Summary of the Bulletin of the International Seismological Centre

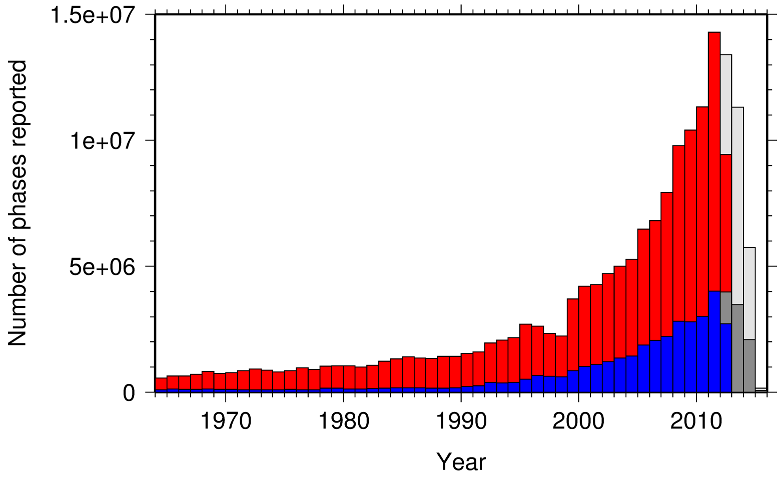
2011

July – December

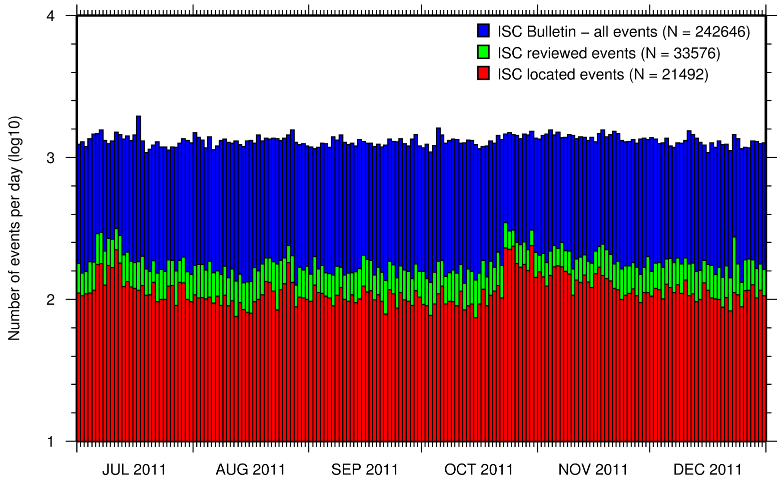
Volume 48 Issue 7-12

www.isc.ac.uk

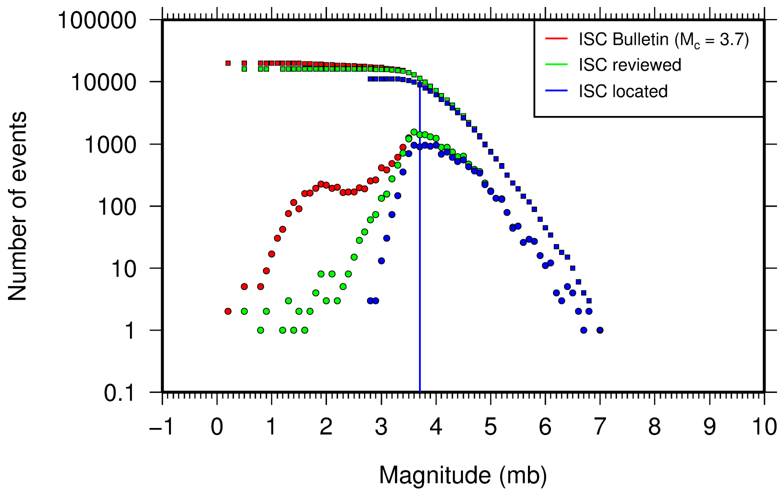
ISSN 2309-236X



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.

Contents

1

Preface

Dear Colleague,

This is the second and concluding 2011 issue of the Summary of the ISC Bulletin which remains the most fundamental reason for the ISC continued operations. This issue covers seismic events that occurred during the period of July-December 2011.

This publication presents a description of the ISC data available on the attached DVD-ROM and from the ISC website. It contains information on the ISC, its 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 the Canadian National Seismic Network to be described.

We hope that you find this relatively new 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, then, please, consider subscribing to this publication by contacting us at admin@isc.ac.uk.

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

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

2

The International Seismological Centre

2.1 The ISC Mandate

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

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

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

The current mission of the ISC is to maintain:

- the ISC **Bulletin** – the longest continuous definitive summary of World seismicity (collaborating with 130 seismic networks and data centres around the world). (www.isc.ac.uk/iscbulletin/)
- the **International** Seismographic Station Registry (**IR**, jointly with the World Data Center for Seismology, Denver). (www.isc.ac.uk/registries/)
- the IASPEI Reference Event List (Ground Truth, **GT**, jointly with IASPEI). (www.isc.ac.uk/gtevents/)

These are fundamentally important tasks. Bulletin data produced, archived and distributed by the ISC for almost 50 years are the definitive source of such information and are used by thousands of seismologists worldwide for seismic hazard estimation, for tectonic studies and for regional and global imaging of the Earth's structure. Key information in global tomographic imaging is derived from the analysis of ISC data. The ISC Bulletin served as a major source of data for such well known products as the ak135 global 1-D velocity model and the EHB (*Engdahl et al.*, 1998) and Centennial (*Engdahl and Villaseñor*, 2002) catalogues. It presents an important quality-control benchmark for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO). Hypocentre parameters from the ISC Bulletin are used by the Data Management Center of the Incorporated Research Institutions for Seismology (IRIS DMC) to serve event-oriented user-requests for waveform data. The ISC-GEM Bulletin is a cornerstone of the ISC-GEM Global Instrumental Reference Earthquake Catalogue for Global Earthquake risk Model (GEM).

The ISC relational database currently holds approximately 90 Gb of unique data. The ISC Bulletin contains over 5 million seismic events: earthquakes, chemical and nuclear explosions, mine blasts and mining induced events. At least 1.5 million of them are regional and teleseismically recorded events that have been reviewed by the ISC analysts. The ISC Bulletin contains approximately 150 million individual seismic station readings of arrival times, amplitudes, periods, SNR, slowness and azimuth, reported by approximately 17,000 seismic stations currently registered in the IR. Over 6,000 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 7802 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

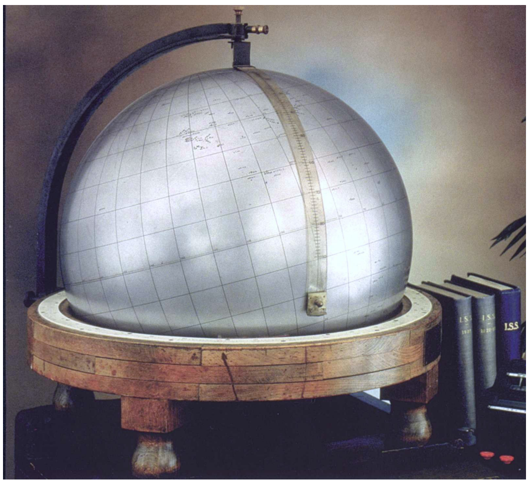


Figure 2.1: *The steel globe bearing positions of early seismic stations was used for locating positions of earthquakes for the International Seismological Summaries.*

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

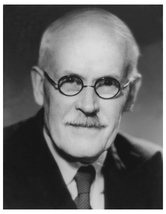
John Milne
Publisher of the Shide Cicular Reports on Earthquakes
1899-1913

Herbert Hall Turner

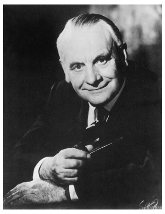
Seismological Bulletins of the BAAS

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-0949072 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.

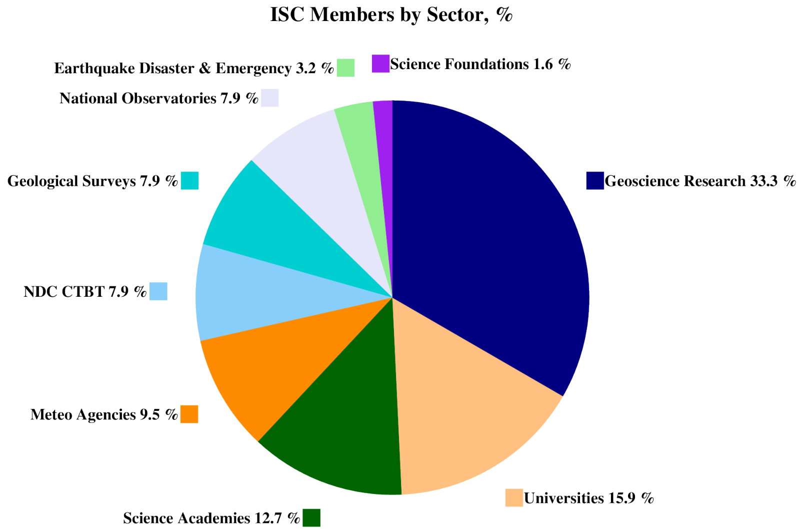


Figure 2.3: *Distribution of the ISC Member Institutions by sector in year 2013 as a percentage of total number of Members.*

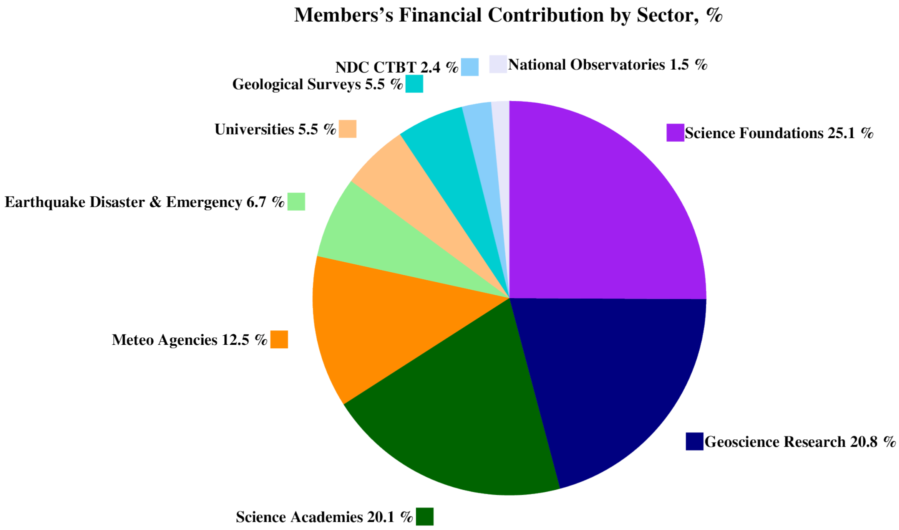


Figure 2.4: *Distribution of Member's financial contributions to the ISC by sector in year 2013 as a percentage of total annual Member contributions.*

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

Instituto Nacional de Prevención Sísmica (INPRES)
Argentina
www.inpres.gov.ar
Category: 1

Seismology Research Centre
Australia
www.seis.com.au
Category: 1

The University of Melbourne
Australia
www.unimelb.edu.au
Category: 1

Geoscience Australia
Australia
www.ga.gov.au
Category: 3

Bundesministerium für Wissenschaft und Forschung
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

Observatoire Royal de Belgique
Belgium
www.astro.oma.be
Category: 1

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

Department of Geophysics, University of Chile
Chile
ingenieria.uchile.cl
Category: 1

China Earthquake Administration
China
www.gov.cn
Category: 5

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

Academy of Sciences of the Czech Republic
Czech Republic
www.cas.cz
Category: 2

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

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

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

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

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

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

India Meteorological Department
India
www.imd.ernet.in
Category: 4

Iraqi Seismic Network
Iraq
www.imos-tm.com
Category: 1

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

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

The Geophysical Institute of Israel
Israel
www.gii.co.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
Jamaica
www.mona.uwi.edu
Category: 1

Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
Japan
www.jamstec.go.jp
Category: 3

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

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

Natural Resources Authority, Amman
Jordan
www.nra.gov.jo
Category: 1

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

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

Institute of Geological and Nuclear Sciences
New Zealand
www.gns.cri.nz
Category: 3

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

Stiftelsen NORSAR
Norway
www.norsar.no
Category: 2

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

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

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

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

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

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

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

Council for Geoscience
South Africa
www.geoscience.org.za
Category: 1

National Defence Research Establishment
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

University of the West Indies
Trinidad and Tobago
sta.uwi.edu
Category: 1

Disaster and Emergency Management Presidency
Turkey
www.deprem.gov.tr
Category: 2

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

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

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

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

The National Science Foundation of the United States. (Grant No. EAR-0949072)
U.S.A.
www.nsf.gov
Category: 9

University of Texas at Austin
U.S.A.
www.utexas.edu
Category: 1

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

National Earthquake Information Center, U.S. Geological Survey
U.S.A.
www.neic.usgs.gov
Category: 2

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), the Global Earthquake risk Model Foundation (GEM), FM Global and Lighthill Risk Network (includes AON Benfield, Catlin, Guy Carpenter and Lloyd's as core members).

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.

2.6 Data Contributing Agencies

In addition to its Members and Sponsors, the ISC owes its existence and successful long-term operations to its 131 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.

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

International Data Centre, CTBTO
Austria
IDC

Österreichischer Geophysikalischer Dienst
Austria
VIE

Republic Center of Seismic Survey
Azerbaijan
AZER

Centre of Geophysical Monitoring
Belarus
BELR

Royal Observatory of Belgium
Belgium
UCC

Observatorio San Calixto
Bolivia
SCB

Instituto Astronomico e Geofísico
Brazil
VAO

Geophysical Institute, Bulgarian Academy of Sciences
Bulgaria
SOF

Canadian Hazards Information Service, Natural Resources Canada
Canada
OTT

Departamento de Geofísica, Universidad de Chile
Chile
GUC

China Earthquake Networks Center
China
BJI

Institute of Earth Sciences, Academia Sinica
Chinese Taipei
ASIES

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

Cyprus Geological Survey Department
Cyprus
NIC

Geophysical Institute, Academy of Sciences of the Czech Republic
Czech Republic
PRU

West Bohemia Seismic Network
Czech Republic
WBNET

Geological Survey of Denmark and Greenland
Denmark
DNK

Observatoire Géophysique d'Arta
Djibouti
ARO

Servicio Nacional de Sismología y Vulcanología
Ecuador
IGQ

National Research Institute of Astronomy and Geophysics
Egypt
HLW

University of Addis Ababa
Ethiopia
AAE

Institute of Seismology, University of Helsinki
Finland
HEL

Centre Sismologique Euro-Méditerranéen (CSEM/EMSC)
France
CSEM

Laboratoire de Détection et de Géophysique/CEA
France
LDG

Institut de Physique du Globe
France
STR

Laboratoire de Géophysique/CEA
French Polynesia
PPT

Seismological Observatory Skopje
FYR Macedonia
SKO

Seismic Monitoring Centre of Georgia
Georgia
TIF

Bundesanstalt für Geowissenschaften und Rohstoffe
Germany
BGR

Seismological Observatory Berggießhübel, TU Bergakademie Freiberg
Germany
BRG

Alfred Wegener Institute for Polar and Marine Research
Germany
AWI

Geophysikalisches Observatorium Collm
Germany
CLL

National Observatory of Athens
Greece
ATH

Department of Geophysics, Aristotle University of Thessaloniki
Greece
THE

Hong Kong Observatory
Hong Kong
HKC

Geodetic and Geophysical Research Institute
Hungary
BUD

Icelandic Meteorological Office
Iceland
REY

National Geophysical Research Institute
India
HYB

India Meteorological Department
India
NDI

Badan Meteorologi, Klimatologi dan Geofisika
Indonesia
DJA

Tehran University
Iran
TEH

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

Iraqi Meteorological and Seismology Organisation
Iraq
ISN

Dublin Institute for Advanced Studies
Ireland
DIAS

The Geophysical Institute of Israel
Israel
GII

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

Istituto Nazionale di Geofisica e Vulcanologia
Italy
ROM

Station Géophysique de Lamto
Ivory Coast
LIC

Jamaica Seismic Network
Jamaica
JSN

Japan Meteorological Agency
Japan
JMA

National Institute of Polar Research
Japan
SYO

National Research Institute for Earth Science and Disaster Prevention
Japan
NIED

The Matsushiro Seismological Observatory
Japan
MAT

Jordan Seismological Observatory
Jordan
JSO

National Nuclear Center
Kazakhstan
NNC

Seismological Experimental Methodological Expedition
Kazakhstan
SOME

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

Kyrgyz Seismic Network
Kyrgyzstan
KNET

National Council for Scientific Research
Lebanon
GRAL

Geological Survey of Lithuania
Lithuania
LIT

Macao Meteorological and Geophysical Bureau
Macao, China
MCO

Geological Survey Department Malawi
Malawi
GSDM

Malaysian Meteorological Service
Malaysia
KLM

Red Sismica del Noroeste de Mexico (RESOM)
Mexico
ECX

Instituto de Geofísica de la UNAM
Mexico
MEX

Institute of Geophysics and Geology
Moldova
MOLD

Research Centre of Astronomy and Geophysics
Mongolia
OBM

Seismological Institute of Montenegro
Montenegro
PDG

The Geological Survey of Namibia
Namibia
NAM

Department of Mines and Geology, Ministry of Industry of Nepal
Nepal
DMN

Koninklijk Nederlands Meteorologisch Instituut
Netherlands
DBN

Institute of Geological and Nuclear Sciences
New Zealand
WEL

University of Bergen
Norway
BER

Stiftelsen NORSAR
Norway
NAO

Sultan Qaboos University
Oman
OMAN

Micro Seismic Studies Programme, PINSTECH
Pakistan
MSSP

Manila Observatory
Philippines
QCP

Philippine Institute of Volcanology and Seismology
Philippines
MAN

Institute of Geophysics, Polish Academy of Sciences
Poland
WAR

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

Instituto Geofisico do Infante Dom Luiz
Portugal
IGIL

Sistema de Vigilância Sismológica dos Açores
Portugal
SVSA

Korea Meteorological Administration
Republic of Korea
KMA

National Institute for Earth Physics
Romania
BUC

Altai-Sayan Seismological Centre, GS SB RAS
Russia
ASRS

Yakutiya Regional Seismological Center, GS SB RAS
Russia
YARS

North Eastern Regional Seismological Centre, GS RAS
Russia
NERS

Geophysical Survey of Russian Academy of Sciences
Russia
MOS

Baykal Regional Seismological Centre, GS SB RAS
Russia
BYKL

Kola Regional Seismic Centre, GS RAS
Russia
KOLA

Sakhalin Experimental and Methodological Seismological Expedition, GS RAS
Russia
SKHL

Kamchatkan Experimental and Methodical Seismological Department, GS RAS
Russia
KRSC

Saudi Geological Survey
Saudi Arabia
SGS

Seismological Survey of Serbia
Serbia
BEO

Geophysical Institute, Slovak Academy of Sciences
Slovakia
BRA

Environmental Agency of the Republic of Slovenia
Slovenia
LJU

Ministry of Mines, Energy and Rural Electrification
Solomon Islands
HNR

Council for Geoscience
South Africa
PRE

Instituto Geográfico Nacional
Spain
MDD

University of Uppsala
Sweden
UPP

Swiss Seismological Sevice (SED)
Switzerland
ZUR

National Syrian Seismological Center
Syria
NSSC

Thai Meteorological Department
Thailand
BKK

University of the West Indies
Trinidad and Tobago
TRN

Kandilli Observatory and Research Institute
Turkey
ISK

Disaster and Emergency Management Presidency
Turkey
DDA

The Earthquake Research Center Ataturk University
Turkey
ATA

Subbotin Institute of Geophysics, National Academy of Sciences
Ukraine
SIGU

Dubai Seismic Network
United Arab Emirates
DSN

British Geological Survey
United Kingdom
BGS

National Earthquake Information Center
U.S.A.
NEIC

The Global CMT Project
U.S.A.
GCMT

Pacific Northwest Seismic Network
U.S.A.
PNSN

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

IRIS Data Management Center
U.S.A.
IRIS

United States Geological Survey
U.S.A.
USGS

Fundación Venezolana de Investigaciones Sismológicas
Venezuela
FUNV

National Center for Scientific Research
Vietnam
PLV

Yemen National Seismological Center
Yemen
DHMR

Geological Survey Department of Zambia
Zambia
LSZ

Goetz Observatory
Zimbabwe
BUL

CWB
Chinese Taipei
TAP

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

- Maureen Aspinwall
- Administration Officer
- United Kingdom

- James Harris
- System and Database Administrator
- United Kingdom

- John Eve
- Data Collection Officer
- United Kingdom

- Emily Delahaye
- Seismologist/Lead Analyst
- Canada

- Blessing Shumba
- Seismologist/Analyst
- Zimbabwe

- Ivana Jukić
- Seismologist/Analyst
- Croatia

- Rosemary Wylie
- Analyst
- United Kingdom

- Rebecca Verney
- Analyst
- United Kingdom

- István Bondár
- Senior Seismologist
- Hungary

- Wayne Richardson
- Senior Seismologist
- New Zealand

- Domenico Di Giacomo
- Seismologist
- Italy

- Konstantinos Lentas
- Seismologist/Developer
- Greece

- Przemek Ozgo
- Junior System Administrator
- Poland

- Natalia Safronova
- Historical Data Entry Officer
- Russia

- Elizabeth Ball
- Historical Data Entry Officer
- United Kingdom

- Daniela Catanescu
- Historical Data Entry Officer
- Romania

3

Availability of the ISC Bulletin

The ISC Bulletin is available from the following sources:

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

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

- CD-ROMs/DVD-ROMs

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

- FTP site

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

Mirror service

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

4

Citing the International Seismological Centre

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

Data retrieved from the ISC web site:

- International Seismological Centre, On-line Bulletin, http://www.isc.ac.uk, Internatl. Seis. Cent., Thatcham, United Kingdom, 2015.

Data transcribed from the IASPEI reference event bulletin:

- International Seismological Centre, Reference Event Bulletin, http://www.isc.ac.uk, Internatl. Seis. Cent., Thatcham, United Kingdom, 2015.

Data transcribed from the EHB bulletin:

- International Seismological Centre, EHB Bulletin, http://www.isc.ac.uk, Internatl. Seis. Cent., Thatcham, United Kingdom, 2015.

Data copied from ISC CD-ROMs/DVD-ROMs:

- International Seismological Centre, Bulletin Disks 1-22 [CD-ROM], Internatl. Seis. Cent., Thatcham, United Kingdom, 2015.

Data transcribed from the printed Bulletin:

- International Seismological Centre, Bull. Internatl. Seis. Cent., 2011(2), Thatcham, United Kingdom, 2015.

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.

BibTex entry example:

```
@manual{ISCcitation2015,
author = "International Seismological Centre",
title = "On-line Bulletin",
organization = "Int. Seis. Cent.",
note = "http://www.isc.ac.uk",
address = "Thatcham, United Kingdom",
year = "2015"
}
```

International Seismological Centre

5

Operational Procedures of Contributing Agencies

5.1 Geological Survey of Canada: Canadian National Seismic Network

Taimi Mulder
Canadian Hazards Information Service
Geological Survey of Canada
Sidney, BC
Canada

5.1.1 Overview

The Geological Survey of Canada (GSC) has a mandate to monitor seismicity in Canada for the purposes of public safety and to mitigate hazard. This is primarily done with data from the national seismic network providing input into the National Building Code of Canada and through outreach and liaison activities with federal and provincial emergency preparedness organisations.

GSC is responsible for prompt issuance of earthquake notifications and for maintenance of the waveform archive and seismic catalogue. GSC mainly uses the seismic catalogue for input into the national hazard map and building codes and the waveform data to understand better the local conditions for disaster mitigation. The waveform and catalogue data are also widely used by universities and institutions worldwide to further the understanding of the earthquakes and earthquake hazard.

5.1.2 Seismicity and Hazard

Seismicity in Canada is concentrated in two distinct regions, as seen in Figure 5.1. Along the west coast the Pacific plate meets the North American plate, and a series of small plates comprising the Juan de Fuca plate system is caught between these two large plates. The stress associated with the Pacific-North American plate interaction extends inland into the Rocky Mountains and north along the boundary between the Yukon and Northwest Territories. In southwestern British Columbia (BC) the main Juan de Fuca plate is being subducted beneath the western edge of the North American plate. This western margin is thus the most seismically active region of Canada.

Eastern Canada also hosts significant seismicity. The St Lawrence River, which runs partially along the Canada-U.S. border on the east coast of the North American continent, follows a failed rift margin. This region and its surrounds have mainly been reactivated in response to intraplate stress and post-glacial rebound. Most of central Canada is relatively aseismic, which has led to a division of responsibility for catalogue production into the western and eastern halves, each managed out of the respective offices located in Sidney, British Columbia (BC), and in Ottawa, Ontario (ON). For the purposes of the archival

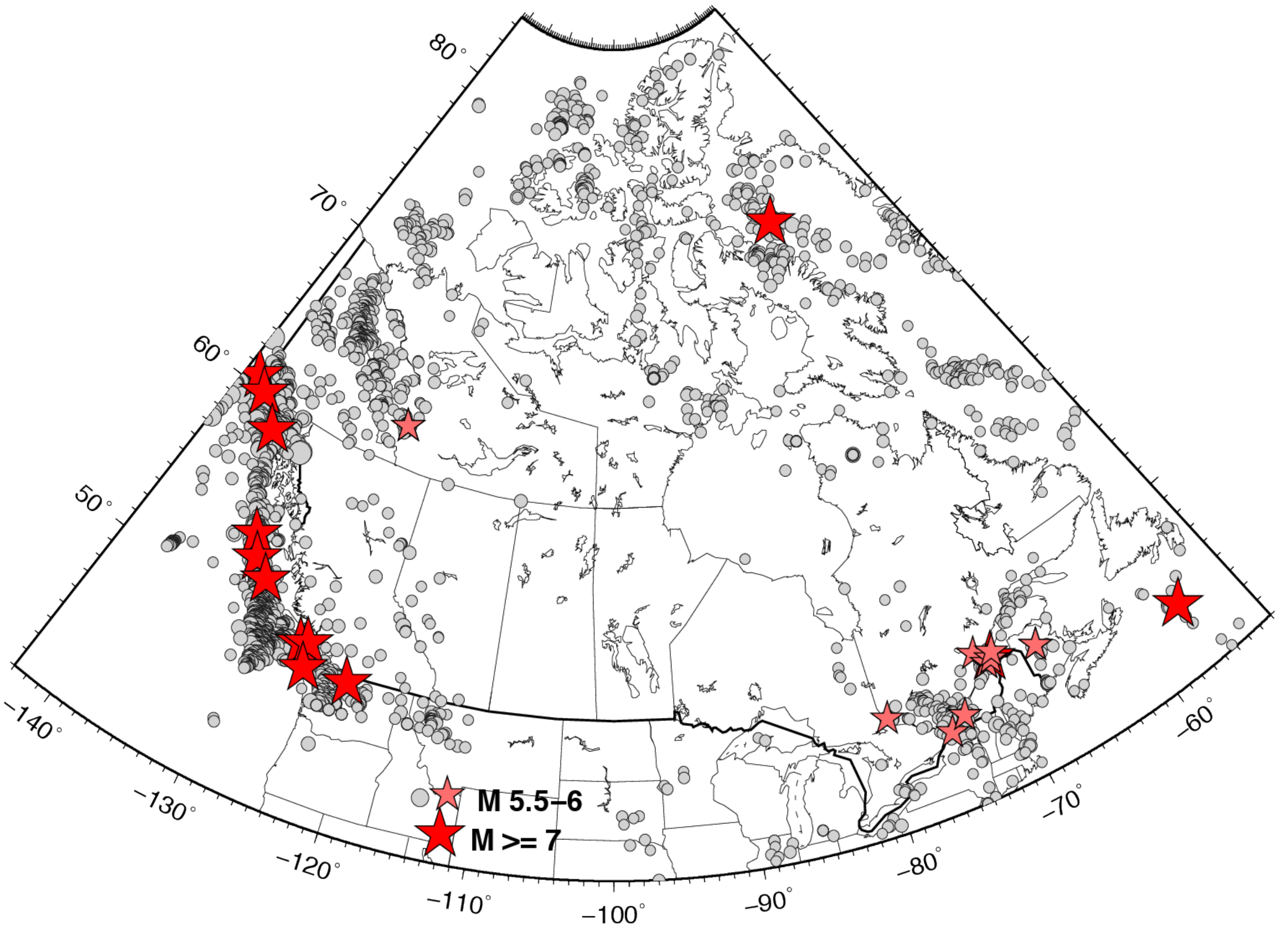


Figure 5.1: *Seismicity of Canada (grey dots: M≥3.5) and significant events (red stars). [Source: NRCan website.]*

database and website access, the information for these two halves is combined into a unified database, which is jointly updated by the two data centres.

Table 5.1 lists significant events that have occurred in Canada, which are also indicated on Figure 5.1. The 1770 January 26 M 9 earthquake, offshore from Vancouver Island in southwestern BC, was the largest event in Canadian history. This earthquake ruptured the entire Cascadia margin, approximately 1000 km from mid Vancouver Island to the Oregon-California border in the U.S., and caused a 10-80 m tsunami that destroyed native coastal villages and removed all trace of them (Rogers, 1991). On the eastern coast lives were lost on the Burin Peninsula in southern Newfoundland as a result of the tsunami associated with the 1929 November 18 M 7.2 Grand Banks earthquake.

5.1.3 Network and Catalogue History

The first-known Canadian seismogram is from a three-component velocity-sensitive Ewing seismograph recorded on a revolving smoked-glass plate at McGill University in Montreal, Quebec, on March 23 in 1897. This was not a continuous recording site, however, but it was soon followed in September 1897 by Canada's first permanent recording seismograph site in Toronto, Ontario, and in September 1898 by a second permanent recording seismograph site in Victoria, BC. The Toronto site was also the first seismograph station in North America with continuous and photographic recording.

Table 5.1: *Significant seismic events in Canada*
[Source: http://www.earthquakescanada.nrcan.gc.ca/historic-historique/map-carteeng.php]

Date	Lat	Lon	Mag	Location region
1663 Feb 5	47.60	-70.10	7.0	Charlevoix-Kamouraska Region 1663
1700 Jan 26	48.50	-125.00	9.0	Cascadia Subduction Zone
1732 Sep 16	45.50	-73.60	5.8	Western Quebec Seismic Zone, Montreal Region
1791 Dec 6	47.40	-70.50	6.0	Région Charlevoix-Kamouraska 1791
1860 Oct 17	47.50	-70.10	6.0	Région Charlevoix-Kamouraska 1860
1870 Oct 20	47.40	-70.50	6.5	Charlevoix-Kamouraska Region 1870
1872 Dec 15	48.60	-121.40	7.4	Washington-B.C. Border
1899 Sep 4	60.00	-140.00	8.0	Yukon-Alaska Border
1918 Dec 6	49.62	-125.92	7.0	Vancouver Island, British Columbia 1918
1925 Mar 1	47.80	-69.80	6.2	Charlevoix-Kamouraska region 1925
1929 Nov 18	44.50	-56.30	7.2	Atlantic Ocean, south of Newfoundland
1933 Nov 20	73.00	-70.75	7.3	Baffin Bay, Northwest Territories
1935 Nov 1	46.78	-79.07	6.1	Quebec - Ontario Border, Temiscamingue region
1944 Sep 5	44.97	-74.90	5.8	Cornwall region, Ontario-New York border
1946 Jun 23	49.76	-125.34	7.3	Vancouver Island, British Columbia 1946
1949 Aug 22	53.62	-133.27	8.1	Offshore Queen Charlotte Islands; now Haida Gwaii
1958 Jul 10	58.60	-137.10	7.9	Near the British Columbia-Alaska Border
1970 Jun 24	51.77	-130.76	7.4	South of Haida Gwaii, British Columbia
1979 Feb 28	60.59	-141.47	7.2	Southern Yukon-Alaska Border
1982 Jan 9	47.00	-66.60	5.7	Miramichi, New Brunswick
1982 Jan 11	47.00	-66.60	5.4	Miramichi, New Brunswick
1985 Oct 5	62.21	-124.22	6.6	Nahanni region; was Northwest Territories 1985-10
1985 Dec 23	62.19	-124.24	6.9	Nahanni region; was Northwest Territories 1985-12
1988 Nov 25	48.12	-71.18	5.9	Saguenay region
2012 Oct 28	52.55	-132.24	7.7	Offshore Haida Gwaii

During the 1960s the Canadian seismic network was expanded to monitor Canada uniformly with standardised instruments. The Canada-wide network was designed with a backbone of stations spaced approximately 500 km apart in a rough grid across Canada. On the west coast a small network of strong-motion seismometers was installed to capture on-scale recordings in the epicentral regions of large earthquakes.

J.H. Hodgson's 1956 seismic zoning map and, subsequently, Milne and Davenport's (1969) research on seismic hazard led, using data from this early network, to the development of Canada's first probabilistic hazard map (Whitham *et al.*, 1970), which was incorporated into the National Building Code of Canada in 1970. Updated editions have been produced as the network has developed.

The first digital stations were deployed in the mid-1970s. The number of stations slowly grew during the 1980s as telemetered seismic networks were developed in eastern and western Canada. The Eastern Canadian Telemetered Network (ECTN) and the Western Canadian Telemetered Network (WCTN) provided denser deployments of stations in areas of high seismicity and greater population density: the St Lawrence River valley region in southeastern Ontario and southwestern Quebec and along the Cascadia margin in southwestern BC. These networks were among the first true digital seismograph networks, as they had the digitizers sited at the seismic stations.

By 1985 the station coverage in southwestern BC was sufficiently dense that the number of earthquakes being routinely located in western Canada was increased significantly. In a later development, the early 1990s saw the first seismic data being transmitted by satellite in Canada. Today GSC operates 78 short-period sites, 285 broadband sites and 113 strong-motion (accelerometer) sites.

The Canadian Seismic Catalogue reflects the development of the main seismic network and the smaller sub-networks. This catalogue includes several historic earthquakes in the pre-1900s, several earthquakes in the late 1800s and 1900s located from phase reports from the sparse analogue seismic network in Canada and international phase reports, and then the greatly increased numbers of earthquakes at lower thresholds since the 1970s that were located using the significantly increased number of seismic stations and digital waveform technologies. As a result the level of catalogue completeness varies over time and space.

This combined catalogue has been corrected to M_w equivalent magnitudes and forms the basis for seismic zoning maps for the current 2015 National Building Code of Canada (NBCC). Research is also being carried out to understand the properties of earthquakes in various regions of Canada to improve and provide further advances in seismic provisions of the building code.

Current research using the GSC network includes studies of seismic tremor in the subduction zone along the west coast of Canada, investigations into Canadian tectonic plate margins and significant events such as the recent M_w 7.8 Haida Gwaii earthquake therein, the mechanics of oil and gas “fracking” and many other research activities such as investigations into temporal changes of earthquake characteristics.

5.1.4 Seismic Station Network and Waveform Data

GSC shares real-time waveform data with other co-operating agencies that have instruments sited in Canada: Canadian Universities, Plate Boundary Observatory (PB), Oceans Network Canada (NV) and USArray (TA); and with adjoining network neighbours: Alaska (AK), Washington (UW), Montana (MN), New York and New England (LD). GSC archives data for the Canadian Universities. GSC also offers assistance internationally to study earthquakes in other countries such as recently in Haiti, and Canada hosts several monitoring stations of the Comprehensive Nuclear Test-Ban Treaty Organization (CTBTO).

In a separate development, the Polaris Consortium was a collaborative project between Natural Resources Canada (NRCan), industry and universities conceived in 2000 and ending in 2014. Key Polaris stations have now been integrated into the Canadian National Seismic Network (CN) but with a number of the stations retaining their original network code (PO).

Currently the Canadian National Seismic Network (Figures 5.2 and 5.3) consists of a variety of instrument types from various manufacturers. Short-period seismometers include Teledyne-Geotech S13 and Mark Products L4 instruments. Broadband seismometers include Guralp CMG-3T, CMG-ESP, CMG-40T, Nanometrics Trillium and a few Streckeisen STS-1 instruments. Digitizers and data-loggers are a combination of GSC Geophysical Digitizers (spd, gd1, and gd2) and Nanometrics Taurus and Trident systems. The recent upgrade of the Yellowknife array included the installation of Guralp DM24 instruments.

The GSC Geophysical Digitizer was designed and built in-house in the late 1980s and early 1990s. It has since had one major upgrade, to gd2, primarily to provide greater sampling rates and to fulfil CTBTO IMS requirements. Currently the majority of the network stations sample at 100 samples/s but some gd1-based broadband stations sample at 40 samples/s. These ditgitizer/data-logger systems send CNSN-format packets that are archived to disc in CA-format files. Historically these CA-format files were 30-minute network-multiplexed files.

