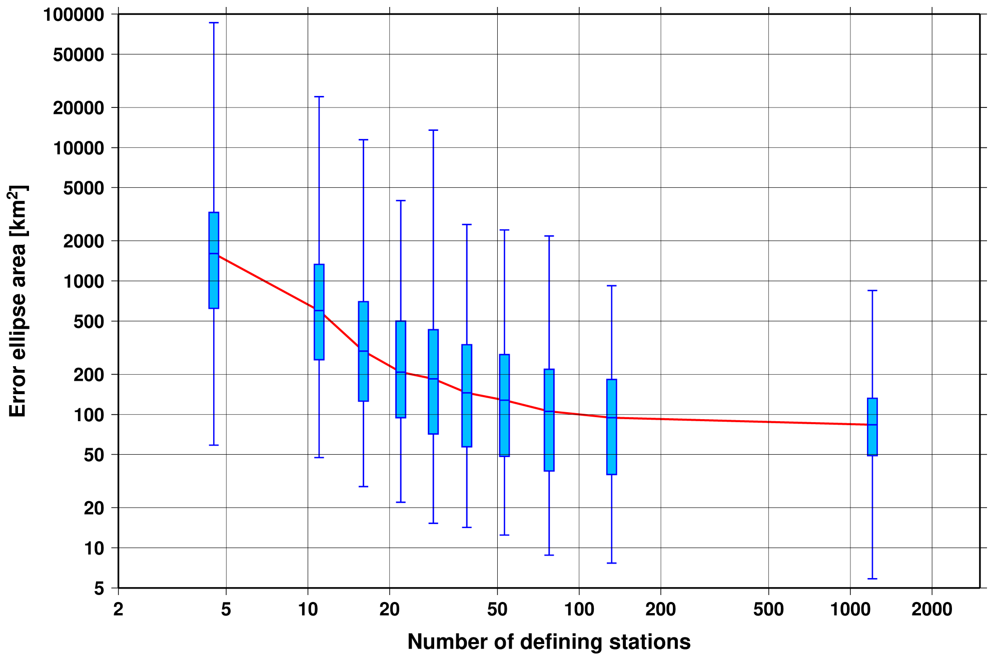


Figure 8.12: *Box-and-whisker plot of the area of the 90% confidence error ellipse of the ISC-located events as a function of the number of defining stations. Each box represents one-tenth-worth of the total number of data. The red line indicates the median 90% confidence error ellipse area.*

8.2 Seismic Phases and Travel-Time Residuals

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

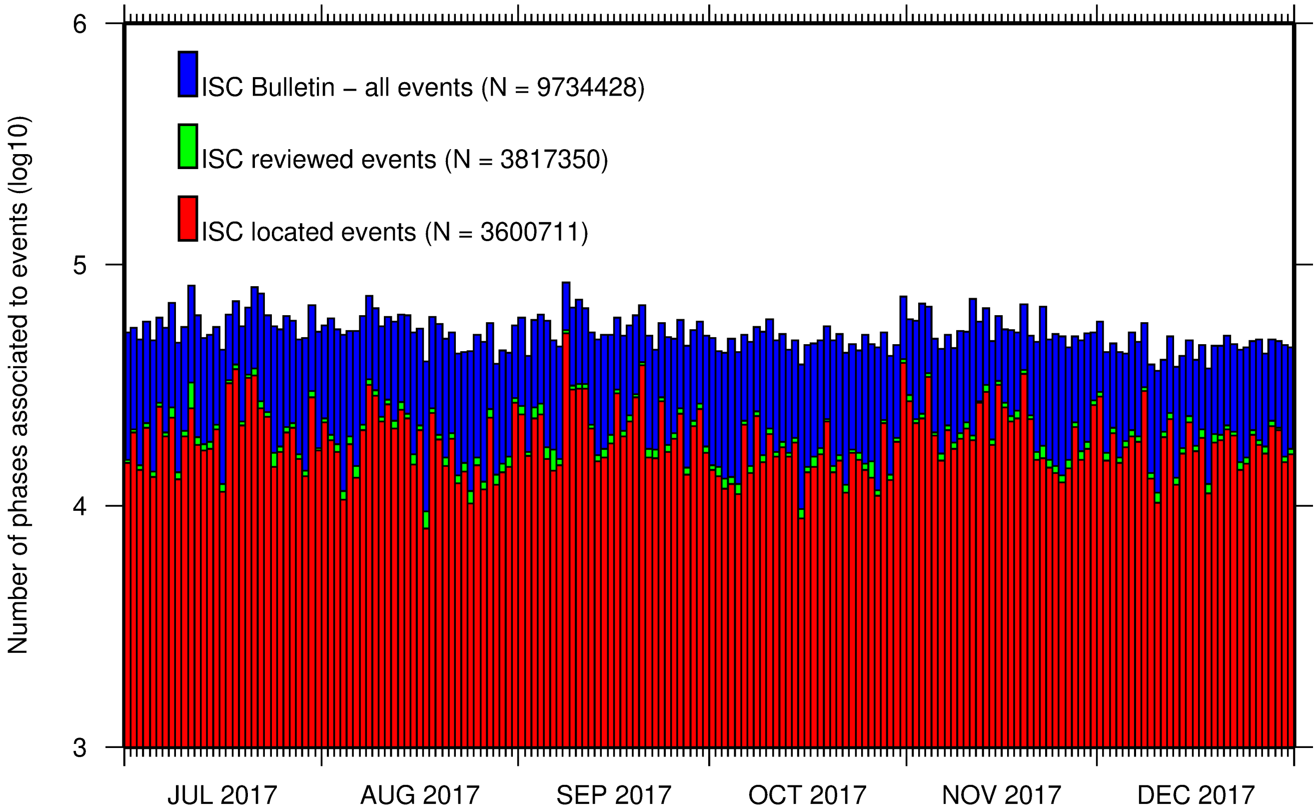


Figure 8.13: *Histogram showing the number of phases (N) that the ISC has associated to events within the ISC Bulletin for the current summary period.*

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

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

Table 8.1: *Numbers of 'time defining' phases (N) within the ISC Bulletin for 19466 ISC located events.*

Phase	Number of 'defining' phases	Number of events	Max per event	Median per event
P	1058939	13188	2599	15
Pn	646218	17943	741	18
Sn	182253	15111	176	6
Pb	92471	8376	128	6
Pg	76863	6538	170	7
PKPdf	58668	4420	898	2
Sb	57360	7646	113	5
Sg	52848	6003	162	5

Table 8.1: *(continued)*

Phase	Number of 'defining' phases	Number of events	Max per event	Median per event
S	49301	3446	838	3
PKiKP	33132	3186	401	2
PKPbc	26718	3183	277	2
PKPab	16870	2755	141	2
PcP	13835	3594	92	2
Pdif	11282	869	463	2
pP	10527	1665	162	3
PP	9597	1435	164	2
sP	5150	1532	56	2
SS	4326	1101	55	2
ScP	3899	1171	49	2
SKSac	2928	476	87	2
pwP	1930	703	32	2
PKKPbc	1734	369	78	2
PnPn	1383	665	12	1
SnSn	1341	656	12	1
ScS	1160	495	24	1
sS	990	431	53	1
pPKPdf	757	339	25	1
SKPbc	748	257	66	2
SKiKP	626	287	15	1
P'P'df	505	130	25	2
PcS	477	369	11	1
PS	466	190	21	2
pPKPab	389	160	26	1
PKKPab	347	163	15	1
pPKPbc	303	175	15	1
SKSdf	297	198	10	1
PKKPdf	289	149	8	1
sPKPdf	284	186	16	1
SKKSac	245	136	7	1
SKPab	167	110	7	1
PnS	162	130	3	1
sPKPab	143	63	13	1
SP	140	51	27	1
sPKPbc	128	75	17	1
SKPdf	114	75	10	1
pS	98	84	3	1
PKSdf	94	57	7	1
Sdif	91	53	8	1
SKKPbc	74	35	19	1
SKKSdf	66	64	2	1
pPKiKP	58	30	7	2
pPdif	52	31	12	1
P'P'bc	35	27	3	1
SPn	22	22	1	1
P'P'ab	16	15	2	1
PbPb	14	10	3	1
sPdif	9	9	1	1
SKKPab	9	8	2	1
SKKPdf	8	7	2	1
sSKSac	8	7	2	1
SbSb	7	7	1	1
sPKiKP	6	6	1	1
sSdif	4	4	1	1
sPn	3	3	1	1
pPn	2	2	1	1
SgSg	2	2	1	1
PgPg	2	2	1	1
PKSab	2	2	1	1
S'S'ac	1	1	1	1
PKSbc	1	1	1	1
sSn	1	1	1	1
PKKSbc	1	1	1	1

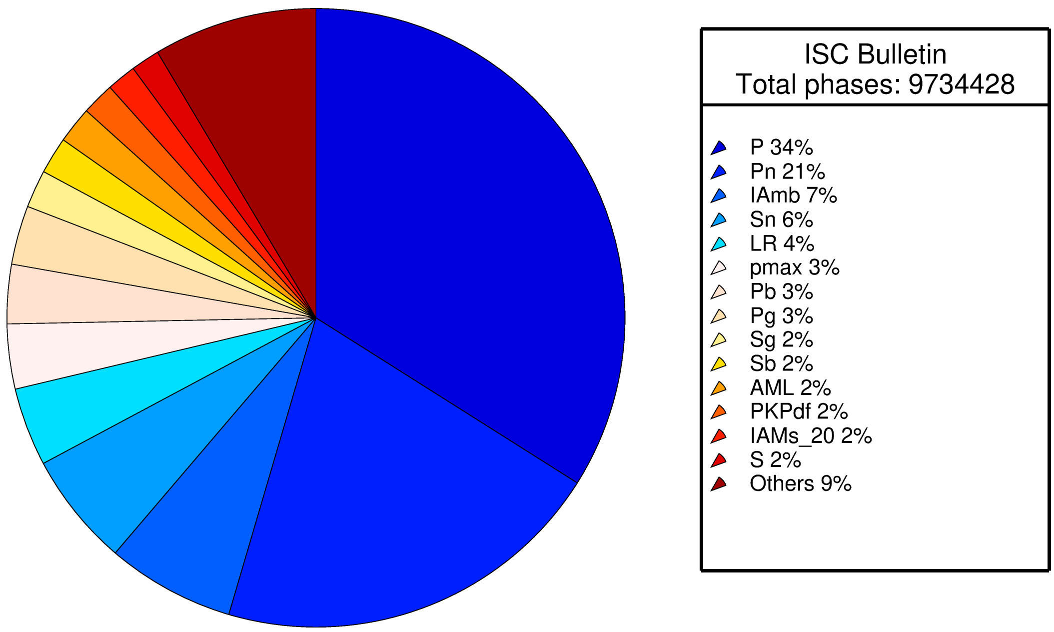


Figure 8.14: *Pie chart showing the fraction of various phase types in the ISC Bulletin for this summary period.*

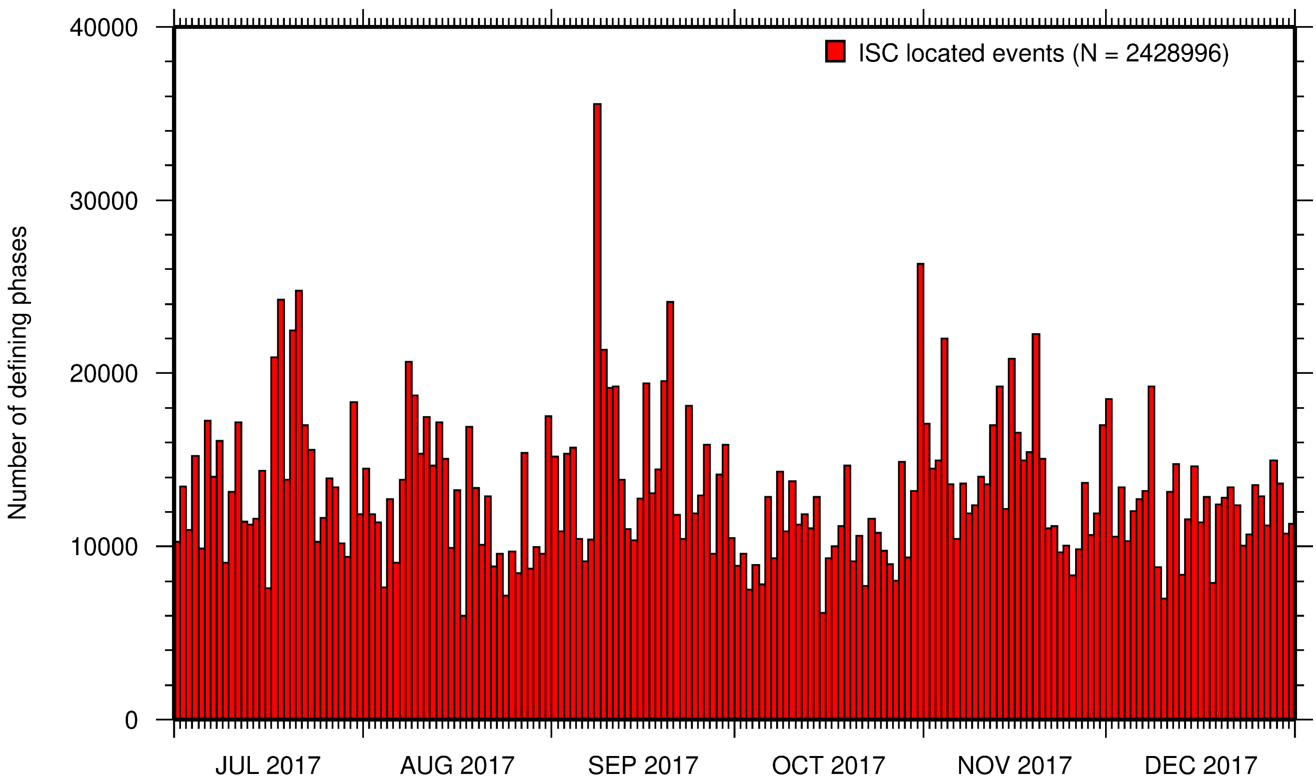


Figure 8.15: *Histogram showing the number of defining phases in the ISC Bulletin, for events located by the ISC.*

