Helmholtz Centre Potsdam
GFZ German Research Centre for Geosciences

Angelo Strollo, Thomas Zieke, Michael Guenther, Karl-Heinz Jäckel, Javier Quinteros, Susanne Hemmleb, Peter Evans, Andres Heinloo, Riccardo Zaccarelli, Joachim Saul, Winfried Hanka and Frederik Tilmann.

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GEOFON Annual Report 2016

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1 Executive summary

- One additional station was added to the GEOFON Global Seismic Network in Myanmar in collaboration with the local Department of Meteorology and Hydrology in the capital city Naypyitaw. 45 stations required corrective maintenance actions. The GEOFON engineering team performed on-site maintenance at seven sites, whereas 16 stations were serviced from remote and/or repaired by our local partners. For six stations spare parts were assembled and tested in Potsdam and delivered to the local partners.
- The GFZ Seismological Data Archive hosted at GEOFON has grown by ~18 TB in 2016. The total size of the archive is ~86 TB. Tailor-made requests from the archive have been served to ~1400 unique users, which cumulatively made more than 18 million requests. Real-time data export is stable at ~100 TB/year to more than 300 clients.
- GEOFON published 5258 events and 1104 moment tensor solutions via the web pages and other dissemination channels.
- Software development focused on *fdsnws_fetch* as alternative to *arclink_fetch* using standard FDSN web services and on the development of the HMB software which functions as a messaging service running over HTTP.

2 Introduction

The GEOFON program consists of a global seismic network (GE Network), a seismological data centre (GEOFON DC) and a global earthquake monitoring system (GEOFON EQinfo). These three pillars are part of the MESI research infrastructure of the Helmholtz Centre Potsdam - GFZ German Research Centre for Geosciences aiming at facilitating scientific research. GEOFON provides real-time seismic data, access to its own and third party data from the archive facilities as well as global and rapid earthquake information. The GEOFON Seismological Software can be considered a fourth cross-cutting module of the GEOFON Program.

Data, services, products and software openly distributed by GEOFON are used by hundreds of scientists and data centres worldwide. Its earthquake information service is accessed directly by tens of thousands of visitors. The *SeisComP* software package is the flagship software provided to the community, which is geared for seismic observatory and data centre needs and used extensively to support our internal operations. Like all other MESI (Modular Earth Science Infrastructure) modules GEOFON has the majority of users outside the GFZ as well as an external advisory committee that provides advice to the GFZ Executive Board and to the GEOFON team. This report describes the main activities carried out within the three GEOFON pillars and the software development group.

3 The GEOFON global seismic network

In the context of the GFZ International Training Course of the GFZ in Myanmar a new station was installed in the capital city Naypyitaw on October 18th. A seismometer and facilities have been provided by the local Department of Meteorology and Hydrology that hosted the training course. The remaining hardware, a Guralp DM24 digitizer, a local seedlink server at the station as well as a SeisComP3 workstation for the office were provided by GFZ. The NPW station will be distributed under the GE network code as well as under the network code of the hosting institution. This is an initial attempt to deploy cost effective stations during the GFZ International Training course where possible Such stations may add important data in areas where coverage is poor as well as provide the initial tools to engage local partners with real-time seismology and open data. During the year several maintenance actions were carried out for the 83 GEOFON stations (including the four former GE stations now belonging to the WM seismic network and the TIO station). In particular 23 stations required corrective maintenance actions. The GEOFON engineering team had to perform on-site maintenance at seven sites, 16 stations were repaired by the local partners and in six cases spare parts were assembled and tested in Potsdam and delivered to the local partners (Fig. 1). Details will be provided in the following section.

3.1 Regular maintenance

At the end of 2015 the station CISI (Indonesia) raised repeated security concerns. The Indonesian partner institute BMKG decided to close the station and relocate to a safer location. With remote support of the group the equipment was reinstalled in the village of Bungbulang, approximately 25 km apart from its original location. The new station BBJI started recording in September 2016.

Other maintenance work mainly focused on corrective technical measures to keep GEOFON stations online and providing high quality seismic data. At station RGN (Germany) a broken digitizer needed to be exchanged in order to continue the recording. Several station outages were caused by problems with the communication system. Issues at two GEOFON stations HALK, MALK (Sri Lanka) were

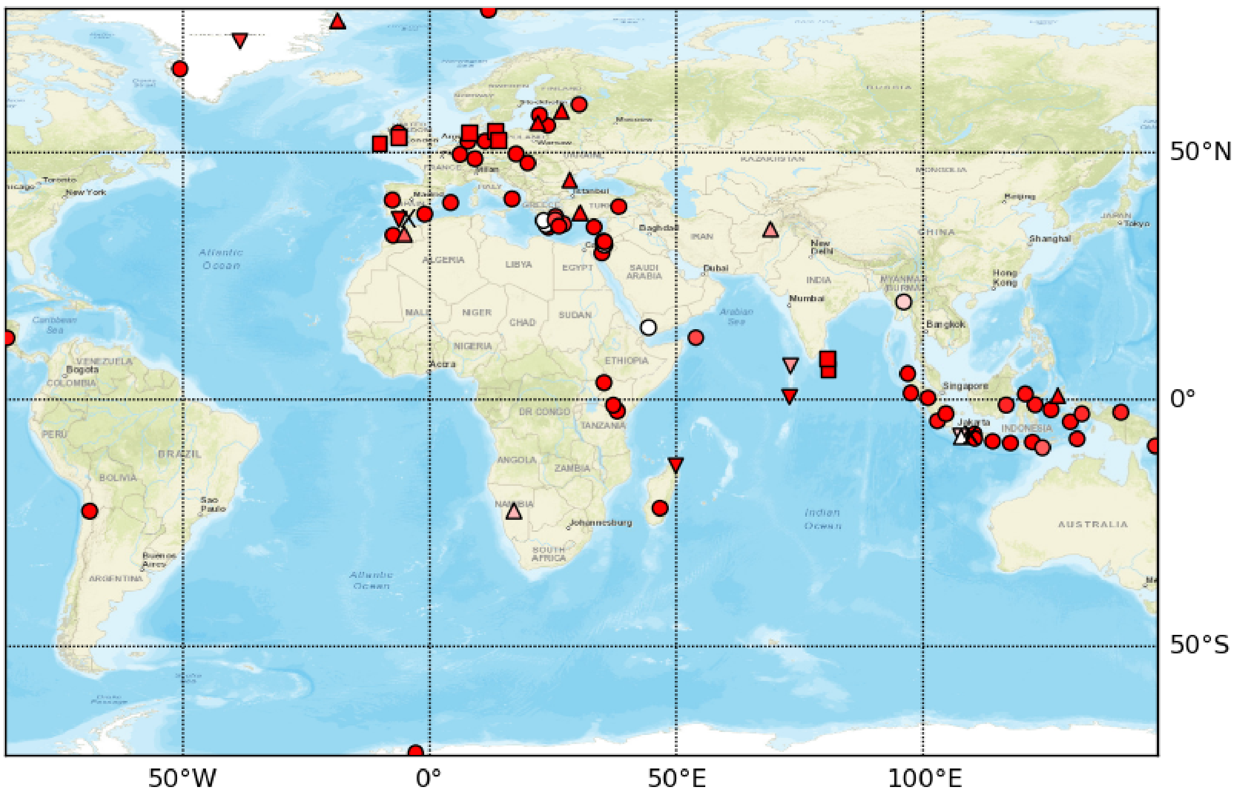

Fig. 1: GEOFON stations operating in 2016. Colors denote the data availability (white: 0% to red: 100% availability). Symbols describe the level of maintenance: circle for "none", square for "on site", triangle (up) for "remote", triangle (down) for "Remote incl. hardware shipment". An "X" next to the symbol indicates metadata updates.

solved by upgrading the VSAT hardware. In HMDM (Maldives) a fault in the terrestrial radio communication system caused station downtime and required the exchange of a modem. Other data transfer problems with DSL-based communication links at DSB (Ireland), HLG and RUE (Germany) were overcome by designing and implementing a new UMTS-based solution. Station SUMG on Greenland experienced multiple problems, with issues related to the data recording system (SeisComP box), the timing system (GPS antenna) and the sensor leveling (Breakout Box), which were solved in close cooperation with the science-tech team on-site. Run-down batteries and faulty chargers caused power problems at SBV (Madagascar) and HMDM (Maldives). Spares have been procured by GFZ and a timely replacement was performed by the local partner institutes with constant remote support. The on-site maintenance in Ireland was also used to optimize the seismic sensors' true alignment using a gyrocompass at both Irish GEOFON stations (DSB and VAL).

