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FOR GEOSCIENCES

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

GEOFON Annual Report 2017

Scientific Technical Report STR 20/05

Version 2.1 2019-06-05

Recommended citation for the report:

Strollo, A., Evans, P., Hanka, W., Heinloo, A., Hemmleb, S., Jäckel, K.-H., Quinteros, J., Saul, J., Zaccarelli, R., Zieke, T., & Tilmann, F. (2019). GEOFON Annual Report 2017. In Scientific Technical Report STR; 20/05 (Version 2.1). GFZ German Research Centre for Geosciences. https://doi.org/10.2312/GFZ.B103-20054

Imprint

Helmholtz Centre Potsdam
GFZ German Research Centre for Geosciences

Telegrafenberg
D-14473 Potsdam

Published in Potsdam, Germany
June 2019

ISSN 2190-7110

DOI: 10.2312/GFZ.b103-20054
URN: urn:nbn:de:kobv:b103-20054

This work is published in the GFZ series
Scientific Technical Report (STR)
and electronically available at GFZ website
www.gfz-potsdam.de

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Contents

1 Executive summary **5**

2 Introduction **6**

3 The GEOFON global seismic network **6**
3.1 Regular maintenance . . . 6
3.2 Technical support to other GFZ groups (e.g. Observatories) . . . 6
3.3 Annexes . . . 7

4 The GEOFON Data Centre **7**
4.1 Archive Service Delivery . . . 8
4.2 New networks (embargo period end reports or any other change) . . . 8
4.3 Real-time data export via seedlink: . . . 10
4.4 Service uptime . . . 10

5 GEOFON Rapid Earthquake Information **11**
5.1 Published earthquake locations and moment tensor solutions . . . 11
5.2 GEOFON web server traffic . . . 12

6 Software development **13**
6.1 Stream2segment . . . 13
6.2 gfzreport . . . 14
6.3 SeisComP 3 releases and usage . . . 14

7 Impact, Outreach and Capacity Building **14**

8 Publications by GEOFON staff **15**

9 GEOFON Team (Human Resources) **16**

10 GEOFON Advisory Committee Members **16**

11 Acknowledgements **17**

12 References **17**

13 Appendices **17**
13.1 Probability Density Functions (PDF) for operational GEOFON stations 01.2017 - 12.2017 . . . 17

14 Annexes **33**
14.1 Summary of GE maintenance team activities . . . 33

1 Executive summary

- The GEOFON Global Seismic Network has required maintenance actions at 14 stations. The GEOFON engineering team performed on-site maintenance at two sites, SUMG in Greenland and VSU in Estonia. The remaining 12 maintenance actions have been performed by the partners with remote guidance when needed. Here, for 8 stations new hardware has been tested in Potsdam and installed by the local partners. A new sensor (Nanometrics Meridian Posthole) has been installed at SUMG.
- The GFZ Seismological Data Archive hosted at GEOFON has grown by ~9 TB in 2017, with the total size of the archive reaching ~94 TB. Tailor made requests have been served to more then 1300 unique users sending more than 25 million requests for 50+ million time windows. Real-time data export remains at about ~100 TB/year to more than 300 clients. A new BMBF project on data management in cooperation with the GFZ central library (LIS) and the instrumental pool (GIPP) started this year and will last for two years.
- GEOFON published 4721 events and 1032 Moment Tensor solutions via the web pages and other dissemination channels. We started to test real-time parametric data exchange with EMSC in order to enhance speed and reliability of the initial locations when the seismic network coverage is not optimal.
- A modular tool to process customized event based windows obtained from EIDA and EMSC/ISC is under development as part of the EPOS-IP project. A new report generator tool has been made available to the users to easily generate and publish technical reports about the archived networks (this report was also generated with this tool). SeisComP3 non-commercial licenses have been released for 53 new institutions. Four new SeisComP3 releases have been published: 2017.124 on May 4th, 2017.124.02 on June 8th, 2017.334 on November 30th, 2017.334.02 on December 15th.

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 SeisComP3 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. As 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

A new sensor has been installed at SUMG, which is a metadata change users should be aware of. The new Nanometrics Meridian Posthole has been deployed in May with the aim to replace the old Trillium sensor at the next maintenance trip (expected in 2019). Being an all-in-one sensor and digitizer we expect the Meridian to require less maintenance effort and to provide better performance for the horizontal components which seems to be the case looking at the first months of data (see appendix).

3.1 Regular maintenance

During the year several maintenance actions were carried out for the 84 GEOFON stations (note that the 4 former stations today belonging to the WM seismic network and WM.TIO are included in the total number of stations). In particular 14 stations required corrective maintenance actions. The GEOFON engineering team performed on-site maintenance at 2 sites (SUMG in Greenland and VSU in Estonia), 12 stations were repaired by our local partners and in 8 cases spare parts were assembled and tested in Potsdam and delivered to the local partners (Figure 1). Four of the GEOFON stations have not delivered any data in 2017 (SOCY and DAMY in Yemen, PUL in Russia and KERA in Greece). Despite the complex political issues we are facing with these stations we expect to have them back on line in the future, thus keep their epochs open. The average availability for the network, excluding the four non- working stations is at 95%.