As of 2012 the waveform archive has been transitioned to one-channel-per-day files in CA-format. The purchase of the BRTT Antelope software package in 2005 now allows archiving in miniSEED format. Future plans involve converting the whole waveform archive to miniSEED format. Legacy software still requiring CA-format data is gradually being modified to work with the standard SEED or miniSEED data format now generally used by the seismological community.

Canada also has one teleseismic array and two smaller research arrays. The seismic array at Yellowknife in the Northwest Territories, NWT, was built by the British in the early 1960s. In 1962 responsibility for this medium-aperture array was transferred to the operators of the Canadian National Seismic Network, at that time the Department of Energy, Mines and Resources. The Yellowknife array is a 25 x 25 km cross-array of short-period (S13) seismometers together with a few broadband instruments and it is co-located with an infrasonic array.

Recently a compact PISA network of six seismometers was installed in 2010 near Sidney, BC, within an area of about one-square-kilometre for detection and location of seismic tremor at the subduction plate interface. In 2013 a local network of seismometers was installed in northern BC in conjunction with the Oil and Gas Commission to monitor fracking and in 2014 another local network was installed near Kitimat, BC, to monitor seismicity along a developing oil pipeline and shipping route.

Of the strong-motion sites, 113 have GSC internet accelerometer (IA) systems that calculate and send PGA, PGV, PGD and kSI parameters (for peak ground acceleration, velocity, displacement and spectral intensity measurements). These systems can store approximately 36 hours of data. In the advent of an earthquake, waveform data are requested and downloaded from the storage systems via the internet using in-house "JIA" software. Software providing an interface to the Antelope processing system is available in the Antelope contributed-data repository. The IA systems sample at 100 samples/s and communication channels are provided by combinations of internet, radio and satellite links. An additional 23 Kinemetrics Etna accelerographs in eastern Canada are triggered locally for events and record at 200 samples/s to local storage.

5.1.5 Data Processing

Digital data acquisition and exchange is organised using the BRTT Antelope system and the Nanometrics Apollo system. The seismic data are processed using legacy in-house software and the *genloc* location program (Pavlis *et al.*, 2004) via the BRTT *dbloc2* software package. GSC is currently moving all the seismic data processing to the BRTT Antelope system, though automatic locations are still determined using various systems. GSC is now also merging the systems used in the eastern and western offices to provide a uniform event processing system for Canada.

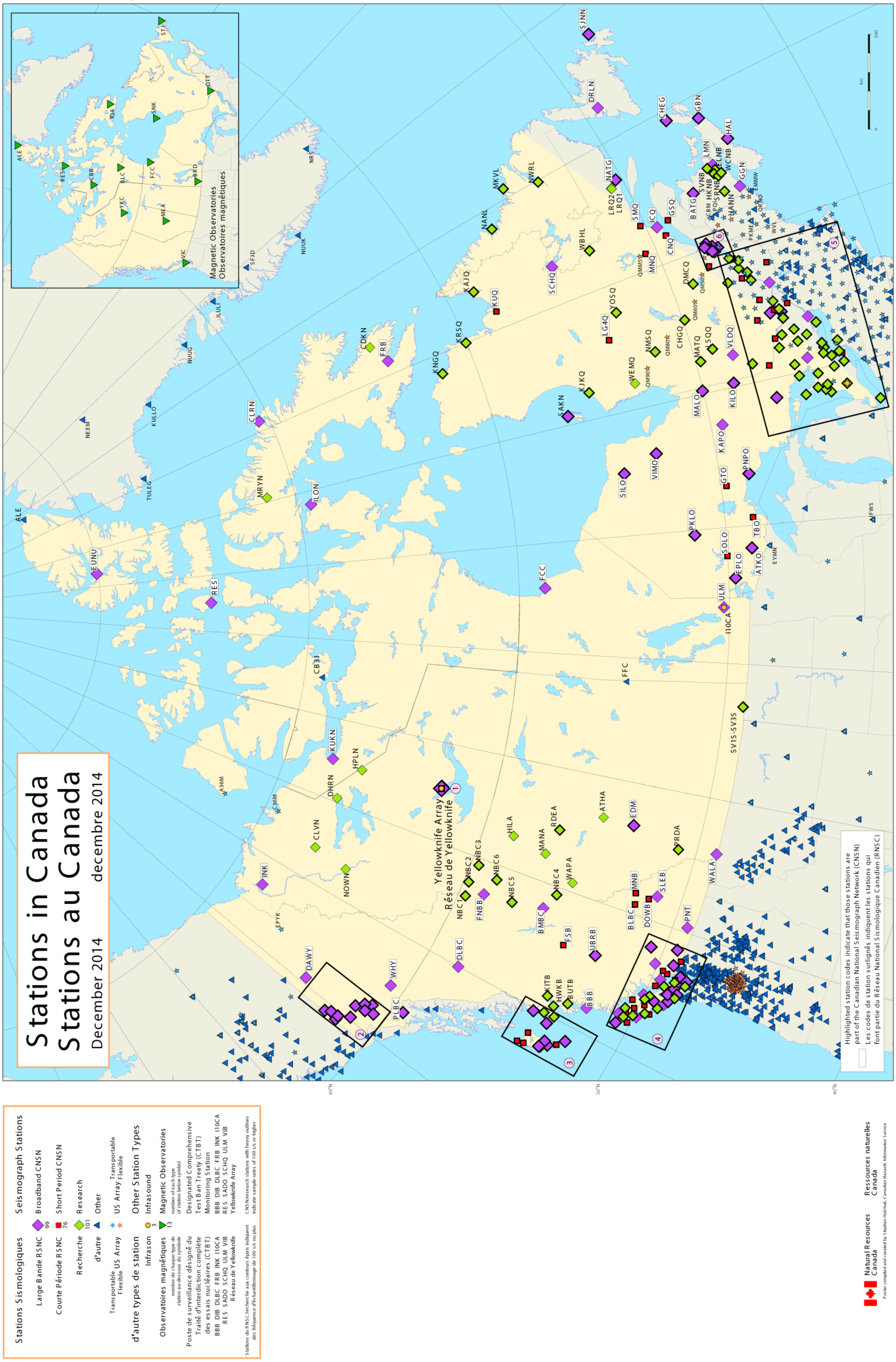


Figure 5.2: Overview of the Canadian seismic network and other contributing stations

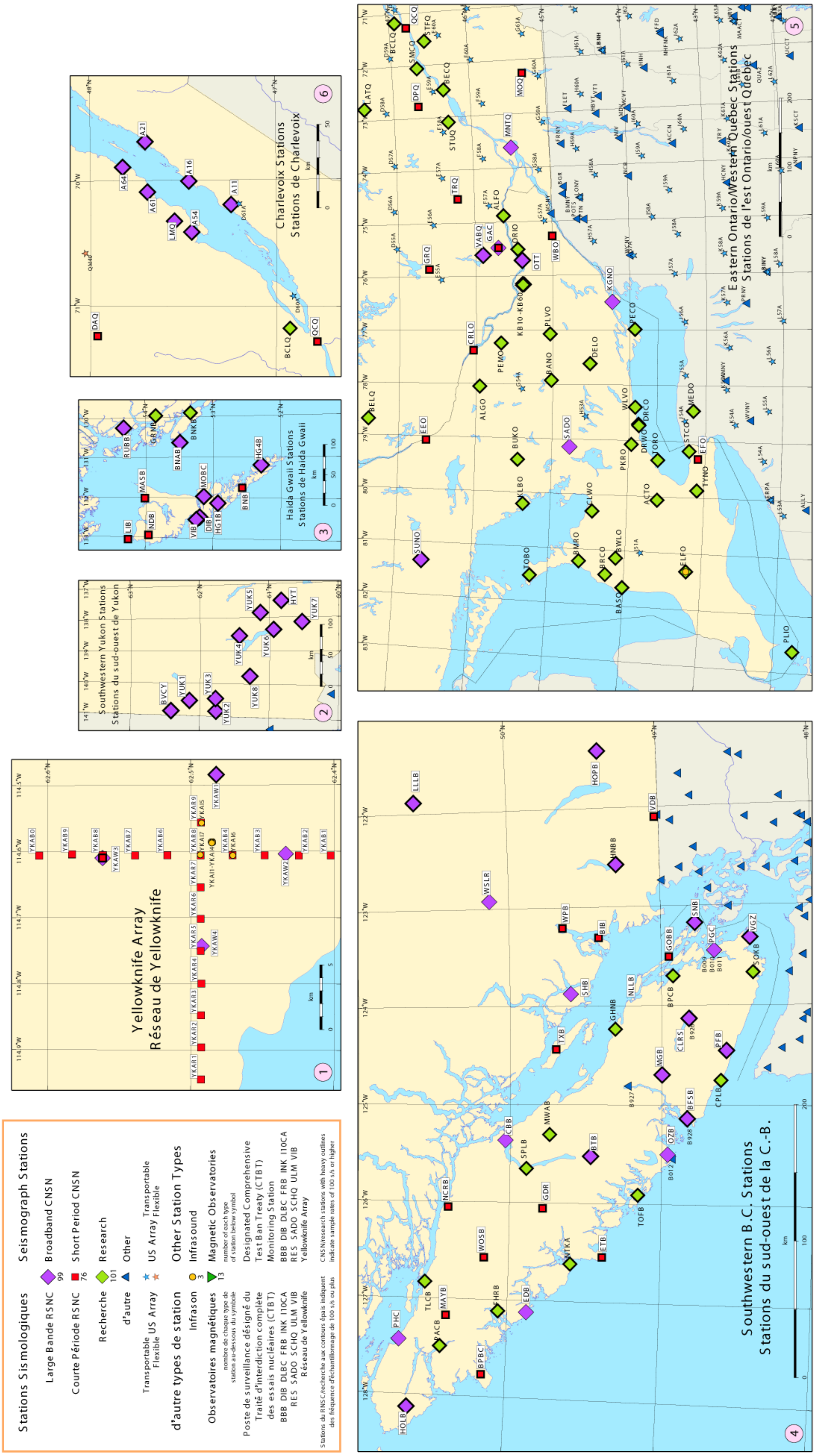


Figure 5.3: Details of Canadian sub-networks and other contributing stations

Dataflow: Automatic Locations and Significant Event Notifications

For eastern Canada (Ottawa data-centre), software developed in-house by GSC is used. Detections are generated based on FFT frequency-band filtering of waveform packets. Four short-term-average/long-term-average (STA/LTA) frequency bands filter the summed power of each packet in the selected frequency bands in the FFT output. These detections are passed to the *Autoloc* processing software that generates automatic event locations. These *Autoloc* solutions are used for event alert purposes: the *Aneas* software package uses the *Autoloc* solutions to send out notifications, based on client criteria, to individual clients. Clients are notified by email, ftp, scp, fax, SMS or digital paging devices.

The STA/LTA detections are also passed to the ULF detection system. This system presents screened detections to analysts wherein waveforms are analysed by frequency, amplitude and coda shape to distinguish real-events from noise. This generates a daily ULF event-list, which drives the analyst processing system. Analysts inspect these events using the *DAN* location program. Noise detections are discarded and real events are located. The final event files are saved and the location parameters are loaded into the INGRES database for the Canadian Seismic Catalogue.

For western Canada (Sidney data-centre) event notifications are determined via the Antelope real-time system. Detections are based on STA/LTA thresholds in selected frequency bands for user-determined STA and LTA window-lengths. These detections are fed into a grid associator that formulates event hypotheses and retains those with a sufficient goodness-of-fit. These locations are then fed into the *genloc* location program with the final estimated location determined using the appropriate velocity model for the region.

These real-time detections, arrivals and origin determinations are written to a database. The automatic origins also drive the routine event-analysis system. Analysts inspect the origins, adjusting the automatic phase picks and adding new phase picks for real events and locating the events with the *genloc* program via the Antelope *dbloc2* module. The final data are kept in the Antelope Datascope database and the location parameters are loaded into the INGRES database for the Canadian Seismic Catalogue.

Canadian Seismic Duty personnel (the "on-call seismologists") carry cellular phones, by which they receive automatic locations from the above mentioned sources as well as from the United States Geological Survey (USGS) and the West Coast and Atlantic Tsunami Warning Center (WCATWC). Duty personnel are on duty for one week at a time and are available on an on-call (24/7) basis. Six duty personnel are mandated for rotating on-call duty at the Ottawa office and at the Sidney office. However, due to staffing shortages, it is not currently possible to maintain this complement of duty personnel. Details of earthquakes of magnitude four or more and all felt events are posted on the website soon after the event occurrences and significant event notices are sent to media and emergency response organisations as required.

Event Analysis – Seismic Catalogue

Events of magnitude 3.5 or more in the Canadian Seismic Catalogue were indicated in Figure 5.1, which showed the virtually aseismic region though the centre of Canada extending from the north-northwest to the south. Although estimations of the event locations and magnitudes are determined at the two data centres, west in Sidney and east in Ottawa, the resulting analyses are combined into the unified INGRES database to produce the Canadian Seismic Catalogue.

Daily Review

Analysts at either data centre process events on a daily basis during normal office hours. The daily routine involves the discrimination of earthquakes from mining and quarry blasts and noise events. Earthquakes and a small fraction of blast events have their locations determined but noise events are discarded. The waveforms are usually scanned for a subset of stations to search for any missed events, primarily small events recorded at three or fewer stations or events where adjacent recording stations are not yet incorporated into the automatic processing.

Monthly Review

Historically the monthly event review involves several tasks: checking for events above the completeness level for the seismic subregion but missing from the catalogue; maintaining consistency of the velocity models and event locations within those subregions based on defining stations and their distances from the hypocentral estimates; assessing general database health; and ensuring that event types are properly assigned.

Due to declining staff levels and the increasing numbers of stations that increase the workload, the analyst monthly review has regrettably languished over recent years. Some of these tasks are nevertheless accomplished using automatic database checks or by the increased diligence of analysts during the daily review. Furthermore, in-house research provides feedback on the state of the catalogue and the yearly reviews of the annual seismicity map and for seismic hazard provide valuable opportunities to address potential issues in the catalogue.

5.1.6 Magnitudes

The following magnitude types used in the Canadian Seismic Catalogue are listed below together with a short description of their domains:

M_L – western and northern Canada; select small events in eastern Canada for which mN cannot be calculated

$M_{L(Sn)}$ – offshore Vancouver Island, British Columbia, and offshore from the Atlantic coast

m_{bLg} – historically used for events in the Rocky Mountains and Alberta

m_N – eastern Canada.

M_S – teleseismic surface-wave determinations

M_w – events $>$ 3.5 - 4.0 Canada-wide, determined by interactive modelling of waveforms

Estimated M_w (M_w') – for events offshore from south-western Canada – a correction is applied to the $M_{L(Sn)}$ value obtained for these events, based on Risteau *et al.*, 2007

5.1.7 Data Availability

Data and resource material are available through the NRCan website:

http://www.earthquakescanada.nrcan.gc.ca

5.1.8 References

Milne, W. G., and A. G. Davenport, 1969. Distribution of Earthquake Risk in Canada. *Bulletin of the Seismological Society of America*, 59:729-754.

Pavlis, G. L., F. Vernon, D. Harvey, and D. Quinlan, 2004. "The generalized earthquake location (*GENLOC*) package: an earthquake-location library", *Computers & Geosciences*, 30:1079-1091.

Ristau, J., G.C. Rogers, and J.F. Cassidy, 2007. "Stress in Western Canada from Regional Moment Tensor Analysis", *Canadian Journal of Earth Sciences*, 44(2):127-148.

Rogers, G.C., 1991. "The History of Earthquake Studies in British Columbia: From Indian Legend to Satellite Technology, Pioneering Geology in the Canadian Cordillera", *Geological Survey of Canada Open File* 1992-19, pp.61-66.

Whitham, K., W.G. Milne, and W.E.T. Smith, 1970. "The New Seismic Zoning Map of Canada", 1970 Edition, *Canadian Underwriter*, Vol. 15.

6

Summary of Seismicity, July - December 2011

The last six months of 2011 saw the continuation of the large sequence of earthquakes off the Pacific coast of Tohoku, Japan, including a large M_W 7.0 aftershock in July. Large earthquakes occurring around the Pacific rim in this summary period, including two on the same day in August in the Vanuatu Islands region, were not devastating.

At least 604 deaths were reported following the shallow M_W 7.3 earthquake in Turkey in October. This event, felt widely throughout the surrounding region, caused much destruction and disruption in the Ercis-Tabanli-Van area, with at least 2,608 other persons reported injured and 40,000 displaced, and 5,739 buildings destroyed and 4,882 damaged.

For earthquakes less than M_W 7, at least 108 deaths were reported following the M_W 6.9 Sikkim earthquake in September, which caused much devastation in the surrounding regions of eastern India and Nepal, Bhutan, Bangladesh and Tibet, China. Elsewhere, there were at least 14 deaths in the Tajikistan-Uzbekistan-Kyrgyzstan region following the M_W 6.2 earthquake in July, and there was at least one death in Guatemala following the M_W 5.6 earthquake there in September.

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

Table 6.1: *Summary of events by type between July and December 2011.*

damaging earthquake	22
damaging rockburst	1
felt earthquake	1793
felt rockburst	1
known earthquake	217581
known chemical explosion	2917
known induced event	2446
known mine explosion	7042
known rockburst	51
known experimental explosion	52
suspected earthquake	9144
suspected chemical explosion	46
suspected induced event	1
suspected mine explosion	3202
suspected rockburst	258
unknown	18
total	244575

The period between July and December 2011 produced 10 earthquakes with $M_W \geq 7$; these are listed in Table 6.2.

Table 6.2: Summary of the earthquakes of magnitude Mw ≥ 7 between July and December 2011.

Date	lat	lon	depth	Mw	Flinn-Engdahl Region
2011-07-06 19:03:20	-29.31	-176.26	25	7.6	Kermadec Islands region
2011-10-21 17:57:17	-28.88	-176.03	34	7.4	Kermadec Islands region
2011-09-15 19:31:03	-21.59	-179.32	628	7.3	Fiji Islands region
2011-10-23 10:41:22	38.73	43.45	7	7.3	Turkey
2011-08-20 16:55:04	-18.28	168.07	34	7.2	Vanuatu Islands
2011-12-14 05:04:57	-7.53	146.81	128	7.1	Eastern New Guinea region
2011-08-20 18:19:24	-18.33	168.23	31	7.1	Vanuatu Islands
2011-08-24 17:46:11	-7.62	-74.54	149	7.0	Peru-Brazil border region
2011-09-03 22:55:35	-20.63	169.78	136	7.0	Vanuatu Islands
2011-07-10 00:57:10	38.06	143.30	24	7.0	Off east coast of Honshu

Figure 6.1 shows the number of moderate and large earthquakes in the second half of 2011. The distribution of the number of earthquakes should follow the Gutenberg-Richter law.

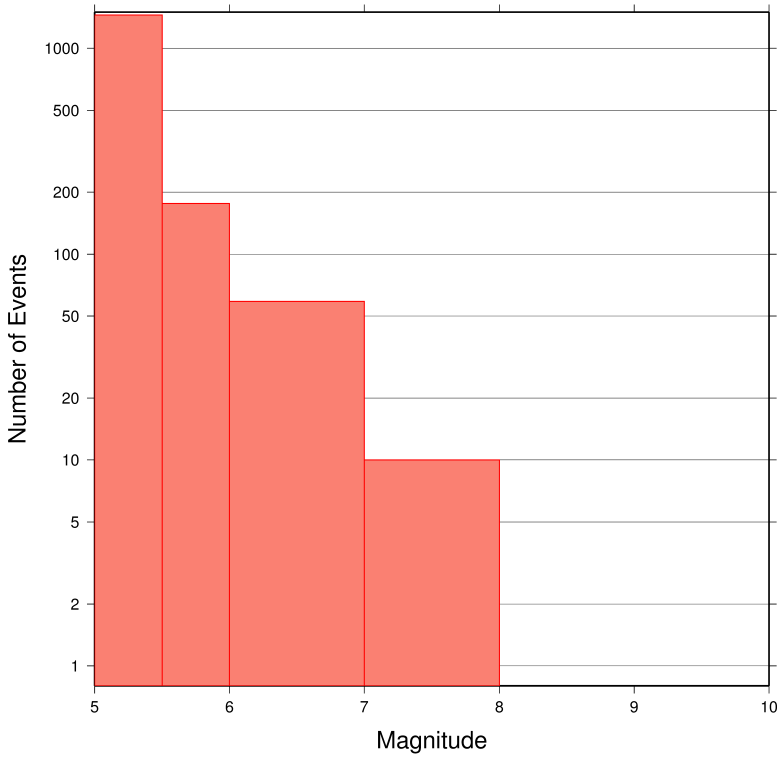


Figure 6.1: Number of moderate and large earthquakes between July and December 2011. The non-uniform magnitude bias here correspond with the magnitude intervals used in Figures 6.2 to 6.5.

Figures 6.2 to 6.5 show the geographical distribution of moderate and large earthquakes in various magnitude ranges.

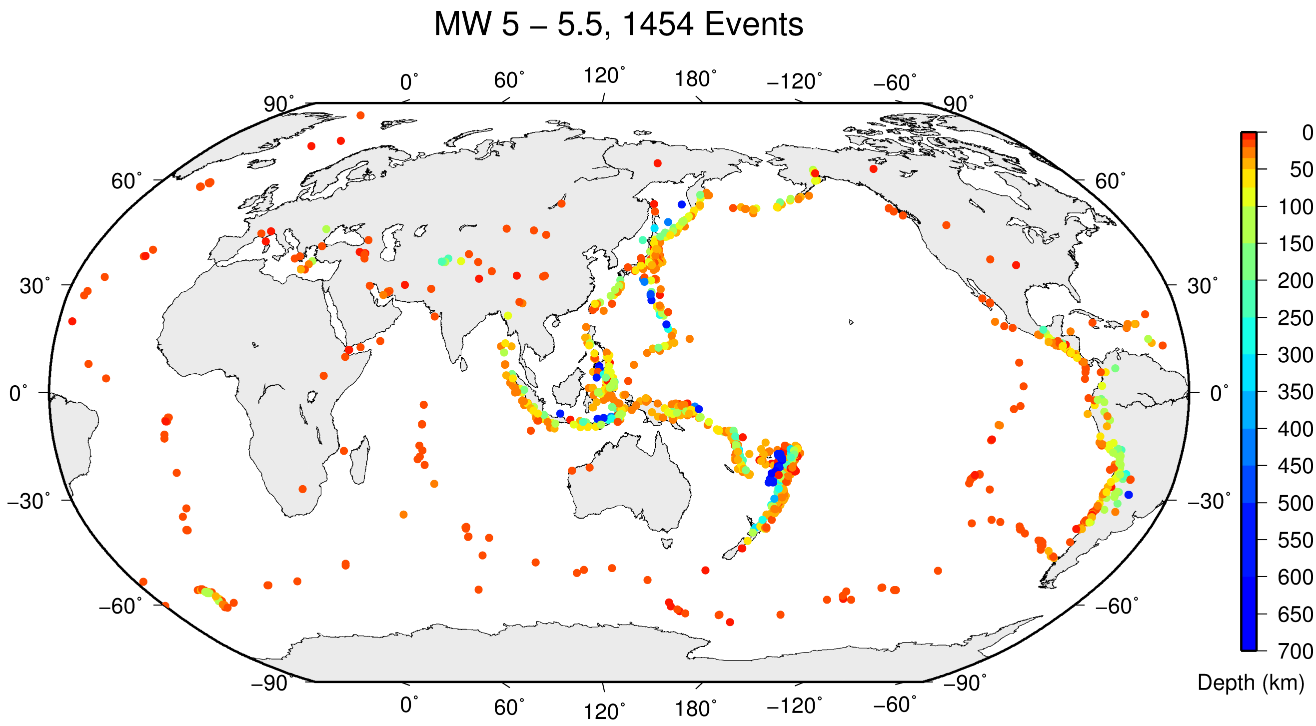


Figure 6.2: *Geographic distribution of magnitude 5-5.5 earthquakes between July and December 2011.*

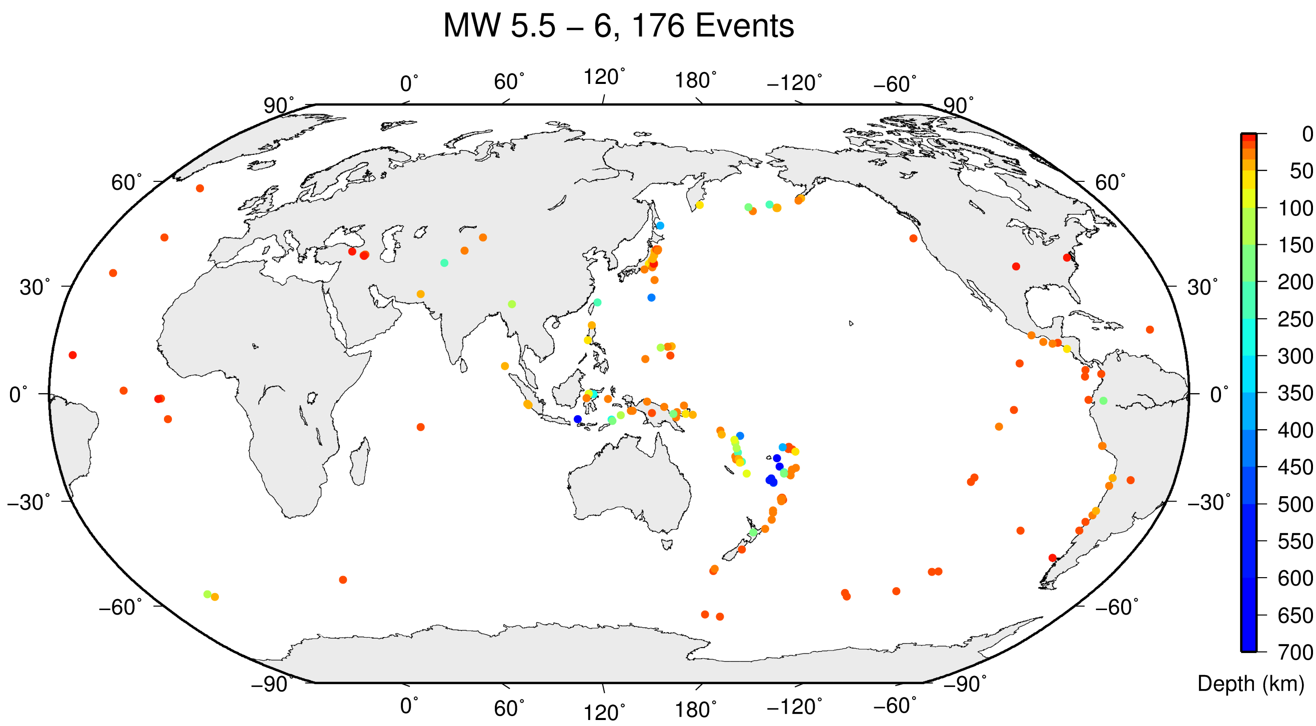


Figure 6.3: *Geographic distribution of magnitude 5.5-6 earthquakes between July and December 2011.*

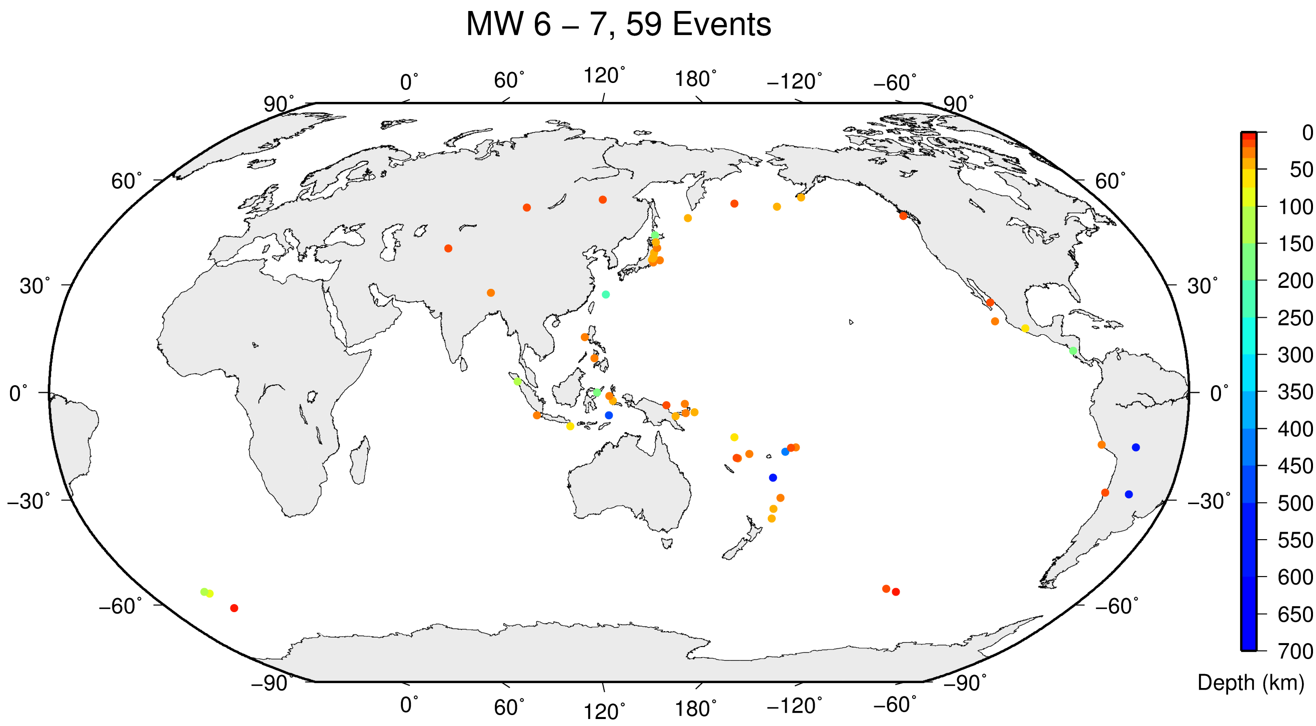


Figure 6.4: *Geographic distribution of magnitude 6-7 earthquakes between July and December 2011.*

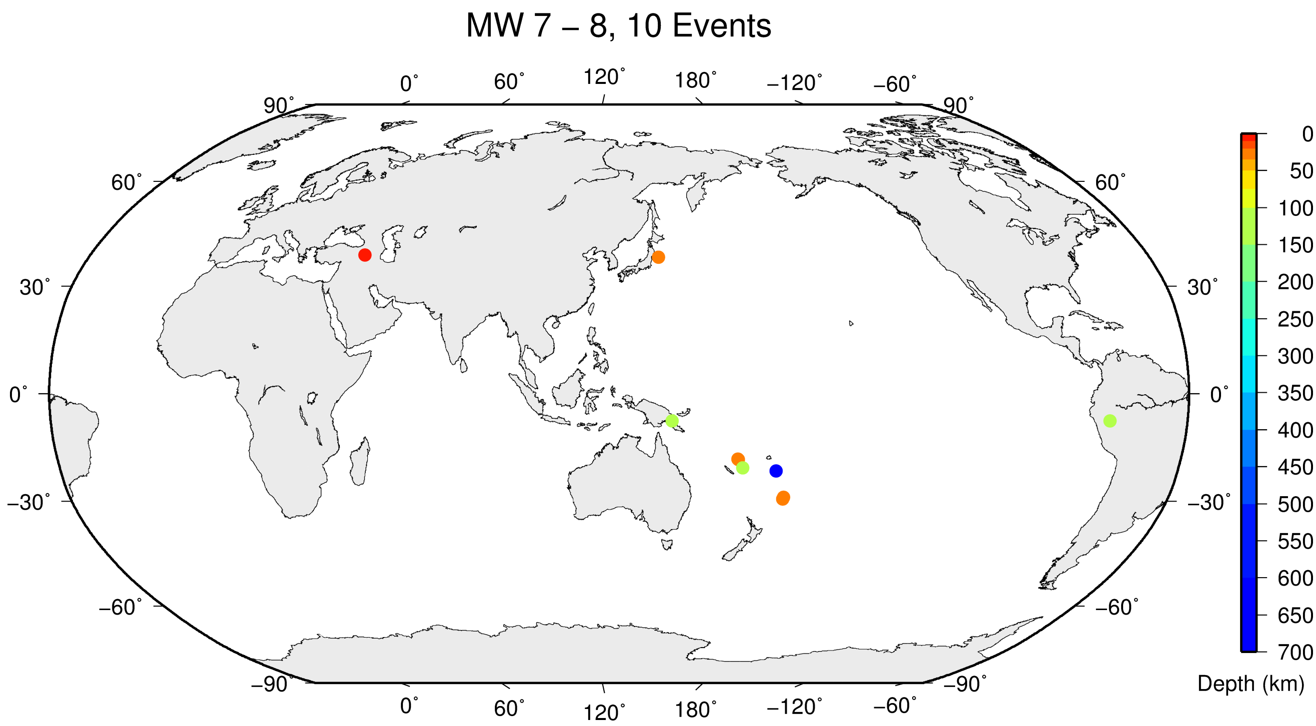


Figure 6.5: *Geographic distribution of magnitude 7-8 earthquakes between July and December 2011.*

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 130 agencies have reported data for July 2011 to December 2011. 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 130 agencies, containing data for this summary period.*

	Number of reports
Total collected	2923
Automatically parsed	2299
Manually parsed	622

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	150	126	691	35	0
CRAAG	Algeria	D	546	177	2440	438	0
LPA	Argentina	D	0	0	0	269	9
SJA	Argentina	D	3080	8	46981	10	6781
NSSP	Armenia	D	57	58	335	0	0
AUST	Australia	D	907	8	17697	0	0
IDC	Austria	D	17279	0	355696	0	324602
VIE	Austria	D	1803	1392	20767	0	20211
AZER	Azerbaijan	D	696	664	19606	0	12
BELR	Belarus	D	0	0	0	3592	818
UCC	Belgium	D	0	24	0	3376	813
SCB	Bolivia	D	156	0	1413	0	226
SAR	Bosnia and Herzegovina	I CSEM	0	362	0	0	0
VAO	Brazil	D	0	0	0	239	0
SOF	Bulgaria	D	64	0	480	2295	0
OTT	Canada	D	1296	28	33615	0	3328
PGC	Canada	I OTT	936	0	21453	0	0
GUC	Chile	D	3048	41	53206	815	13669
BJI	China	D	2127	17	138200	26786	78902
ASIES	Chinese Taipei	D	0	59	0	0	0
TAP	Chinese Taipei	D	10273	3	221330	0	0
RSNC	Colombia	D	6373	2	92637	8147	25379
UCR	Costa Rica	D	329	8	8385	0	633
HDC	Costa Rica	I NEIC	0	1	0	0	0
ZAG	Croatia	D	0	0	0	10001	0
NIC	Cyprus	D	191	137	1279	498	0
IPEC	Czech Republic	I CSEM	0	400	0	0	0
PRU	Czech Republic	D	5414	2628	48649	554	13099
WBNET	Czech Republic	D	47	0	947	0	933
DNK	Denmark	D	0	206	0	6584	2615
ARO	Djibouti	D	17	0	158	0	0
IGQ	Ecuador	D	36	6	1226	0	327
HLW	Egypt	D	268	141	2278	0	287
SNET	El Salvador	I NEIC	0	9	0	0	0
SSS	El Salvador	I UCR	0	3	0	0	0
EST	Estonia	I HEL	421	73	0	0	0
AAE	Ethiopia	D	1	0	4	156	2
SKO	FYR Macedonia	D	531	251	3651	2768	1545
FIA0	Finland	I HEL	42	12	0	0	0
HEL	Finland	D	6327	5830	100240	57	12341
CSEM	France	D	51871	75763	1043732	0	177522
LDG	France	D	1639	1624	29434	4	12490
STR	France	D	617	303	7427	146	0
PPT	French Polynesia	D	1479	0	11607	426	12005
TIF	Georgia	D	0	1770	0	17039	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
AWI	Germany	D	993	0	3045	1912	0
BGR	Germany	D	372	678	11380	0	194
BNS	Germany	I BGR	2	54	0	0	0
BRG	Germany	D	0	0	0	5761	4289
BUG	Germany	I BGR	28	1	0	0	0
CLL	Germany	D	198	0	5959	10988	5409
GDNRW	Germany	I BGR	0	23	0	0	0
GFZ	Germany	I INMG	9	1	0	0	0
LEDBW	Germany	I BGR	17	2	0	0	0
ATH	Greece	D	11227	10833	331812	0	118457
THE	Greece	D	4777	4783	108526	9945	34771
UPSL	Greece	I CSEM	0	200	0	0	0
GCG	Guatemala	I NEIC	0	3	0	0	0
HKC	Hong Kong	D	0	0	0	47	0
BUD	Hungary	D	0	45	0	2599	0
REY	Iceland	D	23	12	624	0	0
HYB	India	D	816	3	7755	12	2490
NDI	India	D	535	287	14165	9571	5452
DJA	Indonesia	D	2972	44	55839	0	34635
TEH	Iran	D	1153	1146	20996	0	8981
THR	Iran	D	119	432	1201	0	445
ISN	Iraq	D	417	346	2811	0	112
DIAS	Ireland	D	0	0	0	168	0
GII	Israel	D	107	85	2302	0	0
GEN	Italy	I CSEM	0	828	0	0	0
ROM	Italy	D	7511	5570	100709	0	43250
TRI	Italy	D	0	0	0	7074	0
LIC	Ivory Coast	D	768	0	2307	0	1516
JSN	Jamaica	D	102	0	590	15	0
JMA	Japan	D	110359	19	779319	825	0
MAT	Japan	D	0	0	0	23859	0
NIED	Japan	D	0	2196	0	0	0
SYO	Japan	D	0	0	0	3823	0
JSO	Jordan	D	7	15	71	0	0
NNC	Kazakhstan	D	6998	86	50805	0	44602
SOME	Kazakhstan	D	4799	83	57842	0	52791
KNET	Kyrgyzstan	D	415	0	3339	0	815
KRNET	Kyrgyzstan	D	2723	0	37556	0	0
LVSN	Latvia	I CSEM	0	369	0	0	0
GRAL	Lebanon	D	317	279	2222	637	0
LIB	Libya	I CSEM	0	9	0	0	0
LIT	Lithuania	D	184	253	1258	949	1044
MCO	Macao, China	D	0	0	0	98	0
GSDM	**Malawi**	**D**	**0**	**0**	**0**	**12**	**0**
KLM	Malaysia	D	334	1	2609	0	0
ECX	Mexico	D	926	6	15022	0	2165
MEX	Mexico	D	2129	141	17768	0	0
MOLD	Moldova	D	0	6	0	2437	736
OBM	Mongolia	D	104	0	2994	0	885
PDG	Montenegro	D	413	301	8867	0	5075
CNRM	Morocco	I CSEM	0	89	0	0	0
NAM	Namibia	D	24	0	180	21	0
DMN	Nepal	D	1805	4	18297	0	13018
DBN	Netherlands	D	0	1	0	1674	484
WEL	New Zealand	D	6232	9	251911	4894	111028
BER	Norway	D	1696	1606	27567	1049	7632
NAO	Norway	D	2939	1129	5614	0	2404
OMAN	Oman	D	999	226	9769	0	3
MSSP	Pakistan	D	0	0	0	716	0
UPA	Panama	I UCR	0	2	0	0	0
ARE	Peru	I NEIC	0	20	0	0	0
MAN	Philippines	D	0	973	0	19278	6522
QCP	Philippines	D	0	0	0	100	0
WAR	Poland	D	0	696	0	13509	442