When corrective on-site repairs were necessary we continued to upgrade power system components to allow a closer monitoring of State of Health (SOH) parameters (e.g. in DSB, HLG, RUE). The long term goal is a unified/standardized power supply system at all GEOFON stations that facilitates remote problem analysis. This will help to minimize travel efforts for the GEOFON team and maximize the maintenance potential of our local partner institutes.

3.2 Technical developments

Development efforts were mainly directed at increasing the robustness, simplifying the station design and reducing operational costs of stations.

Currently under test in the laboratory is a new programmable logic controller (WAGO PFC-200), which allows, in addition to power monitoring, the parameterisation of the output and prioritisation of the consumers without additional hardware (e.g. seismic recording components vs. communication system vs. additional sensors). We also succeeded installing a Seedlink server on it. This potentially opens the opportunity to remove an entire hardware component from the current standard setup (the SeisComP box) thus simplifying the station design and reducing the overall power consumption. However, current tests have to first prove that this setup is sufficiently robust.

The access to global communication systems represents a large part of the operational costs of our stations. At very remote GEOFON stations the cost-intensive INMARSAT BGAN system currently provides a backup link for remote troubleshooting during times the VSAT link fails. An UMTS based alternative has been selected (Teltonika RUT-905) and is currently installed at three pilot stations (HLG, DSB, RUE). If hardware and link access prove to be robust, the BGANs can be replaced by UMTS modems in the mid-term.

3.3 Technical support to other networks

Apart from corrective maintenance and development efforts in the frame of GEOFON, the engineering group also provided support to other projects and groups within and outside GFZ. The engineering group supported the maintenance of the AlpArray stations (10 stations, UNIBRA) and the recovery of the ScanArray stations (10 stations). A substantial effort went into supporting the Integrated Plate Boundary Observatory Chile (IPOC) seismic network with maintenance actions carried out at 13 stations in Chile (CX seismic network). For the DEad SEa Research Venue (DESERVE) a new permanent station for Jordan has been prepared and tested. Other GFZ groups were supported with know-how and work hours, e.g. VSAT installation at a magnetotelluric reference station. We prepared the installation of a new station and one additional station upgrade due in 2017 to support the DESERVE project. Last but not least the group continuously provided assistance to our long term partner BMKG in Indonesia to run their seismic network and data center for tsunami early warning. In addition we contributed to two training classes ("Metadata Change Management" and "Local Seismicity", each training one week) and a workshop on operational procedures of the TEWS (two days).

3.4 Annexes

A detailed report of the actions of the Engineering Group in 2016 and Noise Probability Density Functions (PDFs) for all GE stations (BB channels) in 2016 are provided as separate documents. (Annexes linked at the end of the report.)

4 The GEOFON Data Centre

The GFZ Seismological Data Archive hosted at GEOFON has grown by 18.2 TB in 2016, which is almost twice the 2015 intake and thus higher than projected (10%), and corresponds to a 20% annual growth rate. Fig. 2 shows the added data by actual year of acquisition while Fig. 3 shows the increase of the archive size since 1993.

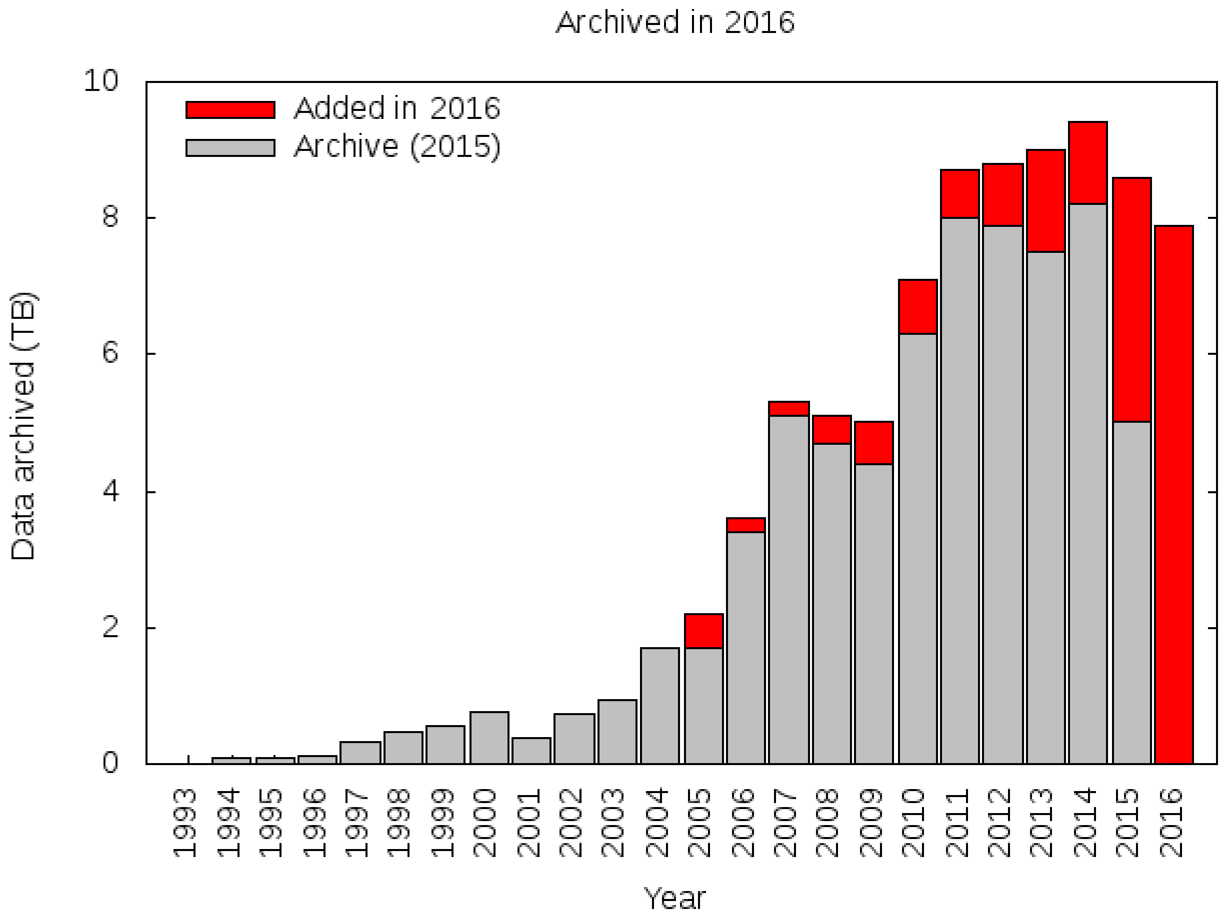

Fig. 2: Data holdings by year of acquisition. Red shows data added to the archive in 2016.