3.2 Technical support to other GFZ groups (e.g. Observatories)

Apart from corrective maintenance and development efforts in the frame of GEOFON, the engineering group also provided support to other projects/groups within the GFZ. In particular within our own section (2.4) we supported the SWATH-D and UniBRA field activities. Last but not least the group continuously provided assistance to our long term partner BMKG in Indonesia to run their seismic

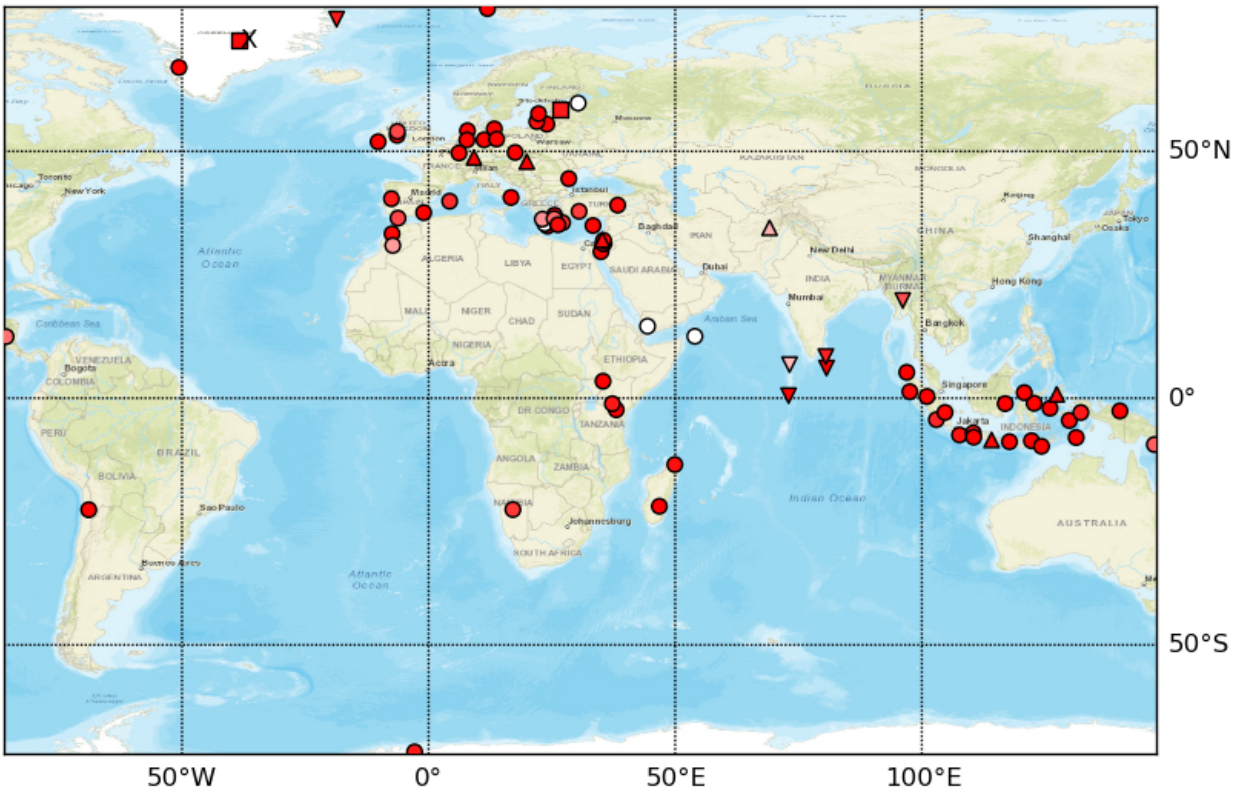


Fig. 1: GEOFON stations in 2017. Colours denote the data availability (white: 0% to red: 100% availability). Symbols represent the level of maintenance needed: circle for “none”, square for “on site”, triangle (up) for “remote”, triangle (down) for “Remote including HW shipment”. An “X” next to the symbol indicates metadata updates.

network and data center for tsunami early warning. One of the GE engineers spent two weeks in Jakarta to deliver several training and workshop sessions for colleagues at BMKG .

3.3 Annexes

A comprehensive report on engineering actions is provided as a separate document linked at the end of the report.

4 The GEOFON Data Centre

The GFZ Seismological Data Archive hosted at GEOFON has grown by ~9 TB in 2017, with most of the data from temporary networks added between 2015 and 2016, but also with some data added for years back in 1997-1999 (Fig. 2). The total size of the archive is ~94 TB, replicated at two different locations, primary and secondary hot copies at GFZ, whereas a cold copy is daily replicated to the

KIT in Karlsruhe. Fig. 3 shows the increase of the archive size since 1993. Service availability of all GEOFON public services was ~98% over the year for the 1300+ users of the data services. Most of the data were served via fdsnws with more than 25 million data request (15 TB), and 8 million via Arclink (13 TB).