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
IGIL	Portugal	D	589	0	2715	0	909
INMG	Portugal	D	1372	650	41634	2180	13418
PDA	Portugal	I CSEM	721	645	0	0	0
SVSA	Portugal	D	812	0	12456	6440	6422
KMA	Republic of Korea	D	22	0	293	0	0
BUC	Romania	D	847	75	11096	43750	0
ASRS	Russia	D	23	0	432	0	0
BYKL	Russia	D	141	0	10620	0	3792
KOLA	Russia	D	98	0	381	0	0
KRSC	Russia	D	495	0	17330	0	0
MOS	Russia	D	2588	411	438745	0	174048
NERS	Russia	D	24	0	777	0	348
SKHL	Russia	D	492	483	14168	0	6405
YARS	Russia	D	525	525	11043	1	4661
SGS	Saudi Arabia	D	4434	30	60378	0	0
BEO	Serbia	D	1609	1280	23775	10	0
BRA	Slovakia	D	0	0	0	20290	0
LJU	Slovenia	D	1182	1287	16399	5070	5194
HNR	Solomon Islands	D	0	0	0	1356	0
PRE	South Africa	D	1364	1	22758	12	7565
MDD	Spain	D	2600	5313	68815	0	56038
MRB	Spain	I CSEM	0	8	0	0	0
SFS	Spain	I CSEM	0	135	0	0	0
UPP	Sweden	D	1340	3637	12562	0	0
ZUR	Switzerland	D	341	359	4134	0	3413
NSSC	Syria	D	1133	250	21531	91	9316
BKK	Thailand	D	1146	42	11014	0	14055
TRN	Trinidad and Tobago	D	6	908	0	22632	0
TUN	Tunisia	I CSEM	0	11	0	0	0
ATA	**Turkey**	**D**	**504**	**0**	**7877**	**0**	**0**
DDA	Turkey	D	16692	13110	198717	10044	0
ISK	Turkey	D	46	20592	0	129729	0
AEIC	U.S.A.	I IRIS	79	74	0	0	0
ANF	U.S.A.	I IRIS	1311	835	0	0	0
BRK	U.S.A.	I NEIC	0	0	0	0	0
BUT	U.S.A.	I IRIS	2	2	0	0	0
CERI	U.S.A.	I IRIS	124	40	0	0	0
GCMT	U.S.A.	D	0	3748	0	0	0
IRIS	U.S.A.	D	3415	3232	290821	0	0
LDO	**U.S.A.**	**I IRIS**	**0**	**6**	**0**	**0**	**0**
NCEDC	U.S.A.	I IRIS	116	64	0	0	0
NEIC	U.S.A.	D	15484	5589	706190	0	259043
OGSO	U.S.A.	I IRIS	1	2	0	0	0
PAL	**U.S.A.**	**I IRIS**	**1**	**0**	**0**	**0**	**0**
PAS	U.S.A.	I IRIS	108	68	0	0	0
PNSN	U.S.A.	D	34	144	0	0	0
REN	U.S.A.	I IRIS	117	21	0	0	0
RSPR	U.S.A.	D	1298	2	15145	0	0
SCEDC	U.S.A.	I IRIS	150	119	0	0	0
SEA	U.S.A.	I IRIS	26	35	0	0	0
SIO	U.S.A.	I IRIS	123	15	0	0	0
SLC	U.S.A.	I IRIS	14	13	0	0	0
SLM	U.S.A.	I NEIC	0	0	0	0	0
TUL	U.S.A.	I IRIS	113	0	0	0	0
TVA	U.S.A.	I NEIC	0	16	0	0	0
UUSS	U.S.A.	I IRIS	0	13	0	0	0
WES	U.S.A.	I NEIC	0	2	0	0	0
SIGU	Ukraine	D	119	119	3108	7	707
DSN	United Arab Emirates	D	493	170	2698	0	0
BGS	United Kingdom	D	219	143	8429	0	3115
SIK	Unknown	I CSEM	0	74	0	0	0
CAR	Venezuela	I NEIC	0	3	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	883	0	11780	0	0
PLV	Vietnam	D	4	0	92	0	36
DHMR	Yemen	D	224	94	2027	1616	815
LSZ	Zambia	D	13	0	54	8	0
BUL	Zimbabwe	D	430	0	2310	39	20

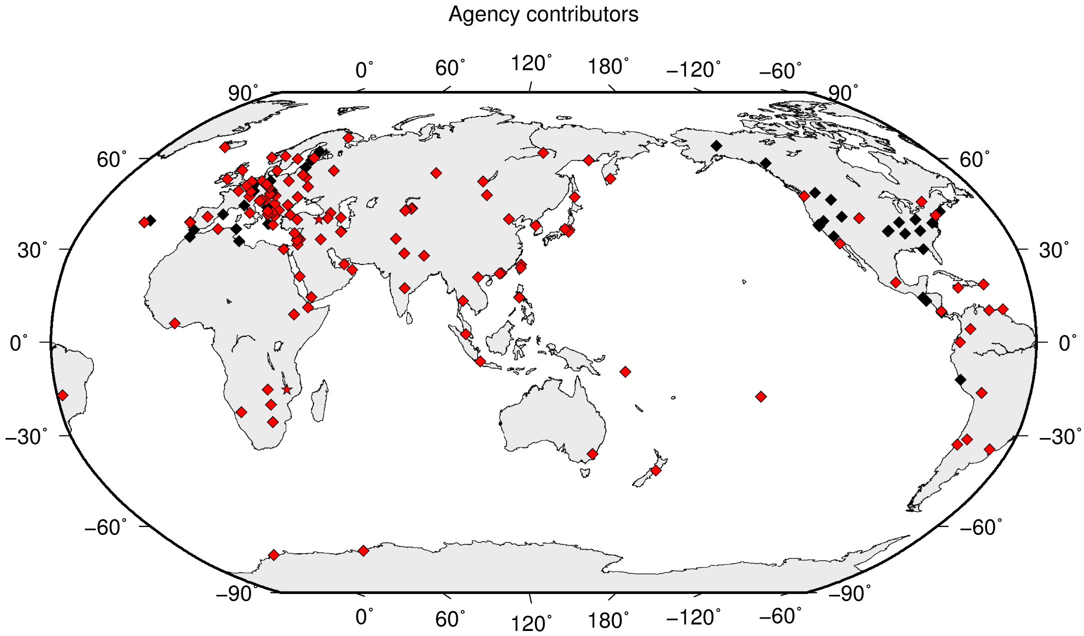


Figure 7.1: *Map of agencies that have contributed data to the ISC for this summary period. Agencies that have reported directly to the ISC are shown in red. Those that have reported indirectly (via another agency) are shown in black. Any new or renewed agencies, since the last six-month period, are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

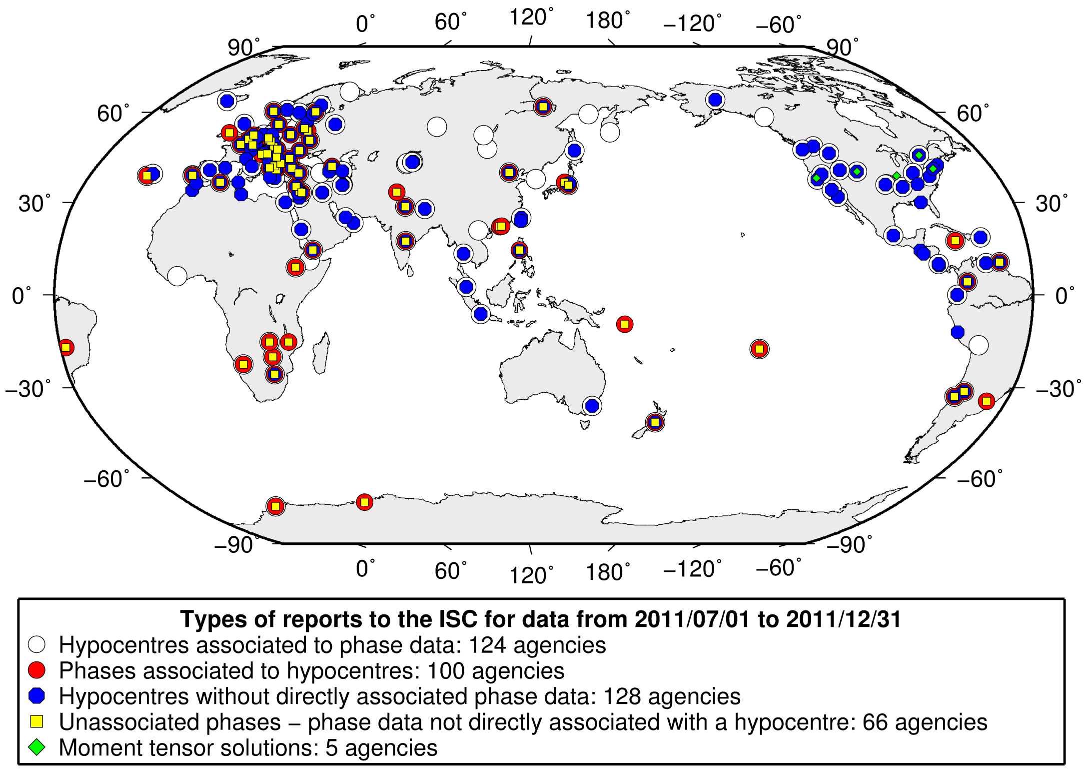


Figure 7.2: *Map of the different data types reported by agencies to the ISC. A full list of the data types reported by each agency is shown in Table 7.2.*

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 reported by each station was 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.

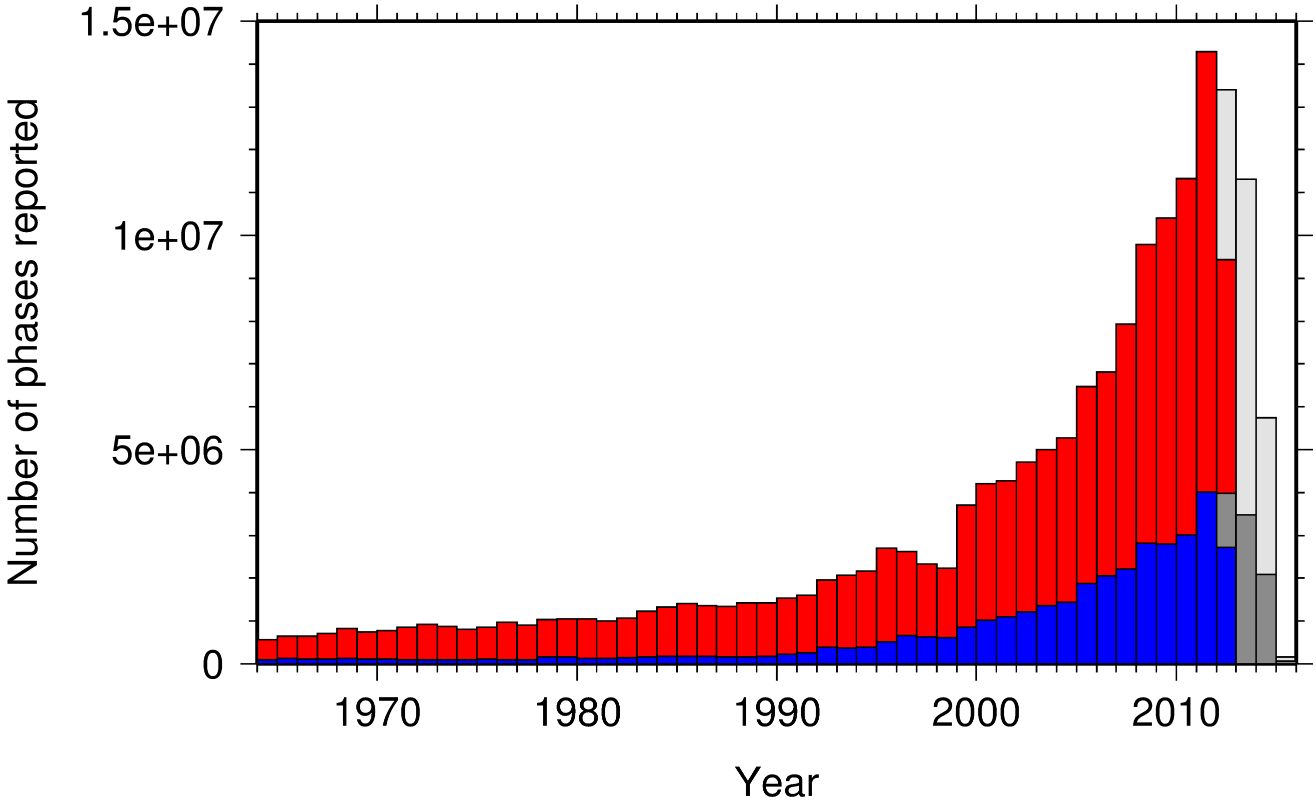


Figure 7.3: *Histogram showing the number of phases (red) and number of amplitudes (blue) collected by the ISC for events each year since 1964. The data in grey covers the current period where data are still being collected before the ISC review takes place and is accurate at the time of publication.*

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

Reports with phase arrivals	2442
Reports with phase arrivals including amplitudes	631
Reports with only phase arrivals (no hypocentres reported)	233
Total phase arrivals received	6728929
Total phase arrival-times received	6416335
Number of duplicate phase arrival-times	1356729 (21.1%)
Number of amplitudes received	1789982
Stations reporting phase arrivals	6738
Stations reporting phase arrivals with amplitude data	2982
Max number of stations per report	2292

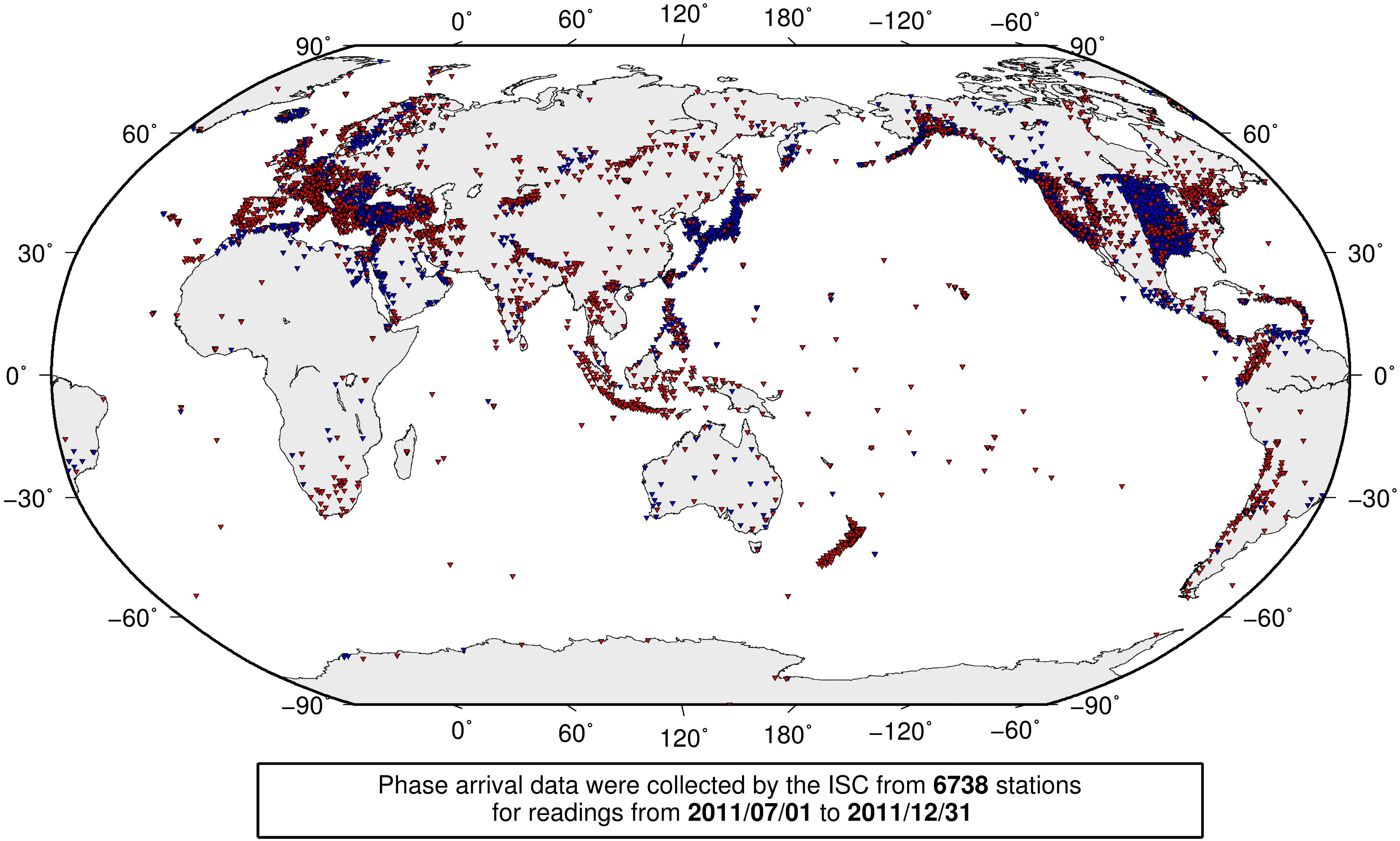


Figure 7.4: *Stations contributing phase data to the ISC for readings from July 2011 to the end of December 2011. Stations in blue provided phase arrival times only; stations in red provided both phase arrival times and amplitude data.*

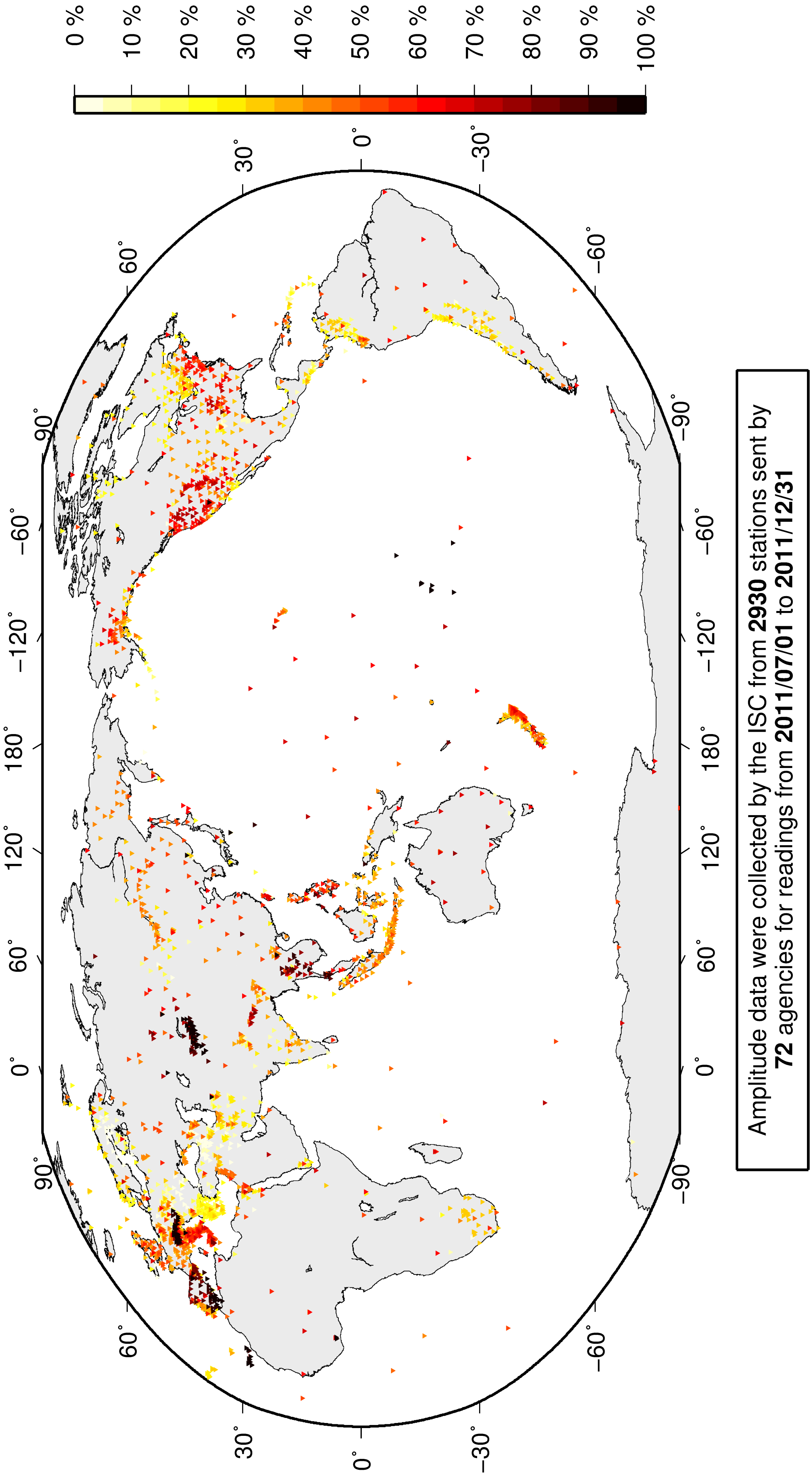


Figure 7.5: *Percentage of events for which phase arrival times from each station are accompanied with amplitude and period measurements.*

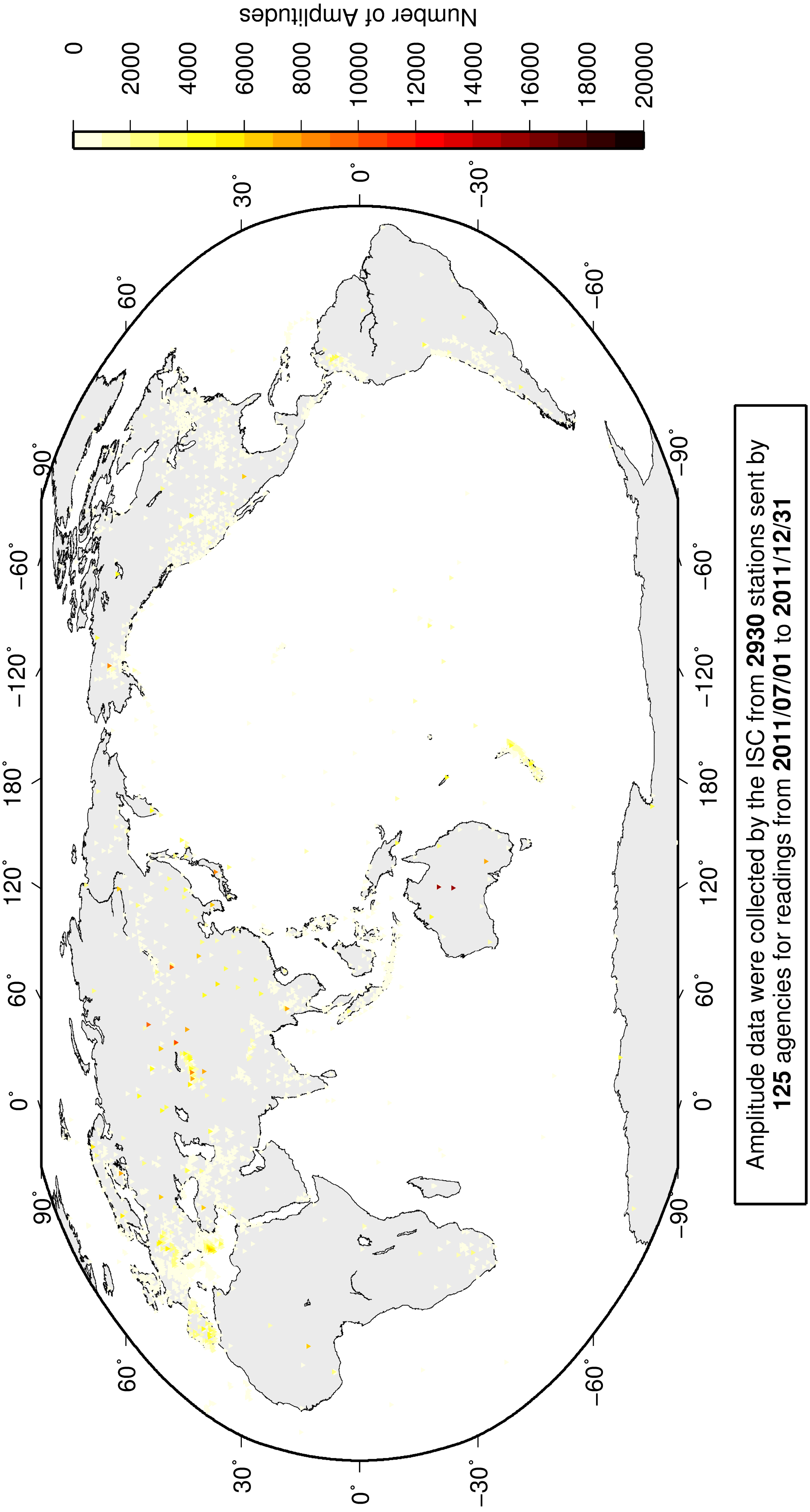


Figure 7.6: *Number of amplitude and period measurements for each station.*

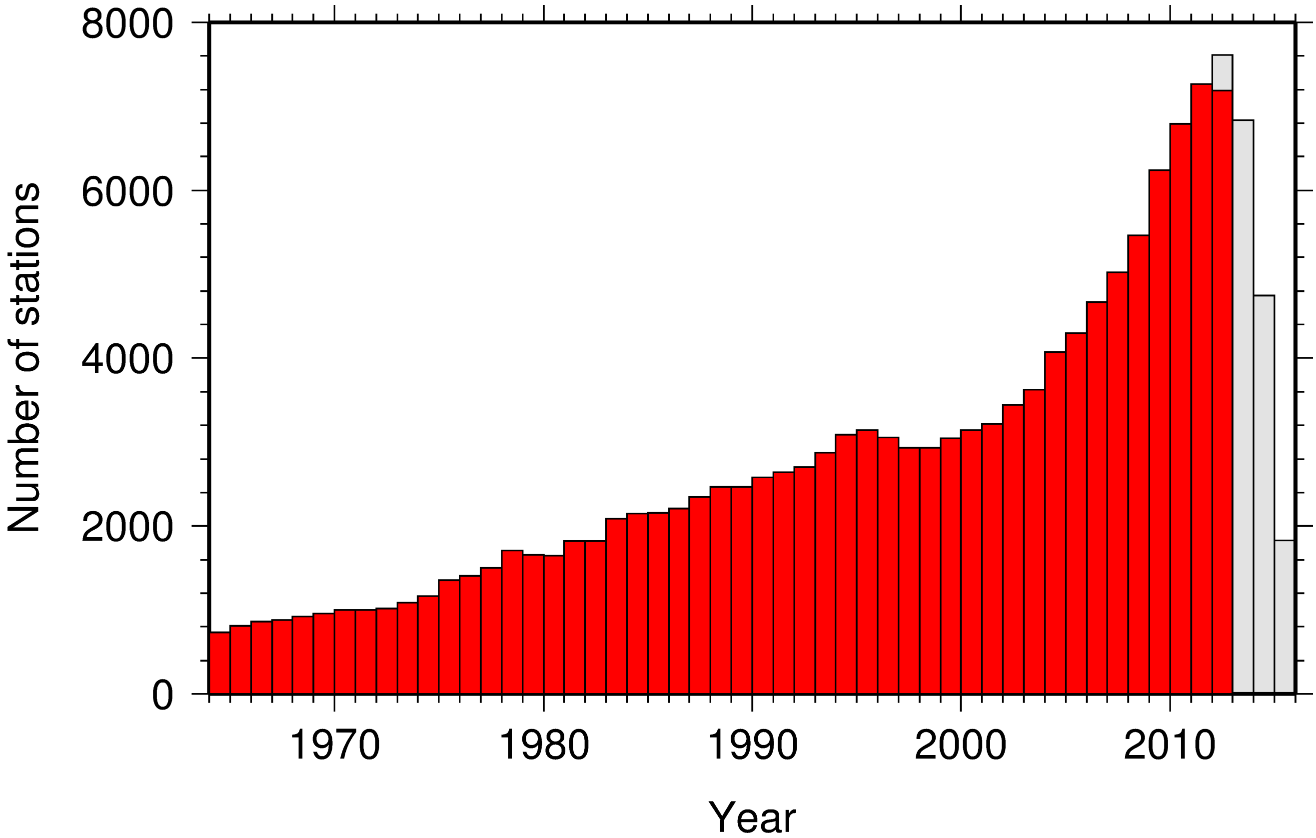


Figure 7.7: *Histogram showing the number of stations reporting to the ISC each year since 1964. The data in grey covers the current period where station information is still being collected before the ISC review of events takes place and is accurate at the time of publication.*

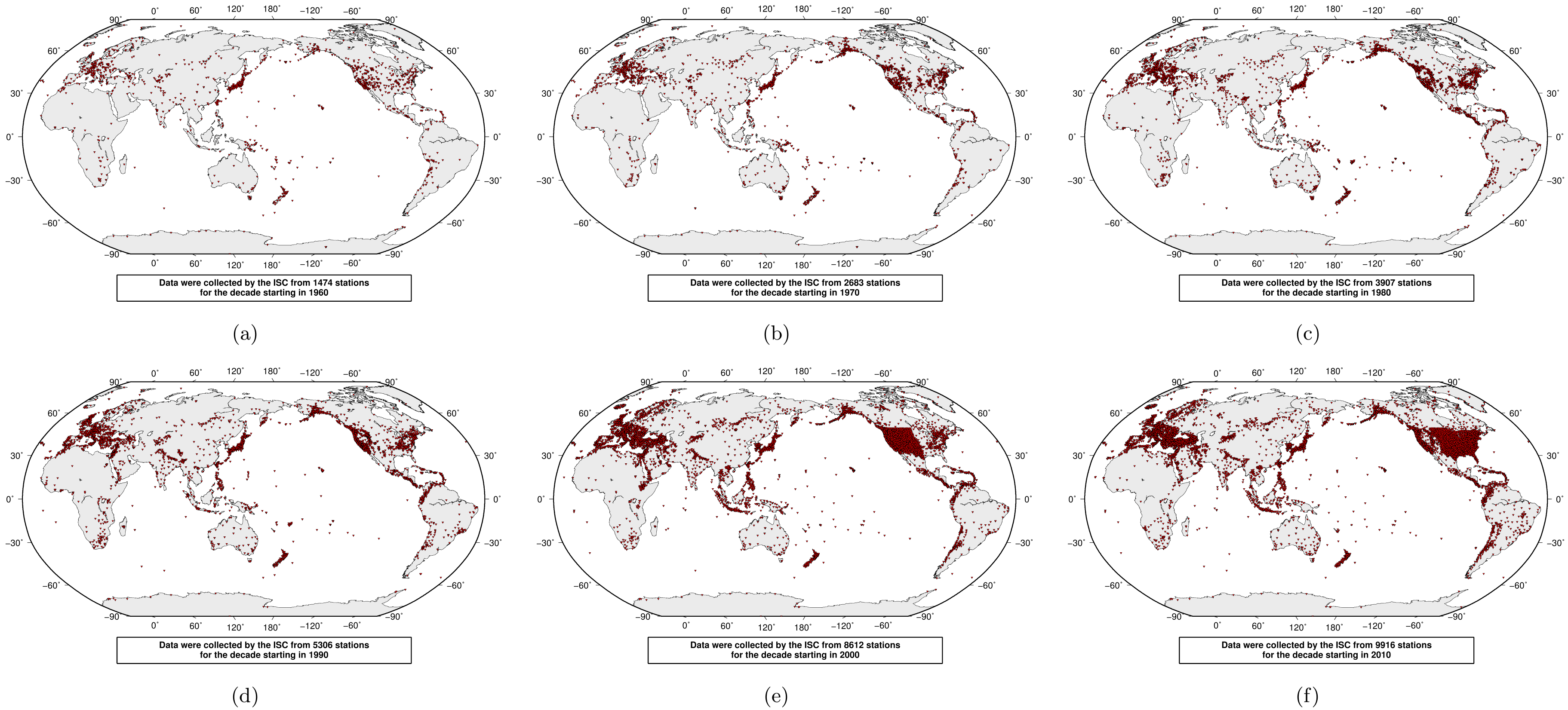


Figure 7.8: *Maps showing the stations reported to the ISC for each decade since 1960. Note that the last map covers a shorter time period.*

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	2690
Reports of hypocentres only (no phase readings)	481
Total hypocentres received	453516
Number of duplicate hypocentres	101538 (22.4%)
Agencies determining hypocentres	158