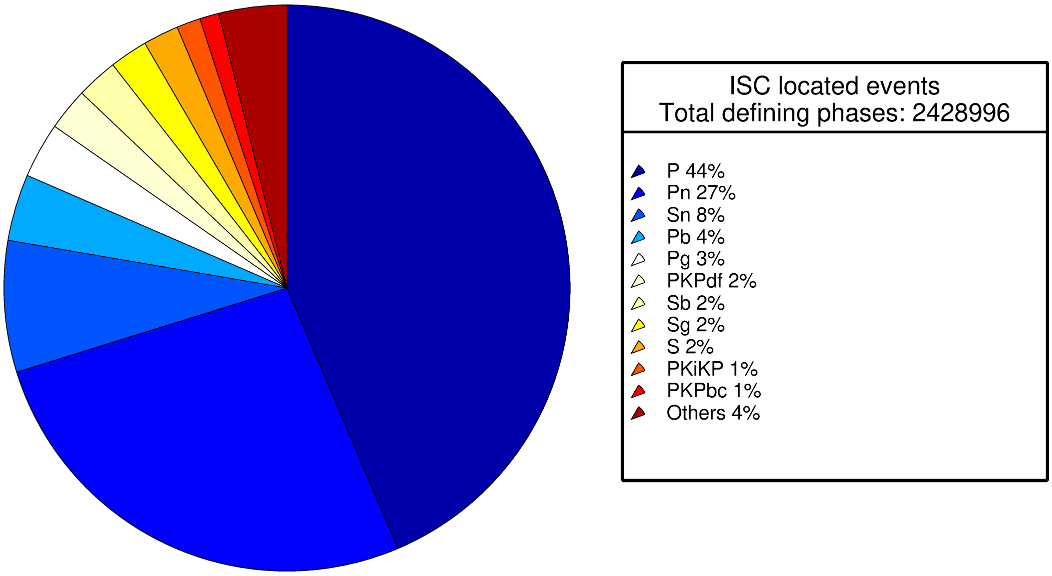


Figure 8.16: *Pie chart showing the defining phases in the ISC Bulletin, for events located by the ISC. A complete list of defining phases is shown in Table 8.1.*

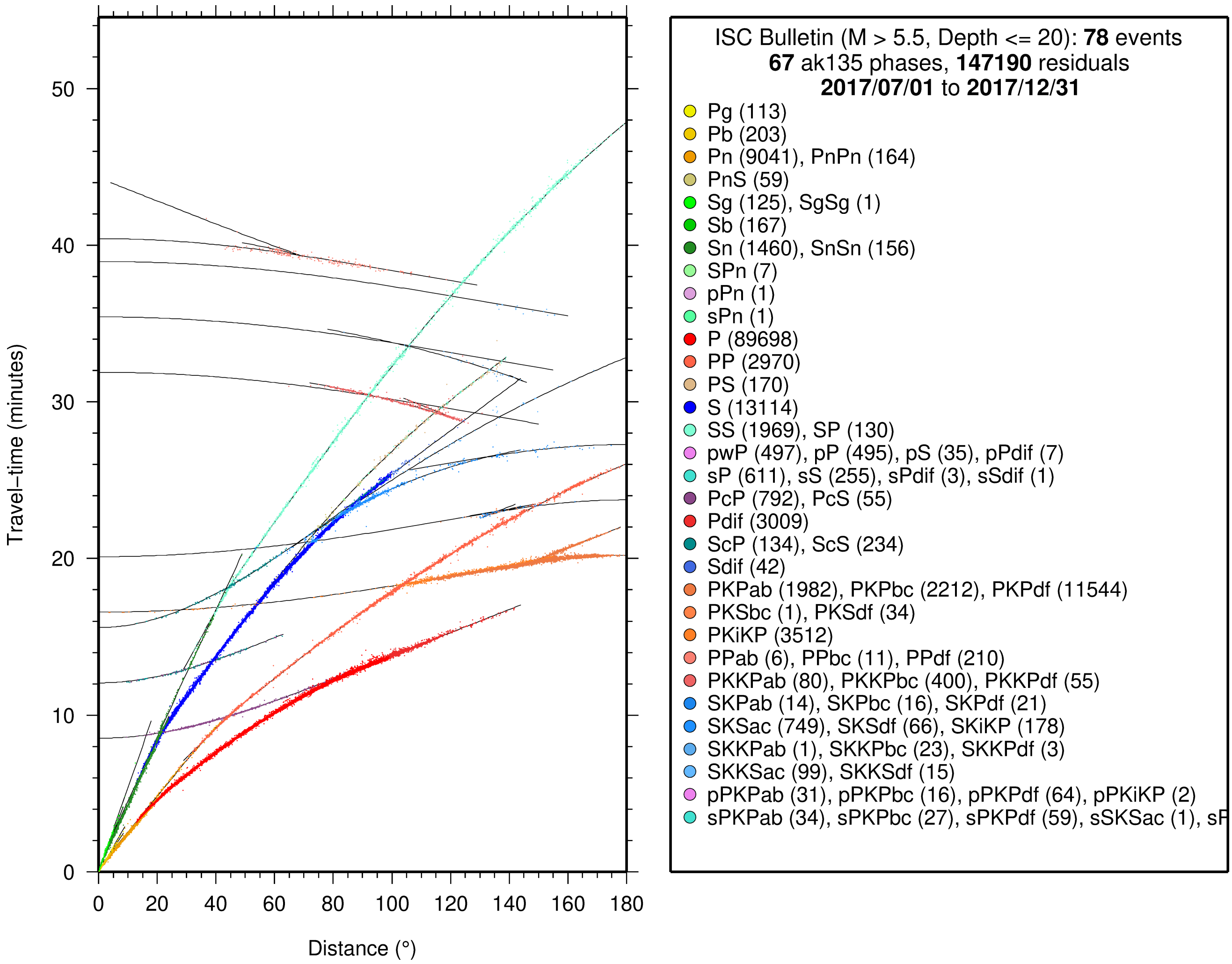


Figure 8.17: *Distribution of travel-time observations in the ISC Bulletin for events with $M > 5.5$ and depth less than 20 km. The travel-time observations are shown relative to a 0 km source and compared with the theoretical ak135 travel-time curves (solid lines). The legend lists the number of each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

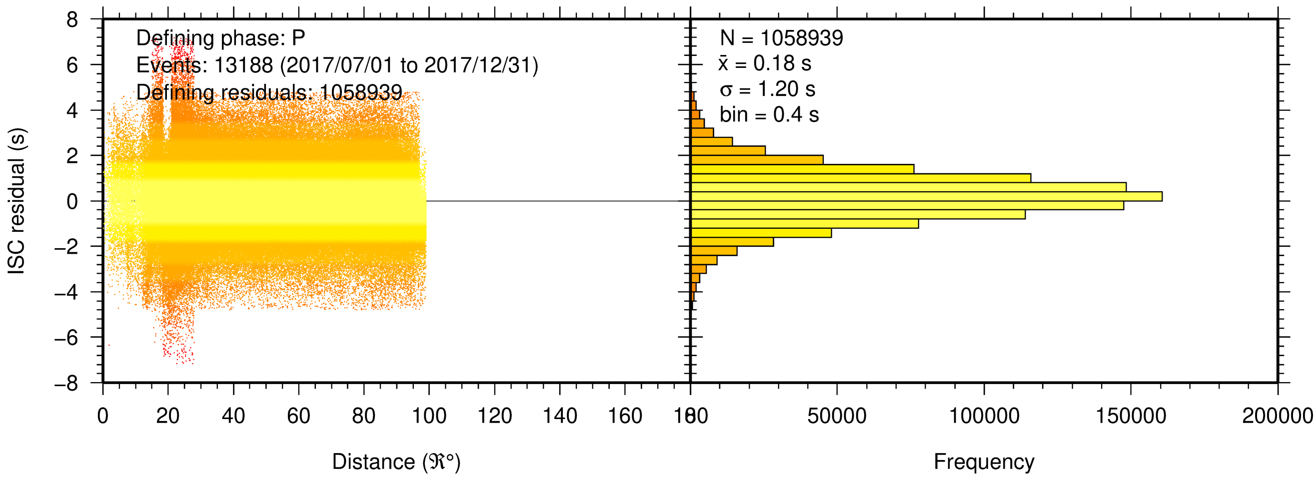


Figure 8.18: *Distribution of travel-time residuals for the defining P phases used in the computation of ISC located events in the Bulletin.*

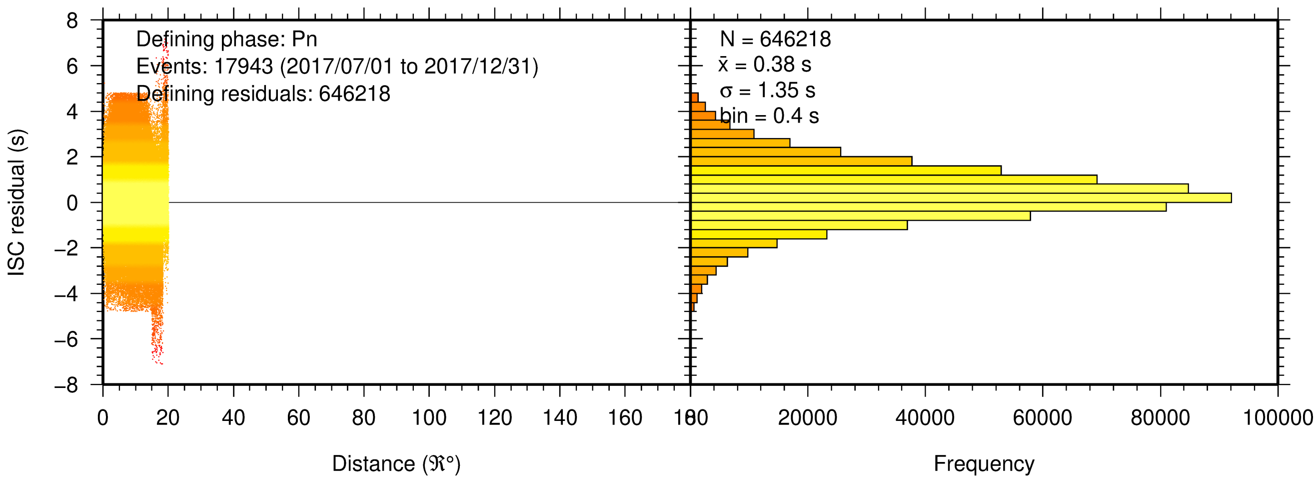


Figure 8.19: *Distribution of travel-time residuals for the defining Pn phases used in the computation of ISC located events in the Bulletin.*

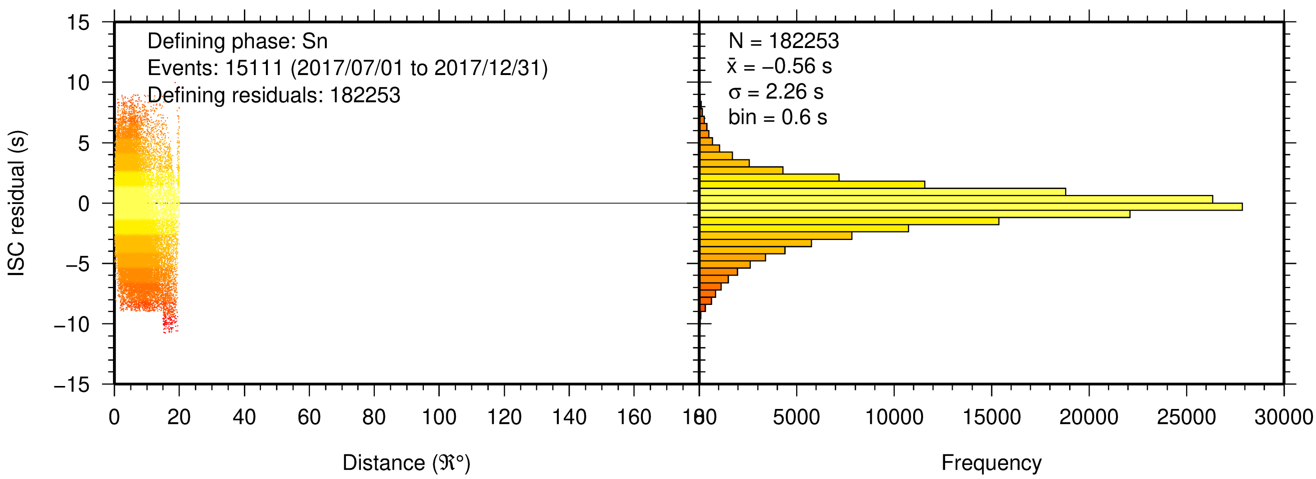


Figure 8.20: *Distribution of travel-time residuals for the defining Sn phases used in the computation of ISC located events in the Bulletin.*