4.1 Services of interest in 2016 (service uptime)

Service availability of all GEOFON public services was >99% for practically all services. The sole exception was the EIDA master table, where availability was 98.2%:

Service	Up	Down/Problem
WebDC	99.986%	0.014%
EIDA Master Table	98.213%	1.787%
fdsnws-dataselect	99.909%	0.091%
fdsnws-station	98.886%	0.114%
routingsvc[*]	99.732%	0.268%
geofon-proc	>99.99%	<0.01%
geofon (ping)	99.985%	0.015%
geofon (web pages)	99.785%	0.215%
geofon (eqinfo)[**]	99.780%	0.220%
geofon (Seedlink)	99.553%	0.447%

[*] For December 2016 only.

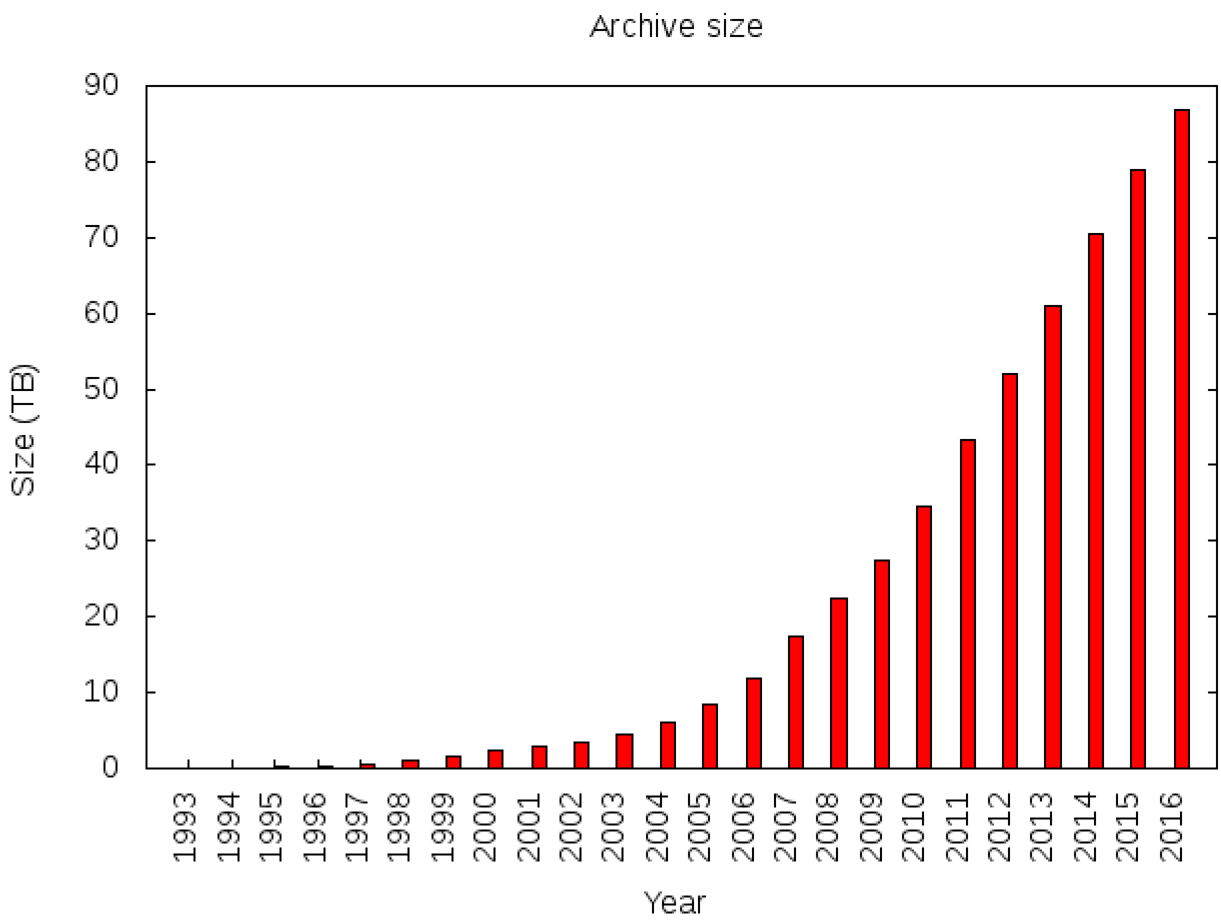

Fig. 3: Cumulative size of the GEOFON archive at each year.

[**] Only checks that /eqinfo/list.php can be displayed.

The service uptime is measured by a Nagios instance running on a local machine. This means that times when the computer running Nagios was down, e.g. during a power outage, would not be included in the analysis, and also times when the connection to the internet was broken would not necessarily be reported as down time. Even though technically this makes the report service uptime an upper bound estimate, no major episodes of either network or power outage are known to us, such that the numbers can probably be taken at face value.

Details of checks carried out:

- WebDC: check Arclink responds on port 18002 at webdc.eu.
- EIDA Master Table: check http://webdc.eu/arclink/table?group=eida is accessible.
- geofon-proc: MySQL (SeisComP db) available, and contains recent events.
- **FDSN web services:**
  - check fdsnws-station at http://geofon.gfz-potsdam.de/fdsnws/station/1/version
  - check fdsnws-dataselect at http://geofon.gfz-potsdam.de/fdsnws/dataselect/1/version
- routing service: This service was still under development at the start of the year. While there were many outages until April, this service is now quite stable.
- geofon (ping): ping of geofon.gfz-potsdam.de responds within three seconds.

- geofon (web pages): visit the front page, http://geofon.gfz-potsdam.de/
- geofon (Seedlink): *telnet geofon.gfz-potsdam.de 18000* succeeds.
- geofon (eqinfo): only to display http://geofon.gfz-potsdam.de/eqinfo/list.php, and respond in <2 sec; not whether fresh content is served. However, MySQL at st13 had 0.119% problems, and st27dmz MySQL had 0.022% problems in December 2016, suggesting there were no serious problems with this service. A more sophisticated check is currently disabled.

4.2 Data and metadata requests made in 2016

Requests by method and by type.

Request method	Requests	Bytes
fdsnws	9504876	7300 GiB
BREQ_FAST	132150	
WebDC3	53634	2243 GiB
Other Arclink		
Total	68983238	16574 GiB

Request type	Requests[*]	Bytes
INVENTORY	3306896	149 GiB
RESPONSE	50849	891 MiB
ROUTING	47385338	21 GiB
WAVEFORM	6034996	16574 GiB
Total	56778079	16745 GiB

[*] successful requests, i.e. at least one line was OK.

In 2016 for the first time data delivered via standard fdsnws services was almost comparable to the data delivery via Arclink. In particular ~9 million out of the ~18 million waveform requests received were made using the fdsnws-dataselect and 7.3 TB out of the total 16.5 TB were delivered by web service. The total numbers of unique userIDs (normally email addresses) was around 1400. This provides a very rough indication of the number of unique users but is heavily biased by two effects working in opposite directions.

1. Different IDs might be used by the same user, either due to typos or deliberately, resulting in an overestimate.
2. User ID only has to be provided for BREQ_FAST and Arclink requests, so users of the web services are not counted, nor those that request their data from WebDC. A similar issue arises for ObsPy users, who use the default settings in the ObsPy request tool, who all appear as a single user in our statistics.

We believe that the second effect is much more important, particularly in light of the much increased usage of web services, such that the reported number of users will be a severe underestimate.