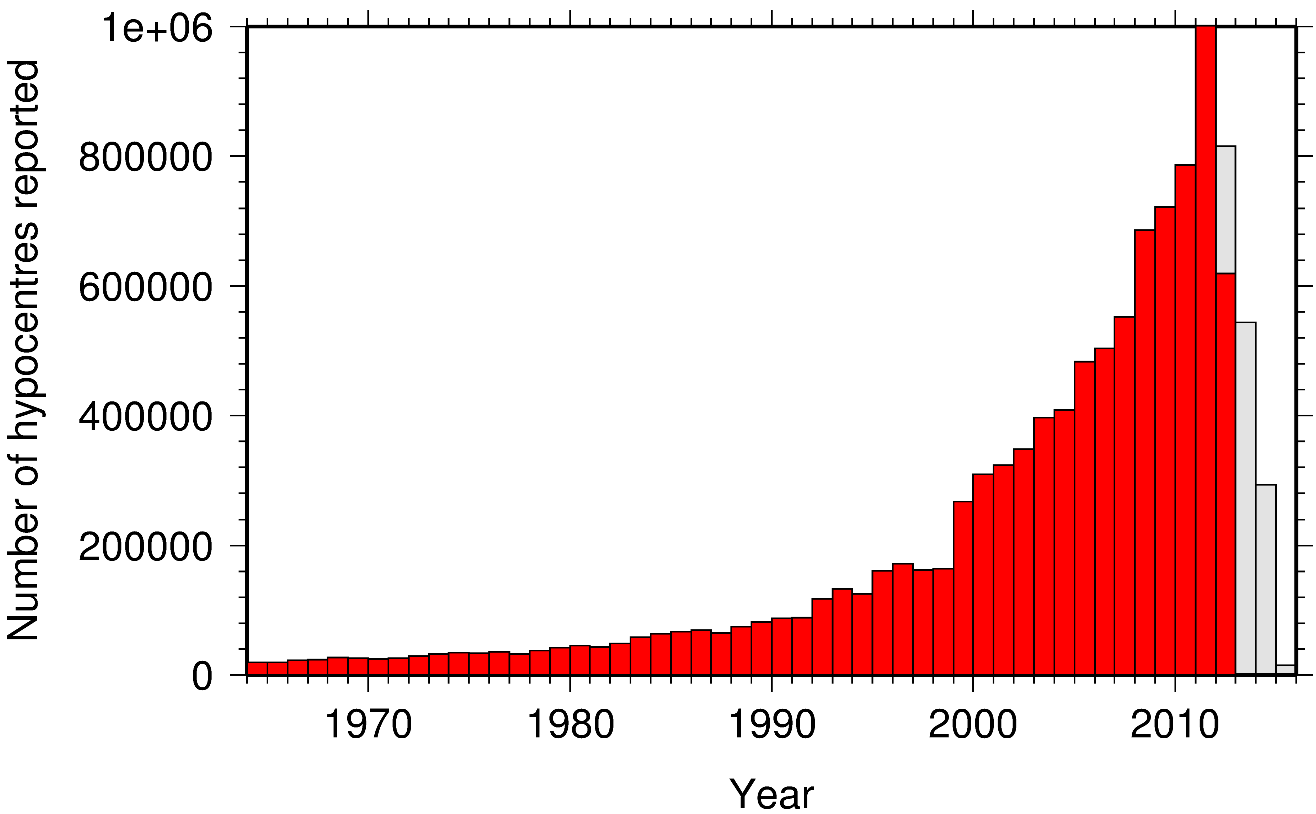


Figure 7.9: *Histogram showing the number of hypocentres collected by the ISC for events each year since 1964. For each event, multiple hypocentres may be reported.*

All the hypocentres that are reported to the ISC are automatically grouped into events, which form the basis of the ISC Bulletin. For this time period 491838 hypocentres (including ISC) were grouped into 250798 events, the largest of these having 85 hypocentres in one event. The total number of events

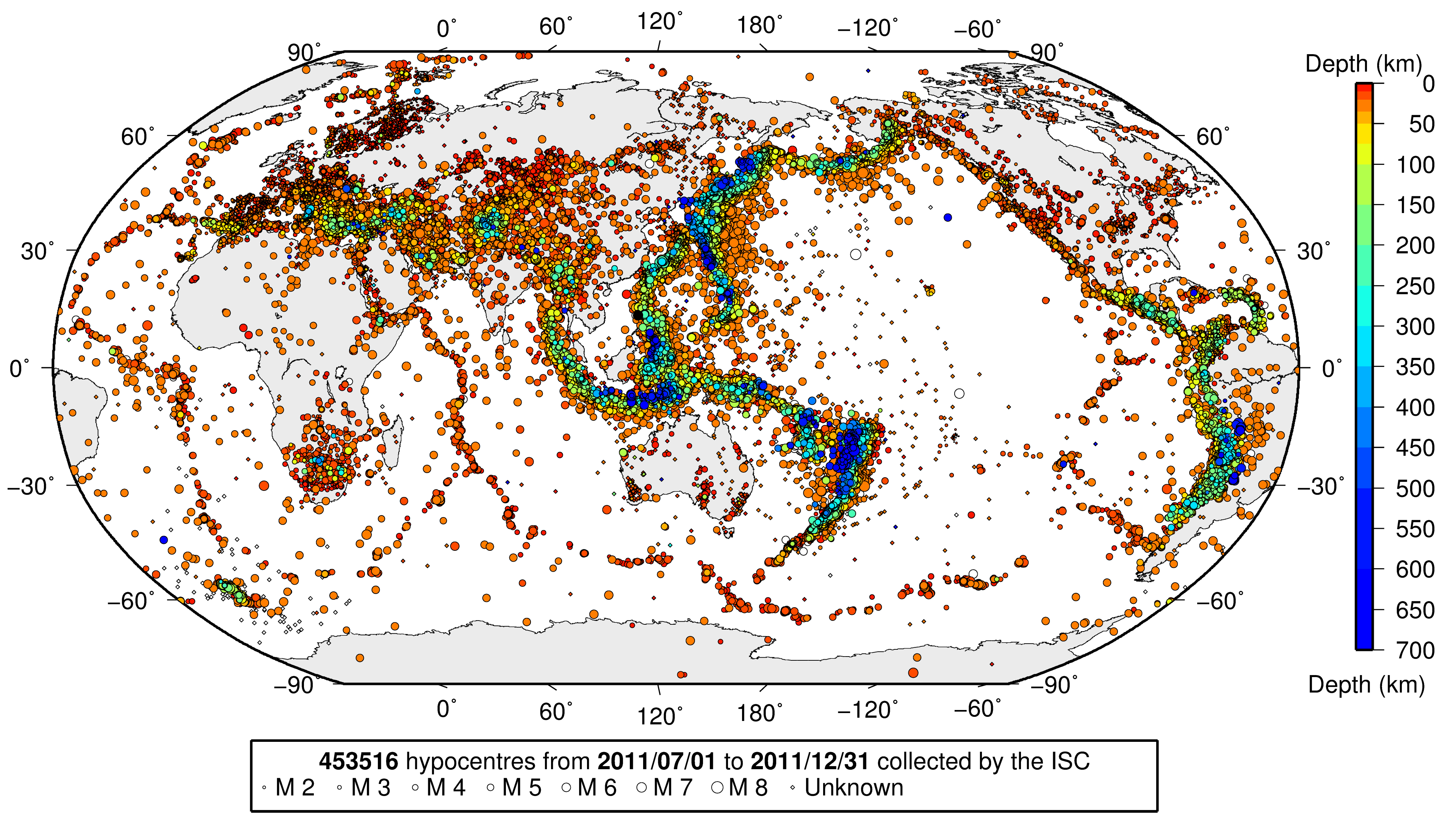


Figure 7.10: *Map of all hypocentres collected by the ISC. The scatter shows the large variation of the multiple hypocentres that are reported for each event. The magnitude corresponds with the reported network magnitude. If more than one network magnitude type was reported, preference was given to values 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 3.3.1 of the January-June 2011 Bulletin Summary. Figure 8.2 on page 69 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 current period.

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

	$M<3.0$	$3.0 \leq M<5.0$	$M \geq 5.0$
Number of seismic events	191627	36531	427
Average number of magnitude estimates per event	1.8	4.9	30.9
Average number of magnitudes (by the same agency) per event	1.3	2.6	4.5
Average number of magnitude types per event	1.1	3.8	10.8
Number of magnitude types	20	29	26

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); *Vanek 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	2752	BEO (1605), DJA (546), SKO (439), BKK (232), FDF (30), PRU (21), IGQ (18)
M1	1	DMN (1)
mB	2142	BJI (1906), DJA (514), BKK (56), IGQ (8)
mb	23322	IDC (16450), NEIC (5917), NNC (3454), KRNET (2693), MOS (2406), BJI (1765), MAN (927), VIE (870), DJA (748), CSEM (617), MDD (173), SIGU (84), BKK (60), NIC (51), IASPEI (39), DSN (38), GII (30), IGQ (25), NDI (5), PGC (5), DMN (4), UCR (3), PDA (3), IGIL (2), CRAAG (1), GUC (1), PDG (1), INMG (1), BGS (1)
mb1	17022	IDC (17022)
mb1mx	17022	IDC (17022)
mbLg	2422	MDD (2422)
mbtmp	17022	IDC (17022)
Mc	45	BER (45)
md	6	PGC (5), HYB (1)

Table 7.7: *Continued.*

Magnitude type	Events	Agencies reporting magnitude type (number of values)
MD	28069	CSEM (11788), DDA (7589), ROM (6961), ISK (6258), MEX (2347), RSPR (1902), LDG (1339), ECX (865), BUC (843), TRN (709), PDA (571), GRAL (315), BER (284), HLW (223), UCR (208), SJA (149), NSSC (141), ATA (135), NCEDC (127), PNSN (114), GII (107), PDG (93), CNRM (87), SOF (62), JSN (59), INMG (55), CERI (54), SEA (38), SNET (32), TUL (31), HVO (27), TUN (11), BUT (8), LSZ (7), NAM (6), JSO (5), IGQ (5), SLC (5), BUL (2), GCG (2), SSS (1), HDC (1), FDF (1), NEIC (1), AAE (1)
ME	93	NEIC (93)
MG	372	AEIC (293), WEL (61), GUC (14), ARE (3), THE (1)
MJMA	108285	JMA (108285)
ML	93666	CSEM (36429), ATH (10930), TAP (10297), IDC (9555), DDA (9150), ROM (7237), RSNC (6356), WEL (6157), HEL (5872), THE (4776), ISK (4503), UPP (3509), GUC (3097), SJA (2663), LDG (1568), AEIC (1537), PRE (1356), VIE (1291), TEH (1141), LJU (1084), BER (1064), ECX (952), MAN (928), INMG (878), GEN (828), NSSC (792), PGC (782), PDA (641), NAO (549), KRSC (495), ATA (447), SKO (432), CRAAG (424), ISN (402), IPEC (399), BGR (370), IGIL (346), ZUR (344), BJI (313), PDG (293), STR (246), UCR (234), PAS (226), HLW (213), DHMR (209), CLL (194), NIC (191), NDI (173), THR (147), SCB (141), NEIC (141), DSN (140), TIR (138), SFS (131), OBM (95), OTT (83), TUL (79), PPT (76), KNET (60), REN (59), BNS (56), BGS (55), FIA0 (54), HVO (42), NCEDC (36), WBNET (31), BUG (28), DMN (25), UCC (24), ARE (23), SLC (20), ARO (16), LDO (14), BUT (13), AUST (9), MRB (8), SEA (6), REY (6), PLV (4), BEO (4), IGQ (4), DNK (3), SVSA (3), HYB (2), RSPR (2), SZGRF (1), DBN (1), SSS (1), MDD (1), ALG (1)
MLSn	178	PGC (178)
MLv	2597	DJA (2352), BKK (236), IGQ (13)
MN	476	OTT (333), NEIC (86), TEH (51), CERI (11), OGSO (5), WES (5), TUL (2), BLA (1)
mpv	3679	NNC (3679)
MS	8850	IDC (7931), BJI (1583), MAN (930), MOS (555), NEIC (224), NSSP (59), CSEM (49), SOME (34), VIE (25), ASRS (23), IASPEI (15), DSN (6), BER (2), OBM (1), ATA (1), INMG (1), LDG (1)
Ms1	7931	IDC (7931)
ms1mx	7931	IDC (7931)
Ms7	1575	BJI (1575)
MW	7753	SJA (2589), NIED (2195), GCMT (1031), FUNV (881), NEIC (487), ATA (411), WAR (307), PGC (273), WEL (107), CSEM (28), BRK (28), DDA (23), SLM (18), OTT (17), RSNC (10), CAR (7), GUC (4), CRAAG (2), UPA (2), BER (2), IEC (2), ISK (1), NDI (1)

Table 7.7: *Continued.*

Magnitude type	Events	Agencies reporting magnitude type (number of values)
Mw(mB)	269	DJA (209), BKK (58), IGQ (8)
Mwp	53	DJA (43), BKK (6), IGQ (5)

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.

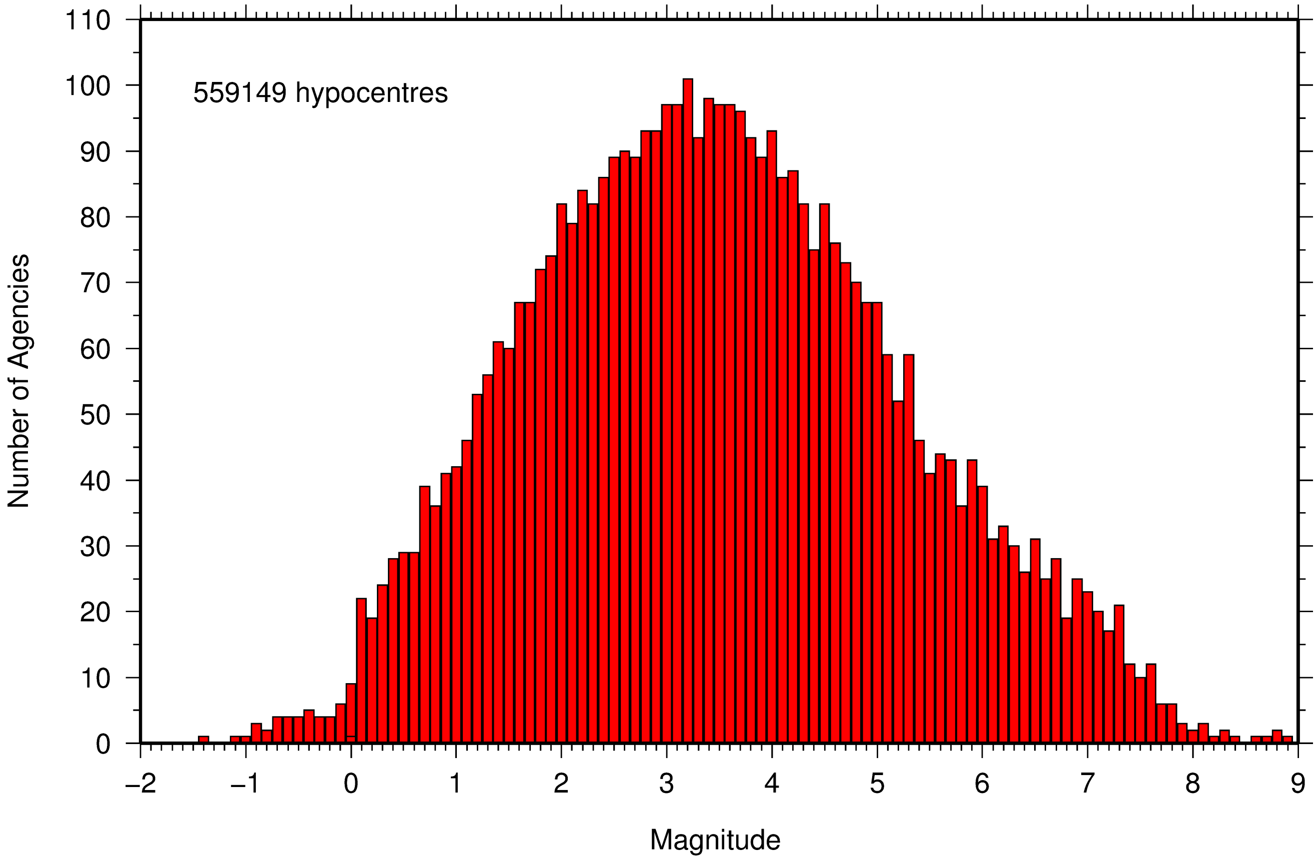


Figure 7.11: *Histogram showing the number of agencies that reported network magnitude values. All magnitude types are included.*

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	12
Total moment tensors received	4910
Agencies reporting moment tensors	5

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.

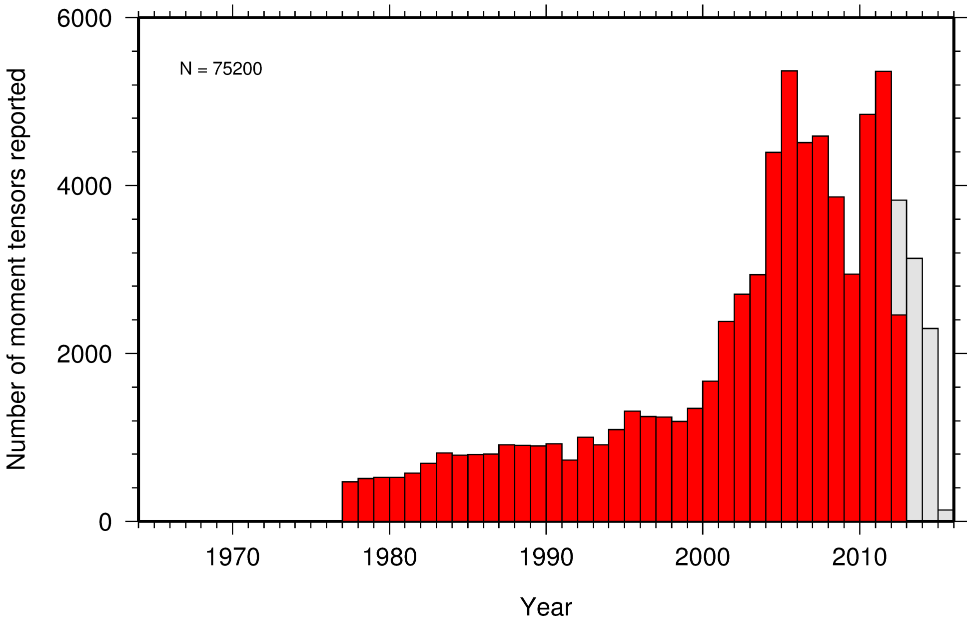


Figure 7.12: *Histogram showing the number of moment tensors reported to the ISC since 1964. The regions in grey represent data that are still being actively collected.*

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

Agency	Number of moment tensor solutions
GCMT	1030
NEIC	445
BRK	25
SLM	15
OTT	12

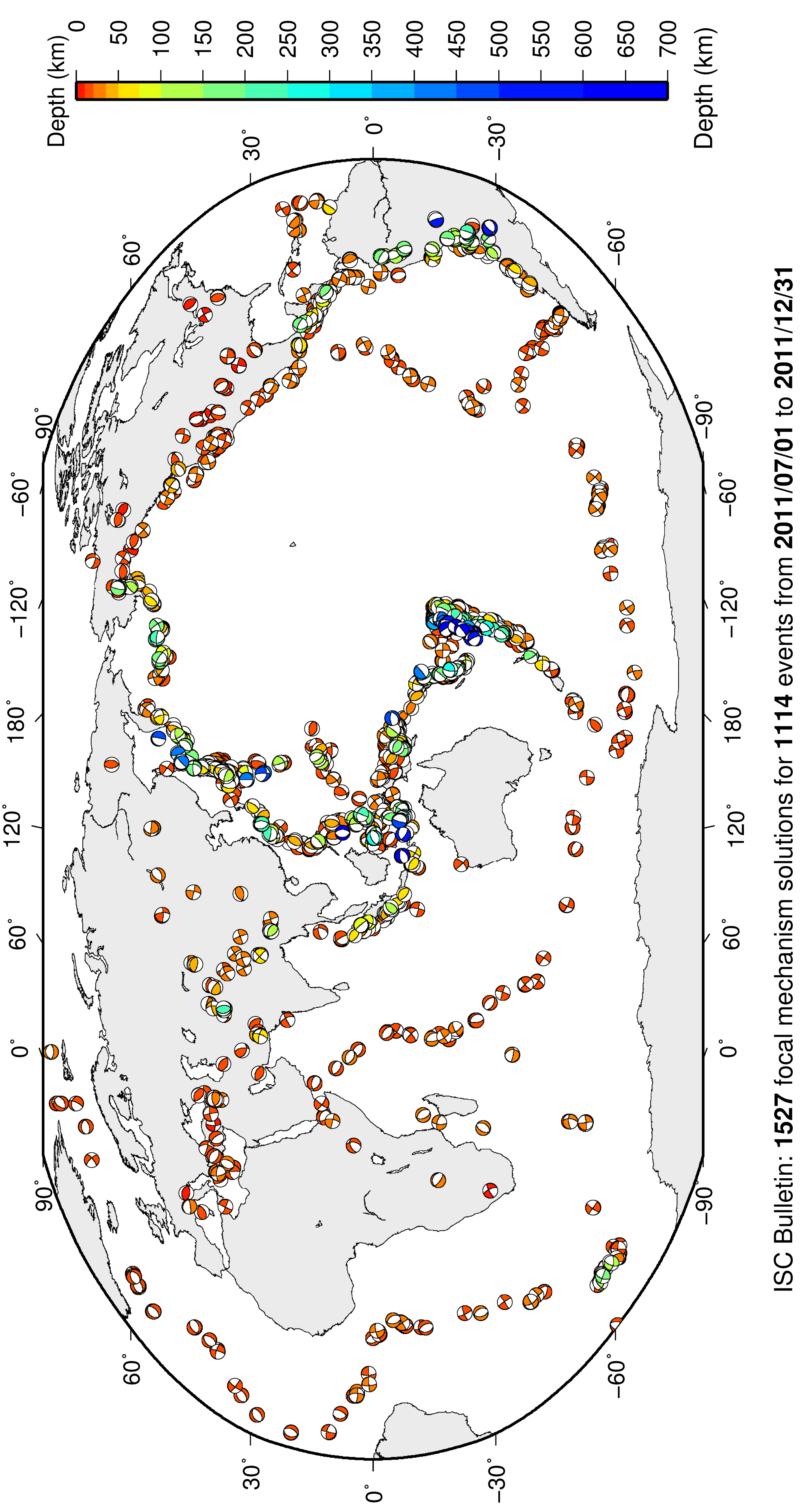


Figure 7.13: *Map of all moment tensor solutions in the ISC Bulletin for this summary period.*

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.

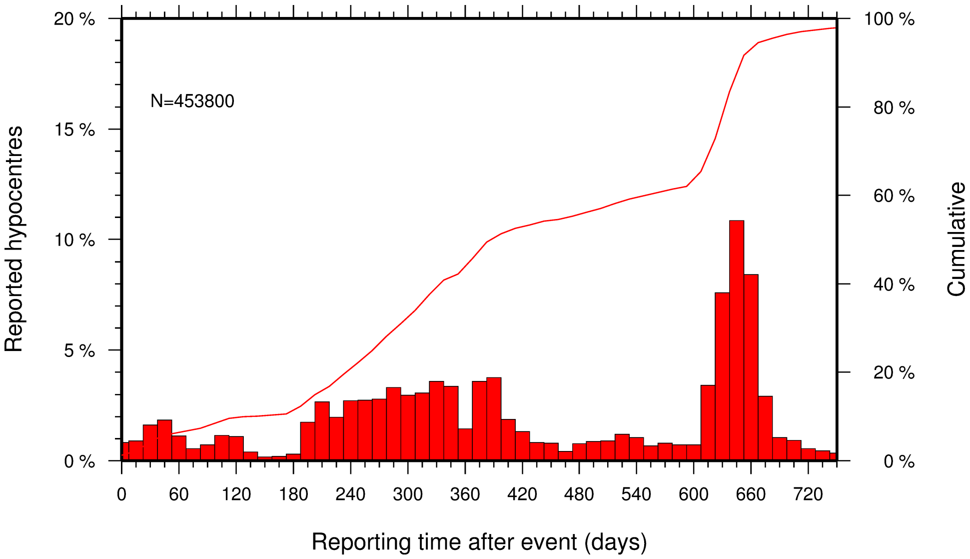


Figure 7.14: Histogram showing the timing of final reports of the hypocentres (total of N) to the ISC. The cumulative frequency is shown by the solid line.

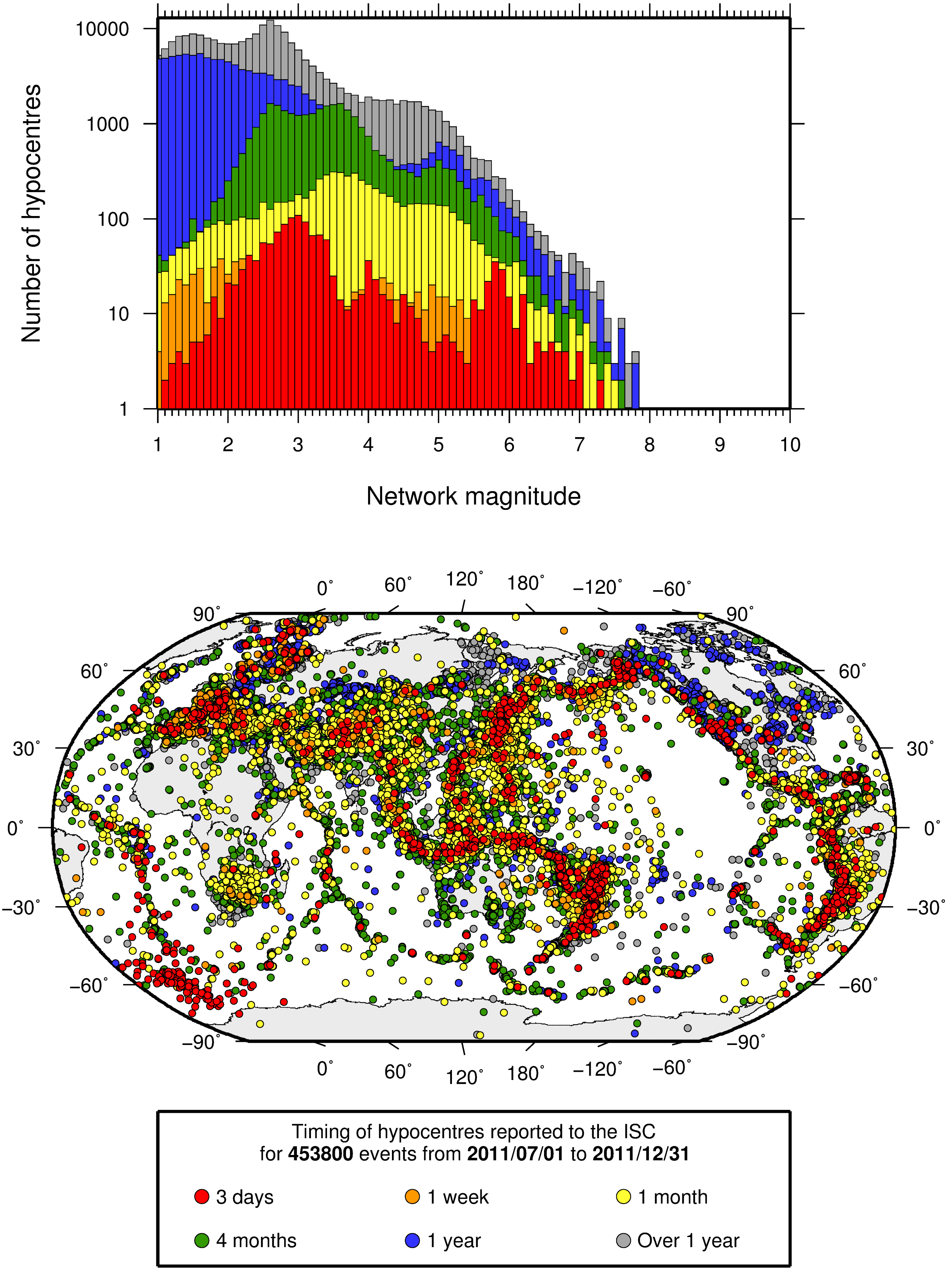


Figure 7.15: *Timing of hypocentres reported to the ISC. The colours show the time after the origin time that the corresponding hypocentre was reported. The histogram shows the distribution with magnitude. If more than one network magnitude was reported, preference was given to a value of M_W followed 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 244576 reported events in the summary period between July and December 2011. Some 93% (228541) of the events were identified as earthquakes, the rest (16035) were of anthropogenic origin (including mining and other chemical explosions, rockbursts and induced events) or of unknown origin. As discussed in Section 3.3.3 of the January-June 2011 Bulletin Summary, typically about 20% of the events are selected for ISC review, and about half of the events selected for review are located by the ISC. In this summary period 13% of the events were reviewed and 8% 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 3.3.1 of the January-June 2011 Bulletin Summary.

Of the 6728930 reported phase observations, 45% are associated to ISC-reviewed events, and 42% 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 3.4 of the January-June

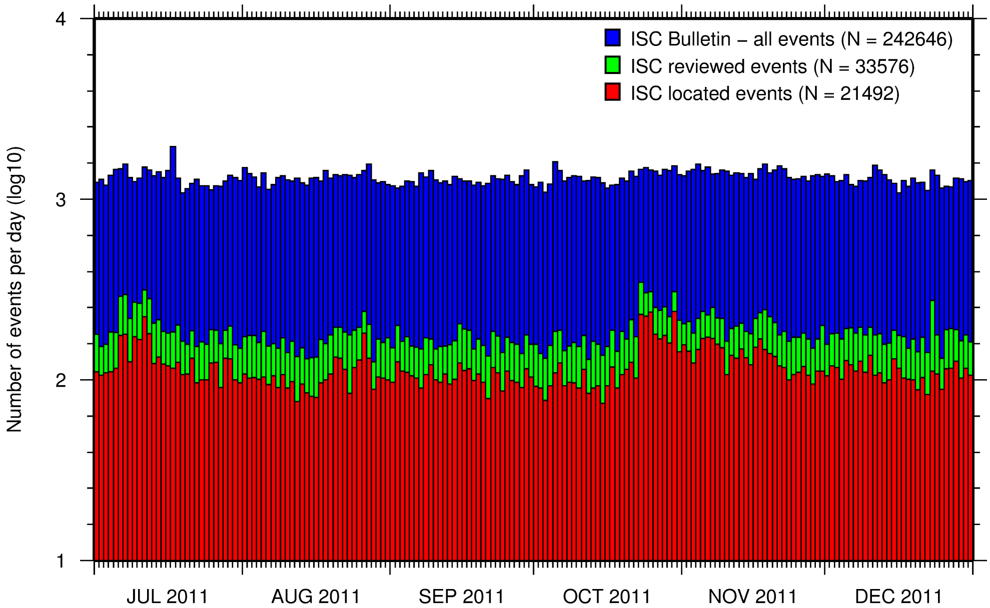


Figure 8.1: *Histogram showing the number of events in the ISC Bulletin for the current summary period. The vertical scale is logarithmic.*

2011 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 8.7 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 3.4 of the January-June 2011 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

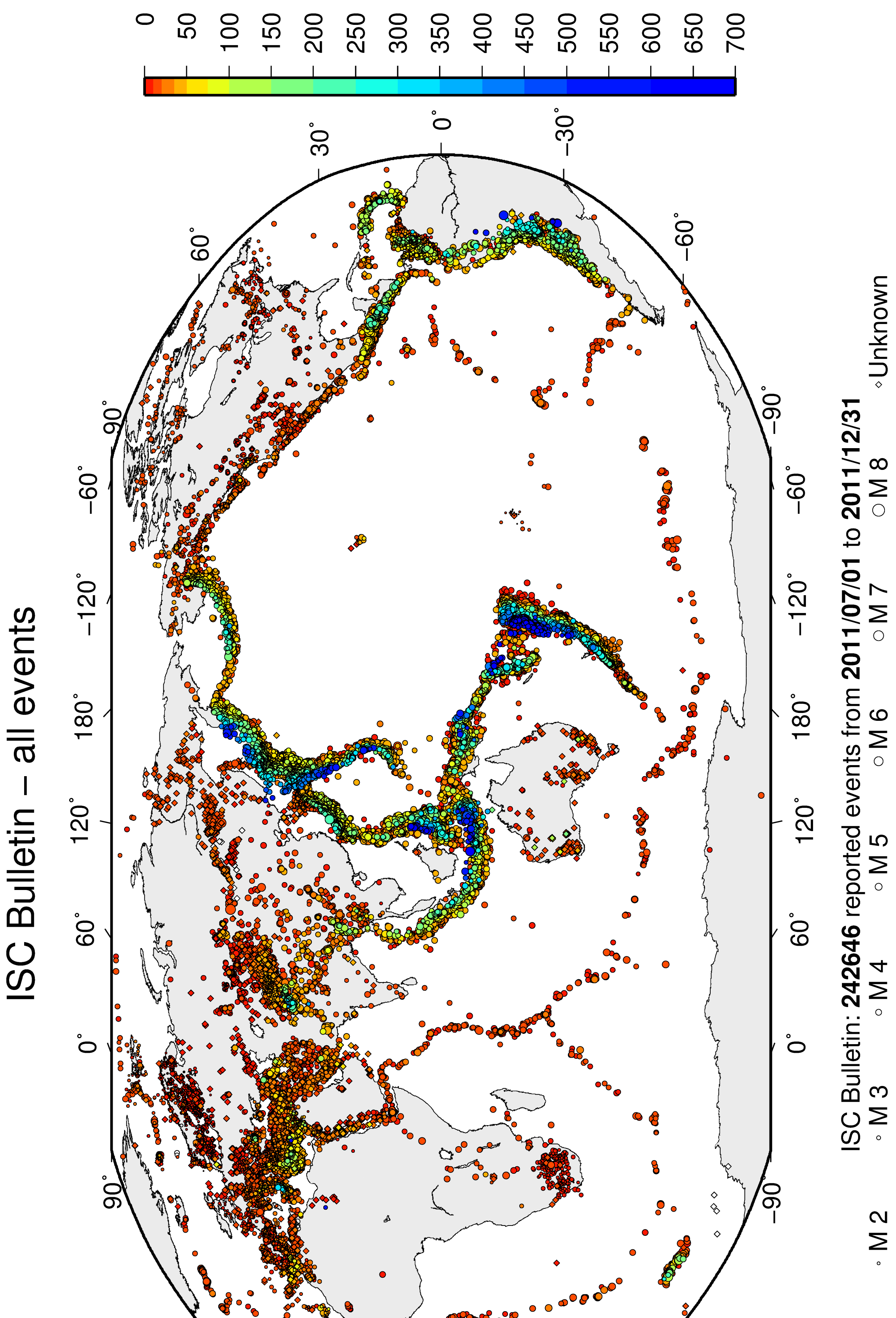


Figure 8.2: *Map of all events in the ISC Bulletin. Prime hypocentre locations are shown. Compare with Figure 7.10.*

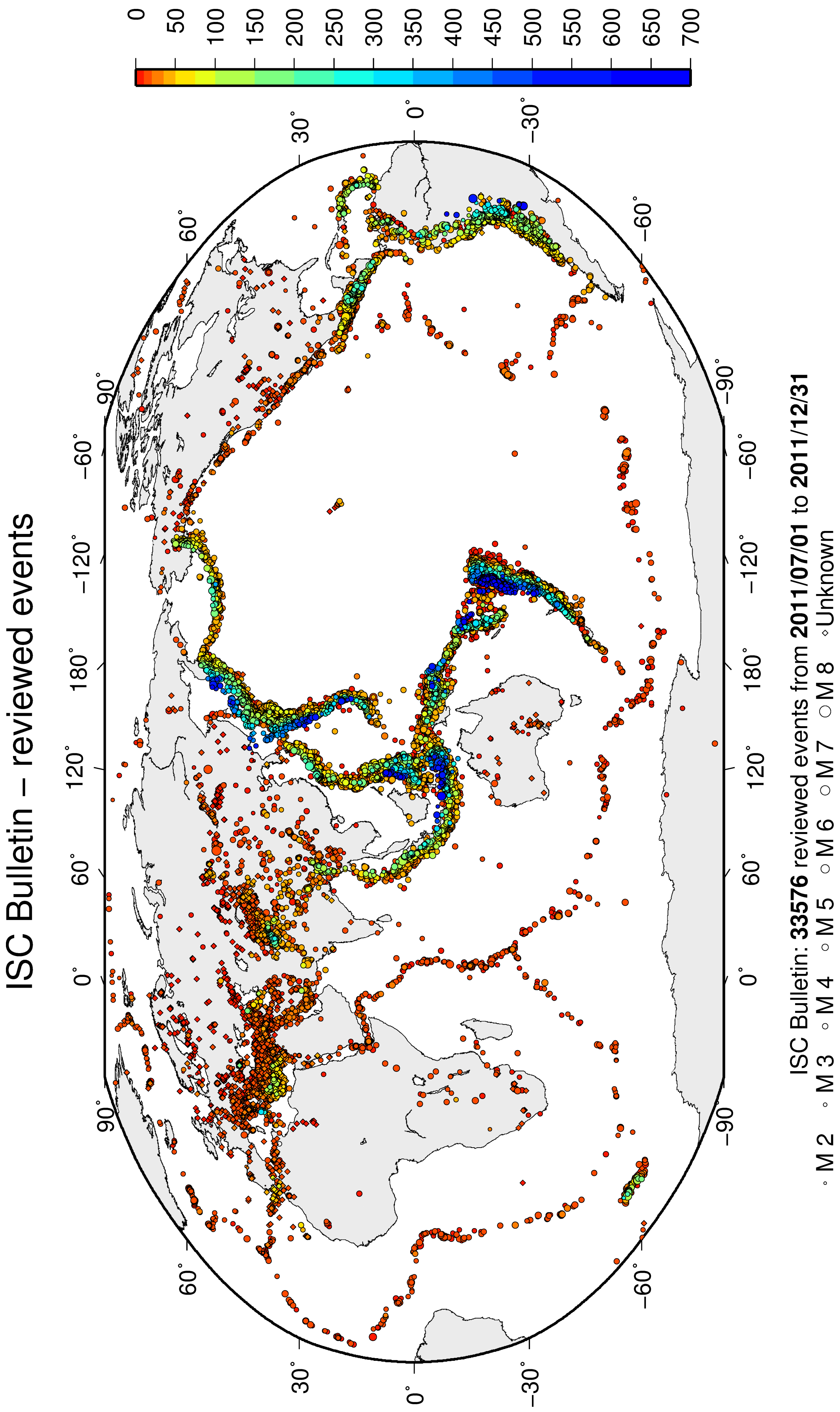


Figure 8.3: *Map of all events reviewed by the ISC for this time period. Prime hypocentre locations are shown.*