4.1 Archive Service Delivery

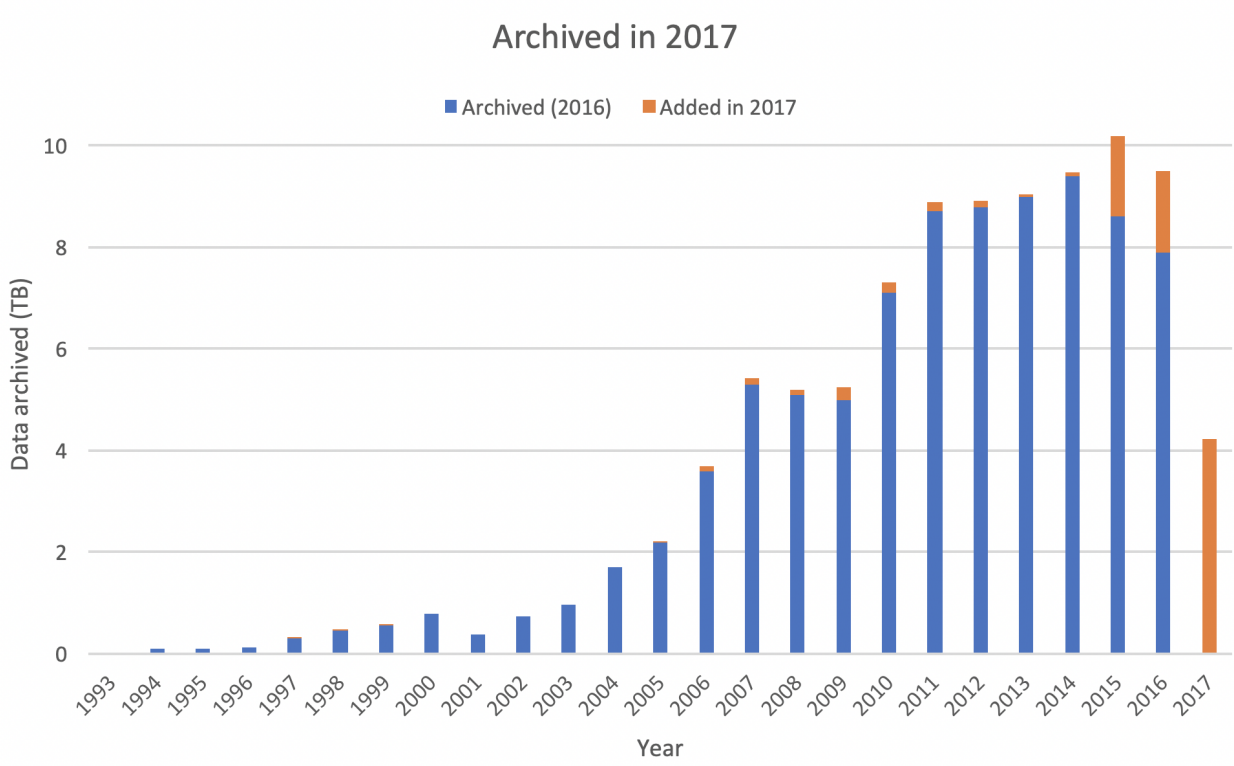


Fig. 2: Data archived by year of acquisition.

Requests by method and by type.

Table 1: Requests by method and by type

Request method	Requests	Timewindows	Volume	Users
fdsnws (external)	13.854.693	20.166.187	10 TB	569
fdsnws (GFZ)	2.951.183	18.670.188	5 TB	99
Arclink (external)	8.457.681	2.266.774	13 TB	1316
Arclink (GFZ)	145.788	670.925	0 TB	56
Total	25.409.345	57.881.709	28 TB	

4.2 New networks (embargo period end reports or any other change)

Two new permanent networks:

- HN Hungarian National Infrasound
- M1 Monet from the Czech Republic)