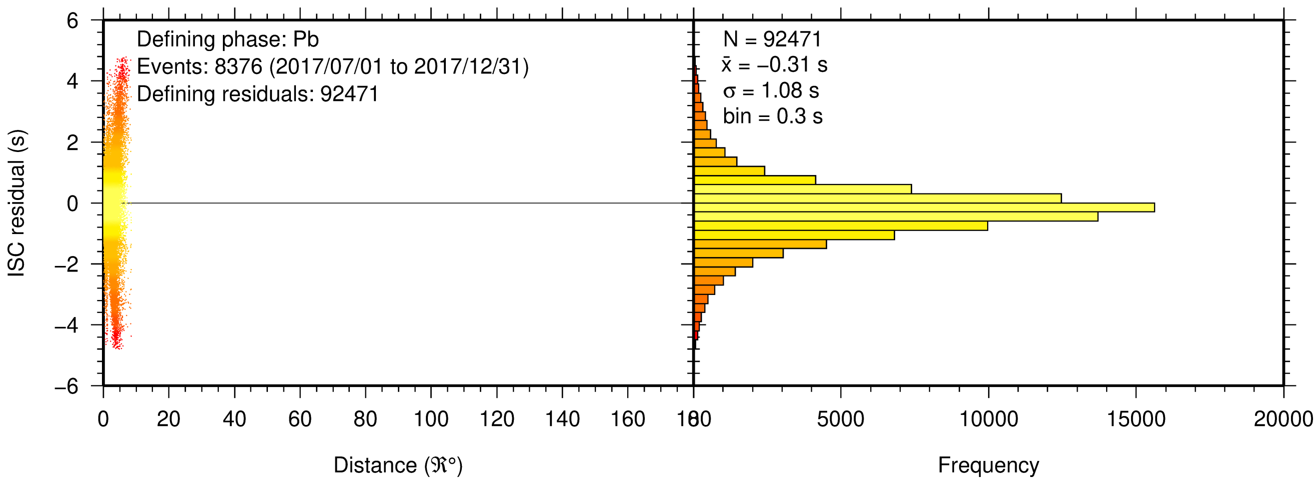


Figure 8.21: *Distribution of travel-time residuals for the defining Pb phases used in the computation of ISC located events in the Bulletin.*

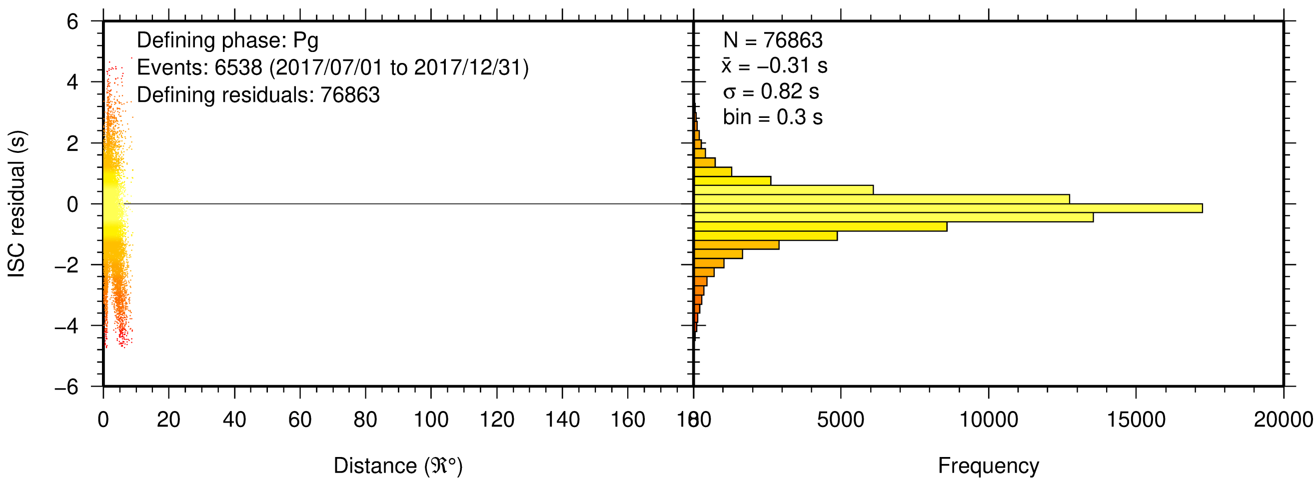


Figure 8.22: *Distribution of travel-time residuals for the defining Pg phases used in the computation of ISC located events in the Bulletin.*

8.3 Seismic Wave Amplitudes and Periods

The ISC Bulletin contains a variety of seismic wave amplitudes and periods measured by reporting agencies. For this Bulletin Summary, the total of collected amplitudes and periods is 3732141 (see Section 7.3). For the determination of the ISC magnitudes MS and mb, only a fraction of such data can be used. Indeed, the ISC network magnitudes are computed only for ISC located events. Here we recall the main features of the ISC procedure for MS and mb computation (see detailed description in Section 11.1.4 of the January to June 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 ≤ 3 s in the distance range 21°-100°.

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

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

	MS	mb
Number of amplitude-period data	173327	443117
Number of readings	154869	439441
Percentage of readings in the ISC located events with qualifying data for magnitude computation	16.0	37.8
Number of station magnitudes	148556	407144
Number of network magnitudes	3702	11624

A small percentage of the readings with qualifying data for MS and mb calculation have more than one amplitude-period pair. Notably, only 16% of the readings for the ISC located (shallow) events included qualifying data for MS computation, whereas for mb the percentage is much higher at 38%. This is due to the seismological practice of reporting agencies. Agencies contributing systematic reports of amplitude and period data are listed in Appendix Table 10.3. Obviously the ISC Bulletin would benefit if more agencies included surface wave amplitude-period data in their reports.

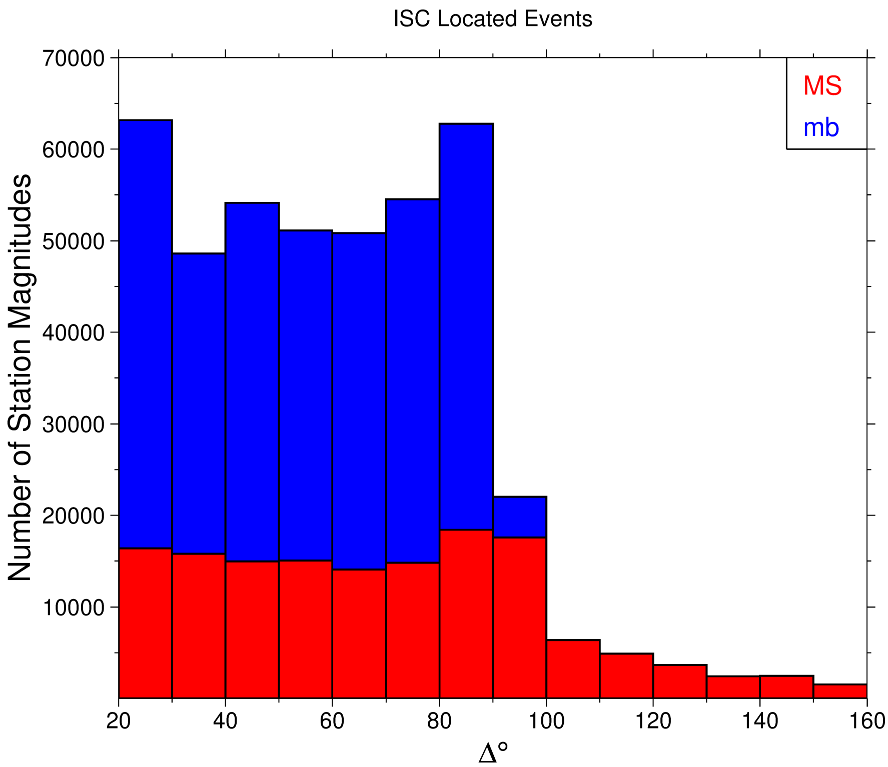


Figure 8.23: *Distribution of the number of station magnitudes computed by the ISC Locator for mb (blue) and MS (red) versus distance.*

Figure 8.23 shows the distribution of the number of station magnitudes versus distance. For mb there is a significant increase in the distance range 70°-90°, whereas for MS most of the contributing stations are below 100°. The increase in number of station magnitude between 70°-90° for mb is partly due to

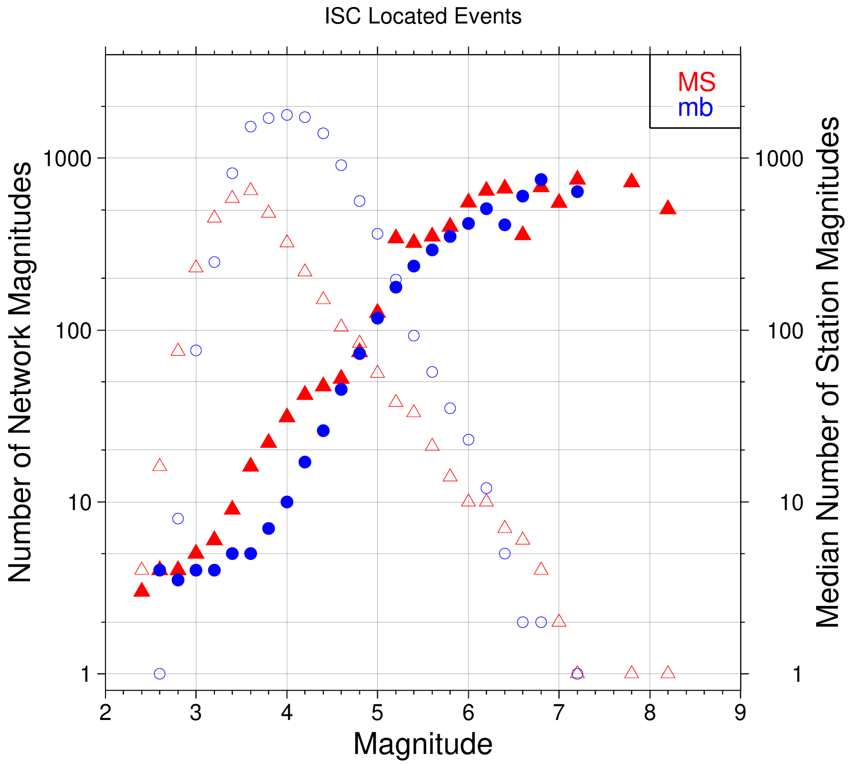


Figure 8.24: *Number of network magnitudes (open symbols) and median number of stations magnitudes (filled symbols). Blue circles refer to mb and red triangles to MS. The width of the magnitude interval δM is 0.2, and each symbol includes data with magnitude in $M \pm \delta M/2$.*

the very dense distribution of seismic stations in North America and Europe with respect to earthquake occurring in various subduction zones around the Pacific Ocean.

Finally, Figure 8.24 shows the distribution of network MS and mb as well as the median number of stations for magnitude bins of 0.2. Clearly with increasing magnitude the number of events is smaller but with a general tendency of having more stations contributing to the network magnitude.

8.4 Completeness of the ISC Bulletin

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

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

The magnitudes of completeness of the ISC Bulletin for this Summary period is shown in Figure 8.25.

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

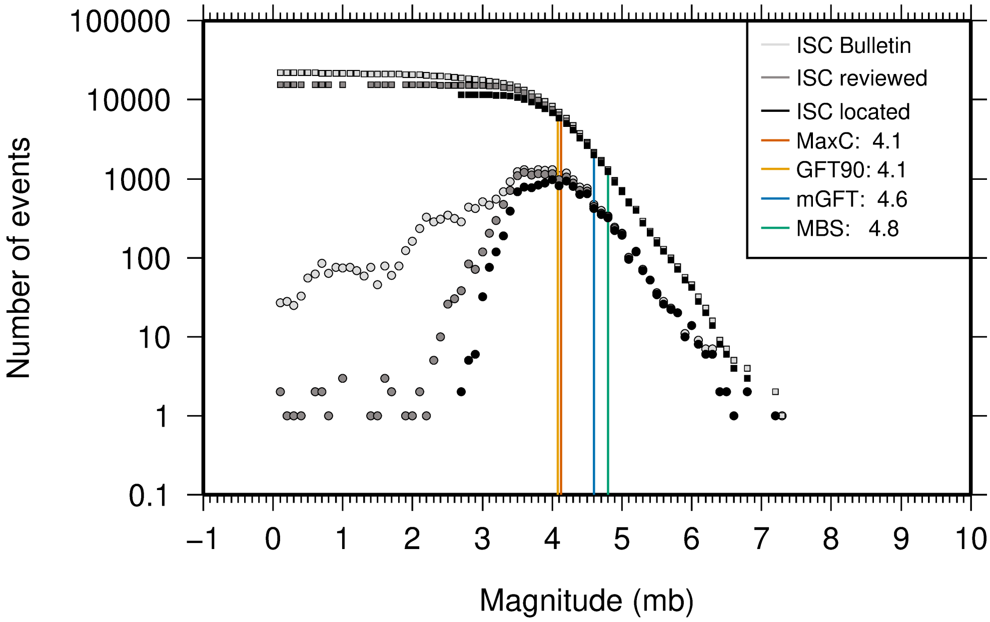


Figure 8.25: *Frequency (circles) and cumulative frequency (squares) magnitude distribution for all events in the ISC Bulletin, ISC reviewed events and events located by the ISC. The magnitudes of completeness (M_C) are shown for the ISC Bulletin. Note: only events with values of mb are represented in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