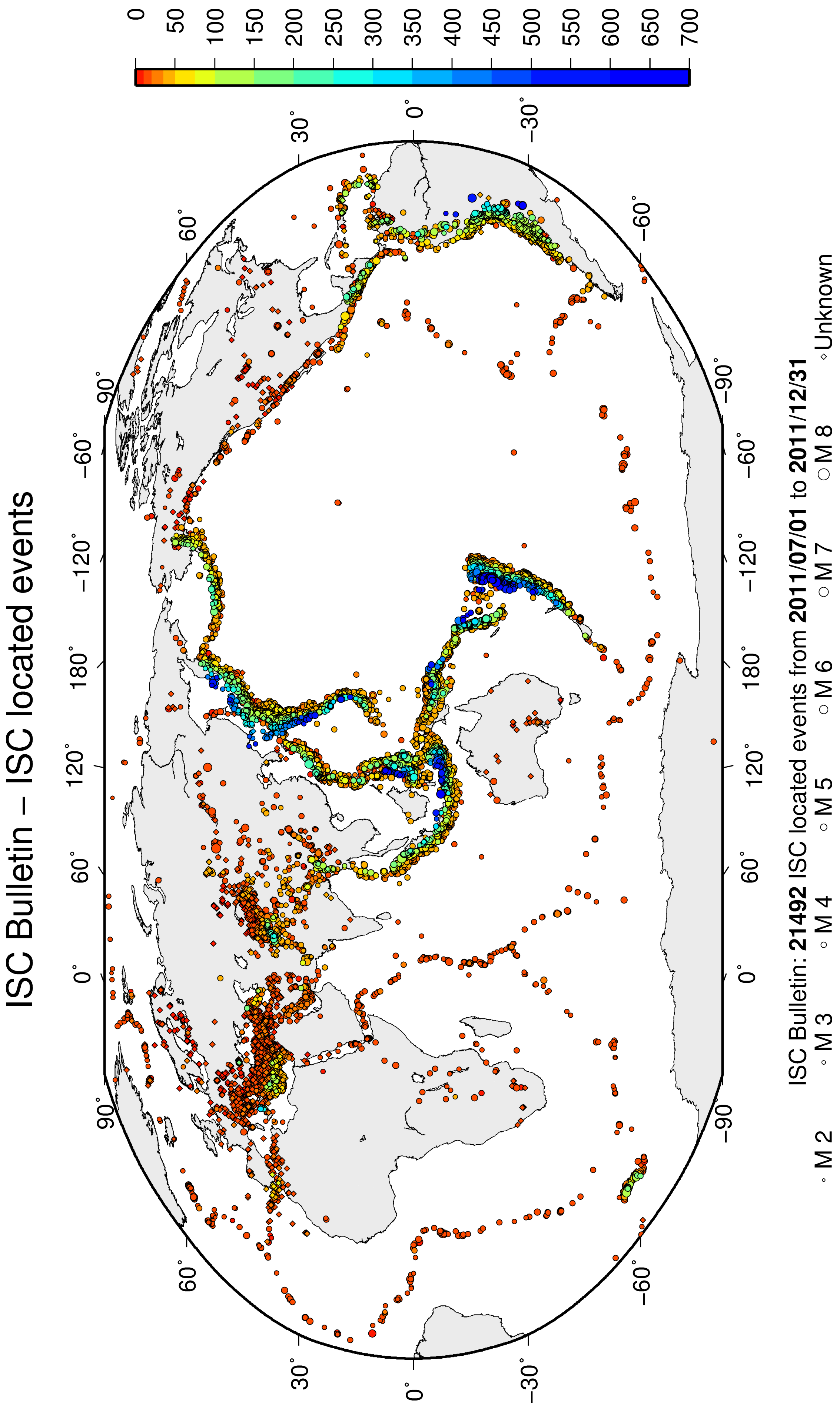


Figure 8.4: *Map of all events located by the ISC for this time period. ISC determined hypocentre locations are shown.*

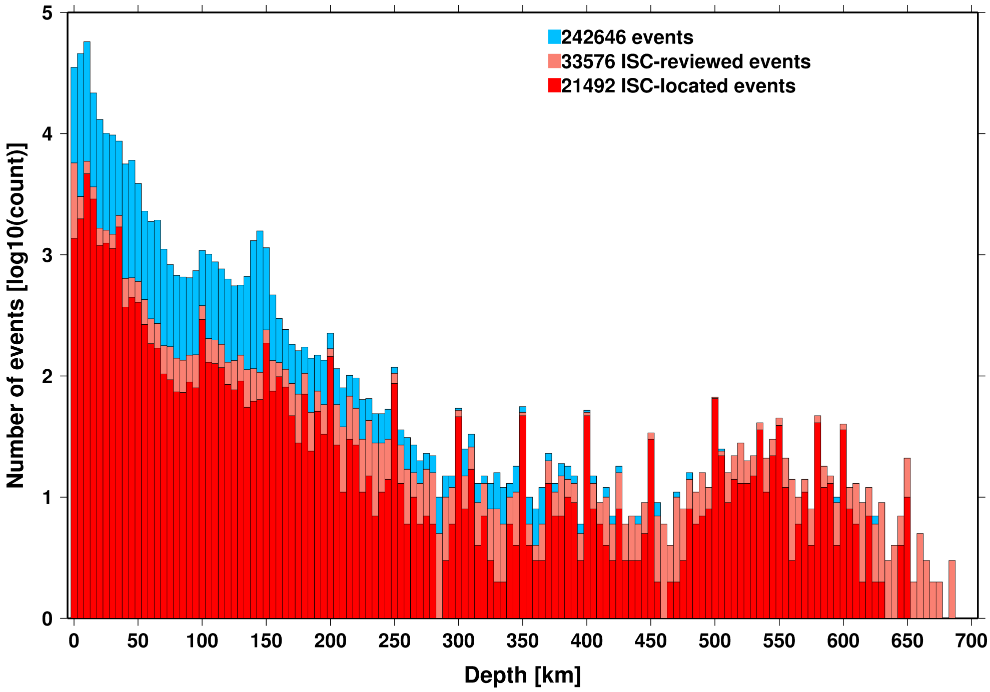


Figure 8.5: *Distribution of event depths in the ISC Bulletin (blue) and for the ISC-reviewed (pink) and the ISC-located (red) events during the summary period. All ISC-located events are reviewed, but not all reviewed events are located by the ISC. The vertical scale is logarithmic.*

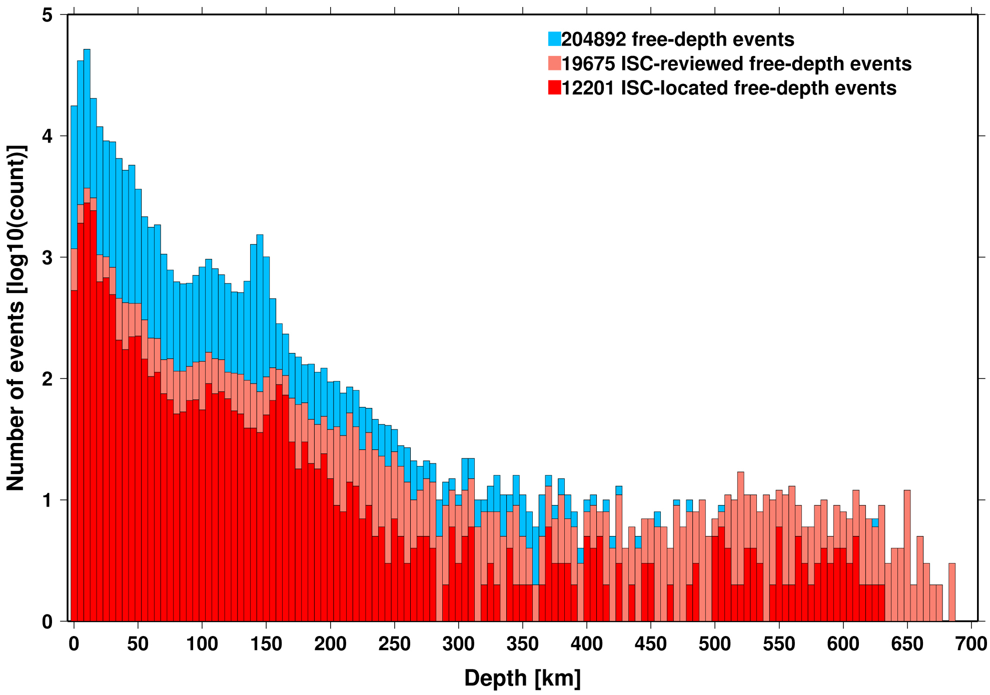


Figure 8.6: *Hypocentral depth distribution of events where the prime hypocentres are reported/located with a free-depth solution in the ISC Bulletin. The vertical scale is logarithmic.*

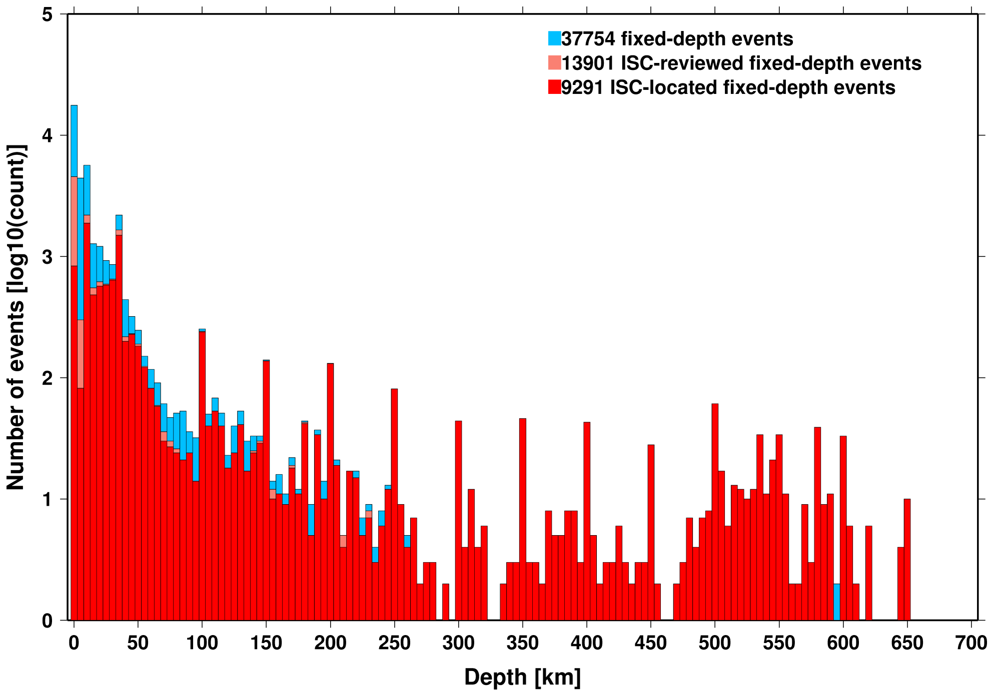


Figure 8.7: *Hypocentral depth distribution of events where the prime hypocentres are reported/located with a fixed-depth solution in the ISC Bulletin. The vertical scale is logarithmic.*

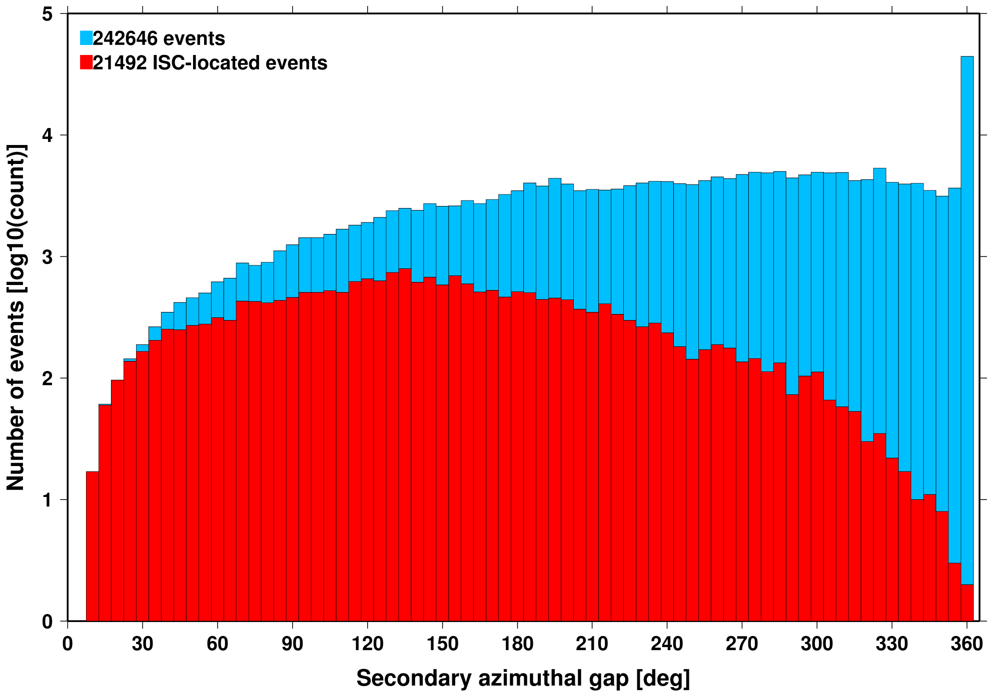


Figure 8.8: *Distribution of secondary azimuthal gap for events in the ISC Bulletin (blue) and those selected for ISC location (red). The vertical scale is logarithmic.*

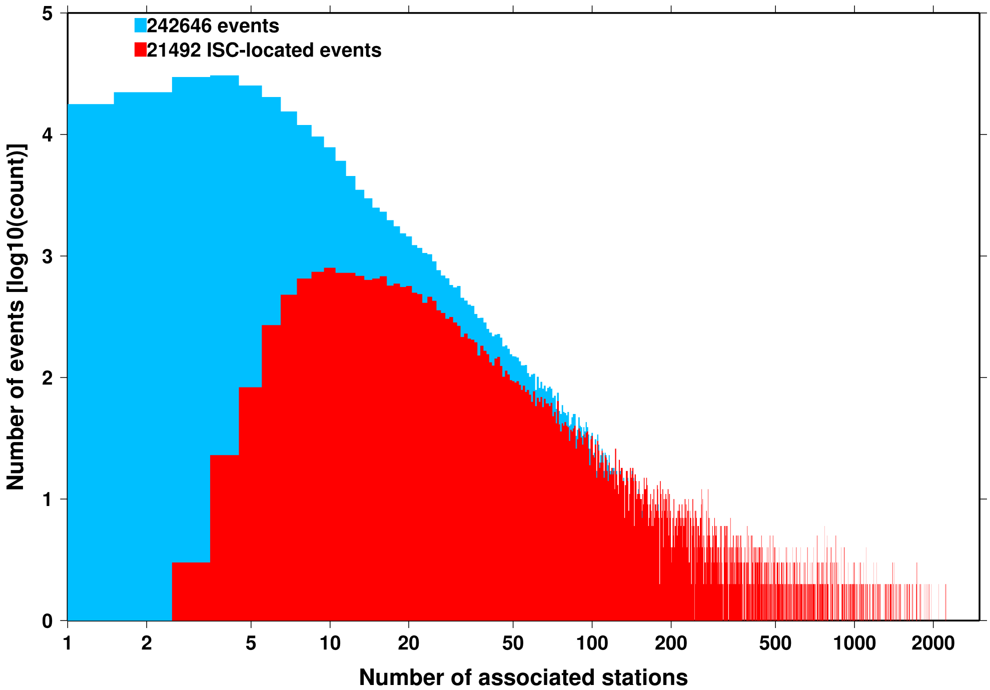


Figure 8.9: *Distribution of the number of associated stations for events in the ISC Bulletin (blue) and those selected for ISC location (red). The vertical scale is logarithmic.*

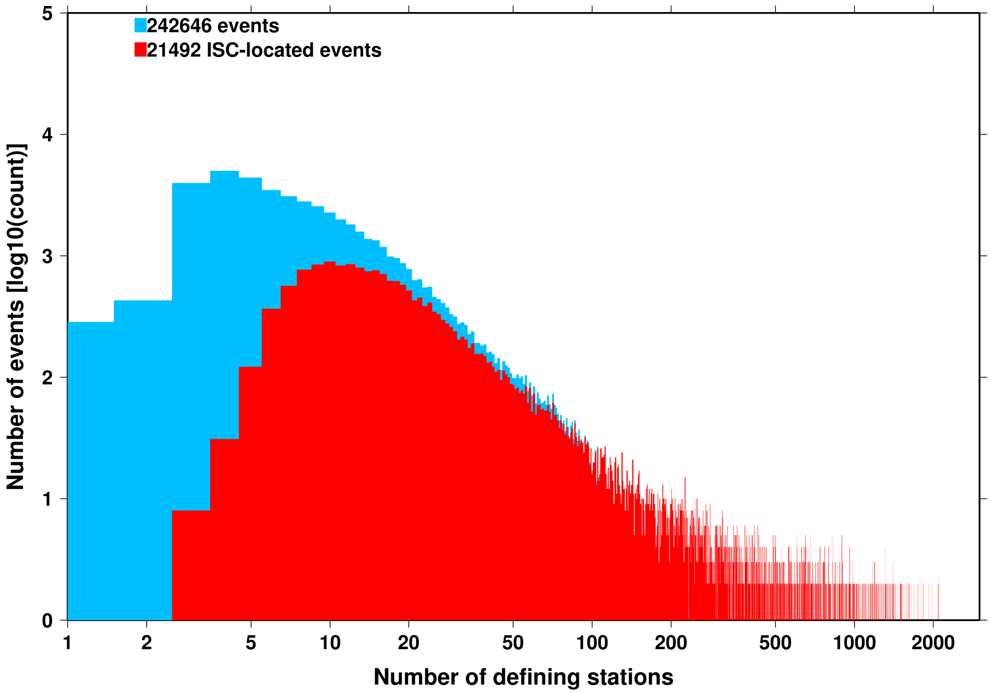


Figure 8.10: *Distribution of the number of defining stations for events in the ISC Bulletin (blue) and those selected for ISC location (red). The vertical scale is logarithmic.*

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 146 km^2, 90% of the events have an error ellipse area less than 930 km^2, and 95% of the events have an error ellipse area less than 1500 km^2.

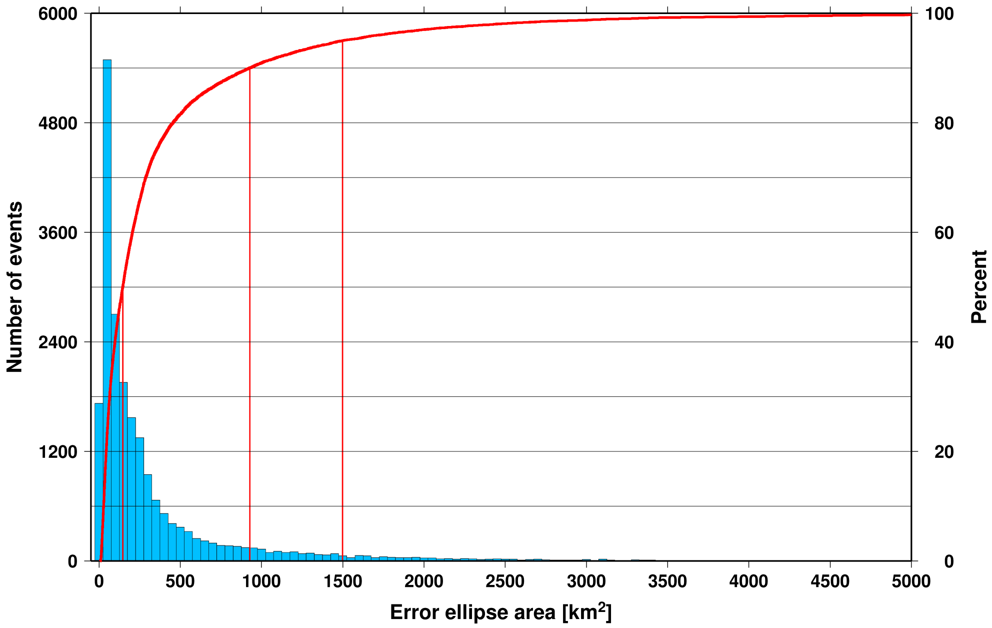


Figure 8.11: *Distribution of the area of the 90% confidence error ellipse of the ISC-located events. Vertical red lines indicate the 50th, 90th and 95th percentile values.*

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.

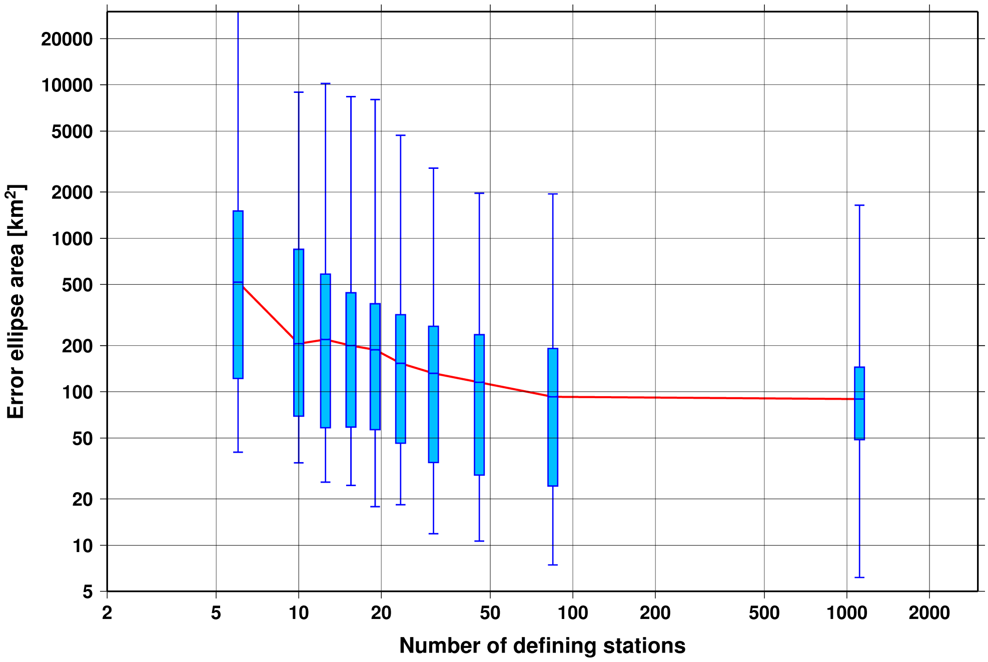


Figure 8.12: *Box-and-whisker plot of the area of the 90% confidence error ellipse of the ISC-located events as a function of the number of defining stations. Each box represents one-tenth-worth of the total number of data. The red line indicates the median 90% confidence error ellipse area.*

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.

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 21492 ISC located events.*

Phase	Number of 'defining' phases	Number of events	Max per event	Median per event
P	877193	12610	2550	10
Pn	489092	19790	950	11
Sn	163715	17466	288	5
Pg	136762	9663	157	12
Pb	114402	11437	121	6
Sg	94251	9417	157	6
PKPdf	83119	4691	969	2
Sb	81204	11455	115	5
S	36795	3526	413	4
PKPbc	34827	4083	260	2
PKPab	23269	3120	274	2
PcP	14984	3512	175	2

Table 8.1: *(continued)*

Phase	Number of 'defining' phases	Number of events	Max per event	Median per event
pP	14213	1647	425	3
Pdif	12433	1002	483	2
PP	12080	2058	166	2
PKiKP	8612	1056	437	2
SS	6100	1649	68	2
ScP	4951	1180	203	2
sP	4449	1230	61	2
SKSac	3204	712	84	2
PKKPbc	2509	399	74	3
ScS	1875	920	50	1
SnSn	1720	777	12	2
PnPn	1653	785	20	1
pPKPdf	1384	415	59	2
SKPbc	1247	301	44	2
PcS	946	719	7	1
SKSdf	866	580	12	1
sS	829	424	20	1
SKKSac	813	567	17	1
PKSdf	773	561	9	1
P'P'df	766	151	33	3
PKKPdf	625	220	26	1
PKKPab	617	228	38	2
SKiKP	603	334	34	1
pPKPab	472	190	35	1
pPKPbc	469	234	16	1
PS	446	115	38	2
SKPab	406	156	41	1
PnS	304	154	11	1
Sdif	284	137	22	1
SP	268	79	20	1
sPKPdf	204	107	19	1
SKPdf	187	53	20	1
SKKPbc	130	34	25	2
sPKPbc	95	51	10	1
pPdif	78	20	12	2
pS	77	57	9	1
pPKiKP	45	23	9	1
SPn	33	18	7	1
sPKPab	33	24	5	1
P'P'ab	28	18	3	1
sPdif	25	8	13	1
SKKPab	20	10	5	2
SKKSdf	19	13	4	1
P'P'bc	12	10	2	1
PKSbc	12	6	4	2
sPKiKP	7	3	5	1
sSdif	7	4	4	1
SKKPdf	5	4	2	1
PbPb	4	4	1	1
S'S'ac	4	2	3	2
sSKSac	3	2	2	2
SbSb	3	3	1	1
pSKSdf	2	1	2	2
pPn	2	1	2	2
PKSab	2	2	1	1
PKKSdf	1	1	1	1
sPn	1	1	1	1
PKKSbc	1	1	1	1
pSKSac	1	1	1	1

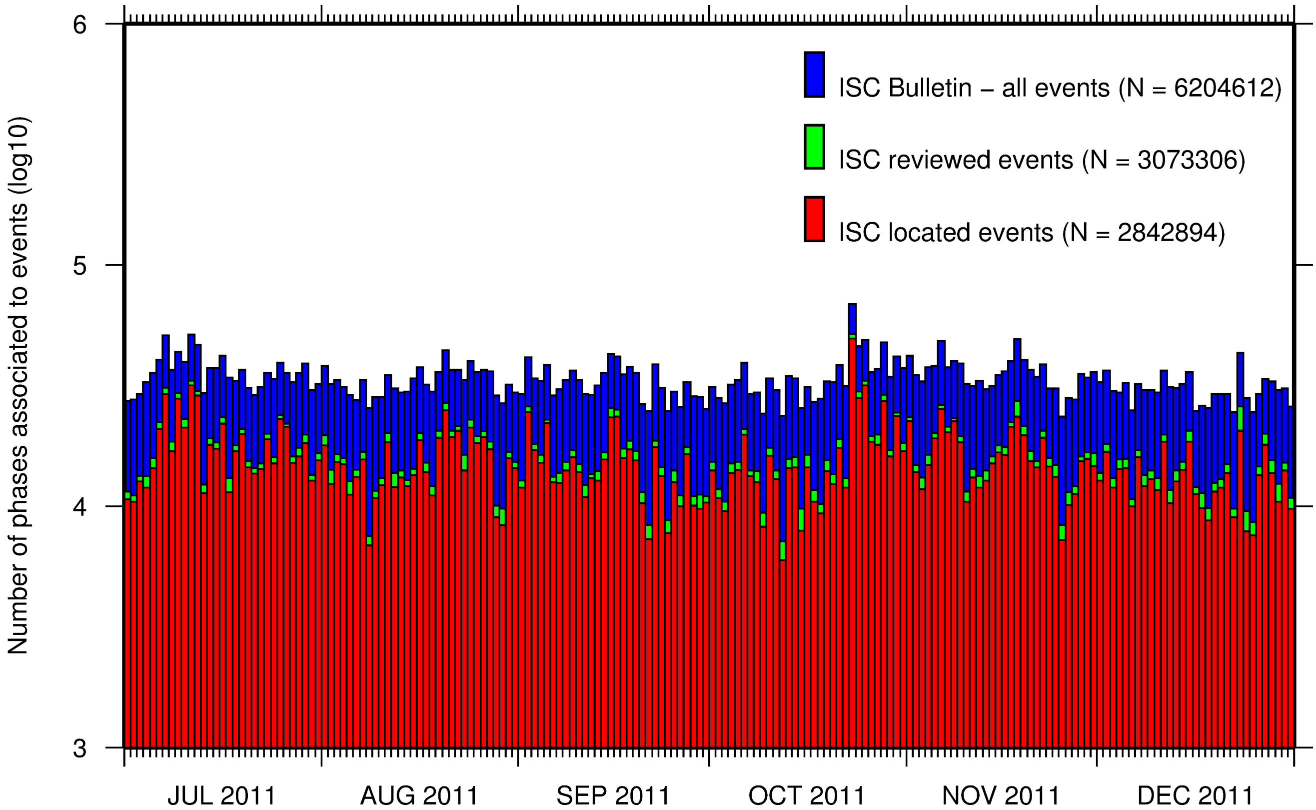


Figure 8.13: *Histogram showing the number of phases (N) that the ISC has associated to events within the ISC Bulletin for the current summary period.*

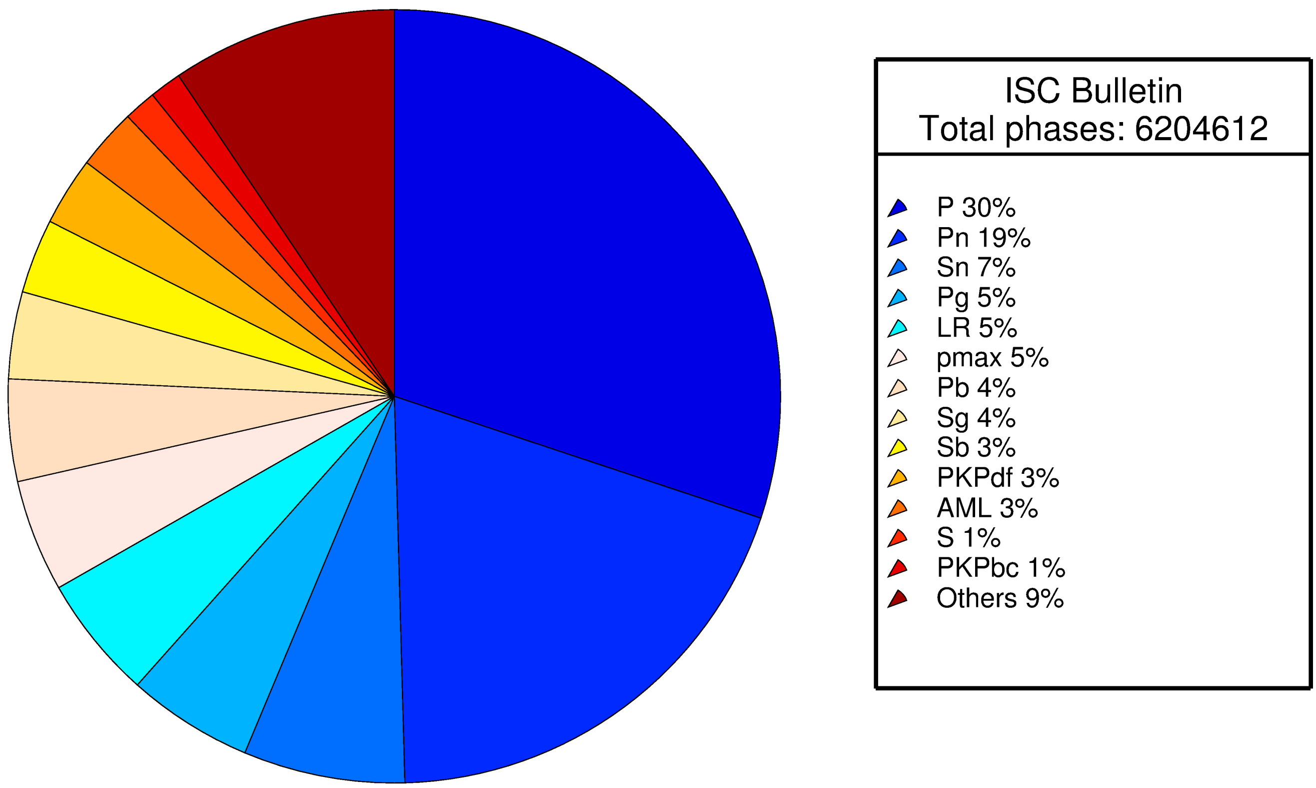


Figure 8.14: *Pie chart showing the fraction of various phase types in the ISC Bulletin for this summary period.*

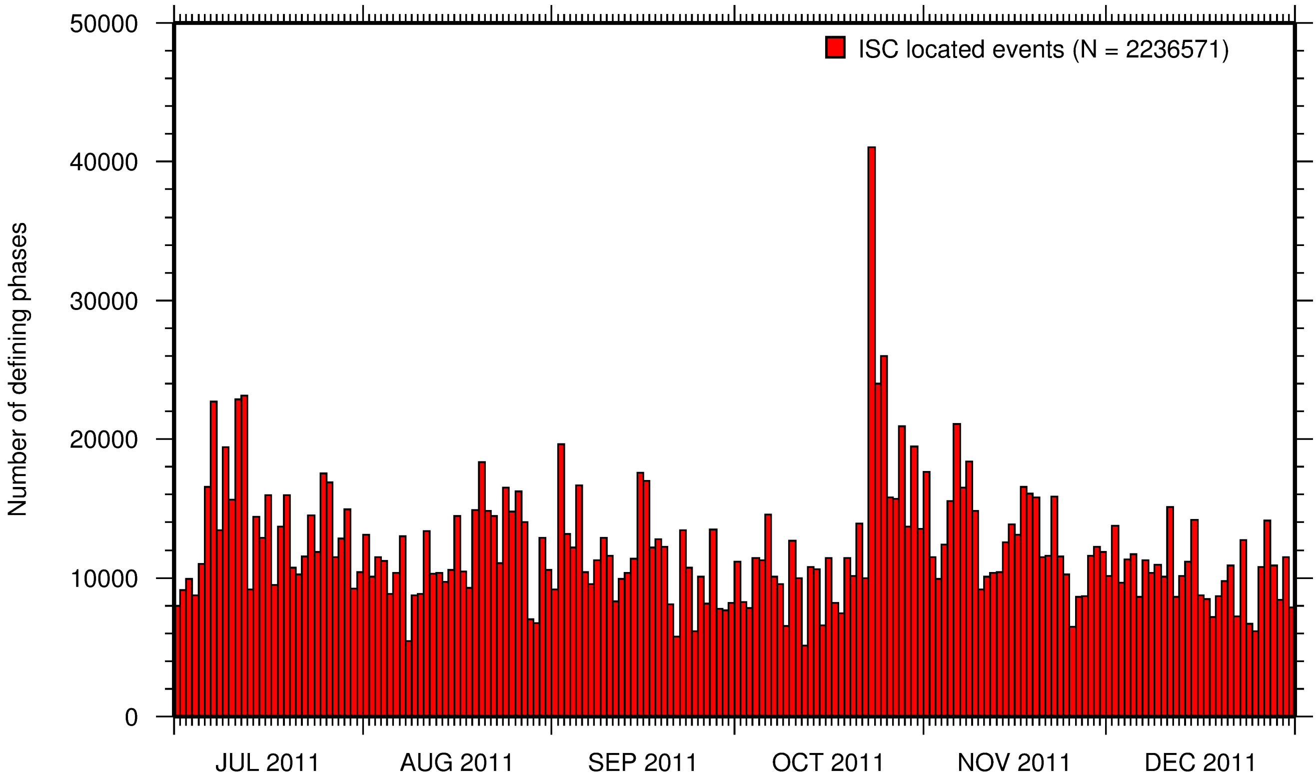


Figure 8.15: *Histogram showing the number of defining phases in the ISC Bulletin, for events located by the ISC.*