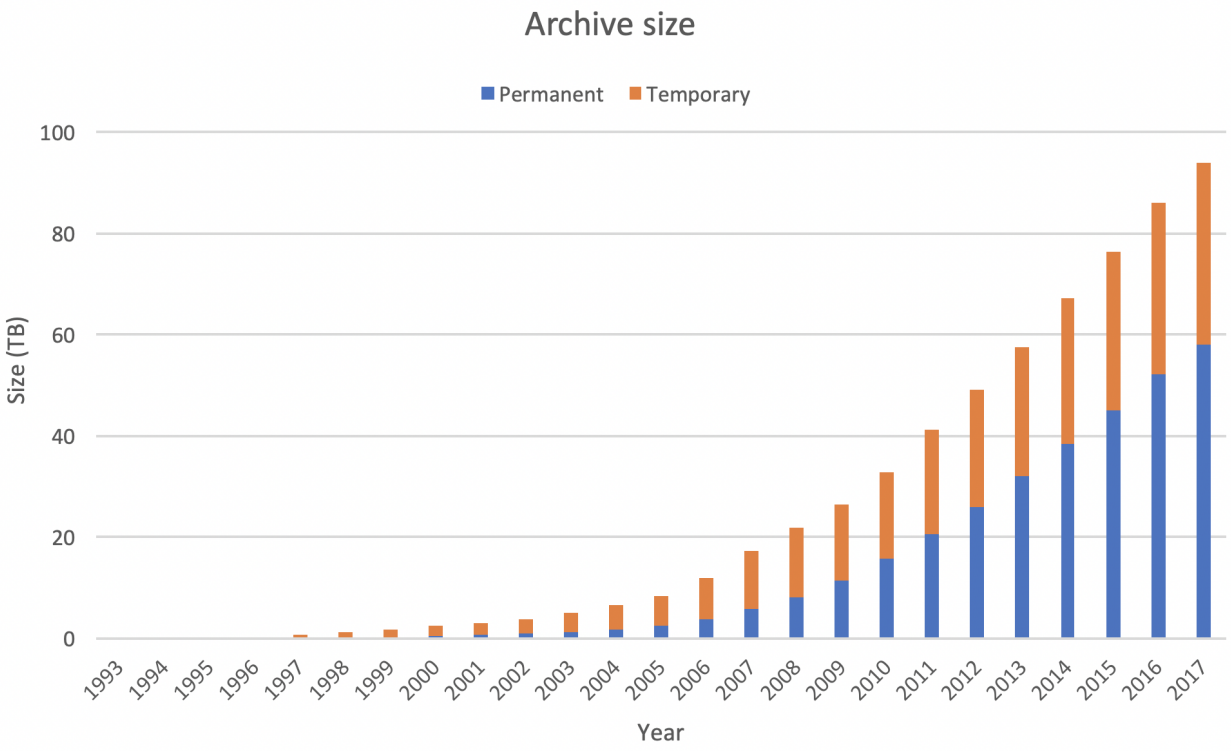


Fig. 3: Cumulative size of the GEOFON archive.

and 7 temporary networks:

- 1A Sri Lanka, restricted
- 2G Lastarria volcano, restr.
- 3H Renland, restr.
- 8E Lascar volcano, restr.
- YZ East Pollino, restr.
- ZS Swath-D (more than 150 stations in Central Alps), restr.
- X9 KISS, (Kamchatka) restr.

Released:

- 7B_2008 TIPAGE
- XO_2007 Indepth IV

Nine new DOIs for network data sets minted:

- 4 permanent (M1 Monet from the Czech Republic, HN Hungarian National Infrasound, SK Slovakia, WM Western Mediterranean)
- 5 temporary (2G_2016 Lastarria volcano, 3H_2009 Norcia Basin Italy, 3H_2016 Renland, 7G Halmahera,8E_2014 Lascar volcano)