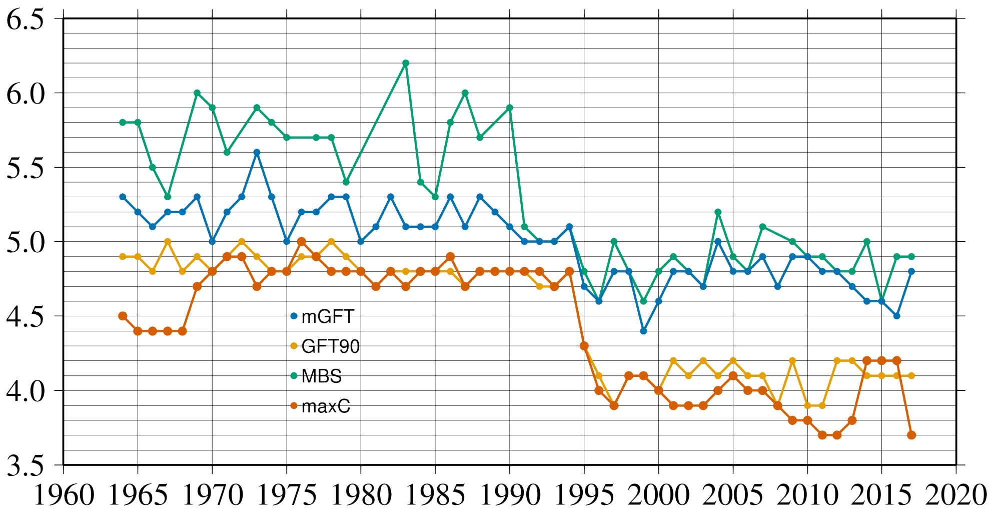


Figure 8.26: *Variation of magnitudes of completeness (M_C) for each year in the ISC Bulletin. Note: M_C is calculated only using those events with values of mb.*

8.5 Magnitude Comparisons

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

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

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

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

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

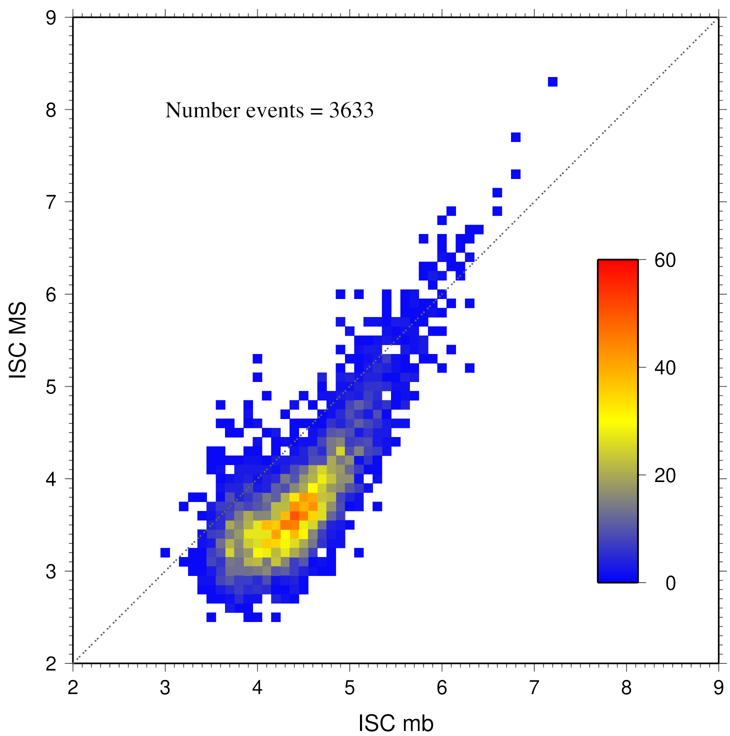


Figure 8.27: *Comparison of ISC values of MS with mb for common event pairs.*

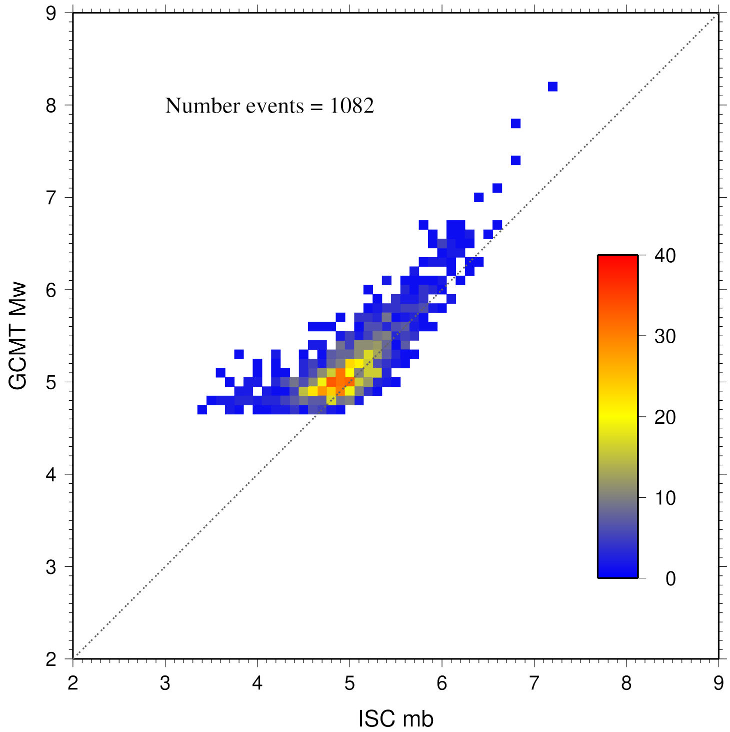


Figure 8.28: *Comparison of ISC values of mb with GCMT M_W for common event pairs.*

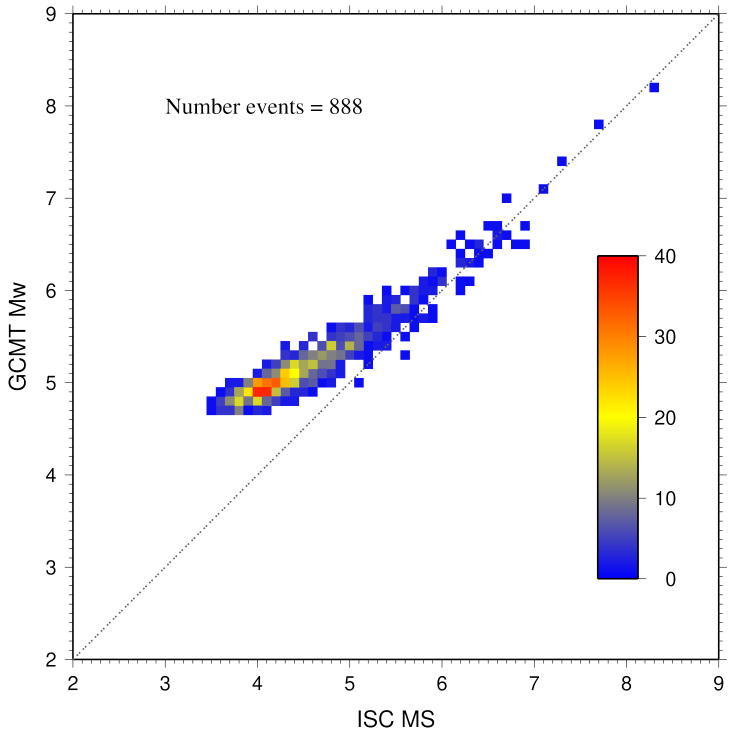


Figure 8.29: *Comparison of ISC values of MS with GCMT M_W for common event pairs.*

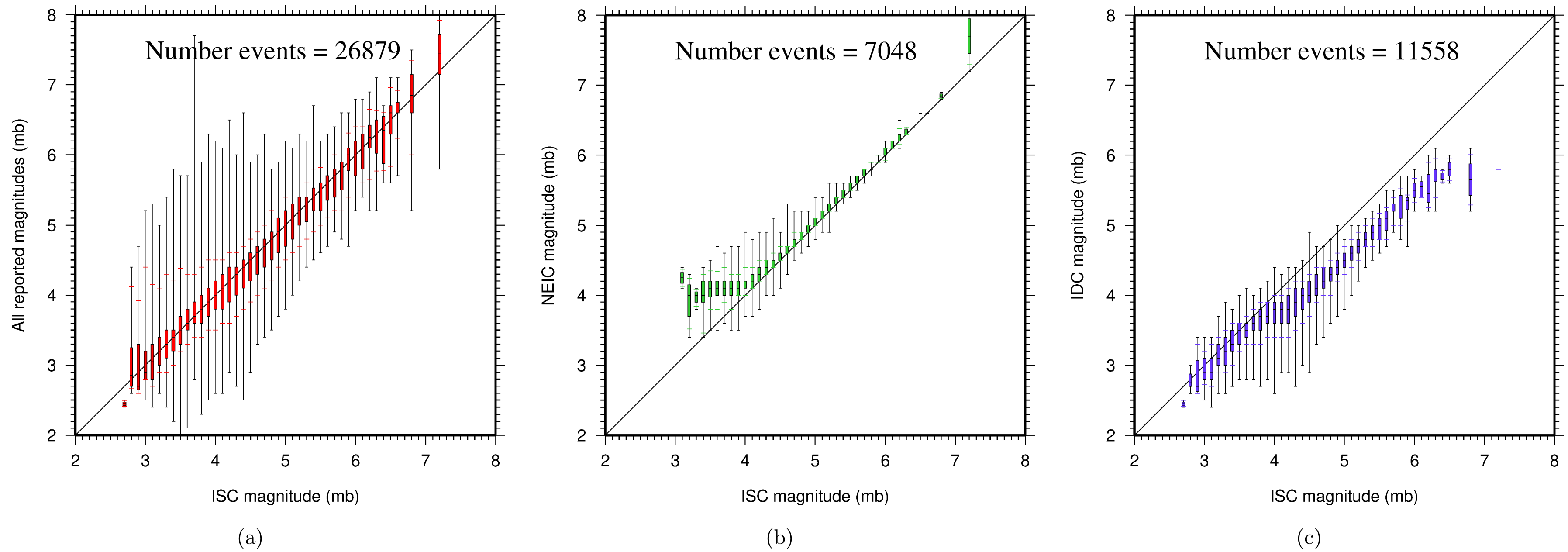


Figure 8.30: *Comparison of ISC magnitude data (mb) with additional agency magnitudes (mb). The statistical summary is shown in box-and-whisker plots where the 10th and 90th percentiles are shown in addition to the max and min values. (a): All magnitudes reported; (b): NEIC magnitudes; (c): IDC magnitudes.*

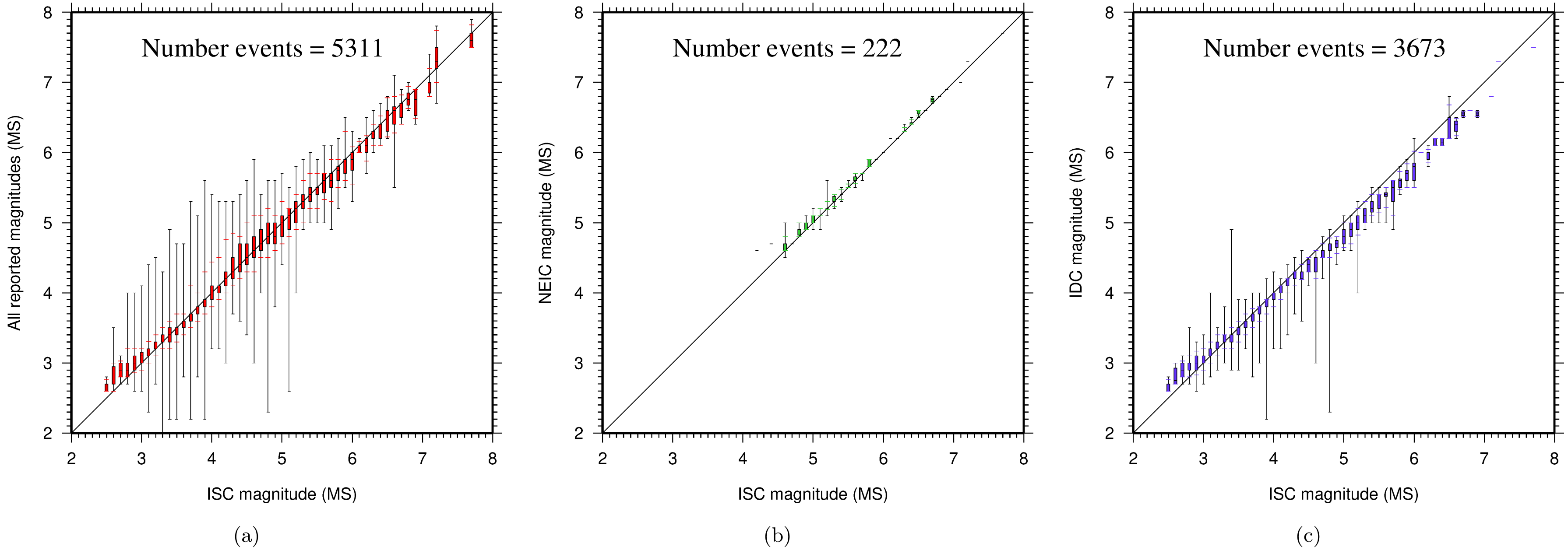


Figure 8.31: *Comparison of ISC magnitude data (MS) with additional agency magnitudes (MS). The statistical summary is shown in the box-and-whisker plots where the 10th and 90th percentiles are shown in addition to the max and min values. (a): All magnitudes reported; (b): NEIC magnitudes; (c): IDC magnitudes.*

9

The Leading Data Contributors

For the current six-month period, 147 agencies reported related bulletin data. Although we are grateful for every report, we nevertheless would like to acknowledge those agencies that made the most useful or distinct contributions to the contents of the ISC Bulletin. Here we note those agencies that:

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

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

9.1 The Largest Data Contributors

We acknowledge the contribution of IDC, NEIC, USArray, MOS, BJI, UCC, PRU, CLL, GCMT and a few others (Figure 9.1) that reported the majority of moderate to large events recorded at teleseismic distances. The contributions of NEIC, IDC, MEX, NOU and several others are also acknowledged with respect to smaller seismic events. The contributions of JMA, ISK, AFAD, TAP, ROM, RSNC 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 9.2). For small magnitude events, these are local agencies in charge of monitoring local and regional seismicity. For moderate to large events, contributions of 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.