4.3 BREQ_FAST requests

In 2016 there were about 70 users of the BREQ_FAST e-mail based service, who made 132,200 requests. Just two users account for over 85% of the BREQ_FAST requests in 2016. Together, just 14 users account for 99% of all BREQ_FAST requests. For now we will continue to provide the BREQ_FAST service but it should be considered deprecated and is no longer actively maintained.

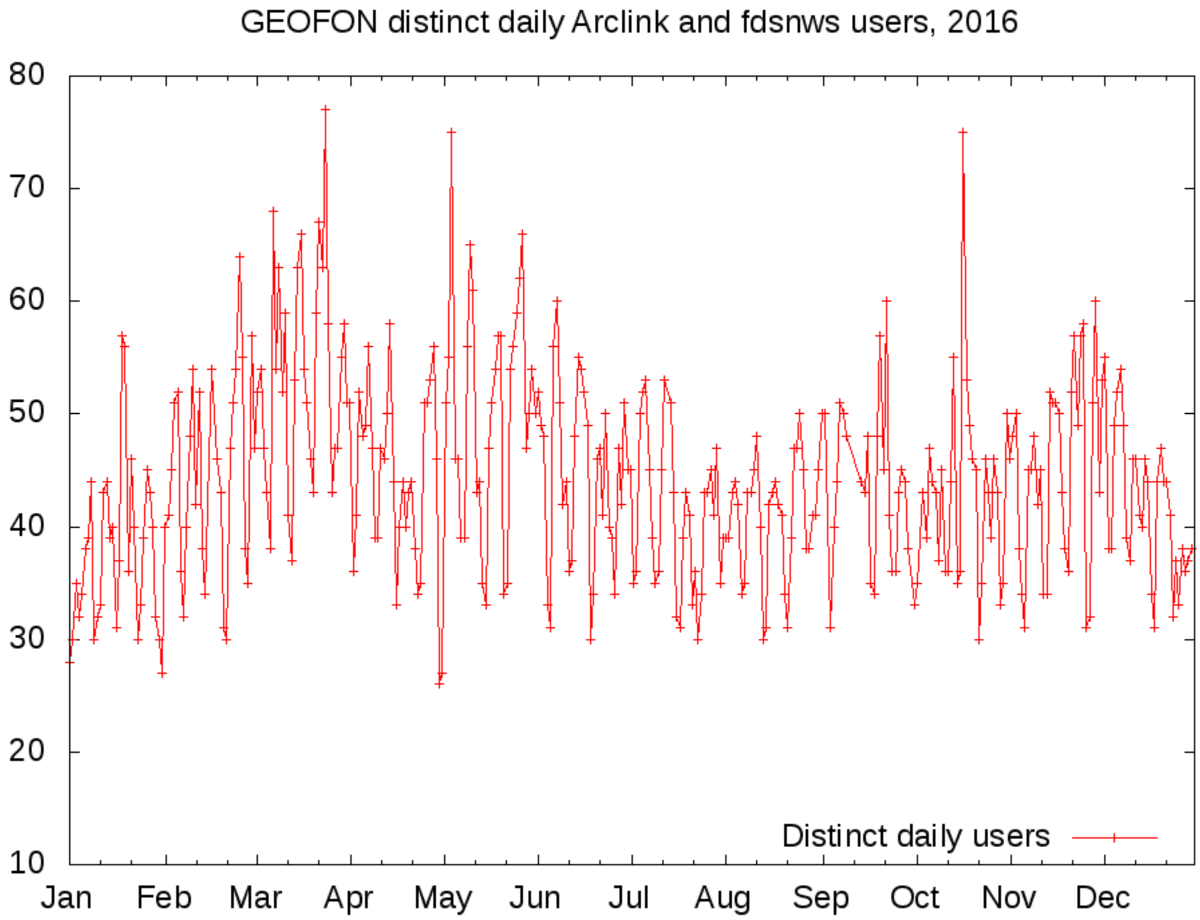

Fig. 4: Number of distinct user IDs provided for Arclink on each day in 2016.

4.4 New networks (embargo period end or any other change)

- New Networks: 3E (Part of RHUM-RUM, restricted), 7G (Halmahera, restricted), 8F (West-Fissure, restricted), KV (KiVuS, restricted), UP (years 2012-2016 as part of ScanArray, metadata at ORFEUS, restricted) 3D (Pisagua, restricted), XN (Nepal, restricted), + IQ (old network code).
- Released: 4A_2012, Y4_2014 (both Pollino, Italy).
- DOIs minted: 11 new DOIs were minted in 2016, for two permanent networks (AW (AWI) and KV (KivuS)) and nine for temporary experiments, five of which concerned past experiments where the PIs used the opportunity to make their datasets citable.

4.5 Real-time data export via seedlink

The real-time data export via seedlink remains stable at ~100 TB/year with 300-400 continuous connections to the public Seedlink server at geofon.gfz-potsdam.de (Fig. 5).

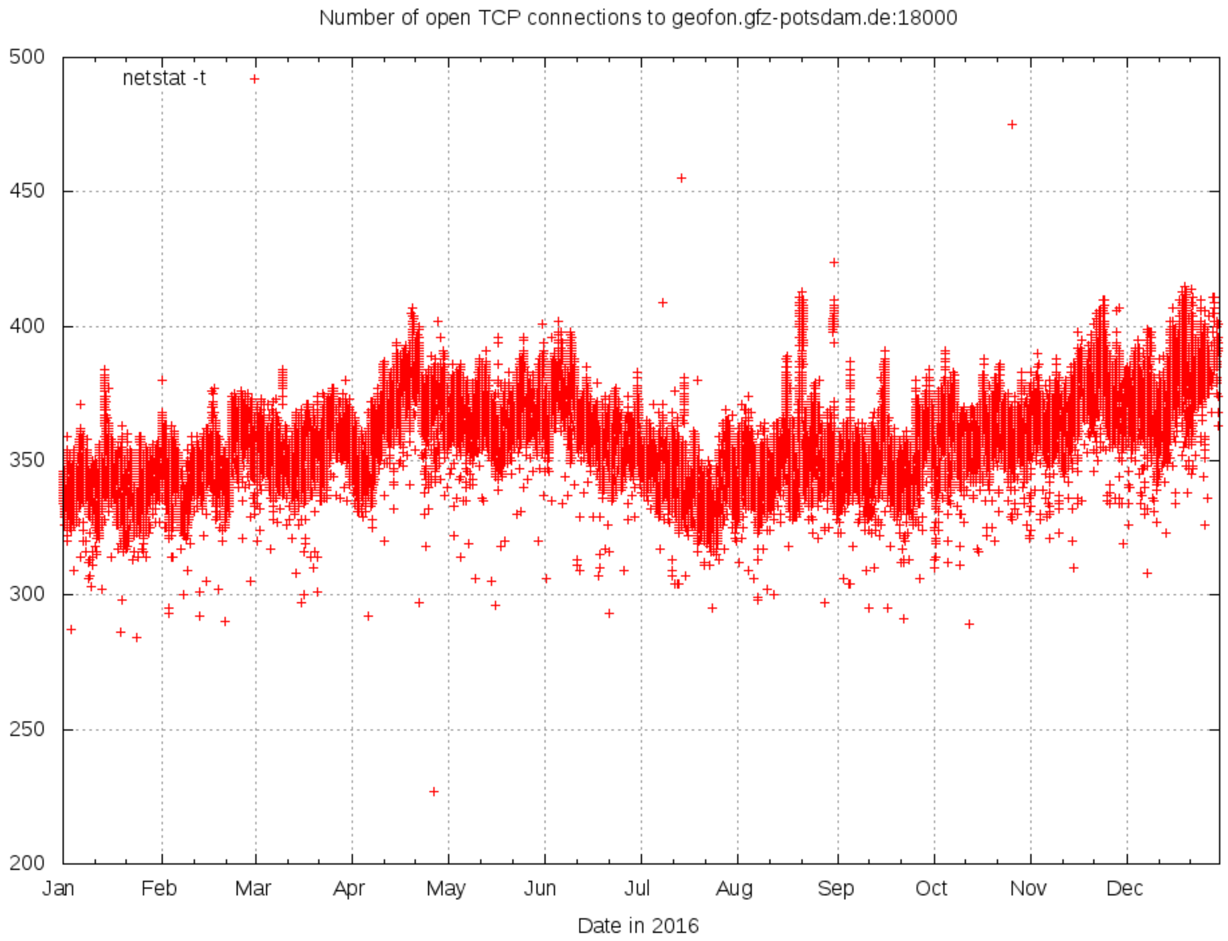

Fig. 5: Clients requesting real-time data from the seedlink server.