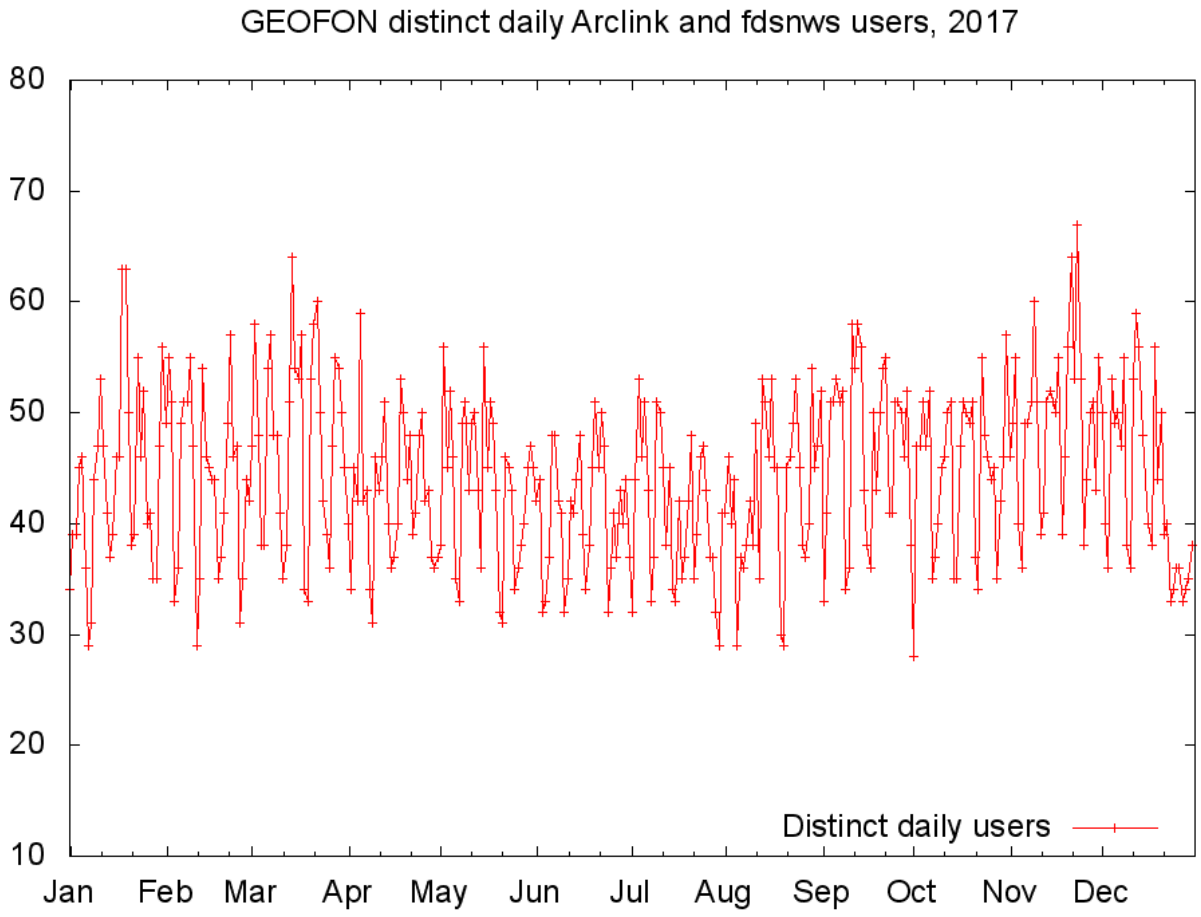


Fig. 4: Number of distinct user IDs provided for fdsnws and/or Arclink on each day in 2017.

4.3 Real-time data export via seedlink:

The real-time data export via seedlink increased to ~110 TB/year with ~320 continuous connections to the public Seedlink server at geofon.gfz-potsdam.de.

4.4 Service uptime

Service	Up	Down/Problem
WebDC	99.957%	0.043%
EIDA Master Table	99.932%	0.068%
fdsnws-dataselect	99.585%	0.415%
fdsnws-station	99.562%	0.401%
routingsvc	94.521%	5.468%
geofon-proc (ping)	100.000%	0.000%
geofon (ping)	99.991%	0.009%
geofon (web pages)	99.479%	0.521%
geofon (eqinfo)	99.844%	0.156%
geofon (Seedlink)	98.870%	1.130%

5 GEOFON Rapid Earthquake Information

Following the trend from last year the Earthquake Information system has got less manual interaction and more automatic solutions. In total GEOFON published 4721 events and 1032 moment tensor solutions via the web pages and other dissemination channels. Fig. 5 shows the geographic distribution of the published events and Fig. 6 the distribution of moment tensors. In cooperation with EMSC we are testing so-called crowdseeded locations, where crowd-sourced information gathered at EMSC (geographic location of website access, app launches and submitted reports on shaking level) is combined with traditional picks to pick and declare earthquakes. GEOFON picks are shared with EMSC using HMB (httpmsgbus), a software developed in-house to facilitate exchange of arbitrary data between data centres and earthquake observatories.