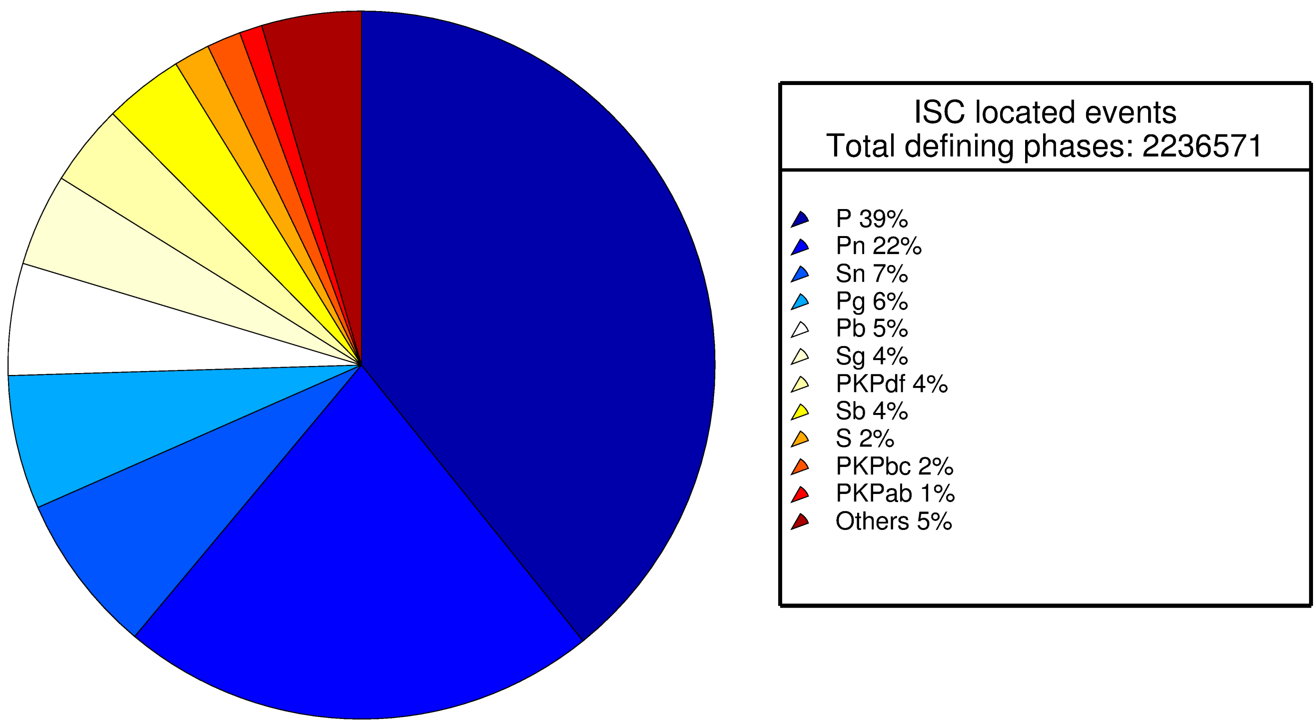


Figure 8.16: *Pie chart showing the defining phases in the ISC Bulletin, for events located by the ISC. A complete list of defining phases is shown in Table 8.1.*

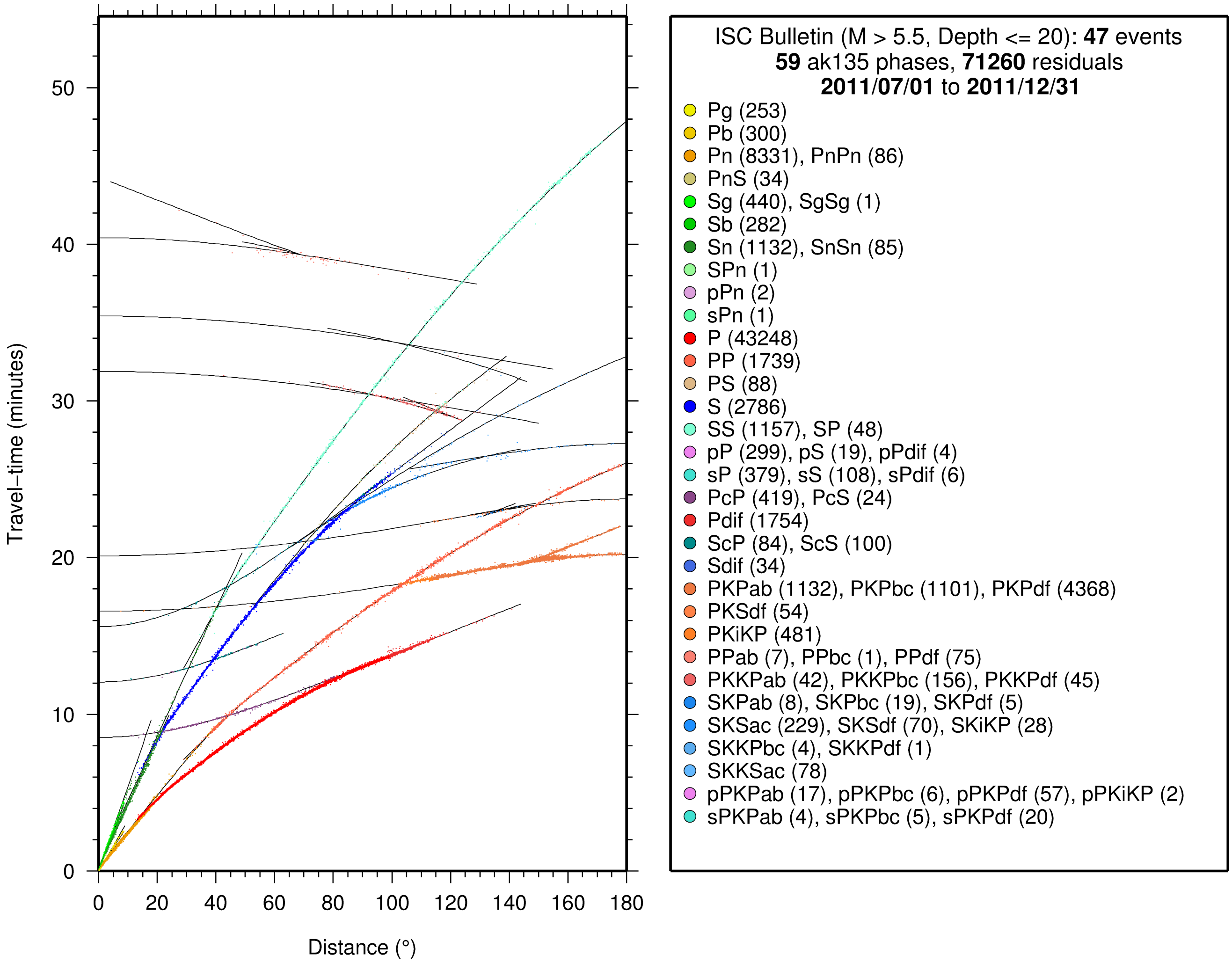


Figure 8.17: *Distribution of travel-time observations in the ISC Bulletin for events with M > 5.5 and depth less than 20 km. The travel-time observations are shown relative to a 0 km source and compared with the theoretical ak135 travel-time curves (solid lines). The legend lists the number of each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

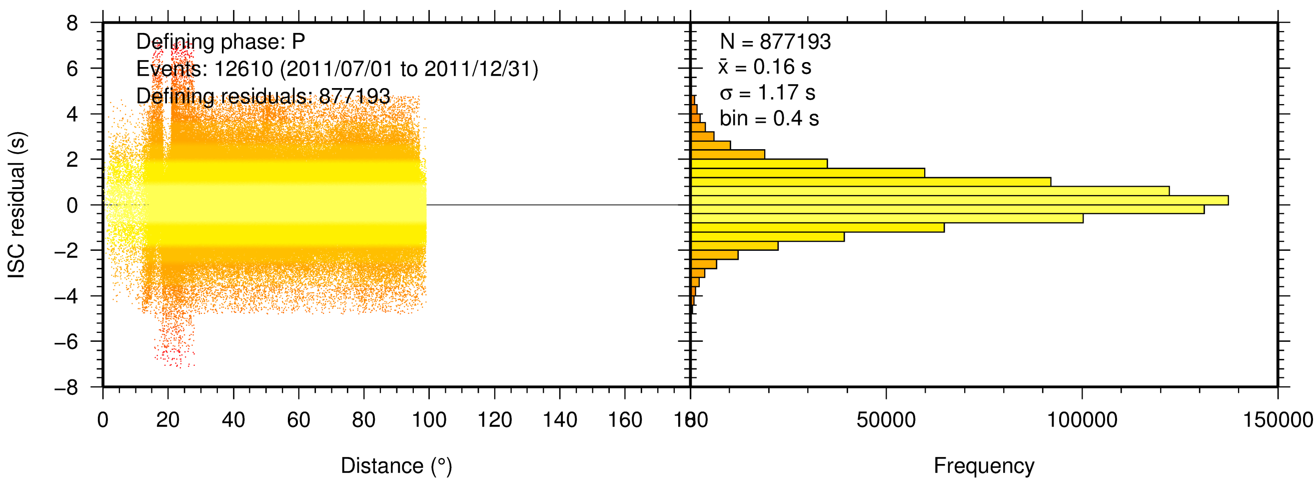


Figure 8.18: *Distribution of travel-time residuals for the defining P phases used in the computation of ISC located events in the Bulletin.*

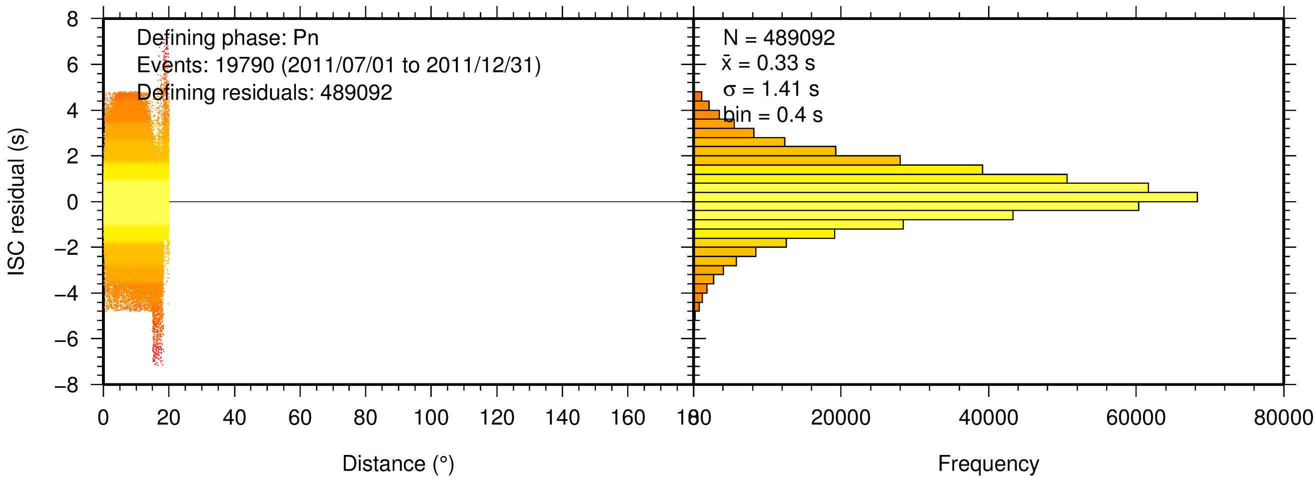


Figure 8.19: *Distribution of travel-time residuals for the defining Pn phases used in the computation of ISC located events in the Bulletin.*

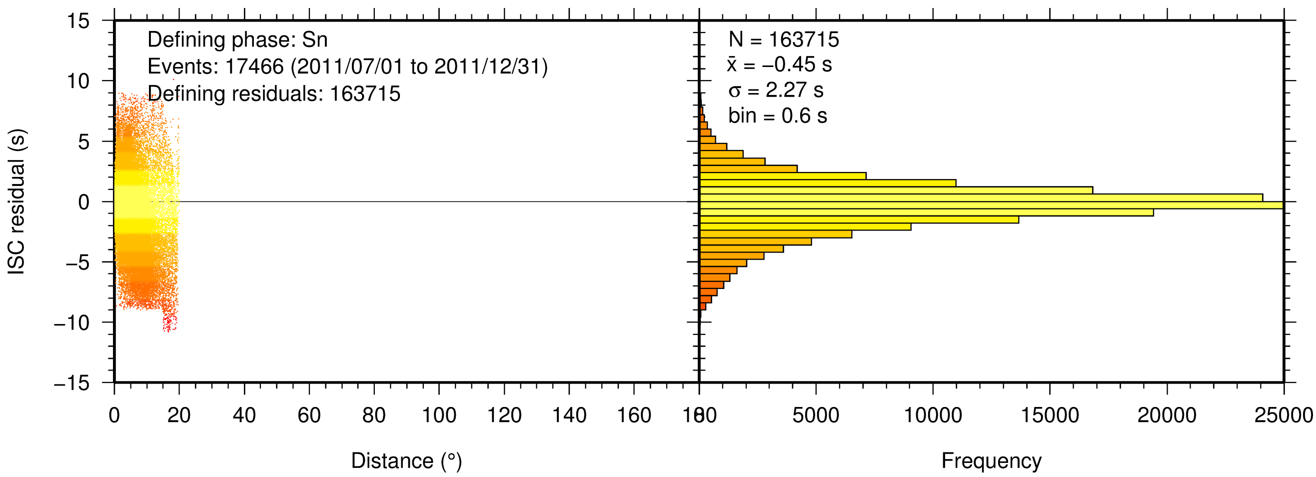


Figure 8.20: *Distribution of travel-time residuals for the defining Sn phases used in the computation of ISC located events in the Bulletin.*

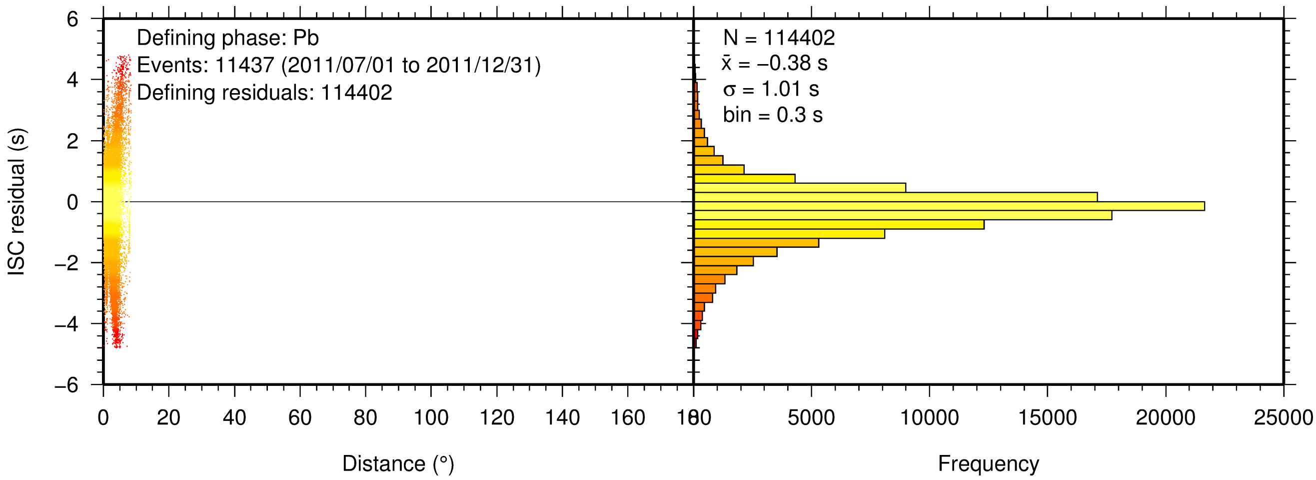


Figure 8.21: *Distribution of travel-time residuals for the defining Pb phases used in the computation of ISC located events in the Bulletin.*

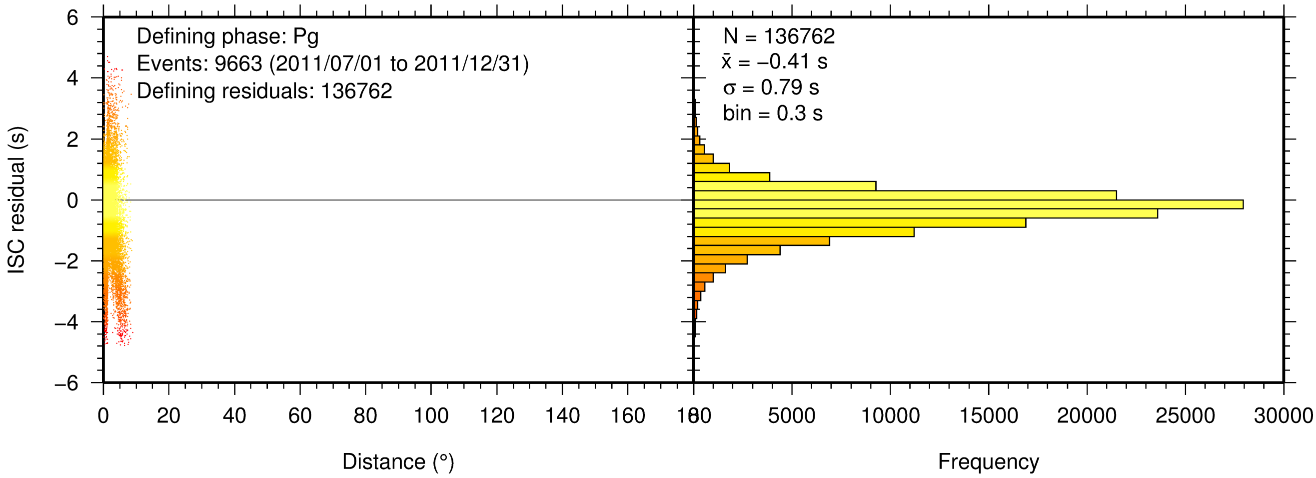


Figure 8.22: *Distribution of travel-time residuals for the defining Pg phases used in the computation of ISC located events in the Bulletin.*

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 1789982 (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 3.4 of the January-June 2011 Bulletin Summary). For each amplitude-period pair in a reading the ISC algorithm computes the magnitude (a reading can include several amplitude-period measurements) and the reading magnitude is assigned to the maximum A/T in the reading. If more than one reading magnitude is available for a station, the station magnitude is the median of the reading magnitudes. The network magnitude is computed then as the 20% alpha-trimmed median of the station magnitudes (at least three required). MS is computed for shallow earthquakes (depth $\leq$ 60 km) only and using amplitudes and periods on all three components (when available) if the period is within 10-60 s and the epicentral distance is between 20° and 160°. mb is computed also for deep earthquakes (depth down to 700 km) but only with amplitudes on the vertical component measured at periods $\leq$ 3 s in the distance range 21°-100°.

Table 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	132692	450774
Number of readings	115581	446980
Percentage of readings in the ISC located events with qualifying data for magnitude computation	14.4	49.4
Number of station magnitudes	106258	375384
Number of network magnitudes	3241	11198

A small percentage of the readings with qualifying data for MS and mb calculation have more than one amplitude-period pair. Notably, only 14% of the readings for the ISC located (shallow) events included qualifying data for MS computation, whereas for mb the percentage is much higher at 49%. This is due to the seismological practice of reporting agencies. Agencies contributing systematic reports of amplitude and period data are listed in Appendix Table 10.3. Obviously the ISC Bulletin would benefit if more agencies included surface wave amplitude-period data in their reports.

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

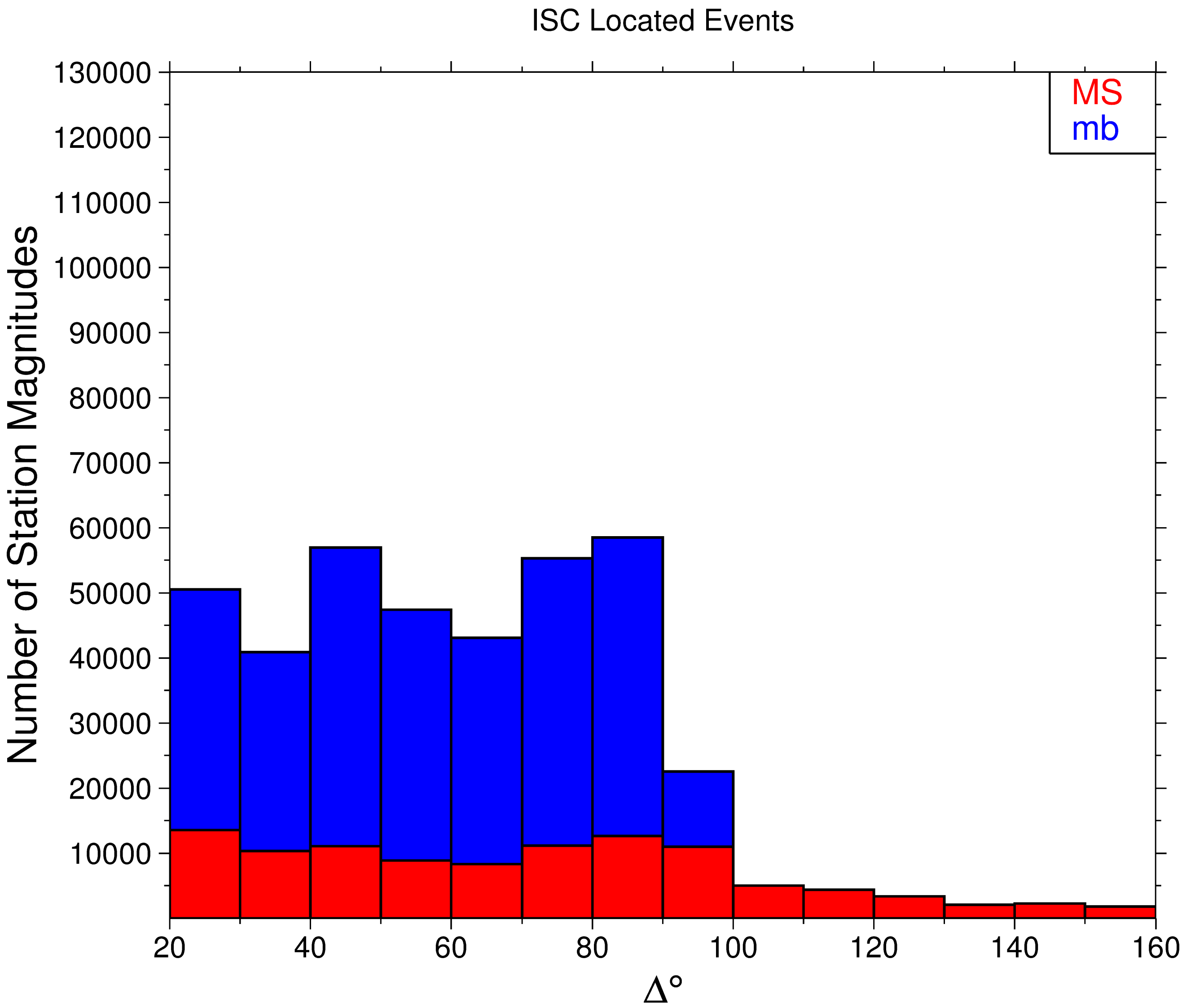


Figure 8.23: *Distribution of the number of station magnitudes computed by the ISC Locator for mb (blue) and MS (red) versus distance.*

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.

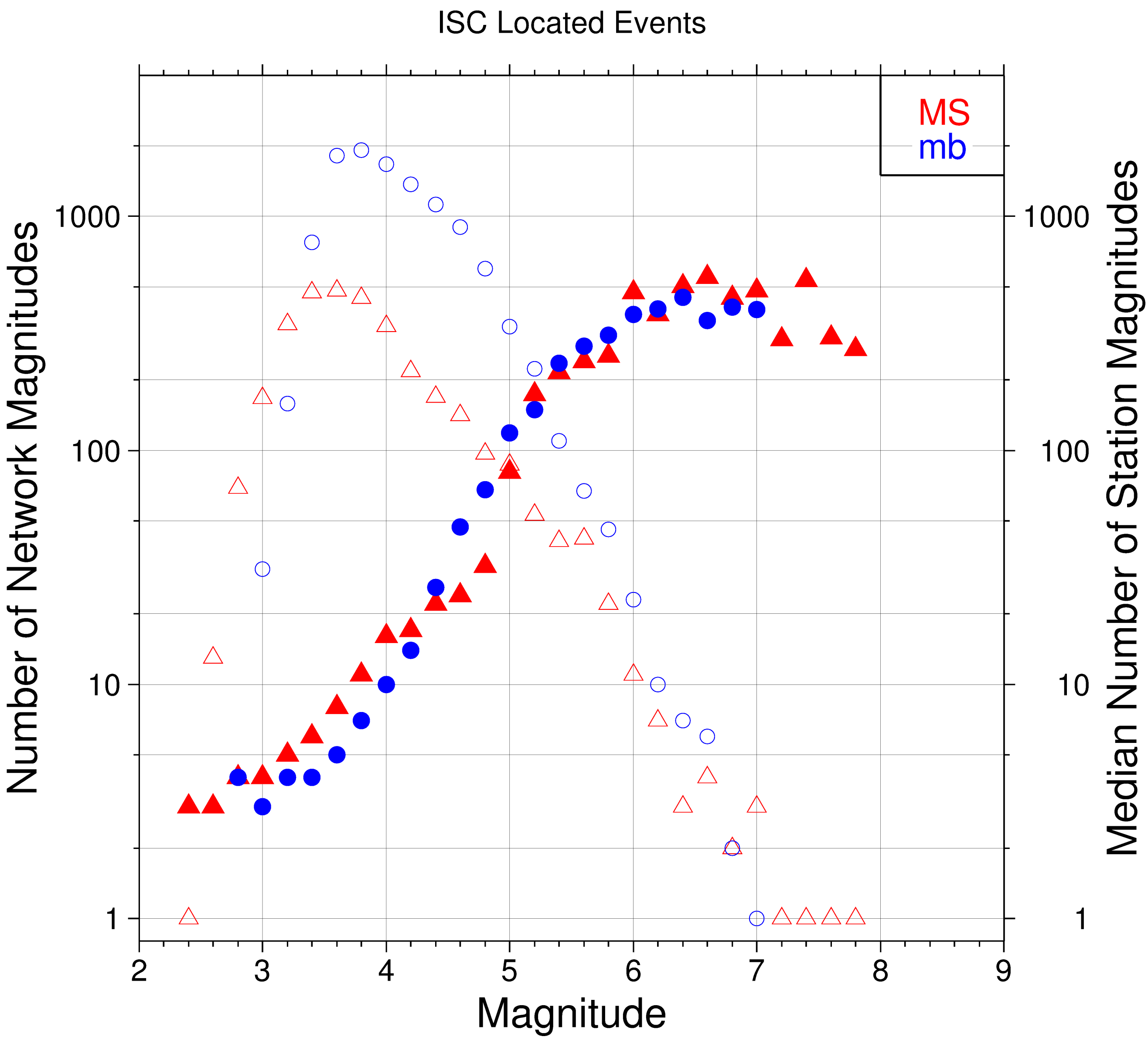


Figure 8.24: *Number of network magnitudes (open symbols) and median number of stations magnitudes (filled symbols). Blue circles refer to mb and red triangles to MS. The width of the magnitude interval* δM *is 0.2, and each symbol includes data with magnitude in* $M \pm \delta M/2$*.*

8.4 Completeness of the ISC Bulletin

The completeness of the ISC Bulletin can be expressed as a magnitude value, above which we expect the Bulletin to contain 100% of events. This magnitude of completeness, M_C can be measured as the point where the seismicity no longer follows the Gutenberg-Richter relationship. We compute an estimate of M_C using the maximum curvature technique of *Woessner and Wiemer* (2005).

The completeness of the ISC Bulletin for this summary period is shown in Figure 8.25. A history of completeness for the ISC Bulletin is shown in Figure 8.26. The step change in 1996 corresponds with the inclusion of the Prototype IDC (EIDC) Bulletin, followed by the Reviewed Event Bulletin (REB) of the IDC.

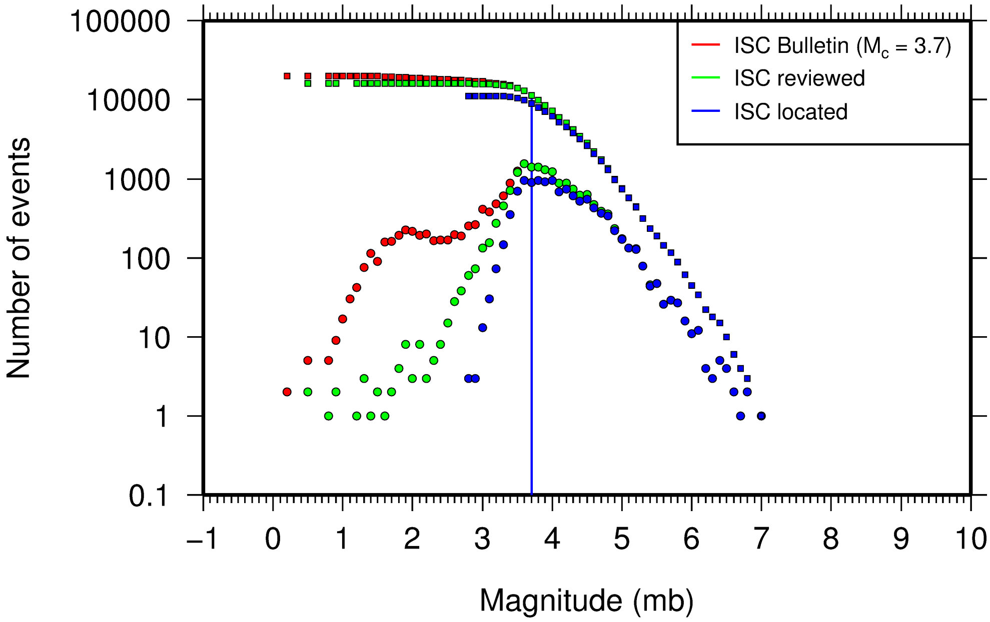


Figure 8.25: *Frequency and cumulative frequency magnitude distribution for all events in the ISC Bulletin, ISC reviewed events and events located by the ISC. The magnitude of completeness (M_C) is shown for the ISC Bulletin. Note: only events with values of mb are represented in the figure.*

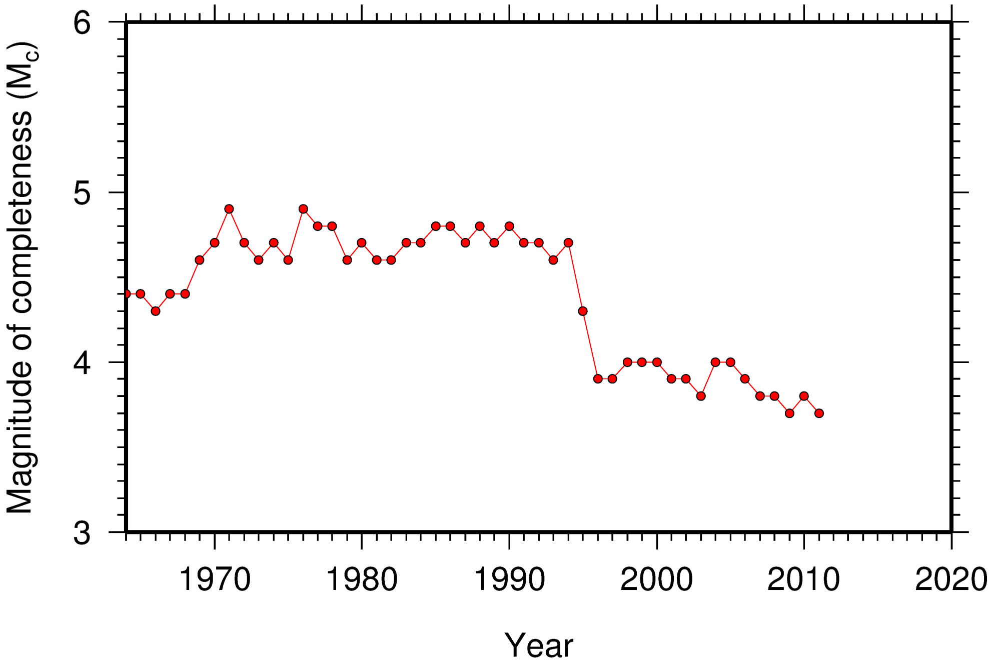


Figure 8.26: *Variation of magnitude of completeness (M_C) for each year in the ISC Bulletin. Note: M_C is calculated only using those events with values of mb.*

8.5 Magnitude Comparisons

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

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

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

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

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

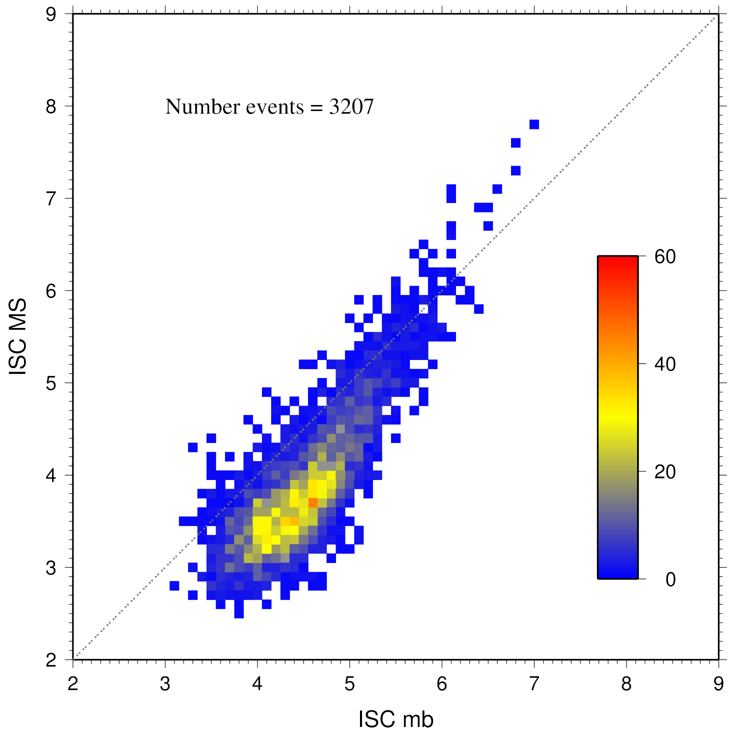


Figure 8.27: *Comparison of ISC values of MS with mb for common event pairs.*

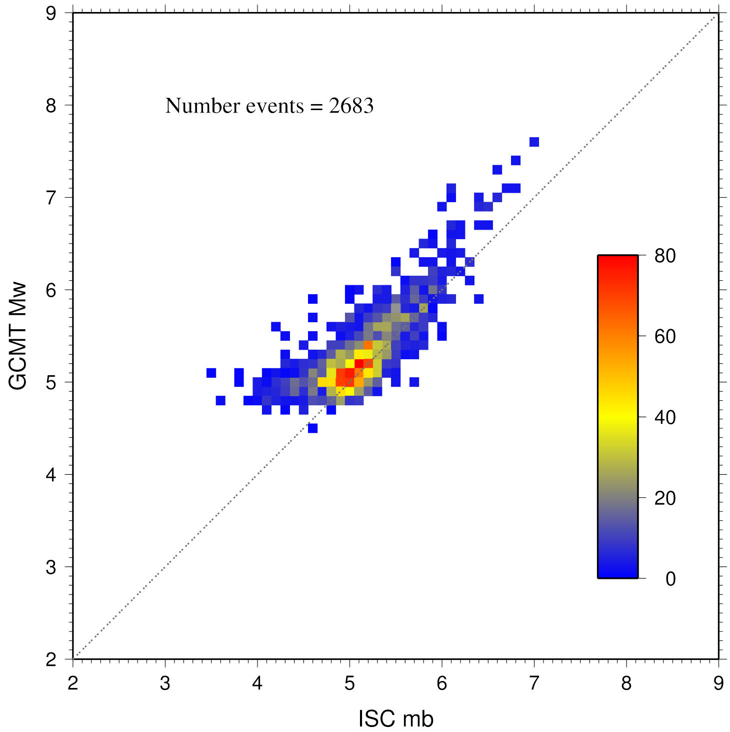


Figure 8.28: *Comparison of ISC values of mb with GCMT M_W for common event pairs.*