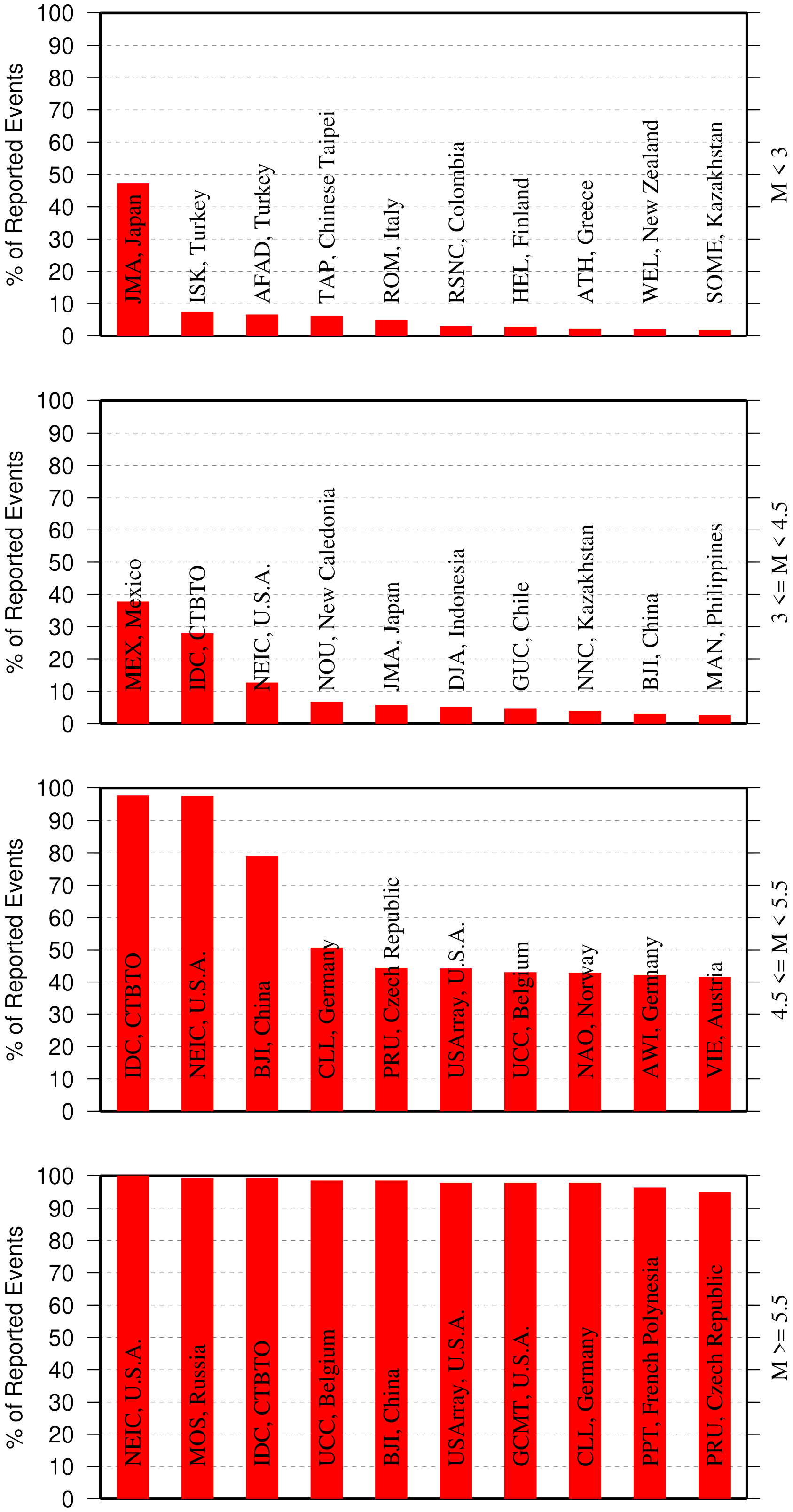


Figure 9.1: *Frequency of events in the ISC Bulletin for which an agency reported at least one item of data: a moment tensor, a hypocentre, a station arrival time or an amplitude. The top ten agencies are shown for four magnitude intervals.*

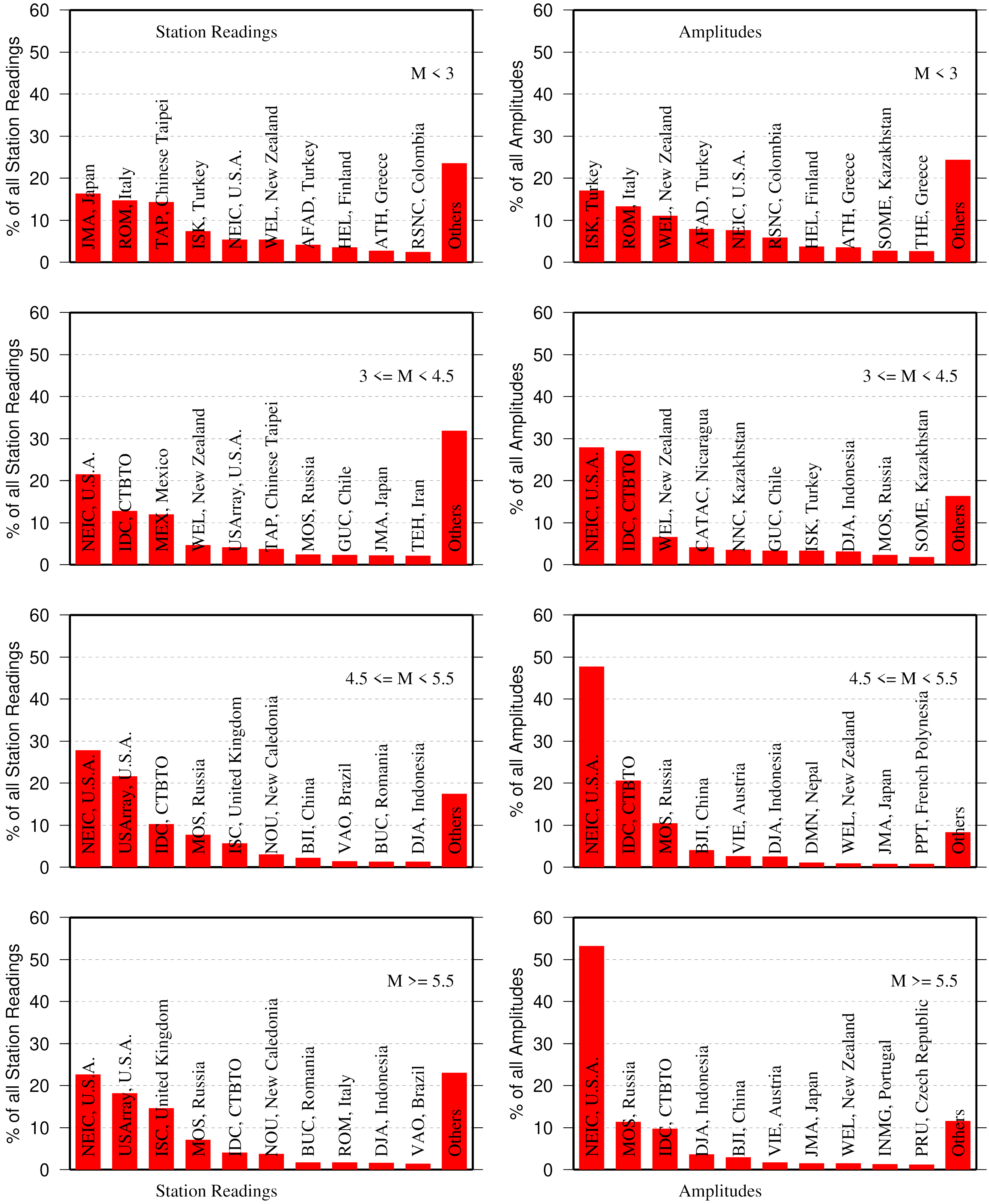


Figure 9.2: *Contributions of station arrival time readings (left) and amplitudes (right) of agencies to the ISC Bulletin. Top ten agencies are shown for four magnitude intervals.*

9.2 Contributors Reporting the Most Valuable Parameters

One of the main ISC duties is to re-calculate hypocentre estimates for those seismic events where a collective wealth of all station reports received from all agencies is likely to improve either the event location or depth compared to the hypocentre solution from each single agency. For areas with a sparse local seismic network or an unfavourable station configuration, readings made by other networks at teleseismic distances are very important. All events near mid-oceanic ridges as well as those in the majority of subduction zones around the world fall into this category. Hence we greatly appreciate the effort made by many agencies that report data for remote earthquakes (Figure 9.3). For some agencies, such as the IDC and the NEIC, it is part of their mission. For instance, the IDC reports almost every seismic event that is large enough to be recorded at teleseismic distance (20 degrees and beyond). This is largely because the International Monitoring System of primary arrays and broadband instruments is distributed at quiet sites around the world in order to be able to detect possible violations of the Comprehensive Nuclear-Test-Ban Treaty. The NEIC reported over 47% 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, CLL, AWI, MOS, PRU, VIE, USArray each reported individual station arrivals for several percent of all relevant events. We encourage other agencies to report distant events to us.

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

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

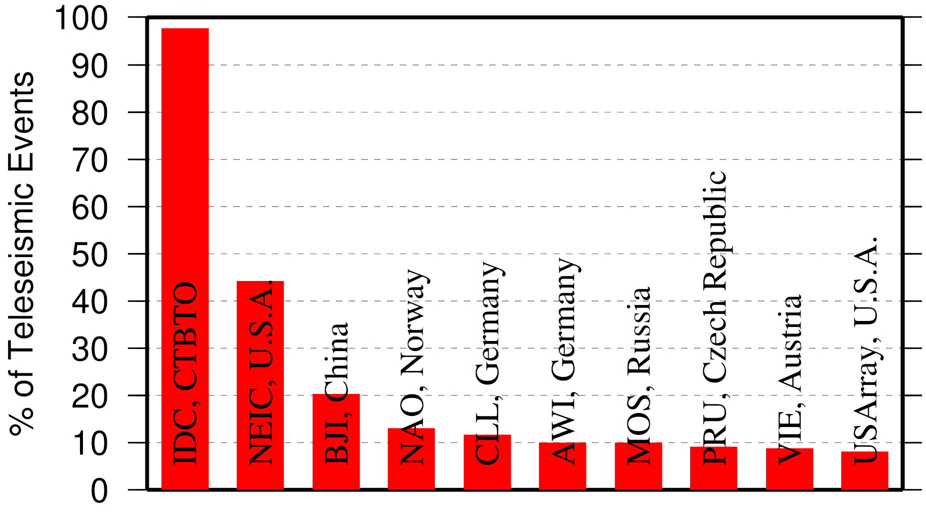


Figure 9.3: *Top ten agencies that reported teleseismic phase arrivals for a large portion of ISC events.*

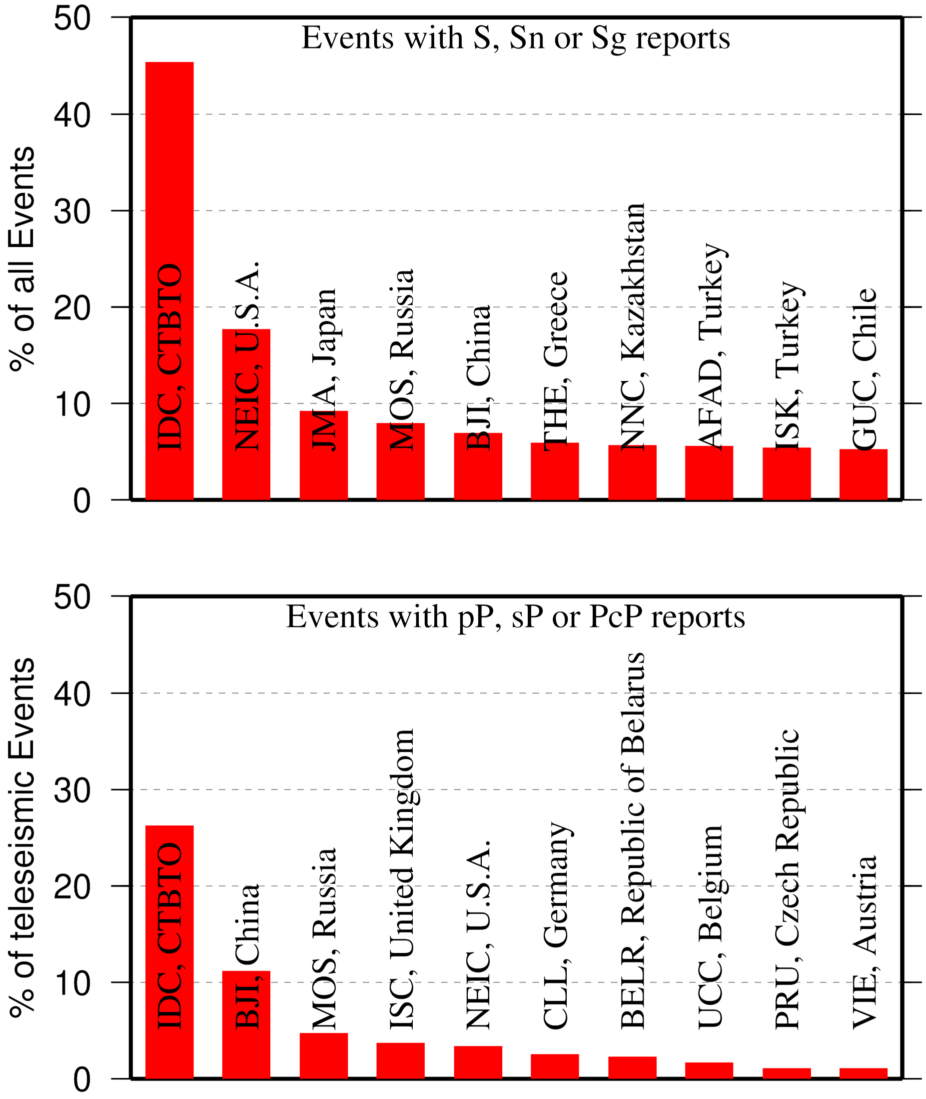


Figure 9.4: *Top ten agencies that reported secondary phases important for an accurate epicentre location (top) and focal depth determination (bottom).*

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

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

The 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 9.6).