5.1 Published earthquake locations and moment tensor solutions

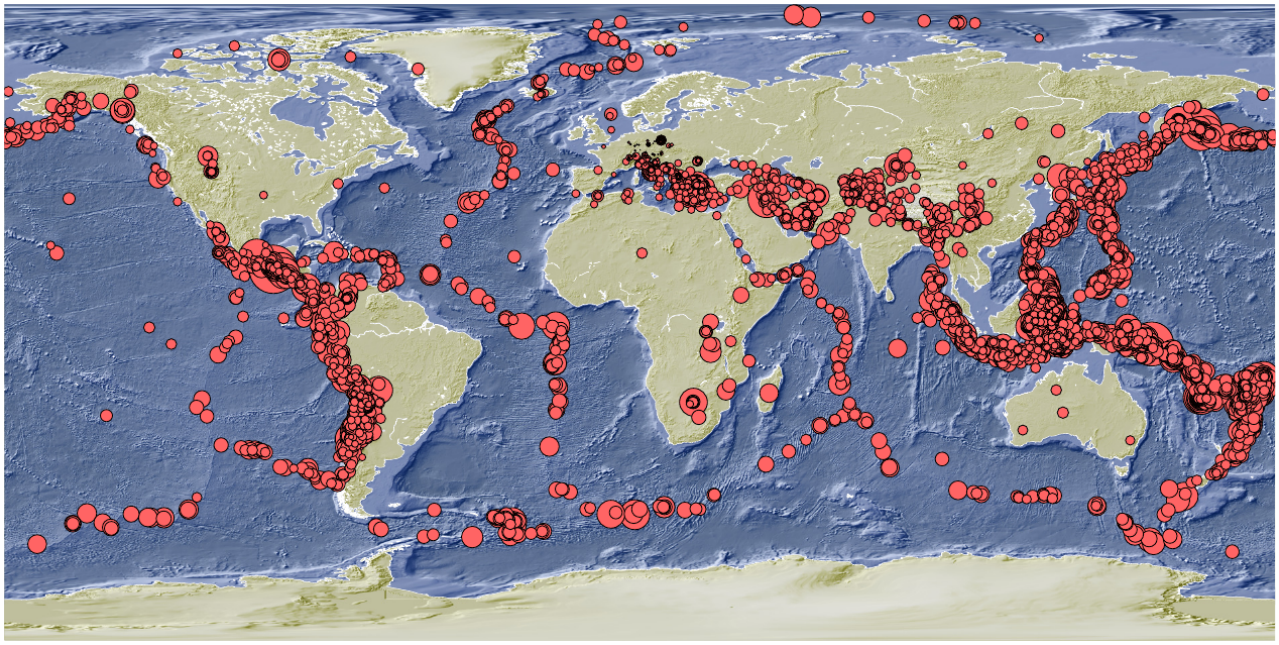


Fig. 5: Geographic distribution of the published events in 2017.

Table 2: Events by magnitude classes in 2017

Mag	Num. events
≥ 7.5	3
≥ 6.5	33
≥ 5.5	337
≥ 4.5	3566
All	4721

Removed “Fake” events are usually characterized by unfavorable azimuthal station coverage or even strongly clustered stations (IPOC, parts of Central Europe, Taiwan).

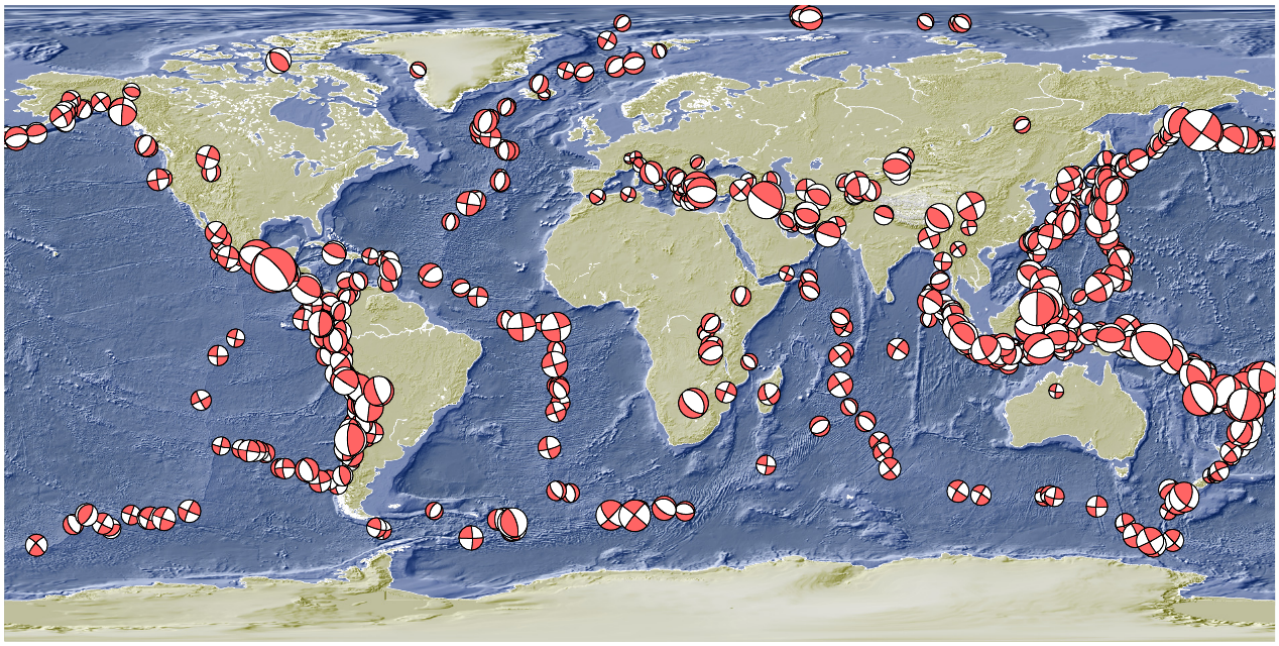


Fig. 6: Geographic distribution of the published moment tensor solutions in 2017.

Table 3: Event dissemination

Events	No MT	Has MT	Total
Published			4721
Status A	825	—	825
Status C	2099	849	2948
Status M	764	184	948
Removed	12	1	13

Event notification delays are shown in Fig. 7 and Fig. 8.