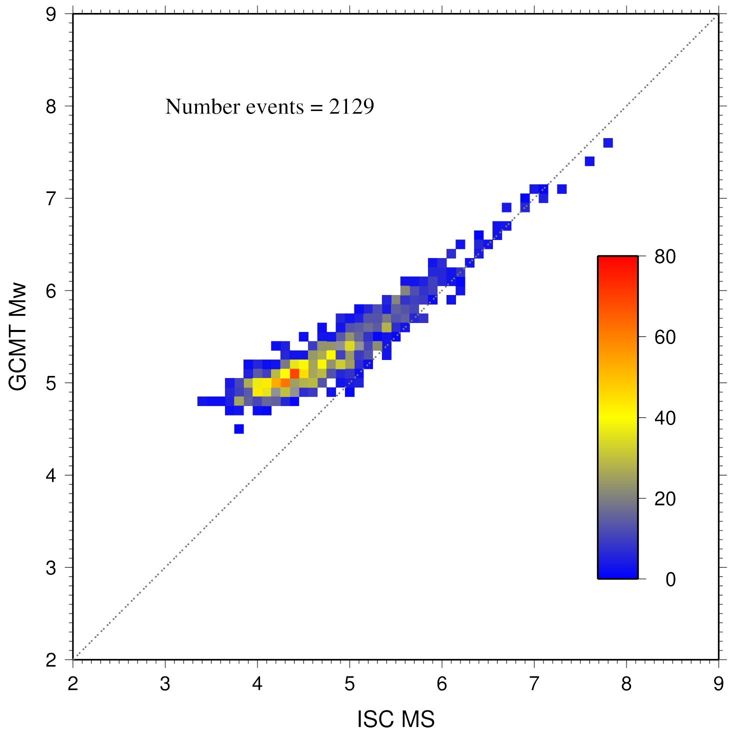
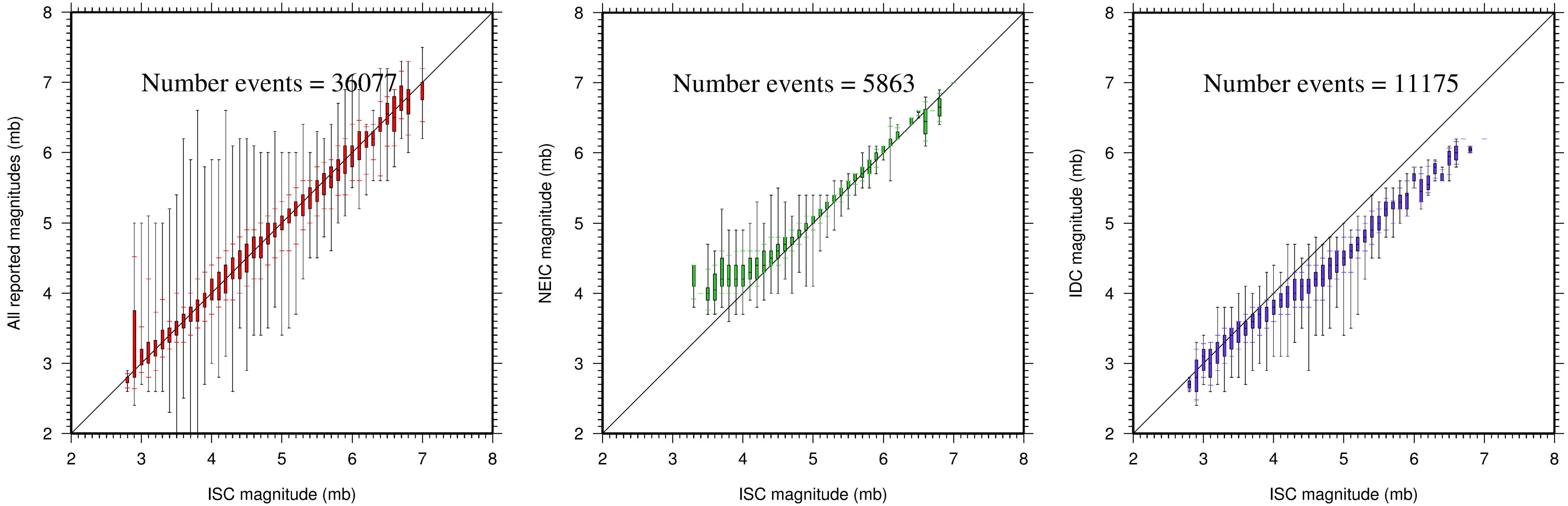


Figure 8.29: *Comparison of ISC values of MS with GCMT M_W for common event pairs.*



(a) (b) (c)

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

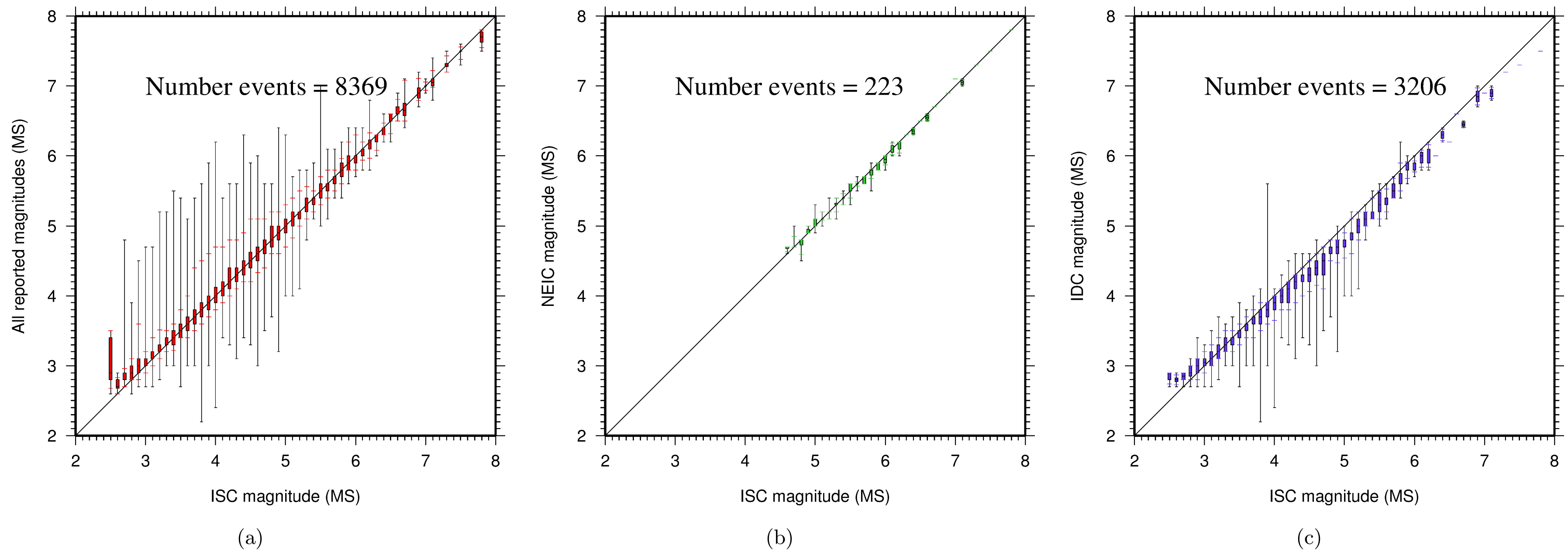


Figure 8.31: *Comparison of ISC magnitude data (MS) with additional agency magnitudes (MS). The statistical summary is shown in the box-and-whisker plots where the 10th and 90th percentiles are shown in addition to the max and min values. (a): All magnitudes reported; (b): NEIC magnitudes; (c): IDC magnitudes.*

9

The Leading Data Contributors

For the current six-month period, 130 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, MOS, BJI, USArray, 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 JMA, NEIC, IDC, CSEM and several others are also acknowledged with respect to smaller seismic events. The contributions of JMA, CSEM 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. Similarly, the CSEM communicates contributions of many tens of European and Mediterranean networks a few of which the ISC does not always receive directly. 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 and Saudia Arabia 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 75% 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.

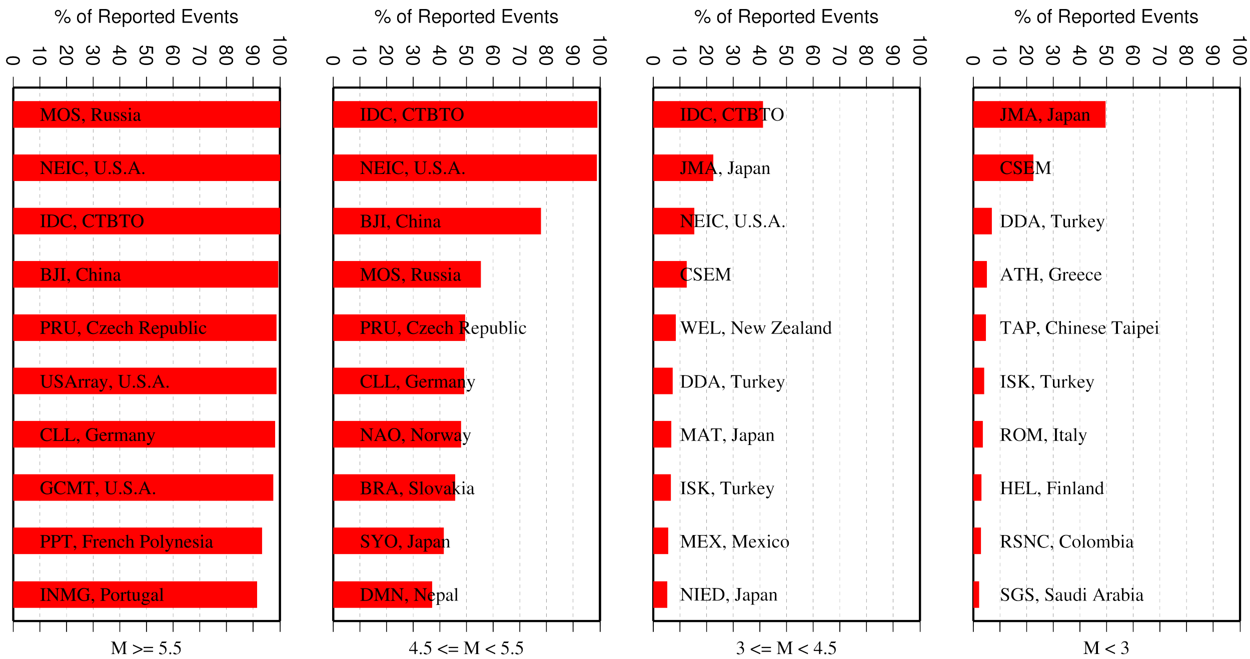


Figure 9.1: *Frequency of events in the ISC Bulletin for which an agency reported at least one item of data: a moment tensor, a hypocentre, a station arrival time or an amplitude. The top ten agencies are shown for four magnitude intervals.*

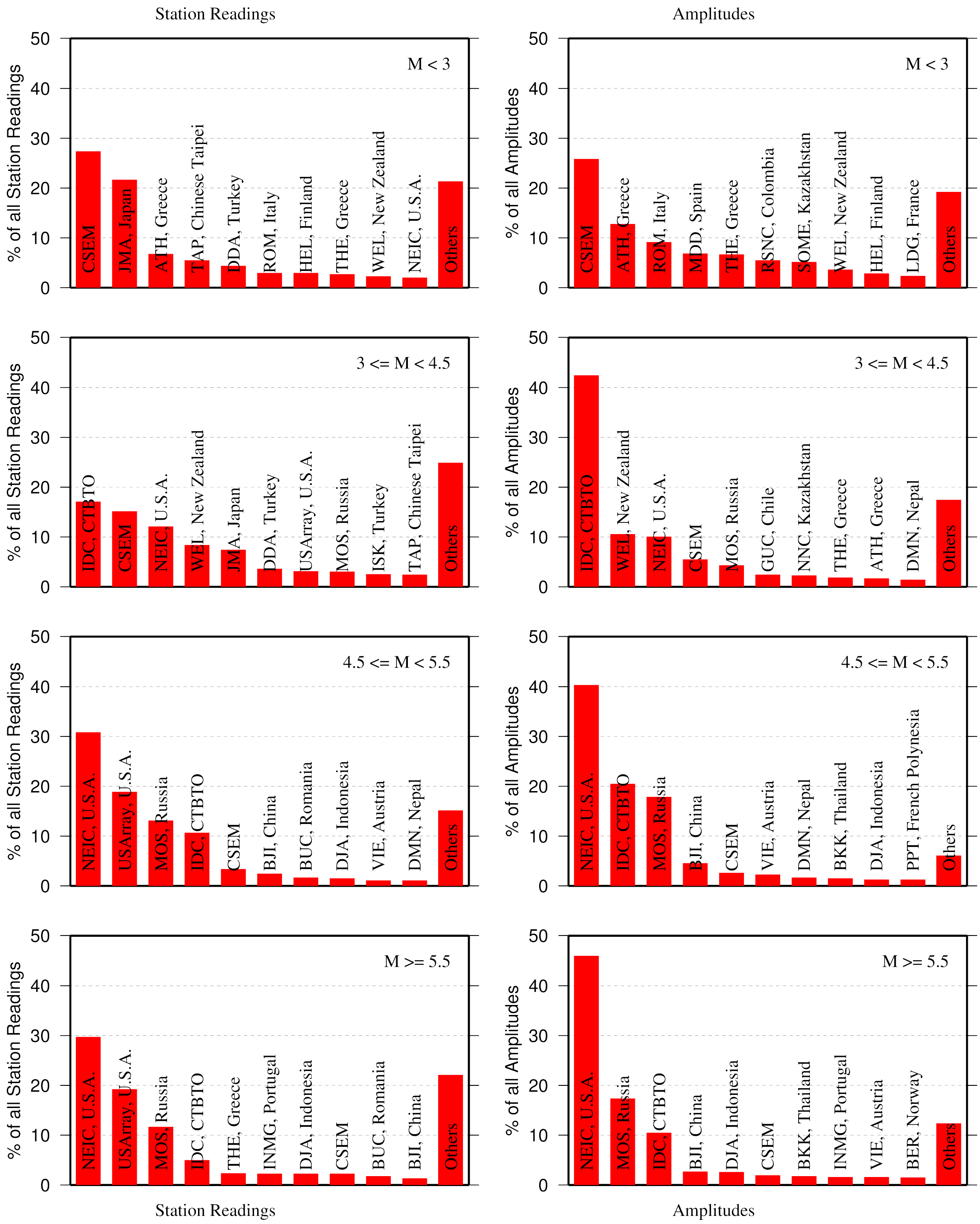


Figure 9.2: *Contributions of station arrival time readings (left) and amplitudes (right) of agencies to the ISC Bulletin. Top ten agencies are shown for four magnitude intervals.*

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 $\sim$ 35% of those events as their mission requires them to report events above magnitude 4.5 outside the United States of America. For other agencies reporting distant events it is an extra effort that they undertake to notify their governments and relief agencies as well as to help the ISC and academic research in general. Hence these agencies usually report on the larger magnitude events. BJI, NAO, MOS, CLL, PRU, BRA, SYO AND PPT each reported individual station arrivals for several percent of all relevant events. We encourage other agencies to report distant events to us.

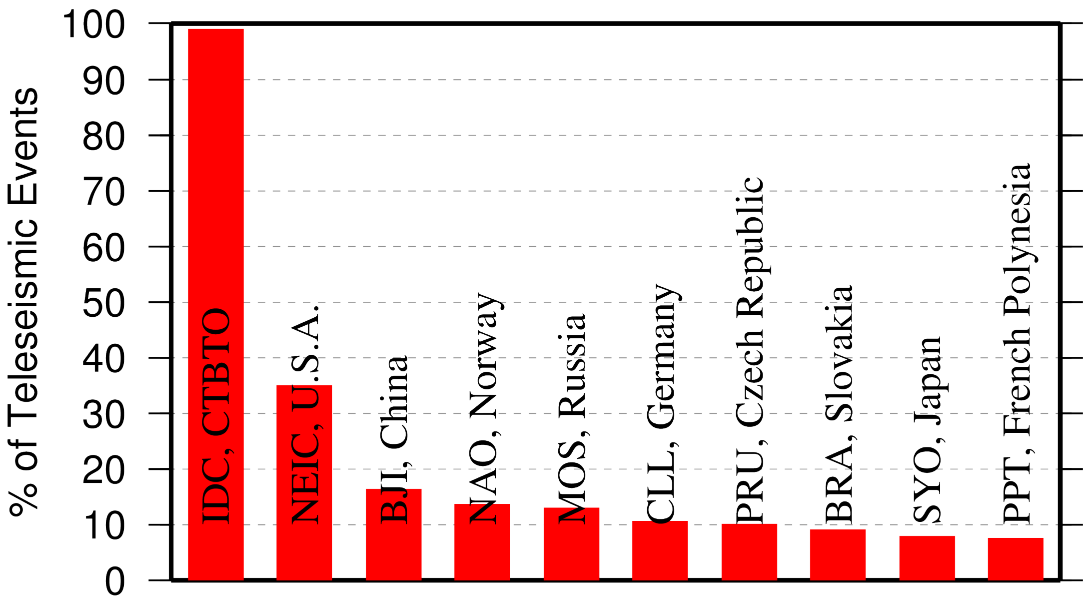


Figure 9.3: *Top ten agencies that reported teleseismic phase arrivals for a large portion of ISC events.*

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

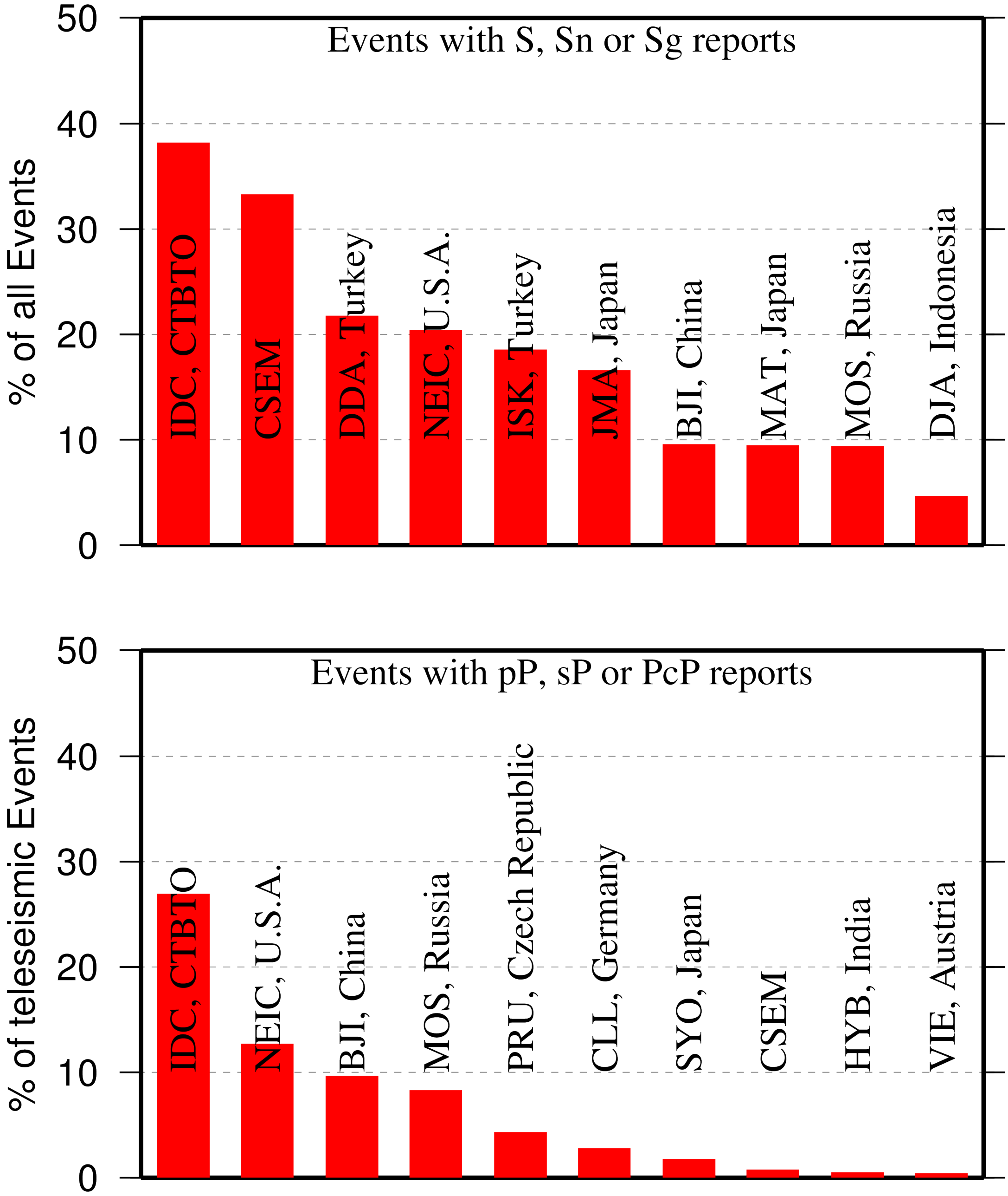


Figure 9.4: *Top ten agencies that reported secondary phases important for an accurate epicentre location (top) and focal depth determination (bottom).*

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

Notably, the IDC reports almost 100% of all events for which MS and mb are estimated. This is due to the standard routine that requires determination of body and surface wave magnitudes useful for discrimination purposes. NEIC, MOS, BJI, NAO, PRU 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.

Since the ISC does not routinely process waveforms, we rely on other agencies to report moment magnitudes as well as moment tensor determinations (Figure 9.6).

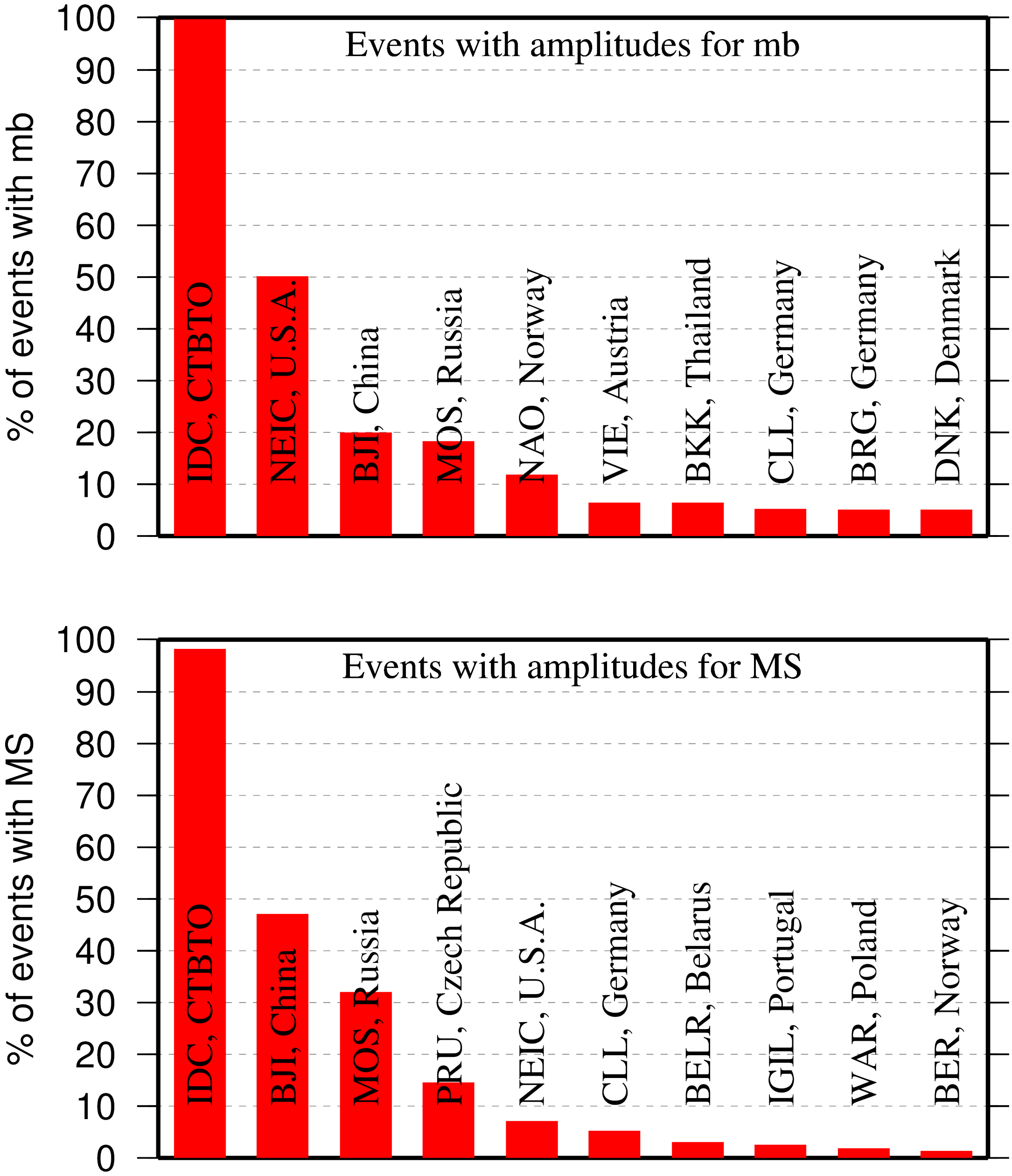


Figure 9.5: *Agencies that report defining body (top) and surface (bottom) wave amplitudes and periods for the largest fraction of those ISC Bulletin events with MS/mb determinations.*

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

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

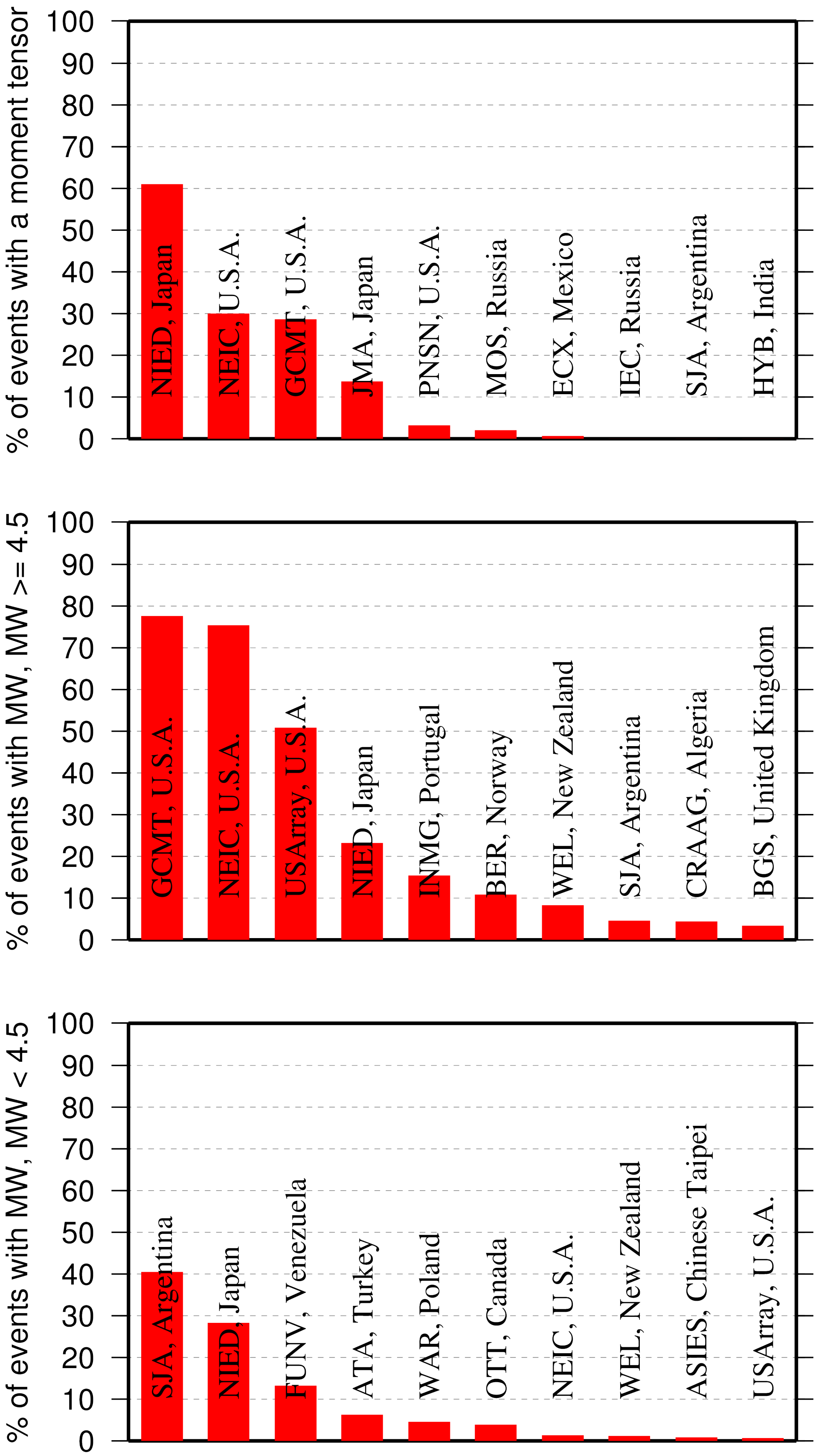


Figure 9.6: *Top ten agencies that most frequently report determinations of seismic moment tensor (top) and moment magnitude (middle/bottom for M greater/smaller than 4.5).*

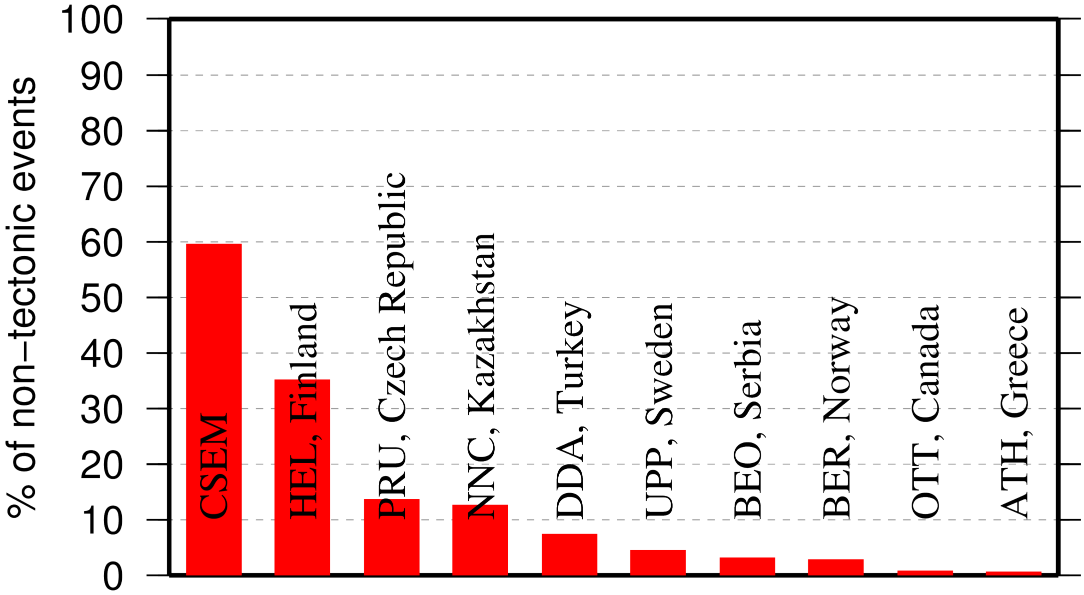


Figure 9.7: *Top ten agencies that most frequently report non-tectonic seismic events to the ISC.*

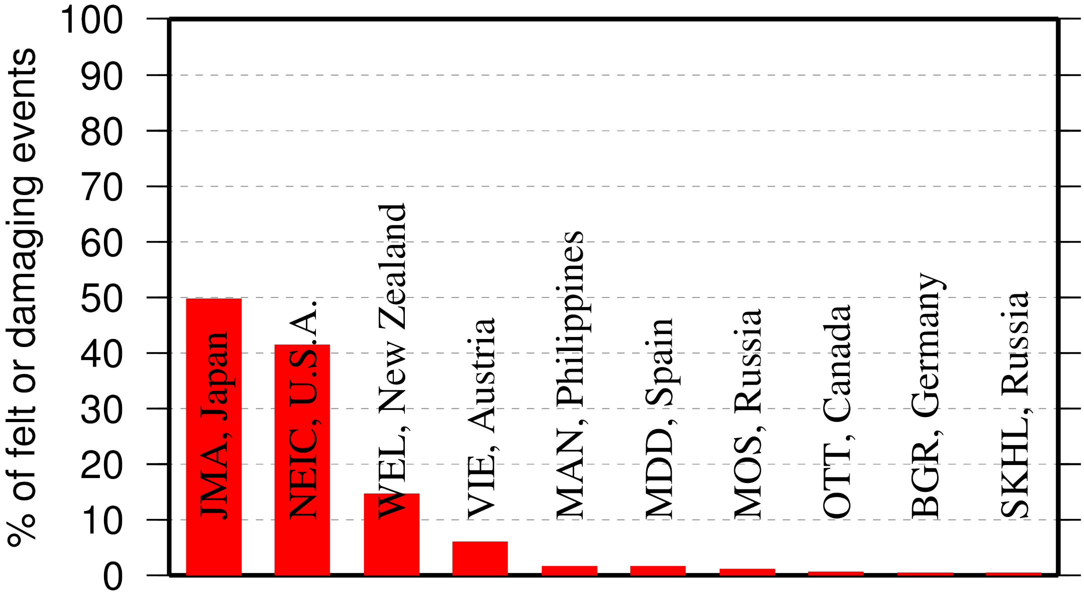


Figure 9.8: *Top ten agencies that most frequently report macroseismic information to the ISC.*

9.3 The Most Consistent and Punctual Contributors

During this six-month period, 39 agencies reported their bulletin data in one of the standard seismic formats (ISF, IMS, GSE or Nordic) 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)
PPT	French Polynesia	22
LDG	France	25
NAO	Norway	26
IGIL	Portugal	32
PDG	Montenegro	35
LIC	Ivory Coast	35
TIR	Albania	39
BUL	Zimbabwe	48
IDC	Austria	48
KRSC	Russia	49
DMN	Nepal	58
SVSA	Portugal	60
UCC	Belgium	62
NAM	Namibia	76
INMG	Portugal	82
SJA	Argentina	101
BJI	China	111
BGR	Germany	124
AUST	Australia	137
THE	Greece	173
ASRS	Russia	174
BER	Norway	187
STR	France	194
LIT	Lithuania	205
ATH	Greece	231
UPP	Sweden	243
BGS	United Kingdom	268
BYKL	Russia	280
NERS	Russia	297
BEO	Serbia	297
ROM	Italy	347
GRAL	Lebanon	348
DSN	United Arab Emirates	349
ZUR	Switzerland	350
TEH	Iran	353

Table 9.1: (continued)

Agency Code	Country	Average Delay from real time (days)
OMAN	Oman	354
NSSC	Syria	362
AZER	Azerbaijan	362
BUC	Romania	363

10

Appendix

Table 10.1: *Listing of all 323 agencies that have directly reported to the ISC. The 130 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
AFAR	The Afar Depression: Interpretation of the 1960-2000 Earthquakes, Israel
ALG	Algiers University, Algeria
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**
AWI	**Alfred Wegener Institute for Polar and Marine Research, Germany**
AZER	**Republic Center of Seismic Survey, Azerbaijan**
BCIS	Bureau Central International de Sismologie, France
BDF	Observatório Sismológico da Universidade de Brasília, Brazil
BELR	**Centre of Geophysical Monitoring, 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**
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**

Table 10.1: Continued.

Agency Code	Agency Name
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**
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
CERI	Center for Earthquake Research and Information, USA
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**
DASA	Defense Atomic Support Agency, USA
DBN	**Koninklijk Nederlands Meteorologisch Instituut, Netherlands**
DDA	**Disaster and Emergency Management Presidency, Turkey**
DHMR	**Yemen National Seismological Center, Yemen**
DIAS	**Dublin Institute for Advanced Studies, Ireland**
DJA	**Badan Meteorologi, Klimatologi dan Geofisika, Indonesia**
DMN	**Department of Mines and Geology, Ministry of Industry of Nepal, Nepal**
DNK	**Geological Survey of Denmark and Greenland, Denmark**
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
ECX	**Red Sismica del Noroeste de Mexico (RESOM), Mexico**
EFATE	OBS Experiment near Efate, Vanuatu, USA
EHB	Engdahl, van der Hilst and Buland, USA
EIDC	Experimental (GSETT3) International Data Center, USA

Table 10.1: Continued.