5 GEOFON Rapid Earthquake Information

5.1 Event dissemination in 2016

During 2016, GEOFON published 5258 events and 1104 moment tensor solutions via the web pages and other dissemination channels. Fig. 6 shows the geographic distribution of the published events and Fig. 7 the distribution of the moment tensors.

Events by magnitude classes in 2016.

Mag.	Number of events
7.5	7
6.5	44
5.5	426
4.5	3990
All	5258

Event dissemination in 2016

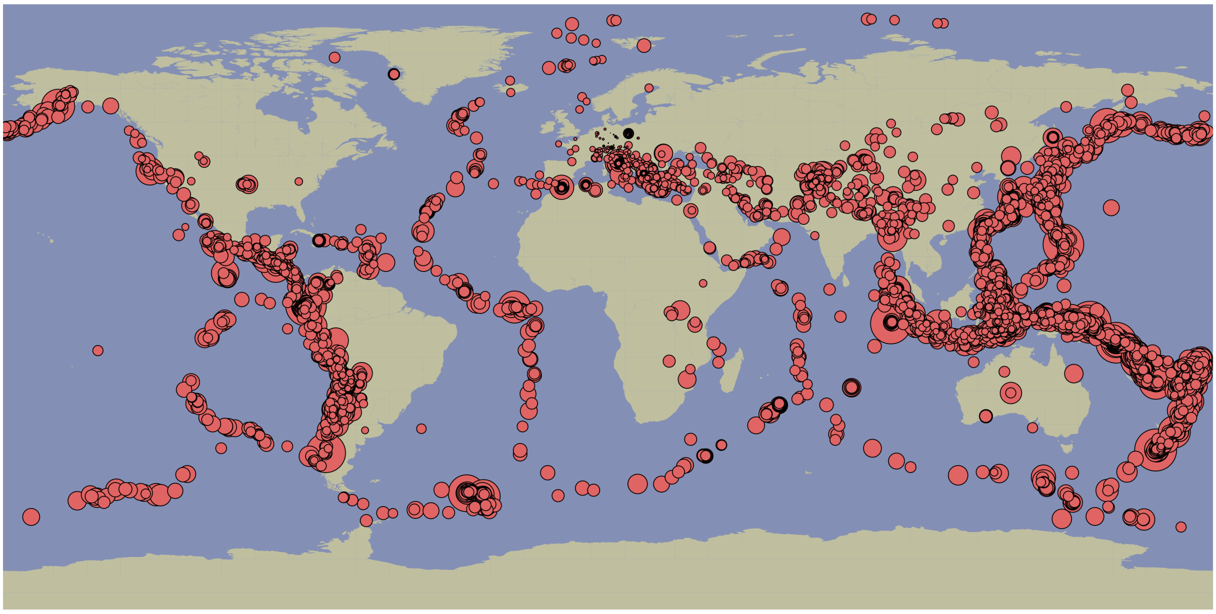

Fig. 6: Geographic distribution of the published events in 2016.

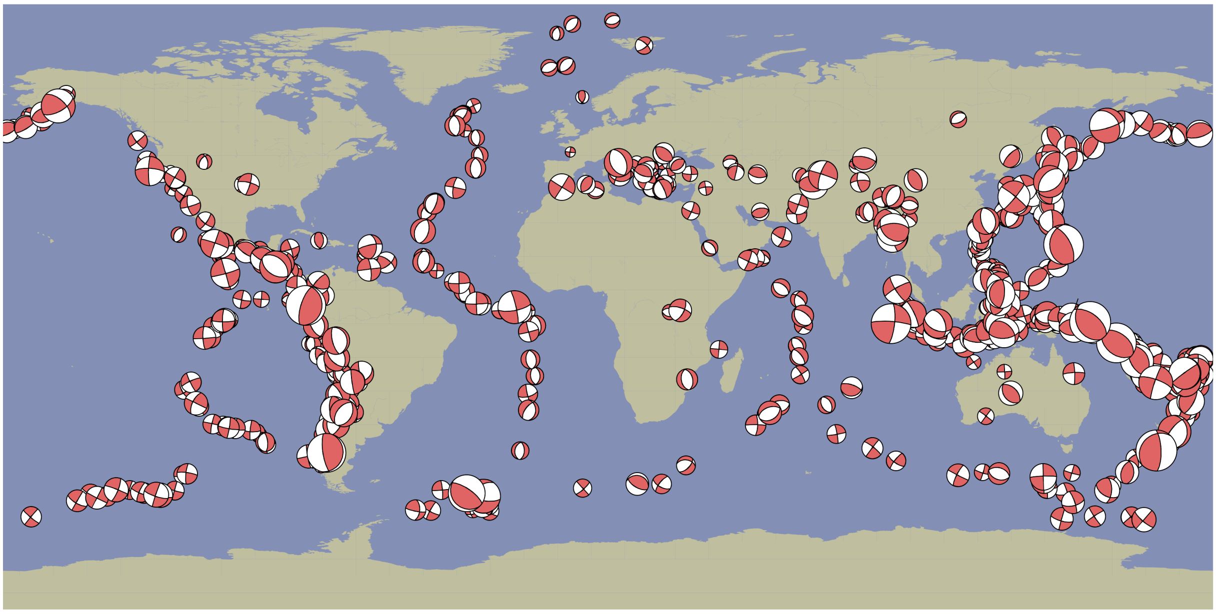

Fig. 7: Geographic distribution of the published moment tensor solutions in 2016.

Events	No MT	Has MT	Total
Published	4154	1104	5258
Status A (automatic)	937	–	937
Status C (confirmed)	1705	787	2492
Status M (manual)	1512	317	1829
Removed (Fake/duplicate)	40	0	40
Special page	2	18	20

“Fake” events are usually characterized by unfavourable azimuthal station coverage or even strongly clustered stations (IPOC, parts of Central Europe, Taiwan). The number of published fake events could be reduced significantly compared to previous years by introducing additional publication criteria such as the maximum “sum of the largest two azimuthal gaps”.

Alerts issued by type for each quarter

2016	xxl	big	Other	All classes
Q1	12	98	86	195
Q2	21	120	102	247
Q3	19	110	124	253
Q4	32	152	129	313
Total	84	480	441	1011

The definitions of these alert types are:

- ‘xxl’ events are those with magnitude larger than 6.5 worldwide, or larger than 5.5 in or near Europe, or 5.0 in central Europe.
- ‘big’ events have magnitude above 5.5 in most of the world, or above 5.0 in the wider Europe/Mediterranean area and M4.5 in central Europe.
- the ‘Other’ category includes internal alerts and some regional notifications.