Table 4: Alerts issued by type

2017	xxl	big	Other	All classes
Total	30	285	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 M>=4.5 in central Europe.
- the 'Other' category includes internal alerts and some regional notifications.

5.2 GEOFON web server traffic

The number of distinct users connecting to geofon.gfz-potsdam.de is on typically ~35000/day. Significant traffic is driven to our web server at geofon.gfz-potsdam.de immediately after large events,

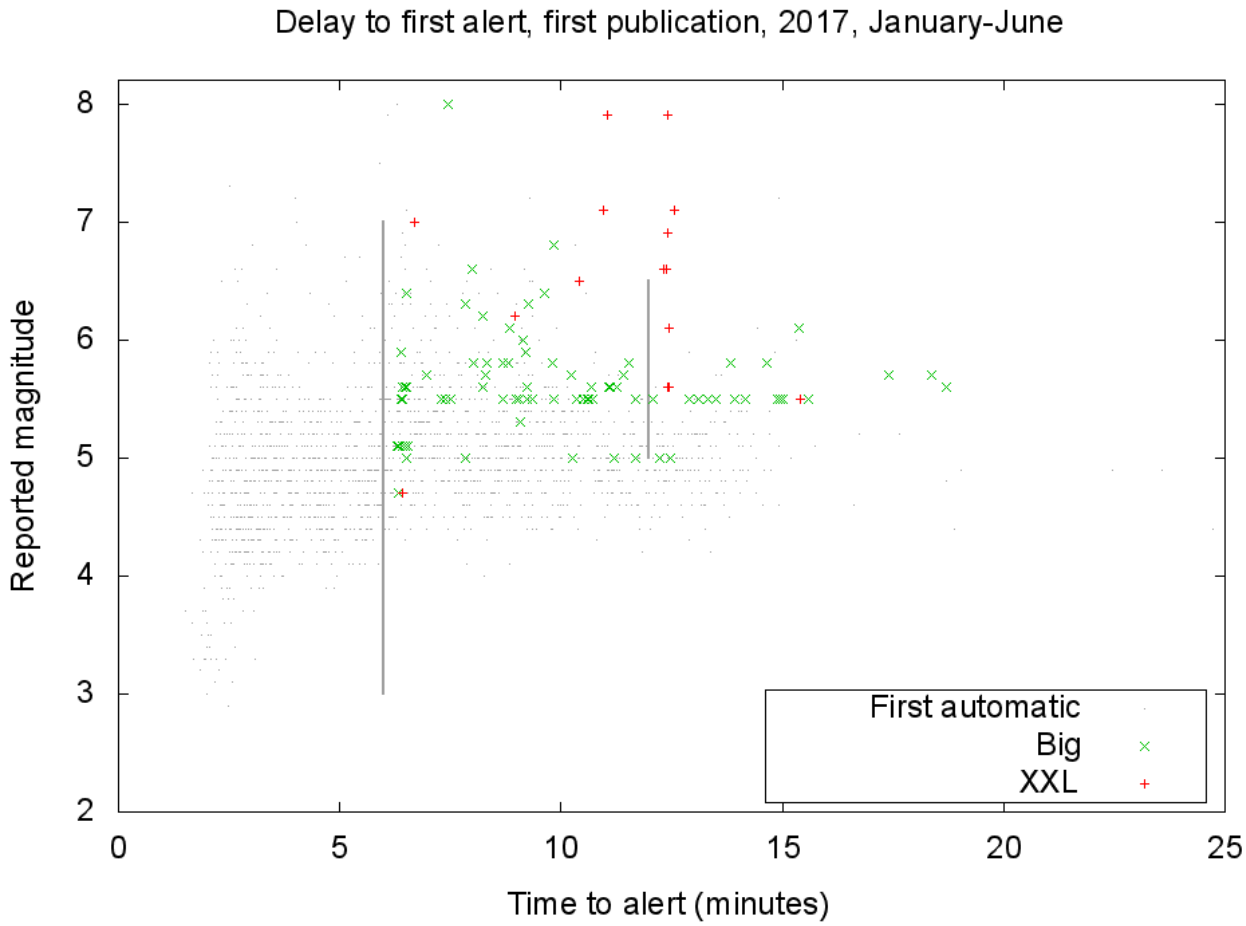


Fig. 7: Event publication (grey dots) and alert delay (big green and xxl red) vs. magnitude in 2017. Alert delay for GEOFON events in 2017 resulting in SMS alerts. Magnitude is the magnitude reported at the time of the alert. Also shown are events with only an automatic detection (status 'A'). Please note that numbers are incomplete due to hardware upgrade/migration during the year.

particularly those in Europe, exceeding 80000 distinct users on peak days ("Distinct" visitors 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 Stream2segment

Stream2segment is a python project to download a large number of short seismic waveform segments and storing them in a database for highly efficient application of pre- and post- processing utilities (https://github.com/rizac/stream2segment). Stream2segment is being developed as a modular tool to process customized event based windows obtained from EIDA and EMSC/ISC.