Agency Code	Agency Name
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
FBR	Fabra Observatory, Spain
FDF	Fort de France, Martinique
FIA0	Finessa Array, Finland
FOR	Unknown Historical Agency, Unknown - historical agency
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
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**
GTFE	German Task Force for Earthquakes, Germany
GUC	**Departamento de Geofísica, Universidad de Chile, Chile**
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
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
IASPEI	IASPEI Working Group on Reference Events, USA

Table 10.1: *Continued.*

Agency Code	Agency Name
ICE	Instituto Costarricense de Electricidad, Costa Rica
IDC	**International Data Centre, CTBTO**, **Austria**
IDG	Institute of Dynamics of Geosphere, Russian Academy of Sciences, Russia
IEPN	Institute of Environmental Problems of the North, Russian Academy of Sciences, Russia
IGIL	**Instituto Geofisico do Infante Dom Luiz**, **Portugal**
IGQ	**Servicio Nacional de Sismología y Vulcanología**, **Ecuador**
IGS	Institute of Geological Sciences, United Kingdom
INDEPTH3	International Deep Profiling of Tibet and the Himalayas, USA
INET	Instituto Nicaragüense de Estudios Territoriales, Nicaragua
INMG	**Instituto Português do Mar e da Atmosfera, I.P.**, **Portugal**
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
IST	Institute of Physics of the Earth, Technical University of Istanbul, 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
KEW	Kew Observatory, United Kingdom
KHC	Geofysikalni Ustav, Ceske Akademie Ved, 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**
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

Table 10.1: *Continued.*

Agency Code	Agency Name
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	**Environmental Agency of the Republic of Slovenia**, **Slovenia**
LPA	**Universidad Nacional de La Plata**, **Argentina**
LSZ	**Geological Survey Department of Zambia**, **Zambia**
LVSN	Latvian Seismic Network, Latvia
MAN	**Philippine Institute of Volcanology and Seismology**, **Philippines**
MAT	**The Matsushiro Seismological Observatory**, **Japan**
MCO	**Macao Meteorological and Geophysical Bureau**, **Macao, China**
MDD	**Instituto Geográfico Nacional**, **Spain**
MED_RCMT	MedNet Regional Centroid - Moment Tensors, Italy
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
MOLD	**Institute of Geophysics and Geology**, **Moldova**
MOS	**Geophysical Survey of Russian Academy of Sciences**, **Russia**
MOZ	Direccao Nacional de Geologia, Mozambique
MRB	Institut Cartogràfic de Catalunya, Spain
MSI	Messina Seismological Observatory, Italy
MSSP	**Micro Seismic Studies Programme, PINSTECH**, **Pakistan**
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	**India Meteorological Department**, **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**
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**

Table 10.1: *Continued.*

Agency Code	Agency Name
OGSO	Ohio Geological Survey, USA
OMAN	**Sultan Qaboos University, Oman**
ORF	Orfeus Data Center, Netherlands
OSUB	Osservatorio Sismologico Universita di Bari, Italy
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	**National Center for Scientific Research, Vietnam**
PMEL	Pacific seismicity from hydrophones, USA
PMR	Alaska Tsunami Warning Center,, USA
PNSN	**Pacific Northwest Seismic Network, USA**
PPT	**Laboratoire de Géophysique/CEA, French Polynesia**
PRE	**Council for Geoscience, South Africa**
PRU	**Geophysical Institute, Academy of Sciences of the Czech Republic, 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**
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
SCB	**Observatorio San Calixto, Bolivia**
SCEDC	Southern California Earthquake Data Center, USA
SDD	Universidad Autonoma de Santo Domingo, Dominican Republic
SEA	Geophysics Program AK-50, USA
SEPA	Seismic Experiment in Patagonia and Antarctica, USA
SET	Setif Observatory, Algeria

Table 10.1: Continued.

Agency Code	Agency Name
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	**Geophysical Institute, Bulgarian Academy of Sciences**, **Bulgaria**
SOME	**Seismological Experimental Methodological Expedition**, **Kazakhstan**
SPA	USGS - South Pole, Antarctica
SPGM	Service de Physique du Globe, Morocco
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	**Institut de Physique du Globe**, **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	**CWB**, **Chinese Taipei**
TAU	University of Tasmania, Australia
TEH	**Tehran University**, **Iran**
TEIC	Center for Earthquake Research and Information, USA
THE	**Department of Geophysics, Aristotle University of Thessaloniki**, **Greece**
THR	**International Institute of Earthquake Engineering and Seismology (IIEES)**, **Iran**
TIF	**Seismic Monitoring Centre of Georgia**, **Georgia**

Table 10.1: *Continued.*

Agency Code	Agency Name
TIR	**The Institute of Seismology, Academy of Sciences of Albania, Albania**
TRI	**Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS), Italy**
TRN	**University of the West Indies, 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
UAV	Red Sismológica de Los Andes Venezolanos, Venezuela
UCC	**Royal Observatory of Belgium, Belgium**
UCR	**Sección de Sismología, Vulcanología y Exploración Geofísica, Costa Rica**
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
UPP	**University of Uppsala, Sweden**
UPSL	University of Patras, Department of Geology, Greece
USAEC	United States Atomic Energy Commission, USA
USCGS	United States Coast and Geodetic Survey, USA
USGS	**United States Geological Survey, USA**
UUSS	The University of Utah Seismograph Stations, USA
UVC	Universidad del Valle, Colombia
VAO	**Instituto Astronomico e Geofísico, Brazil**
VIE	**Österreichischer Geophysikalischer Dienst, Austria**
VKMS	Lab. of Seismic Monitoring, Voronezh region, GSRAS & Voronezh State University, Russia
VSI	University of Athens, Greece
WAR	**Institute of Geophysics, Polish Academy of Sciences, Poland**
WBNET	**West Bohemia Seismic Network, Czech Republic**
WEL	**Institute of Geological and Nuclear Sciences, New Zealand**
WES	Weston Observatory, USA
YARS	**Yakutiya Regional Seismological Center, GS SB RAS, Russia**
ZAG	**Seismological Survey of the Republic of Croatia, Croatia**
ZUR	**Swiss Seismological Sevice (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	2805720	JMA (14%), NEIC (14%), CSEM (13%)
S	1312934	JMA (29%), CSEM (16%)
Pg	334791	CSEM (54%), ROM (17%)
Pn	283558	CSEM (38%), NEIC (30%)
AML	242070	ATH (49%), WEL (41%)
Sg	234416	CSEM (53%), ROM (18%)
PN	181739	WEL (56%), ISK (32%)
pmax	170214	MOS (80%), BJI (20%)
LR	156923	IDC (37%), NEIC (32%), BJI (26%)
Sn	93844	CSEM (26%), NEIC (21%), IDC (12%)
Lg	82190	CSEM (46%), MDD (29%), NNC (13%)
PG	79981	ISK (55%), HEL (18%), PRU (11%)
NULL	75780	MOS (39%), RSNC (33%)
SG	67001	ISK (35%), HEL (25%), PRU (24%)
PKP	39021	IDC (40%), NEIC (26%)
MLR	29770	MOS (100%)
SN	29765	WEL (51%), HEL (20%)
IAML	29611	GUC (46%), SJA (23%), BER (13%)
PKPdf	28904	NEIC (78%)
T	27958	IDC (92%)
PKPbc	27337	NEIC (48%), IDC (40%)
pP	26655	BJI (36%), NEIC (31%), IDC (15%)
PFAKE	25016	NEIC (100%)
P*	24397	WEL (97%)
PKIKP	22862	MOS (96%)
PcP	20493	NEIC (42%), IDC (36%)
PP	18646	BJI (37%), NEIC (19%), IDC (14%)
A	18206	INMG (49%), SVSA (33%), SKHL (18%)
AMB	14868	TEH (60%), SKHL (19%), BJI (11%)
PKPab	12931	NEIC (42%), IDC (29%), VIE (11%)
Sb	12632	IRIS (74%), CSEM (23%)
MSG	12100	HEL (100%)
SS	11488	BJI (46%), MOS (30%)
smax	9715	MOS (85%), BJI (15%)
Pb	9712	IRIS (70%), CSEM (27%)
sP	9438	BJI (86%)
x	8564	NDI (55%), PRU (33%), BUD (12%)
S*	7801	WEL (97%)
PKiKP	6846	IRIS (32%), NEIC (23%), IDC (21%), VIE (18%)
SB	6516	HEL (100%)
ScP	6370	IDC (42%), NEIC (41%), BJI (14%)
PB	5970	HEL (100%)
AMS	5595	PRU (74%), BGS (14%)
IAmb	4965	HYB (27%), BER (26%), LIT (21%), NDI (14%)
Smax	4918	YARS (63%), BYKL (37%)
PKP2	4910	MOS (96%)
*PP	4506	MOS (100%)
Pdiff	4266	IRIS (78%), IDC (13%)
PKKPbc	4095	IDC (51%), NEIC (43%)
sS	3832	BJI (98%)
LG	3418	BRA (65%), OTT (34%)
Trac	3320	OTT (100%)
Pmax	2979	YARS (53%), BYKL (45%)
PKPpre	2748	NEIC (97%)
SKS	2608	BJI (77%)
Pdif	2578	NEIC (75%)
X	2318	JMA (85%), SYO (15%)
SKPbc	2155	IDC (53%), NEIC (46%)
pPKP	2142	PRU (27%), IDC (27%), BJI (23%), NEIC (19%)
IVMs_BB	2064	BER (52%), HYB (47%)
ScS	1954	BJI (79%)
PPP	1884	MOS (80%)
PKHKP	1821	MOS (100%)
PKhKP	1642	IDC (100%)
LQ	1544	PPT (63%), INMG (19%), BELR (13%)

Table 10.2: *(continued)*

Reported Phase	Total	Agencies reporting
LRM	1296	MOLD (34%), SOME (34%), BELR (32%)
SSS	1179	MOS (64%), CLL (18%), BELR (11%)
PKPAB	1123	PRU (100%)
PS	1082	MOS (46%), CLL (12%)
SKKS	1069	BJI (84%)
PcS	1050	BJI (99%)
sPKP	941	BJI (93%)
PKPPKP	905	IDC (92%)
PKKP	904	IDC (50%), NEIC (36%)
pPKPbc	888	IDC (48%), NEIC (33%)
SKSac	878	BER (27%), HYB (24%), INMG (11%)
IVmB_BB	822	BER (100%)
PKS	820	BJI (93%)
*SP	800	MOS (100%)
SP	719	MOS (40%), PRU (28%), BER (15%)
pPKPdf	710	NEIC (44%), VIE (27%)
SKP	690	IDC (43%), NEIC (31%), PRU (16%)
PKKPab	679	IDC (49%), NEIC (46%)
P'P'	597	NEIC (99%)
IAMs_20	588	BER (51%), BGS (34%), NDI (15%)
SKKPbc	542	IDC (58%), NEIC (39%)
max	511	BYKL (100%)
Sgm	495	SIGU (100%)
pPKPab	473	NEIC (28%), VIE (26%), IDC (20%), CLL (15%)
*SS	468	MOS (100%)
LMZ	395	WAR (100%)
PKPDF	393	PRU (100%)
PKP1	376	LIC (98%)
PDIFF	370	BRA (54%), PRU (40%)
Lm	346	CLL (100%)
PKP2bc	339	IDC (100%)
Rg	334	NNC (29%), NAO (22%), BER (22%), DBN (13%), IDC (13%)
AMP	315	HLW (91%)
L	314	MOLD (31%), BRA (31%), DBN (24%), CLL (14%)
LmV	301	CLL (100%)
PM	292	BELR (99%)
Pgm	264	SIGU (100%)
Sgmax	232	NERS (100%)
PPS	226	CLL (52%), MOS (25%), MOLD (14%)
(P)	210	BRG (59%), CLL (40%)
LmH	208	CLL (100%)
SN4	200	ISN (100%)
PCP	199	PRU (70%)
P3KPbc	191	IDC (100%)
Snm	176	SIGU (100%)
AMb	167	IGIL (68%), NDI (17%)
SKPab	161	IDC (54%), NEIC (45%)
PkiKP	157	IRIS (99%)
PN4	147	ISN (100%)
Sm	147	SIGU (99%)
PKKPdf	145	NEIC (54%), VIE (18%), BUD (15%)
E	140	ZAG (60%), UCC (38%)
Pm	136	SIGU (100%)
pPn	136	OMAN (88%)
P4KPbc	134	IDC (100%)
SKPdf	134	NEIC (32%), BER (28%)
pPKiKP	120	VIE (71%)
pPcP	117	IDC (59%), NEIC (41%)
APKP	115	UCC (100%)
Pnm	111	SIGU (100%)
Pgmax	110	NERS (99%)
SKKP	110	IDC (48%), NEIC (32%), PRU (15%)
AP	106	UCC (93%)
SSSS	98	CLL (98%)
sPKPdf	97	VIE (91%)
PKP2ab	97	IDC (100%)
SmS	86	BGR (100%)

Table 10.2: *(continued)*

Reported Phase	Total	Agencies reporting
P'P'ab	85	NEIC (100%)
PmP	81	BGR (100%)
SKKSac	80	CLL (59%), WAR (24%)
P'P'df	78	NEIC (74%), VIE (14%), PPT (12%)
Sdif	73	CLL (41%), INMG (22%), PPT (18%), NEIC (15%)
SH	70	SYO (100%)
Lmax	69	CLL (100%)
IVMsBB	69	BER (71%), HYB (28%)
SDIF	67	PRU (100%)
PN12	62	ATA (100%)
LQM	60	BELR (88%), MOLD (12%)
PSKS	58	CLL (97%)
XS	57	PRU (100%)
Pu	57	NEIC (100%)
(sP)	53	CLL (100%)
P3KP	53	IDC (100%)
MSN	48	HEL (100%)
SN5	45	ISN (100%)
sPKiKP	45	VIE (89%)
PN5	43	ISN (86%)
pPdiff	43	VIE (40%), SYO (30%), IDC (16%), LJU (12%)
PsP	42	MOLD (81%), BELR (19%)
PKPPKPdf	41	BUD (56%), CLL (44%)
PKKKP	38	NEIC (100%)
pPP	38	CLL (66%), LPA (29%)
Sdiff	37	IDC (30%), LJU (24%), VIE (19%), BUD (16%)
IVmBBB	37	BER (100%)
SKiKP	36	IDC (64%), UCC (28%)
SKSP	36	BELR (42%), MOLD (36%), CLL (17%)
rx	36	SKHL (100%)
sPP	36	CLL (100%)
Pmn	35	SIGU (100%)
PKPdiff	34	CLL (100%)
AMSG	32	BER (62%), BGS (38%)
SKSdf	32	BER (41%), WAR (25%), VIE (22%)
Smn	31	SIGU (100%)
sPKPbc	31	VIE (55%), IDC (16%), NEIC (13%)
PKPdif	31	NEIC (90%)
sPKPab	30	VIE (97%)
pPdif	29	HYB (79%), CLL (17%)
PKPM	28	BELR (100%)
AMPG	27	BER (70%), BGS (30%)
SPP	27	CLL (33%), MOS (33%), WAR (26%)
PKSdf	27	BER (56%), CLL (41%)
M	24	MOLD (83%), NDI (17%)
PA	24	JSN (100%)
XP	24	UCC (88%), MOS (12%)
SKKPdf	23	BUD (96%)
PPPP	22	CLL (95%)
RG	22	HEL (95%)
PPM	21	BELR (100%)
(PP)	20	CLL (100%)
(pP)	20	CLL (100%)
(S)	20	CLL (80%), SKO (20%)
sSS	19	CLL (100%)
pPg	19	SKHL (100%)
sPdif	19	HYB (74%), CLL (26%)
APKPbc	18	UCC (100%)
TT	18	NEIC (100%)
PgPg	18	BYKL (100%)
PPlp	16	CLL (100%)
Smg	16	SIGU (100%)
Pmg	15	SIGU (100%)
PCS	15	NDI (60%), PRU (27%), LPA (13%)
(SS)	15	CLL (100%)
PnPn	14	OMAN (79%)
P(2)	14	CLL (100%)

Table 10.2: (continued)

Reported Phase	Total	Agencies reporting
SM	14	BELR (100%)
SKKKS	13	BELR (100%)
Plp	13	CLL (100%)
sPg	13	SKHL (92%)
SCS	12	NDI (58%), LPA (25%)
SCP	12	PRU (58%), BRG (42%)
PKKSdf	12	NEIC (83%), HYB (17%)
SMZ	12	BJI (100%)
PKPc	11	WAR (100%)
PPPrev	11	CLL (100%)
SKKPab	11	IDC (73%), NEIC (27%)
PKKS	11	BRG (36%), NEIC (27%), IDC (27%)
SDIFF	11	BRG (91%)
sPdiff	11	VIE (100%)
PN8	11	ATA (100%)
(PKiKP)	11	CLL (100%)
(Pg)	10	CLL (90%)
SKKSdf	10	NEIC (60%), WAR (30%)
mb	10	OTT (100%)
XM	10	MOLD (100%)
Li	10	MOLD (100%)
(PPP)	9	CLL (100%)
(SSS)	9	CLL (100%)
PKPabd	9	WAR (100%)
SKIKS	9	LPA (100%)
Pgd	9	WAR (100%)
sSdiff	9	CLL (56%), LJU (44%)
MPN	8	HEL (100%)
LV	8	CLL (100%)
PKPlp	8	CLL (100%)
PSS	8	CLL (100%)
SKIKP	8	LPA (100%)
PKSbc	8	CLL (50%), UCC (50%)
XSKS	7	PRU (100%)
PN11	7	ATA (100%)
sSSS	7	CLL (100%)
(PKP)	7	CLL (71%), BRG (29%)
SgSg	7	BYKL (100%)
P5KP	6	NEIC (50%), IDC (50%)
R	6	OBM (83%), LDG (17%)
P4KP	6	IDC (67%), NEIC (33%)
(PKPdf)	6	CLL (100%)
sPn	6	SKHL (83%), OMAN (17%)
sPb	6	BUD (100%)
VmB_BB	5	BUL (100%)
H	5	IDC (100%)
(SSSS)	5	CLL (100%)
I	5	NDI (40%), RSNC (40%), BER (20%)
p	5	OMAN (80%), NDI (20%)
PSPS	5	CLL (100%)
sPS	5	CLL (100%)
pwP	5	NEIC (100%)
PSSrev	5	CLL (100%)
SKSDF	5	BRA (100%)
(Sg)	4	CLL (75%), BGR (25%)
PcPPKPre	4	CLL (100%)
Lg1	4	MOLD (100%)
PCN	4	NDI (100%)
PSP	4	LPA (50%), WAR (50%)
Pdi	4	SKO (100%)
SKPa	4	NAO (75%), BER (25%)
(sSS)	4	CLL (100%)
Lg2	4	MOLD (100%)
PKPab(2)	4	CLL (100%)
PKIKS	4	LPA (100%)
sSSSS	4	CLL (100%)
(sPP)	4	CLL (100%)

Table 10.2: (continued)

Reported Phase	Total	Agencies reporting
PN6	4	ISN (100%)
(PKPab)	4	CLL (100%)
LgX	4	CSEM (100%)
(Pn)	4	CLL (100%)
(SP)	4	CLL (100%)
APKPab	3	UCC (100%)
(PcP)	3	CLL (100%)
(Sdif)	3	CLL (100%)
pPmax	3	CLL (100%)
SKKSacre	3	CLL (100%)
SPKiKP	3	UCC (100%)
SKSSKSac	3	CLL (100%)
PKPPKPab	3	BUD (100%)
pSKSdf	3	HYB (100%)
pPKP1	3	BELR (100%)
i	3	MOLD (100%)
PKPbc(2)	3	CLL (100%)
(Sn)	3	CLL (100%)
SN6	3	ISN (100%)
pPKS	3	LPA (100%)
pPDIFF	2	BRG (100%)
PKPPKPbc	2	CLL (100%)
PKPac	2	WAR (100%)
sPKKPbc	2	CLL (100%)
Px	2	WAR (100%)
Lgm	2	SIGU (100%)
PPPPrev	2	CLL (100%)
pPKPdiff	2	CLL (100%)
PN7	2	ATA (100%)
(sSSS)	2	CLL (100%)
LRM1	2	BELR (100%)
(Pdif)	2	CLL (100%)
SKPPKPbc	2	CLL (100%)
SKKSDF	2	BRA (100%)
LmV(360	2	CLL (100%)
P–	2	BUD (100%)
sPPP	2	CLL (100%)
sPPS	2	CLL (100%)
SKSp	2	BRA (100%)
(PG)	2	BRG (100%)
PKPBC	2	PRU (100%)
sScP	2	CLL (50%), BJI (50%)
PKPdf(2)	2	CLL (100%)
SN8	2	ATA (100%)
Sglp	2	CLL (100%)
PGN	2	HEL (100%)
PPmax	2	CLL (100%)
(SN)	2	BRG (100%)
(pPKPdf)	2	CLL (100%)
PPk	2	CLL (100%)
PKHKPM	2	BELR (100%)
SPS	2	WAR (100%)
sp	1	SYO (100%)
SZ	1	TIR (100%)
(SPP)	1	CLL (100%)
sPKKPab	1	CLL (100%)
PPP(2)	1	LPA (100%)
pSKPdf	1	CLL (100%)
(SKPbc)	1	CLL (100%)
pScP	1	IDC (100%)
Sg(2)	1	CLL (100%)
PDN	1	NDI (100%)
(PKSbc)	1	CLL (100%)
Pgc	1	WAR (100%)
(sPKiKP)	1	CLL (100%)
pPKPPKPd	1	CLL (100%)
sPKKPdf	1	CLL (100%)

Table 10.2: *(continued)*

Reported Phase	Total	Agencies reporting
P*P	1	ZUR (100%)
PN10	1	ATA (100%)
R(Pg)	1	CLL (100%)
PP(2)	1	CLL (100%)
LRM2	1	MOLD (100%)
QP	1	MOLD (100%)
(sPKPdf)	1	CLL (100%)
SKSPrev	1	CLL (100%)
pSKSac	1	CLL (100%)
pP(2)	1	CLL (100%)
(PSPS)	1	CLL (100%)
(PSS)	1	CLL (100%)
pSP	1	CLL (100%)
pS	1	CLL (100%)
SKPPKPdf	1	CLL (100%)
AnL	1	INMG (100%)
PGDN	1	NDI (100%)
(SKSac)	1	CLL (100%)
(PSKS)	1	CLL (100%)
(pPcP)	1	CLL (100%)
sSKSac	1	CLL (100%)
—	1	BUD (100%)
sPcP	1	CLL (100%)
SN9	1	ATA (100%)
-MP	1	INMG (100%)
pPS	1	CLL (100%)
sSKS	1	BRG (100%)
(sS)	1	CLL (100%)
Sn(2)	1	CLL (100%)
(PPS)	1	CLL (100%)
(sPS)	1	CLL (100%)
pPb	1	OMAN (100%)
SN12	1	ATA (100%)
sPKPPKPd	1	CLL (100%)
CZJ	1	PRU (100%)
LMN	1	WAR (100%)
(SKKSdf)	1	CLL (100%)
PKP(2)	1	LPA (100%)
pSKKPbc	1	CLL (100%)
pPPP	1	CLL (100%)
sPPPP	1	CLL (100%)
s	1	SKHL (100%)
lg	1	MDD (100%)
pPSKS	1	CLL (100%)
(PSSrev)	1	CLL (100%)
pPKIK	1	MOLD (100%)
3PKPbc	1	CLL (100%)
(pPP)	1	CLL (100%)
PKSP	1	NDI (100%)
PKKSab	1	HYB (100%)
SN11	1	ATA (100%)
(PKPbc)	1	CLL (100%)
–P	1	BUD (100%)
PC	1	ECX (100%)
q	1	KRSC (100%)
aPKP	1	DBN (100%)
SN2	1	RSNC (100%)
PKPM1	1	BELR (100%)
PSKSrev	1	CLL (100%)
EKPab	1	INMG (100%)
SKPPKP	1	BRG (100%)
(SKKSac)	1	CLL (100%)
PD	1	NDI (100%)
P5KPbc	1	IDC (100%)
(sPPPP)	1	CLL (100%)
PKPS	1	NDI (100%)
-ML	1	SVSA (100%)

Table 10.2: *(continued)*

Reported Phase	Total	Agencies reporting
PDIF	1	BRG (100%)
(sSKSac)	1	CLL (100%)
PKbc	1	CLL (100%)
Pcp	1	SYO (100%)
O	1	SYO (100%)
(Sb)	1	CLL (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
IDC	324602	298739	122678	35435
NEIC	259043	258376	180973	48151
CSEM	177522	43434	12531	0
MOS	174048	137422	65263	16715
ATH	118457	13484	0	0
WEL	111028	21968	0	0
BJI	78902	75422	16720	23296
MDD	56039	7165	1	0
SOME	52791	12165	1173	0
NNC	44602	12219	35	0
ROM	43250	6040	0	0
THE	34771	6336	0	0
DJA	34635	20311	4582	0
RSNC	25379	2293	0	0
VIE	20211	19004	7457	0
BKK	14055	12859	6351	0
GUC	13669	4238	0	0
INMG	13418	6310	2973	0
PRU	13099	7812	0	3137
DMN	13018	12550	16	0
LDG	12490	3443	1	0
HEL	12341	379	0	0
PPT	12005	10208	1100	0
NSSC	9316	4636	0	0
TEH	8981	3426	0	0
BER	7632	4203	1120	264
PRE	7565	466	45	0
SJA	6781	2260	0	0
MAN	6522	2786	0	0
SVSA	6422	502	277	0
SKHL	6405	4983	0	0
NDI	5453	3042	900	91
CLL	5409	4530	615	301
LJU	5194	600	4	0
PDG	5075	3690	0	0
YARS	4661	102	0	0
BRG	4289	3258	590	0
BYKL	3792	1894	0	0
ZUR	3413	370	0	0
OTT	3328	373	0	0
BGS	3115	2564	1128	886
DNK	2615	2467	1549	0
HYB	2490	2473	1182	0
ATA	2465	1873	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
NAO	2404	2314	1328	0
ECX	2165	548	0	0
SKO	1545	312	0	0
LIC	1516	1426	727	0
LIT	1044	1016	547	0
WBNET	933	0	0	0
IGIL	909	473	84	187
OBM	885	637	0	0
BELR	818	769	0	287
KNET	815	204	0	0
DHMR	815	145	4	0
UCC	813	786	580	0
MOLD	736	462	68	0
SIGU	707	97	0	0
UCR	633	366	2	0
DBN	484	321	185	0
THR	445	445	0	0
WAR	442	422	7	355
NERS	348	109	0	0
IGQ	327	327	0	0
HLW	287	147	0	0
SCB	226	193	0	0
BGR	194	148	0	0
ISN	112	0	0	0
PLV	36	6	0	0
BUL	20	9	1	0
AZER	12	2	0	0
LPA	9	3	0	0
OMAN	3	3	2	0
AAE	2	1	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, 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 3.3.4 of the January-June 2011 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 3.3.3 of the January-June 2011 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.

12

Acknowledgements

We thank Taimi Mulder of Geological Survey of Canada for kindly accepting our invitation and submitting an article for this issue of the Summary.

We are also grateful to all the developers of the Generic Mapping Tools (GMT) suite of software (Wessel and Smith, 1998), used extensively here in producing the graphical figures.

Finally, we thank the ISC Member Institutions, Data Contributors, Funding Agencies (including NSF Award 0949072) and Sponsors for supporting the ISC long-term operations.

References

Balfour, N., R. Baldwin, and A. Bird (2008), Magnitude calculations in Antelope 4.10, *Analysis Group Note of Geological Survey of Canada*, pp. 1–13.

Bisztricsany, E. A. (1958), A new method for the determination of the magnitude of earthquakes, *Geofiz. Kozl*, pp. 69–76.

Bondár, I., and D. Storchak (2011), Improved location procedures at the International Seismological Centre, *Geophysical Journal International*, *186*, 1220–1244.

Bormann, P., and J. W. Dewey (2012), The new iaspei standards for determining magnitudes from digital data and their relation to classical magnitudes, is 3.3, *New Manual of Seismological Observatory Practice 2 (NMSOP-2), P. Bormann (Ed.)*, pp. 1–44, doi:10.2312/GFZ.NMSOP-2_IS_3.3,10.2312/GFZ.NMSOP-2, `http://nmsop.gfz-postsdam.de`.

Bormann, P., and J. Saul (2008), The new IASPEI standard broadband magnitude mB, *Seism. Res. Lett*, *79*(5), 698–705.

Bormann, P., R. Liu, X. Ren, R. Gutdeutsch, D. Kaiser, and S. Castellaro (2007), Chinese national network magnitudes, their relation to NEIC magnitudes and recommendations for new IASPEI magnitude standards, *Bulletin of the Seismological Society of America*, *97*(1B), 114–127, doi:10.1785/012006007835.

Bormann, P., R. Liu, Z. Xu, R. Ren, and S. Wendt (2009), First application of the new IASPEI teleseismic magnitude standards to data of the China National Seismographic Network, *Bulletin of the Seismological Society of America*, *99*, 1868–1891, doi:10.1785/0120080010.

Choy, G. L., and J. L. Boatwright (1995), Global patterns of readiated seismic energy and apparent stress, *J. Geophys. Res.*, *100*(B9), 18,205–18,228.

Dziewonski, A. M., T.-A. Chou, and J. H. Woodhouse (1981), Determination of earthquake source parameters from waveform data for studies of global and regional seismicity, *J. Geophys. Res.*, *86*, 2825–2852.

Engdahl, E. R., and A. Villaseñor (2002), Global seismicity: 1900-1999, *International Handbook of Earthquake Engineering and Seismology, International Geophysics series*, *81A*, 665–690.

Engdahl, E. R., R. van der Hilst, and R. Buland (1998), Global teleseismic earthquake relocation with improved travel times and procedures for depth determination, *Bulletin of the Seismological Society of America*, *88*, 722–743.

Gutenberg, B. (1945a), Amplitudes of P, PP and S and magnitude of shallow earthquakes, *Bulletin of the Seismological Society of America*, *35*, 57–69.

Gutenberg, B. (1945b), Magnitude determination of deep-focus earthquakes, *Bulletin of the Seismological Society of America*, *35*, 117–130.

Gutenberg, B. (1945c), Amplitudes of surface waves and magnitudes of shallow earthquakes, *Bulletin of the Seismological Society of America*, *35*, 3–12.

Hutton, L. K., and D. M. Boore (1987), The ML scale in southern California, *Bulletin of the Seismological Society of America*, *77*, 2074–2094.

IASPEI (2005), Summary of magnitude working group recommendations on standard procedures for determining earthquake magnitudes from digital data, `http://www.iaspei.org/commissions/CSOI.html#wgmm`,`http://www.iaspei.org/commissions/CSOI/summary_of_WG_recommendations_2005.pdf`.

IASPEI (2013), Summary of magnitude working group recommendations on standard procedures for determining earthquake magnitudes from digital data, `http://www.iaspei.org/commissions/CSOI/Summary_of_WG_recommendations_20130327.pdf`.

IDC (1999), IDC processing of seismic, hydroacoustic and infrasonic data, *IDC Documentation*.

Kanamori, H. (1977), The energy release in great earthquakes, *J. Geophys. Res.*, *82*, 2981–2987.

Lee, W. H. K., R. Bennet, and K. Meagher (1972), A method of estimating magnitude of local earthquakes from signal duration, *U.S. Geol. Surv.*, Open-File Rep.

Nuttli, O. W. (1973), Seismic wave attenuation and magnitude relations for eastern North America, *J. Geophys. Res.*, *78*, 876–885.

Richter, C. F. (1935), An instrumental earthquake magnitude scale, *Bulletin of the Seismological Society of America*, *25*, 1–32.

Ringdal, F. (1976), Maximum-likelihood estimation of seismic magnitude, *Bulletin of the Seismological Society of America*, *66*(3), 789–802.

Tsuboi, C. (1954), Determination of the Gutenberg-Richter's magnitude of earthquakes occurring in and near Japan, *Zisin (J. Seism. Soc. Japan), Ser. II*(7), 185–193.

Tsuboi, S., K. Abe, K. Takano, and Y. Yamanaka (1995), Rapid determination of Mw from broadband P waveforms, *Bulletin of the Seismological Society of America*, *85*(2), 606–613.

Vanek, J., A. Zapotek, V. Karnik, N. V. Kondorskaya, Y. V. Riznichenko, E. F. Savarensky, S. L. Solov'yov, and N. V. Shebalin (1962), Standardization of magnitude scales, *Izvestiya Akad. SSSR., Ser. Geofiz.*(2), 153–158, pages 108–111 in the English translation.

Woessner, J., and S. Wiemer (2005), Assessing the quality of earthquake catalogues: estimating the magnitude of completeness and its uncertainty, *Bulletin of the Seismological Society of America*, *95*(2), doi:10/1785/012040,007.

WHITE PAPER

COMPLETE INTEGRATED AFTERSHOCK SYSTEM PROVIDES QUICK AND EASY SOLUTION FOR RAPID AFTERSHOCK DEPLOYMENT

LEONID ZIMAKOV

TRIMBLE INFRASTRUCTURE, PLANO, TEXAS, USA

INTRODUCTION

Rapid aftershock mobilization plays an essential role in the understanding of both focal mechanism and rupture propagation caused by strong earthquakes. A quick assessment of the data provides a unique opportunity to study the dynamics of the entire earthquake process in-situ. Aftershock study also provides practical information for local authorities regarding post-earthquake activity, which is very important in order to conduct the necessary actions for public safety in the area affected by a strong earthquake.

Due to a relatively short aftershock activity period (several weeks to several months), it is critical to rapidly deploy emergency personnel to the affected area in order to minimize the time required to estimate the extent and amplitude of strong shaking from aftershock events.

A dense array of seismic stations consisting of high resolution seismic recorders with short period seismometers and accelerometers is required in order to reduce the time needed to detect an event and provide high resolution maps of ground accelerations across the affected earthquake region. Therefore, the rapid aftershock mobilization of seismic equipment should comply with the following critical requirements:

- Lightweight and small in size
- Integrated design with minimal or no external peripheral equipment
- Very low power consumption
- Minimal or no field programming
- Easy and quick data download in the field
- Low maintenance

©Trimble Navigation Limited. All rights reserved. Trimble, the Globe & Triangle logo, are trademarks of Trimble Navigation Limited, registered in the United States Patent and Trademark Office and in other countries. REF TEK is a division of Trimble Navigation Limited. All other trademarks are the property of their respective owners. Last updated March 2014.

WHAT DOES THE 160-03 OFFER?

The REF TEK High Resolution Aftershock System, Model 160-03, is a self-contained, fully integrated Aftershock System providing the customer with simple and quick deployment during aftershock emergency mobilization. The 160-03, six channel recorder, contains three major components integrated in one case:

- 24-bit resolution low power ADC with CPU and lid interconnect boards;
- power source; and
- three component 2 Hz sensors (two horizontals and one vertical and a triaxial +/-4g MEMS accelerometer.

Figure 1: REF TEK 160-03 High Resolution Aftershock System

Figure 2: Inside the case of the REF TEK 160-03 High Resolution Aftershock System

The self-contained rechargeable battery pack provides power autonomy for up to 7 days during continuous data acquisition at 200 sps on three weak motion and three triggered strong motion recording channels. For longer power autonomy, the 160-03 Aftershock System battery pack can be charged from an external source (solar power system). To download recorded data the customer has two options:

- Connect a laptop to the 160-03 and the data is then automatically uploaded; or
- Connect the REF TEK Wi-Fi Serial Adaptor to upload data to the REF TEK iFSC Controller.

The 160-03 configuration is fixed based on a configuration file stored in the system, so no external command/control interface is required for parameter setup in the field. For visual control of the system performance in the field, the 160-03 has a built-in LED display which indicates the system's recording status, as well as a hot swappable USB drive and battery status. As an added customer convenience, four 160-03 systems can be housed in a small, lightweight, watertight rolling case that will keep the recorders safe during transport. The ease of having an all-in-one aftershock system also provides the customer flexibility in sending the equipment to the affected region via a more cost effective way as the equipment/carrying case can easily be checked on both domestic and international commercial flights.

160-03 SPECIFICATIONS

Model	160-03 (Part No. 97124-00)
Mechanical	
Size: Weight: Watertight Integrity:	6” (15.2cm) high x 8.63” (21.9cm) diameter 11.7 lbs. (5.3 kg) IP67
Environmental	
Operating Temp.:	-30°C to +60°C
Storage Temp.:	-40°C to +70°C
Power	
Average Power:	<400 mW
A/D Convertor	
Type:	Delta-Sigma Modulation, 24-bit output resolution
Dynamic Range:	>138 dB@100 sps
Channels:	6
Input Impedance:	Matched to sensors
Sample Rates:	200 sps default; 100, 250, 500 sps optional
Seismometer	
Type:	Moving coil / mass
Natural Frequency:	2 Hz
Accelerometer	
Type:	± 4g
Frequency Response:	DC – 45 Hz
Damping:	0.7 to critical
Data Storage	
Type:	USB Flash
User Interface	
Type:	LED array consisting of 16 LED display recording status, USB drive status, battery voltage, etc.
Power Control:	Magnetic switch to turn on both power and acquisition

Table 1: 160-03 Specifications

CONTACT US

Phone: +1 (214) 440 1265

Email: sales@reftek.com