Total number of events catalogued with M 6.5 or higher (44) is smaller than number of ‘xxl’ alerts becaus

- The initial magnitude estimate may be higher, triggering an alert which refined analysis later would disqualify it as ‘xxl’.
- There is a lower magnitude threshold, 5.5, for events in and near Europe (+6 events).
- Some alerts are also sent from our backup processing system (+20).

5.2 Event notification delays in 2016

5.3 Monitoring connections to the GEOFON web server

The number of distinct users connecting to geofon.gfz-potsdam.de is on typically ~30000/day. Significant traffic is driven to our web server at geofon.gfz-potsdam.de immediately after large events, particularly those in Europe, reaching up to 270000 distinct users on peak days (e.g. the Italy earthquake in August, Fig. 10) (“Distinct” users are those with distinct IP address and User-Agent, on mobile devices IP may change and thus increase the numbers of counts.)

6 Software development

6.1 httpmsgbus

httpmsgbus (HMB) is a new software development which functions as a messaging service running over HTTP. It facilitates the transfer of objects, such as SeisComP 3 (SC3) data model items, but also other content, between a server and a client. Messages sent by one client can be received by multiple clients connected to the same bus. JSON and BSON formats are used for communication. HMB supports out-of-order messaging, message filtering, and can cope with network outages without loss of messages.

Current use cases include (i) dissemination of live event data (*scimex*) and Nagios alerts (internal GEOFON use) and (ii) dissemination of published events in QuakeML format and picks to EMSC. HMB

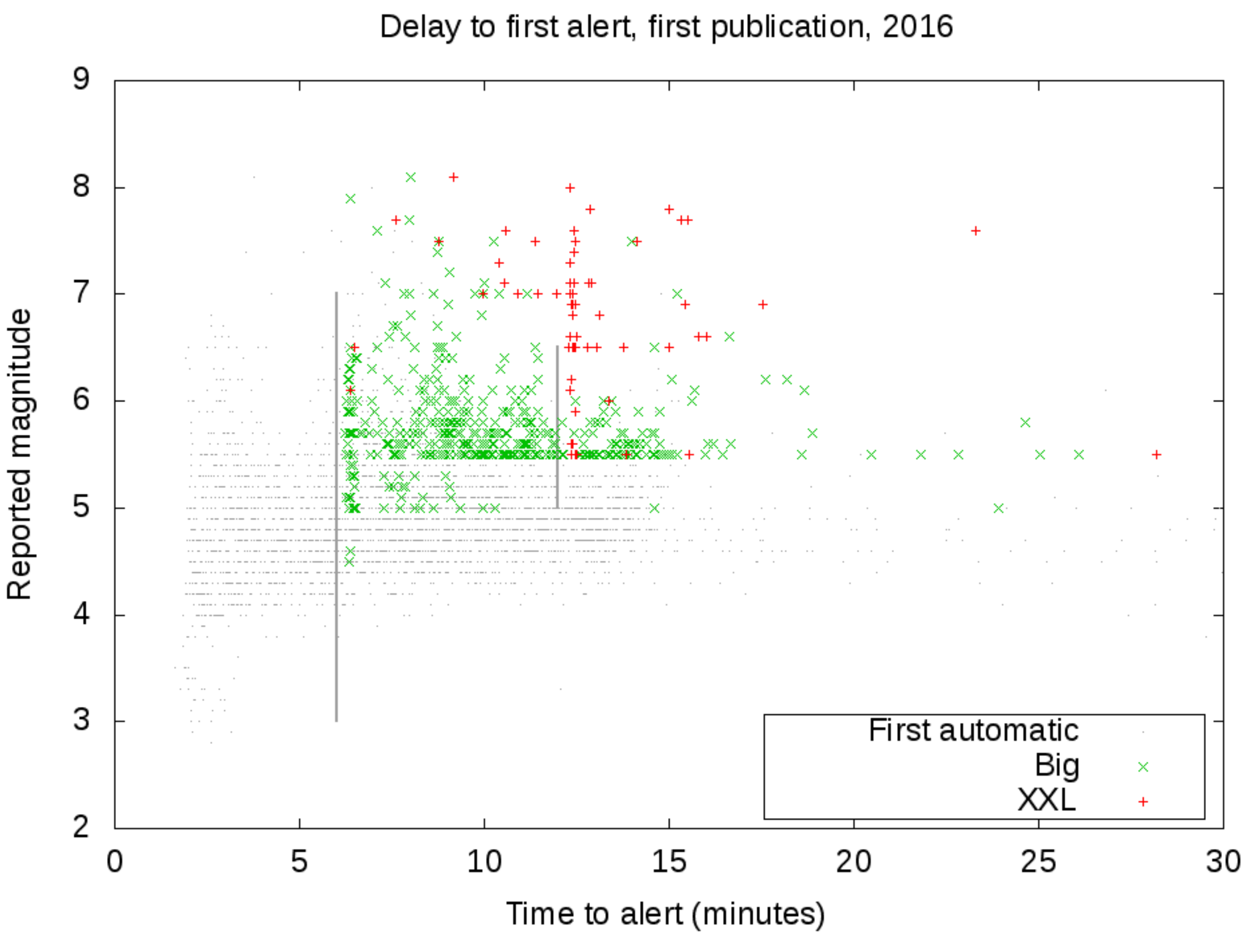

Fig. 8: Event publication (grey dots) and alert delay (big green and xxl red) vs. magnitude in 2016. Alert delay for 785 GEOFON events in 2016 resulting in SMS alerts. Magnitude is the magnitude reported at the time of the alert. Also shown are 3693 events with only an automatic detection (status 'A').

can be used as a standalone program or as an add-on to SeisComP 3. It is written in Go language. The software is rather mature and well-tested, but the protocol may require formal definition to avoid future compatibility problems with alternative implementations.

6.2 fdsnws

FDSNws are standardised web services for access to continuous waveform data and metadata on stations and responses.

The SeisComP 3 fdsnws server was extended to support statistics and EIDA authentication. CORS headers were added to support Javascript applications. The new version has been included in SeisComP 3 since the 2016.333 release.

fdsnws_fetch

fdsnws_fetch is a client implementation for the waveform webservices <http://geofon.gfz-potsdam.de/software/fdsnws_fetch>. Major development of *fdsnws_fetch* also took place in 2016. Integration with ObsPy was improved and support for EIDA authentication was added. It has been included