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

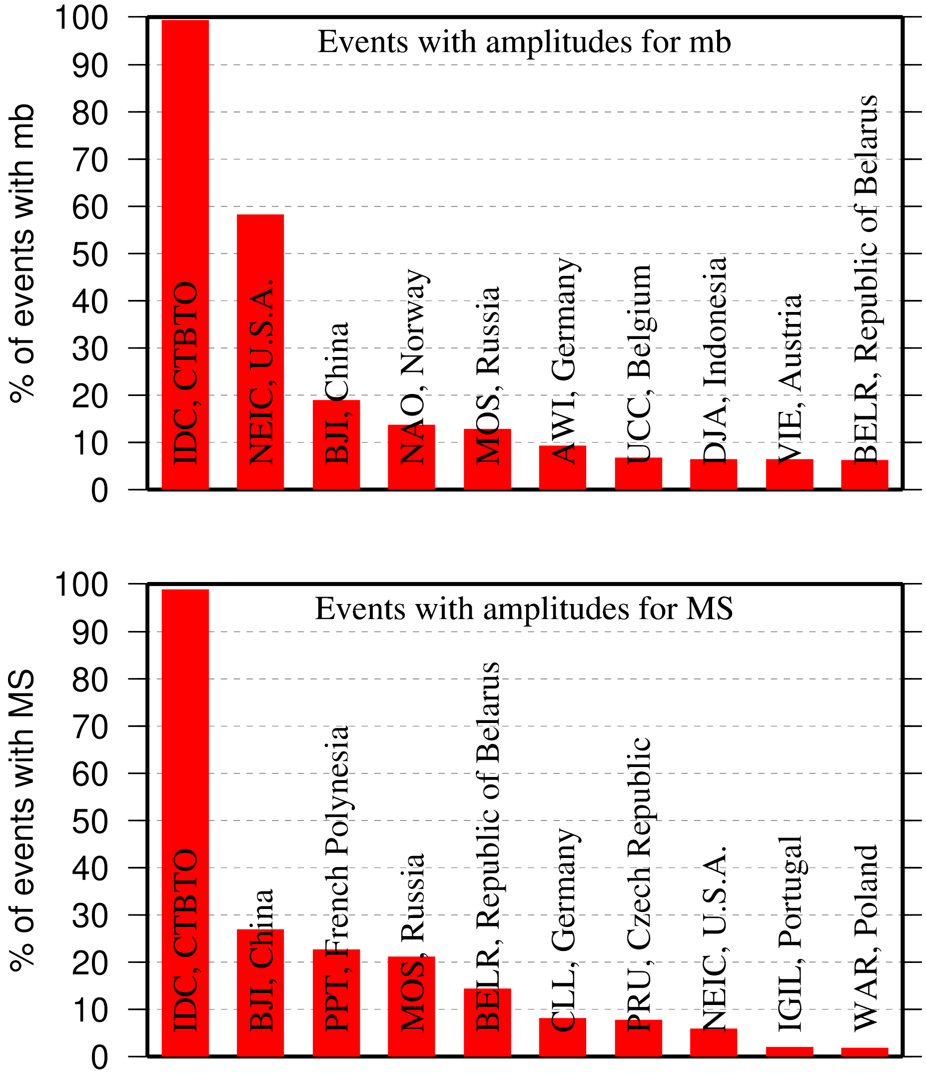


Figure 9.5: *Agencies that report defining body (top) and surface (bottom) wave amplitudes and periods for the largest fraction of those ISC Bulletin events with MS/mb determinations.*

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

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

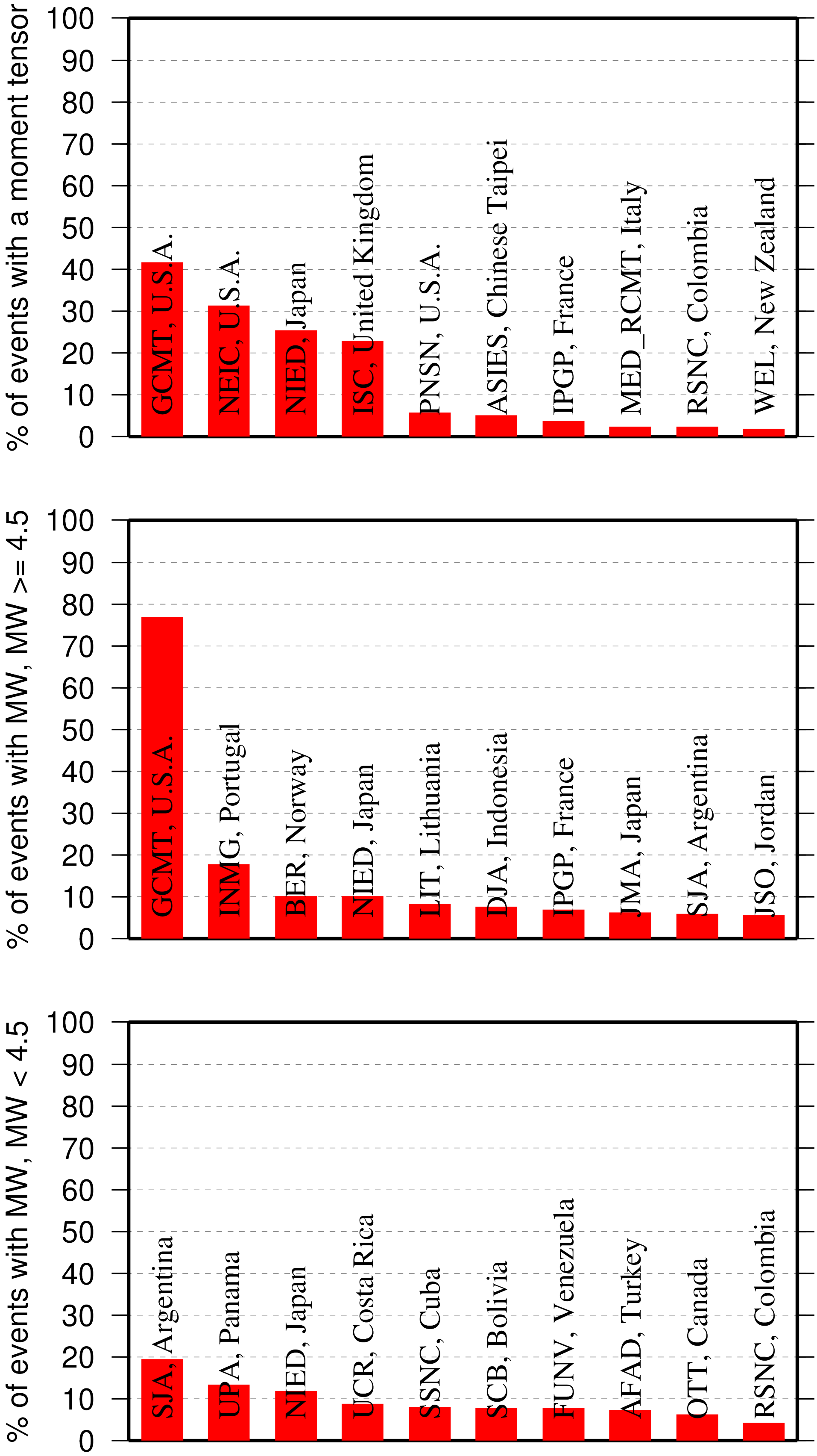


Figure 9.6: *Top ten agencies that most frequently report determinations of seismic moment tensor (top) and moment magnitude (middle/bottom for M greater/smaller than 4.5).*

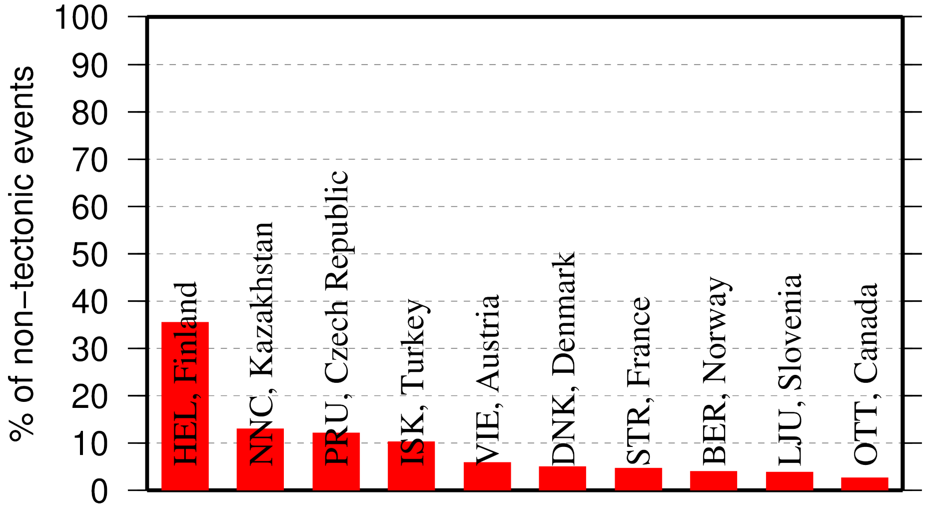


Figure 9.7: *Top ten agencies that most frequently report non-tectonic seismic events to the ISC.*

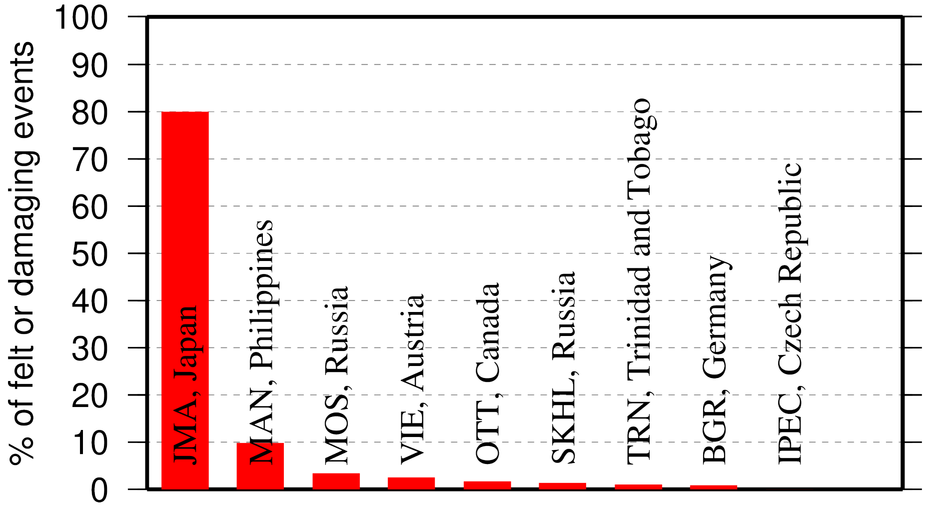


Figure 9.8: *Top ten agencies that most frequently report macroseismic information to the ISC.*

9.3 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 9.1 lists all agencies that have been helpful to the ISC in this respect during the six-month period.

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

Agency Code	Country	Average Delay from real time (days)
ZUR	Switzerland	9
PPT	French Polynesia	23
ATH	Greece	27
NAO	Norway	28
IDC	Austria	28
IGIL	Portugal	33
KNET	Kyrgyzstan	33
ECX	Mexico	35
LIC	Ivory Coast	40
BUC	Romania	41
LDG	France	42
WEL	New Zealand	43
QCP	Philippines	51
INMG	Portugal	82
SVSA	Portugal	88
BJI	China	98
AUST	Australia	99
ISK	Turkey	119
NAM	Namibia	122
BGS	United Kingdom	177
VIE	Austria	186
NEIC	U.S.A.	194
IRIS	U.S.A.	216
UPP	Sweden	221
THE	Greece	224
UCC	Belgium	254
SSN	Sudan	256
IPEC	Czech Republic	282
NIC	Cyprus	284
BYKL	Russia	287
SOME	Kazakhstan	290
BER	Norway	299
NDI	India	301
MOS	Russia	314
SNET	El Salvador	326
SSNC	Cuba	327
ASRS	Russia	327
KMA	Republic of Korea	331
THR	Iran	338
GII	Israel	339
KEA	Democratic People's Republic of Korea	360

10

Appendix

10.1 Tables

Table 10.1: *Listing of all 385 agencies that have directly reported to the ISC. The 147 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	**Seismological Survey of Serbia, 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 10.1: *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 10.1: *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 10.1: Continued.

Agency Code	Agency Name
HAN	Hannover, Germany
HDC	Observatorio Vulcanológico y Sismológico de Costa Rica, Costa Rica
HEL	**Institute of Seismology, University of Helsinki, Finland**
HFS	Hagfors Observatory, Sweden
HFS1	Hagfors Observatory, Sweden
HFS2	Hagfors Observatory, Sweden
HIMNT	Himalayan Nepal Tibet Experiment, USA
HKC	**Hong Kong Observatory, Hong Kong**
HLUG	Hessisches Landesamt für Umwelt und Geologie, Germany
HLW	**National Research Institute of Astronomy and Geophysics, Egypt**
HNR	Ministry of Mines, Energy and Rural Electrification, Solomon Islands
HON	Pacific Tsunami Warning Center - NOAA, USA
HRVD	Harvard University, USA
HRVD_LR	Department of Geological Sciences, Harvard University, USA
HVO	Hawaiian Volcano Observatory, USA
HYB	**National Geophysical Research Institute, India**
HYD	National Geophysical Research Institute, India
IAG	Instituto Andaluz de Geofisica, Spain
IASBS	Institute for Advanced Studies in Basic Sciences, Iran
IASPEI	IASPEI Working Group on Reference Events, USA
ICE	Instituto Costarricense de Electricidad, Costa Rica
IDC	**International Data Centre, CTBTO, Austria**
IDG	Institute of Dynamics of Geosphere, Russian Academy of Sciences, Russia
IEC	Institute of the Earth Crust, SB RAS, Russia
IEPN	**Institute of Environmental Problems of the North, Russian Academy of Sciences, Russia**
IFREE	Institute For Research on Earth Evolution, Japan
IGGSL	Seismology Lab, Institute of Geology & Geophysics, Chinese Academy of Sciences, China
IGIL	**Instituto Dom Luiz, University of Lisbon, Portugal**
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
ISK	**Kandilli Observatory and Research Institute, Turkey**
ISN	**Iraqi Meteorological and Seismology Organisation, Iraq**
ISS	International Seismological Summary, United Kingdom

Table 10.1: Continued.

Agency Code	Agency Name
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	**Kamchatkan Experimental and Methodical Seismological Department, GS 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**
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**

Table 10.1: *Continued.*

Agency Code	Agency Name
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 Prevention**, **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	Research Centre of Astronomy and Geophysics, Mongolia
OGAUC	Centro de Investigação da Terra e do Espaço da Universidade de Coimbra, Portugal
OGSO	Ohio Geological Survey, USA
OMAN	**Sultan Qaboos University**, **Oman**
ORF	Orfeus Data Center, Netherlands
OSPL	**Observatorio Sismologico Politecnico Loyola**, **Dominican Republic**
OSUB	Osservatorio Sismologico Universita di Bari, Italy

Table 10.1: Continued.

Agency Code	Agency Name
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	**Seismological Institute of Montenegro**, **Montenegro**
PEK	Peking, China
PGC	Pacific Geoscience Centre, Canada
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
SAR	Sarajevo Seismological Station, Bosnia and Herzegovina
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**

Table 10.1: Continued.

Agency Code	Agency Name
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**, **FYR 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
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**

Table 10.1: Continued.

Agency Code	Agency Name
THR	**International Institute of Earthquake Engineering and Seismology (IIEES), Iran**
TIF	**Institute of Earth Sciences/ National Seismic Monitoring Center, Georgia**
TIR	**The Institute of Seismology, Academy of Sciences of Albania, 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
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
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

Table 10.1: *Continued.*

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

Reported Phase	Total	Agencies reporting
P	4156743	ROM (13%)
S	1973206	JMA (19%), TAP (19%), ROM (13%)
AML	1014178	ROM (82%), AFAD (13%)
NULL	519070	IDC (31%), NEIC (25%), AEIC (14%), RSNC (12%)
IAmb	455599	NEIC (98%)
Pg	446314	ISK (36%)
IAML	351852	NEIC (57%), CATAC (14%), GUC (11%)
Pn	334129	NEIC (34%), ISK (20%)
Sg	293604	ISK (29%), STR (12%)
LR	146541	IDC (69%), BJI (26%)
pmax	123293	MOS (67%), BJI (33%)
IAMs_20	108886	NEIC (99%)
Sn	80754	IDC (13%)
SG	76170	HEL (58%), PRU (21%), IPEC (11%)
PG	68501	HEL (61%), PRU (16%), IPEC (12%)
Lg	67940	NNC (43%), SOME (32%)
PKP	37798	IDC (39%), VIE (16%), PRU (13%)
MSG	35183	HEL (100%)
IAmb_Lg	32726	NEIC (100%)
PN	32384	MOS (38%), HEL (37%)
A	31516	INMG (34%), JMA (25%), SVSA (24%), SKHL (17%)
T	26979	IDC (95%)
SN	25530	HEL (81%)
pP	20053	BJI (44%), ISC1 (15%), IDC (13%)
PKPbc	17803	IDC (54%), BGR (21%), NEIC (11%)
Vmb_Lg	16914	MDD (100%)
MLR	15325	MOS (100%)
PKIKP	14879	MOS (98%)
PcP	14441	IDC (56%), BJI (12%)
PP	13209	BJI (31%), IDC (16%), BELR (14%)
SB	12725	HEL (100%)
PKPdf	10673	NEIC (53%), INMG (12%)
PB	10171	HEL (100%)
SS	9795	BJI (29%), MOS (29%), BELR (19%)
sP	9059	BJI (75%), ISC1 (15%)
PA	8827	CATAC (100%)
smax	7074	MOS (77%), BJI (23%)
Sb	6980	IRIS (99%)
PKiKP	6181	IRIS (40%), IDC (22%), VIE (21%)
Amp	5603	BRG (100%)
AMS	5359	PRU (80%), CLL (12%)
PKPab	5261	IDC (50%), INMG (15%), NEIC (15%)
x	4771	CLL (34%), PRU (33%), NDI (16%)
SPECP	4527	AFAD (100%)
Trac	4288	OTT (100%)
LRM	4187	BELR (93%)
ScP	3919	IDC (68%), BJI (17%), ISC1 (11%)
AMB	3791	SKHL (78%), BJI (22%)
PPP	3448	BELR (49%), MOS (44%)
Pdiff	3177	IRIS (63%), IDC (17%)
Pb	2947	IRIS (93%)
SSS	2929	BELR (59%), MOS (31%)
AMP	2733	IEPN (49%), TIR (34%), UPA (15%)
PKP2	2726	MOS (94%)
sS	2705	BJI (84%), BELR (12%)
LG	2701	BRA (77%), OTT (22%)
LQ	2676	BELR (56%), IEPN (19%), INMG (16%)
END	2440	ROM (100%)
*PP	2167	MOS (100%)
pPKP	2148	VIE (50%), IDC (16%), BJI (14%)
I	1935	IDC (100%)
IVmB_BB	1934	CATAC (66%), BER (25%)
PKKPbc	1838	IDC (96%)
Vmb_V	1710	MDD (100%)
SKS	1682	BJI (39%), BELR (31%), PRU (15%)
AMl	1660	NIC (100%)
PKhKP	1526	IDC (100%)
L	1457	BGR (49%), WAR (32%), MOLD (14%)
ScS	1211	BJI (76%)
PS	1157	MOS (37%), BELR (36%), CLL (13%)

Table 10.2: *(continued)*

Reported Phase	Total	Agencies reporting
Smax	1088	BYKL (99%)
pPKPbc	1043	BGR (55%), IDC (26%), CLL (15%)
SKPbc	950	IDC (90%)
X	944	JMA (97%)
Pdif	841	NEIC (26%), BJI (19%), BER (12%)
IVMs_BB	839	BER (88%)
Pmax	825	BYKL (91%)
SA	765	CATAC (100%)
PKPPKP	652	IDC (94%)
SKSac	635	BER (48%), CLL (12%)
PKKP	625	VIE (36%), IDC (32%), AWI (14%)
PKHKP	584	MOS (99%)
SKKS	546	BELR (53%), BJI (40%)
PcS	544	BJI (96%)
PKPAB	506	PRU (100%)
E	493	ZAG (97%)
SP	472	MOS (30%), BER (22%), PRU (11%)
SKP	447	IDC (42%), BELR (18%), VIE (12%), INMG (11%)
*SP	441	MOS (100%)
*SS	428	MOS (100%)
sPKP	422	BJI (79%), BELR (15%)
PDIFF	387	PRU (41%), BRA (36%), IPEC (21%)
max	387	BYKL (100%)
PKPDF	355	PRU (99%)
PKP1	259	LIC (79%), PPT (19%)
Sm	245	CFUSG (52%), SIGU (48%)
AmB	239	KEA (100%)
PPS	232	CLL (66%), MOS (19%)
IVmBBB	232	BER (97%)
pPKiKP	230	VIE (82%)
PKP2bc	218	IDC (100%)
Sgmax	200	NERS (100%)
PKKPab	190	IDC (96%)
Pm	180	SIGU (65%), CFUSG (35%)
PKS	178	BELR (52%), BJI (40%)
pPKPdf	174	BER (28%), INMG (16%), CLL (12%), NEIC (11%)
P3KPbc	157	IDC (100%)
SKKPbc	134	IDC (98%)
SSSS	133	CLL (100%)
SmS	126	BGR (94%)
Snm	126	SIGU (98%)
Rg	123	IDC (50%), NNC (26%), DNK (19%)
SKPdf	120	CLL (46%), BER (37%), AWI (13%)
pPKPab	111	CLL (51%), IDC (44%)
PmP	111	BGR (58%), ZUR (42%)
SKKSac	108	CLL (57%), WAR (22%)
LQM	106	MOLD (100%)
p	100	ROM (97%)
Sgm	97	SIGU (92%)
r	94	BRG (99%)
P4KPbc	86	IDC (100%)
PKPpre	83	NEIC (81%), PRU (12%)
del	82	AUST (90%)
m	76	SIGU (100%)
Sdif	71	CLL (59%), BELR (37%)
H	70	IDC (99%)
Lm	67	CLL (100%)
Px	65	CLL (98%)
PCP	64	LPA (41%), PRU (22%), MOS (17%)
pPP	63	LPA (48%), CLL (46%)
Pgmax	61	NERS (100%)
SKKP	57	VIE (40%), AWI (18%), IDC (16%)
P'P'	56	VIE (89%), NAO (11%)
PKKPdf	55	AWI (73%), CLL (25%)
PKP2ab	52	IDC (100%)
(sP)	49	CLL (100%)
Pgm	44	SIGU (91%)
LmV	41	CLL (100%)
sPP	40	CLL (100%)
MSN	40	HEL (65%), BER (28%)
PPPP	39	CLL (100%)

Table 10.2: (continued)

Reported Phase	Total	Agencies reporting
Pnm	39	SIGU (97%)
pwP	39	ISC1 (100%)
SKIKS	38	LPA (100%)
PSKS	35	CLL (100%)
pPdiff	34	VIE (88%)
PgPg	32	BYKL (100%)
LmH	32	CLL (100%)
PKIKS	31	LPA (100%)
Plp	31	CLL (100%)
SKIKP	31	LPA (100%)
pPcP	30	IDC (87%), CLL (13%)
sSKS	29	BELR (100%)
P3KP	27	IDC (100%)
P*	26	BGR (46%), MOS (42%), BJI (12%)
SCS	26	LPA (100%)
AMSG	23	PRE (100%)
SKPab	23	IDC (74%), IEPN (22%)
SKSdf	21	BER (48%), CLL (29%), HYB (19%)
pPdif	21	BELR (67%), CLL (33%)
R2	20	CLL (100%)
(PP)	20	CLL (100%)
mb	20	KMA (90%)
M	20	MOLD (65%), LJU (35%)
(pP)	20	CLL (100%)
SgSg	19	BYKL (84%), UCC (16%)
Sdiff	19	IDC (53%), LJU (37%), VIE (11%)
SKPa	19	NAO (100%)
(Sn)	17	SIGU (71%), CLL (29%)
PKPdif	17	CLL (76%), LJU (18%)
Lmax	17	CLL (100%)
Pif	17	BRG (100%)
RG	16	IPEC (94%)
PKPPKPdf	16	CLL (94%)
rx	16	SKHL (100%)
(Pn)	15	SIGU (67%), CLL (33%)
Pn_2	15	ATH (100%)
sPdif	15	BELR (73%), CLL (27%)
SCP	15	PRU (73%), IPEC (20%)
SPP	15	BELR (53%), CLL (47%)
PKPf	15	BRG (100%)
(PKPdf)	15	CLL (100%)
ASSG	14	OSPL (79%), BER (21%)
ATPG	14	OSPL (79%), BER (21%)
ASPG	14	OSPL (79%), BER (21%)
SDIFF	14	LPA (100%)
MPN	14	HEL (50%), BER (50%)
PKPlp	14	CLL (100%)
ATSG	14	OSPL (79%), BER (21%)
S*	14	BGR (71%), BJI (29%)
PPlp	13	CLL (100%)
(PKPab)	13	CLL (100%)
(Pg)	13	CLL (62%), SIGU (31%)
sPKiKP	13	UCC (31%), CLL (31%), HYB (23%), VIE (15%)
PSP	13	LPA (100%)
Sx	13	CLL (100%)
PKSdf	13	CLL (62%), BER (38%)
(SSS)	12	CLL (100%)
(SS)	12	CLL (100%)
(SSSS)	12	CLL (100%)
IVMsBB	12	BER (83%), HYB (17%)
AP	12	MOS (100%)
SbSb	11	UCC (100%)
Sglp	11	CLL (100%)
LqM	11	MOLD (100%)
sPKPdf	10	CLL (90%)
sSS	10	CLL (100%)
P(2)	9	CLL (100%)
Sif	9	BRG (100%)
AMPG	9	PRE (100%)
PKKS	9	IEPN (67%), INMG (22%), BJI (11%)
sSKSac	8	CLL (100%)