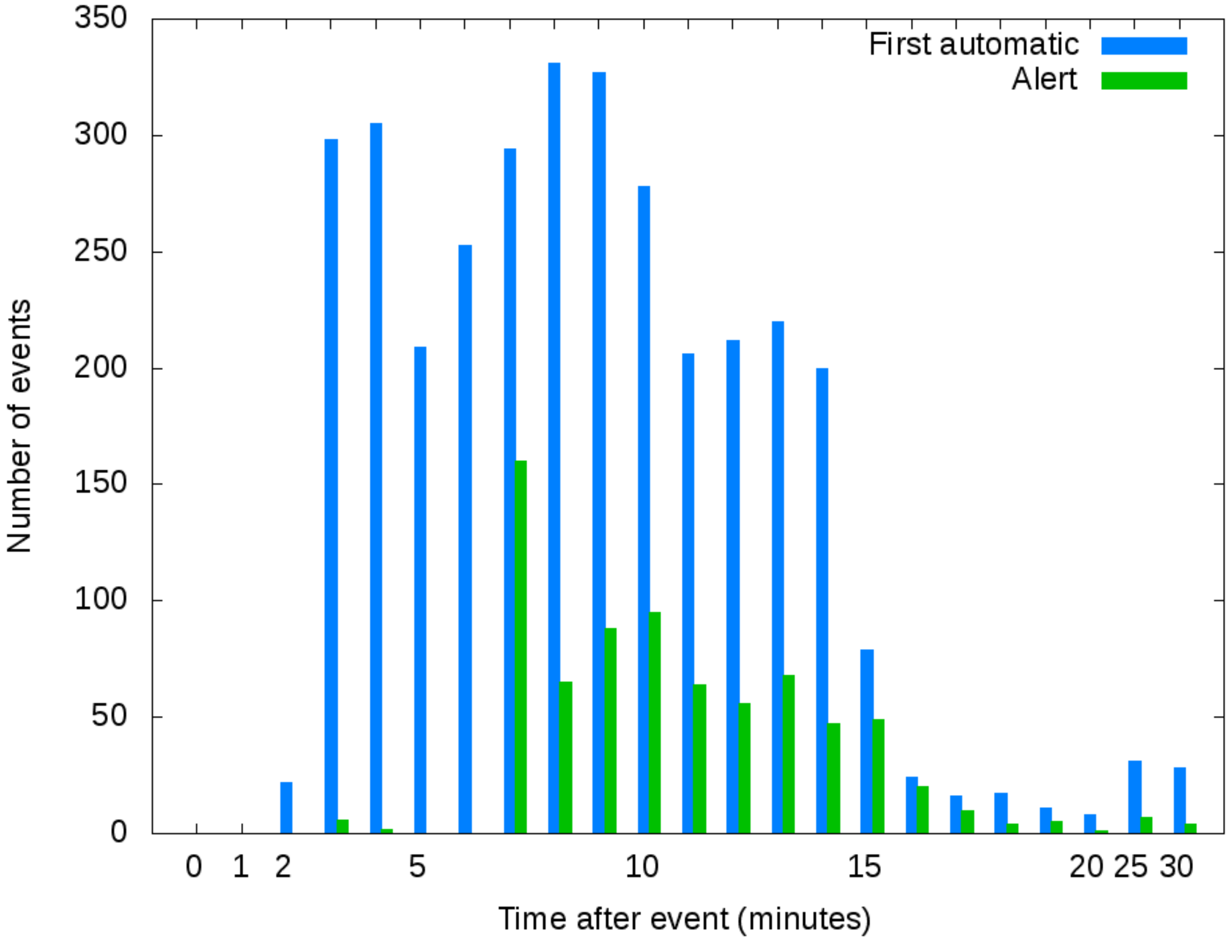

Fig. 9: GEOFON alert delay vs. first automatic publication.

in SeisComP 3 since the 2016.333 release and is planned to be included in ObsPy in the form of a reusable Python module.

fdsnws_fetch is also available as a standalone package that requires neither SC3 nor ObsPy.

fdsnws2sds

fdsnws2sds was developed for users who want to download large amounts of data for offline processing. *fdsnws2sds* allows suspending and resuming downloads and saves the data in an SDS file system structure (i.e. daily files organised by network, year, station, channel and day). Internally the script uses *fdsnws_fetch*. *fdsnws2sds* is not currently included in SeisComP 3, but will possibly be included in a future version.

6.3 WebDC3

A new version of WebDC3 that supports FDSN Web Services was implemented.

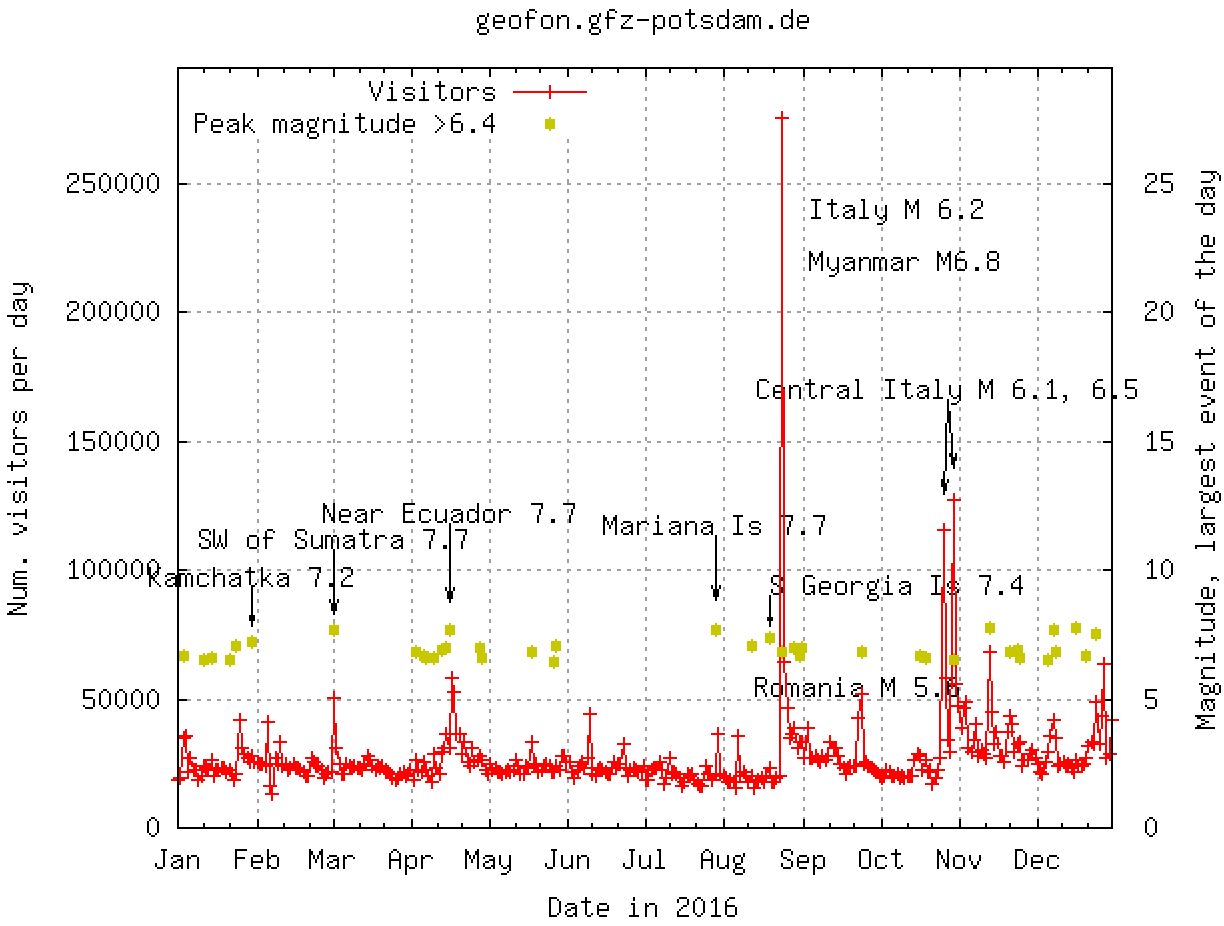

Fig. 10: Daily distinct visitors to geofon.gfz-potsdam.de during 2016 (unique IP + user application which is dominated by automatic applications including mobile devices apps). Also shown is the magnitude of the *largest* event recorded on each day, when this exceeds 6.4. (The threshold for 'xxl' alerts is 6.5 in most of the world).

6.4 Routing service

The routing service redirects requests to the correct data centres within EIDA. Two major improvements have been accomplished in 2016.

- A configuration of the routes completely independently from Arclink is in operation.
- The service providing quality metrics at EIDA was included and is now discoverable from the routing service.

6.5 SeisComP 3 releases and usage

Three releases of SeisComP 3 were made in 2016: 2016.062, 2016.161, 2016.333.

53 new non-commercial licenses were released in 2016 (total 424, 12.2016) and one additional commercial license was negotiated (total 6, 12.2016).

7 Outreach and Capacity Building

GEOFON data, services and products have been cited in 46 papers published in ISI journals in 2016 (total 470 citations). The full list of publications which explicitly acknowledged use of GEOFON products is available at http://geofon.gfz-potsdam.de/references.php and updated to December 2016.

Within 2016, GEOFON team members have presented at several conferences and contributed to several trainings. In particular lecture about the usage of GEOFON products were given at the following events:

- ORFEUS Observatory meeting, Dubrovnik, Croatia.
- ESC Young Seismologist Training Course, Trieste, Italy.
- GFZ International Training course Naypitaw, Myanmar.
- BMKG Jakarta, Indonesia.
- DESERVE Winter School, Madaba, Jordan.

In total more than 200 participants attended the lectures. Dedicated documentation was prepared an example from the DESERVE Winter School is available here.

8 GEOFON Team (Human Resources, 2016)

Name	GE Net.	GE DC	EQ info	GE op.	Soft. Dev.	Out-reach	Fin. Project
Angelo Strollo	x	x	x	x		x	GFZ
Thomas Zieke	x						GFZ
Michael Guenther	x	x				x	BMKG/Oth./GFZ
Karl-Heinz Jäckel[*]	x						GFZ
Javier Quinteros		x			x	x	EUDAT
Susanne Hemmmleb		x					GFZ
Riccardo Zaccarelli[*]		x			x		EPOS-IP/GFZ
Joachim Saul[*]		x	x		x	x	GFZ
Winfried Hanka[*]			x				GFZ
Andres Heinloo	x	x	x	x	x		GFZ
Peter Evans	x	x	x	x	x	x	GFZ

[*] Not working full time for GEOFON.

9 GEOFON Advisory Committee Members (2016)

- Dr. Florian Haslinger, Chair ETH Zurich Zurich,CH
- Dr. Christian Bönnemann, BGR Hannover, D
- Prof. Dr. Wolfgang Friederich, RU Bochum, Bochum, D

- Prof. Dr. Thomas Meier, CAU Kiel, D
- Prof. Dr. Max Wyss, International Centre for Earth Simulation, Geneva, CH
- Dr. Jan Zednik, GFU Prague, CZ

10 Acknowledgements

We acknowledge partners co-operating GEOFON stations and data providers enabling us to create the so-called GEOFON Extended Virtual Network (GEVN) used for the rapid earthquake information. We are also thankful to users and in particular to our advisory committee for their valuable feedback.

11 References

McNamara, Daniel & Buland, Raymond. (2004). Ambient Noise Levels in the Continental United States. Bulletin of the Seismological Society of America. 94. 1517-1527. doi:10.1785/012003001.

12 Annexes

1. Summary of GE maintenance team activities (2016)

   An overview of the activity is provided in Annex 1. For each action at the station a short description is included. The summary includes also support activities for other groups within GFZ.

2. Probability Density Functions (PDF) for operational GEOFON stations 01.2016 - 12.2016

   The PDF displayed in this appendix have been calculated with PQLX v. 2011.365.P4 (McNamara & Buland 2004) only for the primary channels, that is generally a broadband sensor at 20 Hz. Only operational stations during the year have been included, stations that were off-line for most of time are not included in this appendix.

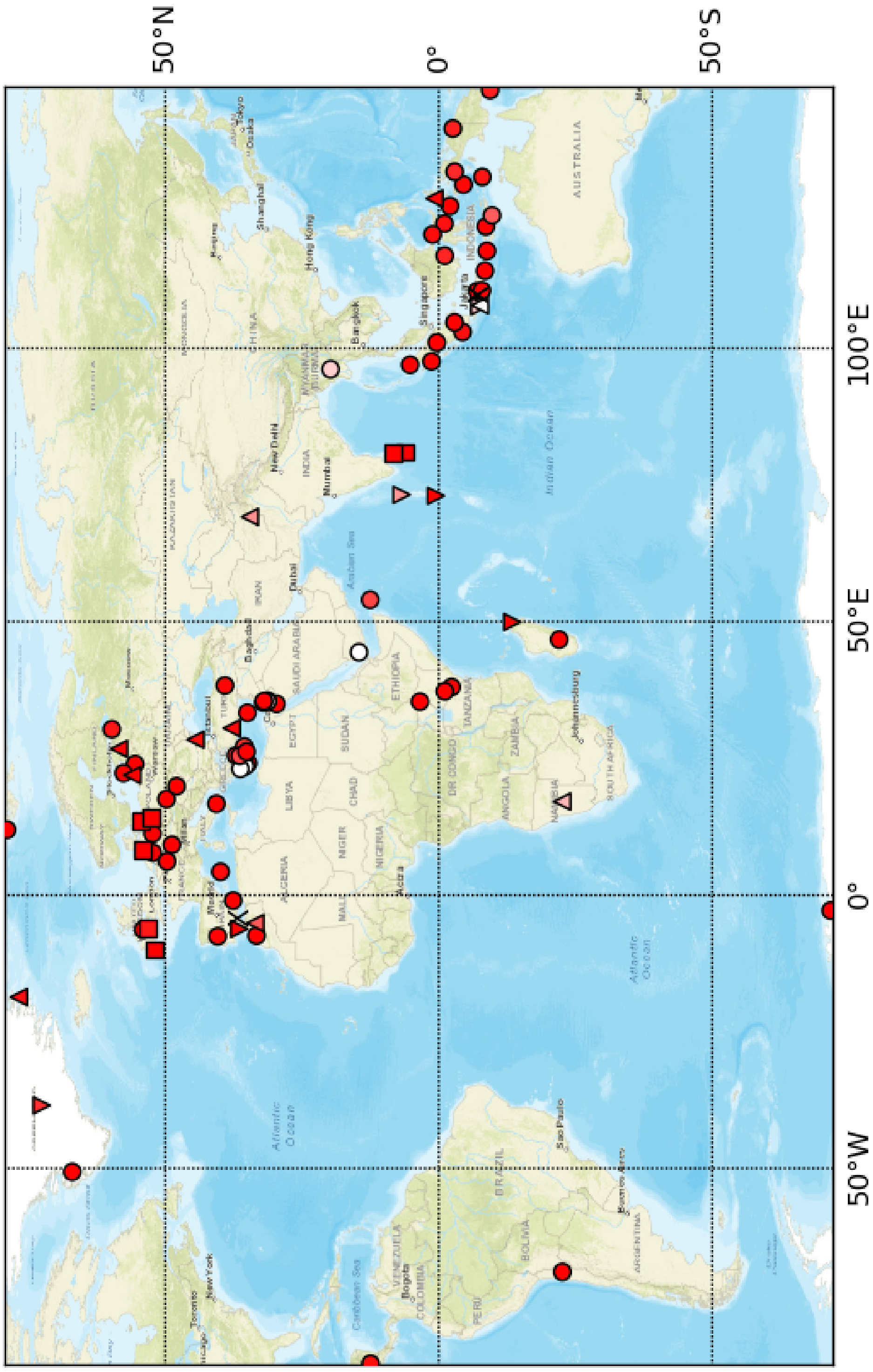

Fig. 11: GEOFON stations in operation. Colors denote the data availability (white: 0% to red: 100% availability). Symbols describe the level of maintenance activity: circle for “none”, square for “on site”, triangle (up) for “remote”, triangle (down) for “Remote incl. HW shipment”. An “X” next to the symbol indicates metadata updates.

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