Table 10.2: (continued)

Reported Phase	Total	Agencies reporting
PKPmax	8	CLL (100%)
SKiKP	8	UCC (50%), BGR (12%), HYB (12%), IEPN (12%), IDC (12%)
LV	8	CLL (100%)
sSdif	8	CLL (62%), BELR (38%)
SKSp	8	BRA (62%), WAR (38%)
PPmax	8	CLL (100%)
SKSP	8	CLL (62%), MOLD (38%)
sPPP	8	CLL (100%)
PnPn	7	SOME (71%), INMG (29%)
SKKPdf	7	CLL (100%)
(PKPbc)	7	CLL (100%)
PPPrev	7	CLL (100%)
sPS	7	CLL (100%)
sPPS	7	CLL (100%)
(Sg)	7	CLL (57%), SIGU (43%)
(PcP)	7	CLL (100%)
tx	7	IEPN (100%)
(pPKPab)	6	CLL (100%)
PKPM	6	MOLD (100%)
APKP	6	MOS (100%)
P1	6	ZUR (100%)
(PKiKP)	6	CLL (100%)
pS	6	CLL (67%), HYB (17%), BELR (17%)
OW	6	AWI (100%)
Lq	5	MOLD (100%)
PSPS	5	CLL (100%)
sPKKPbc	5	CLL (100%)
msx	5	AUST (100%)
P4KP	5	IDC (100%)
(sPP)	5	CLL (100%)
pPS	5	CLL (100%)
(SKSac)	4	CLL (100%)
sPKPab	4	CLL (100%)
SKKSdf	4	CLL (100%)
PM	4	MOLD (100%)
P'P'df	4	LJU (100%)
(PPP)	4	CLL (100%)
sPn	4	HYB (50%), BJI (25%), LJU (25%)
(sSdif)	4	CLL (100%)
(PPS)	4	CLL (100%)
sSSS	4	CLL (100%)
LH	4	CLL (100%)
(SP)	4	CLL (100%)
PSS	4	CLL (100%)
PKPc	4	WAR (100%)
SKPPKPdf	3	CLL (100%)
SKKPab	3	IDC (100%)
(Pdif)	3	CLL (100%)
rg	3	BRG (100%)
(Sdif)	3	CLL (100%)
pSKKSac	3	CLL (100%)
Sr	3	MEX (100%)
pPmax	3	CLL (100%)
SSSrev	3	CLL (100%)
sSP	3	CLL (100%)
PKPbc(2)	3	CLL (100%)
PSSrev	3	CLL (100%)
ESg	2	ZAG (100%)
sPmax	2	CLL (100%)
LMZ	2	WAR (100%)
Unk	2	IEPN (100%)
SKKSacre	2	CLL (100%)
V	2	CLL (100%)
AMSN	2	LSZ (100%)
(pPKiKP)	2	CLL (100%)
pPif	2	BRG (100%)
3PKPab	2	CLL (100%)
pSKSac	2	CLL (100%)
pPKKPbc	2	CLL (100%)
R3	2	CLL (100%)
sPPPP	2	CLL (100%)

Table 10.2: *(continued)*

Reported Phase	Total	Agencies reporting
Io	2	LDG (100%)
sSKKSac	2	CLL (100%)
SSS(2)	2	LPA (100%)
PPPPrev	2	CLL (100%)
(pPKPdf)	2	CLL (100%)
(SKPdf)	2	CLL (100%)
PKPPKPbc	2	CLL (100%)
(PS)	2	CLL (100%)
pPPS	2	CLL (100%)
SKSSKSac	2	CLL (100%)
PP(2)	2	CLL (50%), LPA (50%)
P5KP	2	IDC (50%), NAO (50%)
sPKPbc	2	CLL (100%)
D	2	CATAC (100%)
SS(2)	2	LPA (100%)
SSmax	2	CLL (100%)
PKKSdf	1	CLL (100%)
sSKPdf	1	CLL (100%)
Pv	1	RSNC (100%)
PPPPmax	1	CLL (100%)
(pPKPbc)	1	CLL (100%)
ePP	1	BELR (100%)
pPg	1	NDI (100%)
PKPPKPab	1	CLL (100%)
SKPd	1	NAO (100%)
(PPPrev)	1	CLL (100%)
pPKKPdf	1	CLL (100%)
sSif	1	BRG (100%)
(PcS)	1	CLL (100%)
P1D	1	ECX (100%)
S4	1	RSNC (100%)
(PKP)	1	CLL (100%)
R	1	MOLD (100%)
pPn	1	LJU (100%)
PKKPb	1	BRG (100%)
sSKSP	1	CLL (100%)
SKKSf	1	BRG (100%)
pSP	1	CLL (100%)
sPKPPKPd	1	CLL (100%)
3	1	MEX (100%)
(sSSSS)	1	CLL (100%)
SnSn	1	UCC (100%)
PKKPmax	1	CLL (100%)
(sSS)	1	CLL (100%)
AMb	1	LVSN (100%)
PE	1	BRA (100%)
VMs	1	AFAD (100%)
Pg(2)	1	CLL (100%)
(pPS)	1	CLL (100%)
PKKPbcma	1	CLL (100%)
IAMb	1	LJU (100%)
(SKKSdf)	1	CLL (100%)
(PSKS)	1	CLL (100%)
P2	1	RSNC (100%)
sPKSbc	1	CLL (100%)
(ScS)	1	CLL (100%)
pPKP2	1	BJI (100%)
pPKPdflp	1	CLL (100%)
(pPcP)	1	CLL (100%)
S2	1	RSNC (100%)
SKKSa	1	BRG (100%)
Sg_2	1	ATH (100%)
pPSKS	1	CLL (100%)
PKKPf	1	BRG (100%)
sPif	1	BRG (100%)
pPP(2)	1	LPA (100%)
LKP	1	MOLD (100%)
Sg_3	1	ATH (100%)
Sd1	1	ATH (100%)
PKKPabma	1	CLL (100%)
Pn_3	1	ATH (100%)

Table 10.2: *(continued)*

Reported Phase	Total	Agencies reporting
PKSab	1	CLL (100%)
PSPSrev	1	CLL (100%)
(PSPS)	1	CLL (100%)
SN8	1	GUC (100%)
(PKPm)	1	CLL (100%)
Pdifmax	1	CLL (100%)
SSrev	1	CLL (100%)
3PKPbc	1	CLL (100%)
IVmBB	1	HYB (100%)
SSP	1	CLL (100%)
P4	1	RSNC (100%)
sSPS	1	CLL (100%)
PKPdfmax	1	CLL (100%)
pPPP	1	CLL (100%)
PPPmax	1	CLL (100%)
(SKKSac)	1	CLL (100%)
PPSmax	1	CLL (100%)
Pf	1	BELR (100%)
PKiK	1	UPA (100%)
(SKSP)	1	CLL (100%)
SPS	1	CLL (100%)
SSSmax	1	CLL (100%)
pPPPP	1	CLL (100%)
PKPPKPf	1	BRG (100%)
Pg_2	1	ATH (100%)
LQR	1	MOLD (100%)
pSKS	1	BELR (100%)
Pmlp	1	CLL (100%)
PKPbcmax	1	CLL (100%)
Pg_3	1	ATH (100%)
(sPKPdf)	1	CLL (100%)
PKSbc	1	CLL (100%)
(PPPP)	1	CLL (100%)
UNC	1	MOLD (100%)
pPKPbc2	1	CLL (100%)
sg	1	ISN (100%)
sPcP	1	BJI (100%)
(SPP)	1	CLL (100%)
Li	1	MOLD (100%)
Sd2	1	ATH (100%)

Table 10.3: *Reporters of amplitude data*

Agency	Number of reported amplitudes	Number of amplitudes in ISC located events	Number used for ISC mb	Number used for ISC MS
ROM	829055	21443	0	0
NEIC	785826	315032	193735	51669
IDC	513605	484634	123373	74074
WEL	221142	41005	145	0
ISK	180154	20984	0	0
AFAD	131799	11116	0	0
MOS	109322	104372	51880	10827
NNC	101958	31160	49	0
DJA	80820	48130	9314	0
BJI	80030	73752	19962	23420
SOME	75441	19688	2010	0
ATH	64729	13376	0	0
RSNC	61766	4153	0	0
CATAC	50577	16689	0	0
VIE	48001	26779	9297	0
GUC	37983	9095	9	21
HEL	35046	1290	0	0
THE	31804	7225	0	0
WBNET	26575	523	0	0
LDG	26498	3493	0	0
MDD	18624	4404	0	0
INMG	15993	8982	4068	0
JMA	15682	15635	0	0
PRU	12926	5461	0	3467
SJA	11283	10716	0	0
DMN	11142	10547	0	0
BER	11109	4126	1079	106
PPT	9899	8691	633	3205
PRE	9860	3082	1096	0
AWI	9324	6921	2636	0
SKHL	8671	4077	0	0
DNK	8500	4748	3564	160
ZUR	8098	247	0	0
SVSA	7990	676	352	0
BELR	7798	5436	988	1379
LJU	6774	441	0	1
MAN	6586	983	0	0
SKO	6412	725	0	0
BGR	6066	5715	4137	0
SDD	5879	3471	0	0
BUC	5808	1601	0	0
NIC	5747	2092	0	0
ECX	5634	489	0	0
BRG	5603	2500	0	0
MRB	4393	83	0	0
OTT	4288	423	0	0

Table 10.3: *Continued.*

Agency	Number of reported amplitudes	Number of amplitudes in ISC located events	Number used for ISC mb	Number used for ISC MS
CLL	3754	3208	482	489
PDG	3715	2792	0	0
SSNC	3683	711	1	0
BGS	3638	2156	1264	471
KRSZO	3426	362	0	0
YARS	3184	69	0	0
KNET	3012	1341	0	0
NDI	2990	2610	752	46
NOU	2854	2723	1913	0
SNET	2591	559	0	0
NAO	2360	2232	1606	0
LVSN	2360	283	0	0
UCC	2267	2086	1908	0
BYKL	2249	673	0	0
SCB	1860	368	0	0
OSPL	1819	1060	0	0
IEPN	1772	1463	34	0
IPEC	1488	243	0	0
LIC	1244	1111	653	0
ISN	1223	1062	0	0
MIRAS	1150	120	0	0
IGIL	1114	577	90	180
ASRS	1043	563	0	0
KEA	943	532	0	84
TIR	935	635	0	0
MOLD	670	453	59	0
CFUSG	512	372	0	0
WAR	450	428	0	341
UPA	409	66	0	3
SIGU	400	221	0	0
EAF	381	130	0	2
THR	381	381	0	0
NERS	266	110	0	0
AAE	172	129	0	50
HYB	157	156	1	0
INET	55	41	0	0
LIT	29	20	0	0
BEO	11	11	11	0
PLV	11	0	0	0
LSZ	5	2	0	0
SSN	4	0	0	0

11

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 11.1.3 of the January to June 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 11.1.3 of the January to June 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.

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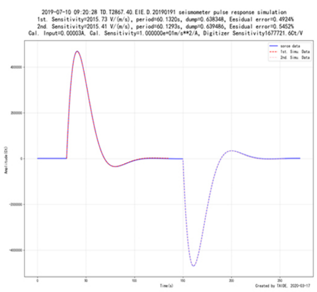

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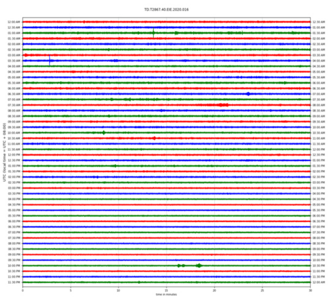

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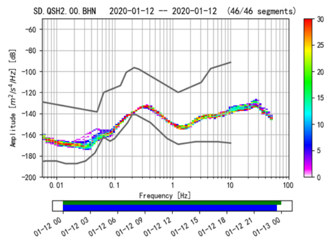

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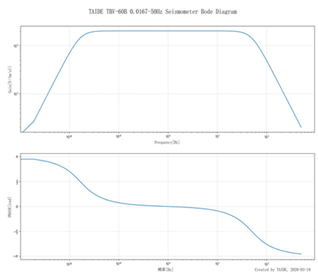

Built-in seismometer response analysis

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Channels	TDE-324CI: 3 channels TDE-324FI: 6 channels	Main channel resolution	True 26 bits, ≥145dB@100sps Support 24 bits output
Input noise	＜1.0μVrms(input ±20Vpp)	Interface	Standard 10/100M RJ45/LAN
Time Service	Support Beidou,GPS Satellites Support NTP Time Service Time error: better than 0.01ms Timing accuracy:better than 0.05ppm	Signal input	Differential Input, ±20Vpp Full Scale, Program Gain 1/2/4
Sample rate	1sps、10sps、20sps、50sps、100sps、200sps、500sps、1000sps	Environment	Temperature: -40℃～70℃, Humidity: 0～100%(RH),IP67

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