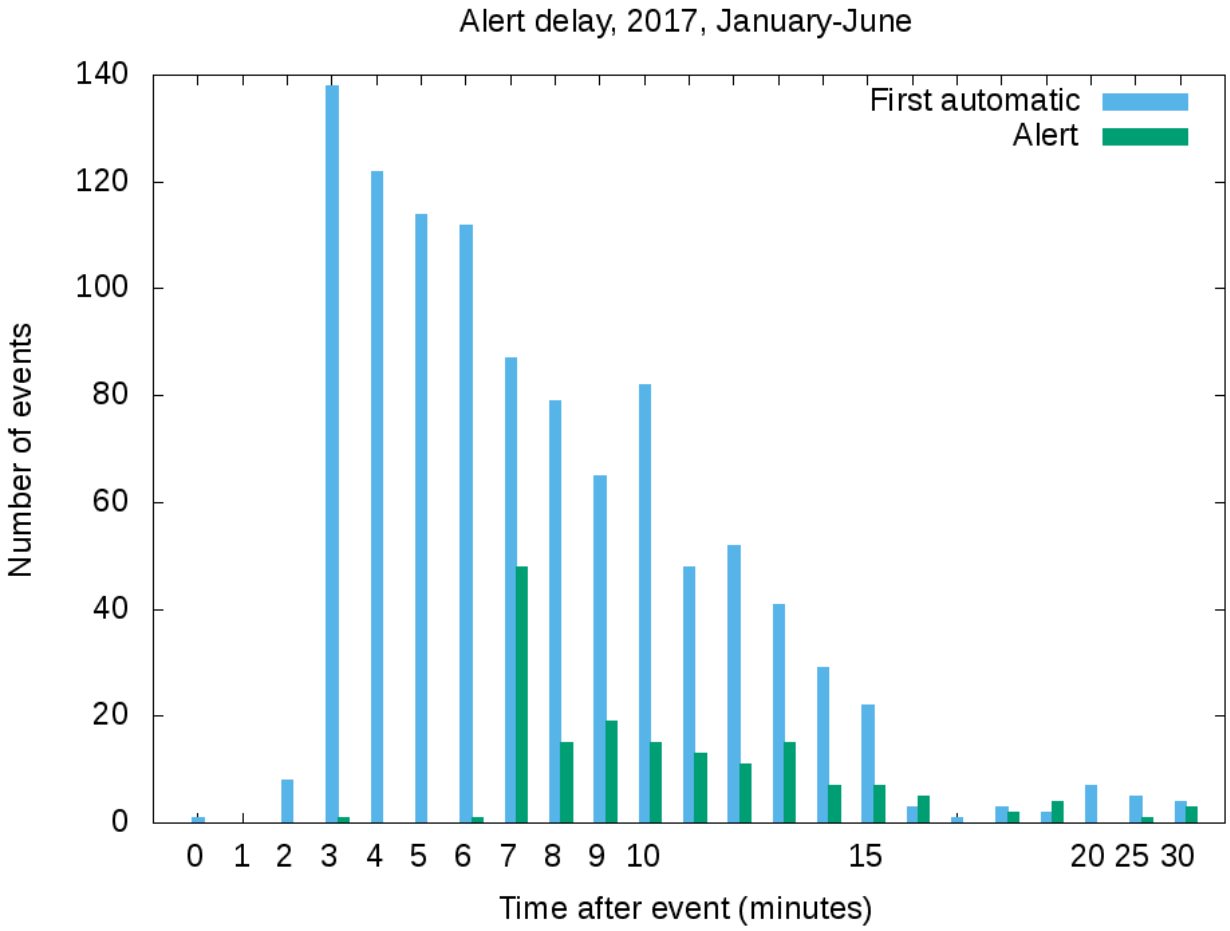


Fig. 8: GEOFON alert delay vs. first automatic publication. Please note that numbers are incomplete due to hardware upgrade/migration during the year.

6.2 gfzreport

A sphinx-based report generation for use at GFZ. The tool has been made available to the users to easily generate and publish technical reports about the archived networks.

6.3 SeisComP 3 releases and usage

The following SeisComP 3 releases were published in 2017: 2017.124 on May 4th, 2017.124.02 on June 8th, 2017.334 on November 30th, 2017.334.02 on December 15th. SeisComP3 non-commercial licenses have been released for 53 new institutions (total 480, 12.2017).

7 Impact, Outreach and Capacity Building

GEOFON data, services and products have been acknowledged or cited in 71 peer-reviewed papers and book chapters in 2017. The full list of publications which explicitly acknowledged use of GEOFON products is available at http://geofon.gfz-potsdam.de/references.php.

Within 2017 GEOFON team members have presented at several conferences and contributed to several trainings. In particular lectures and presentations about the usage of GEOFON products were

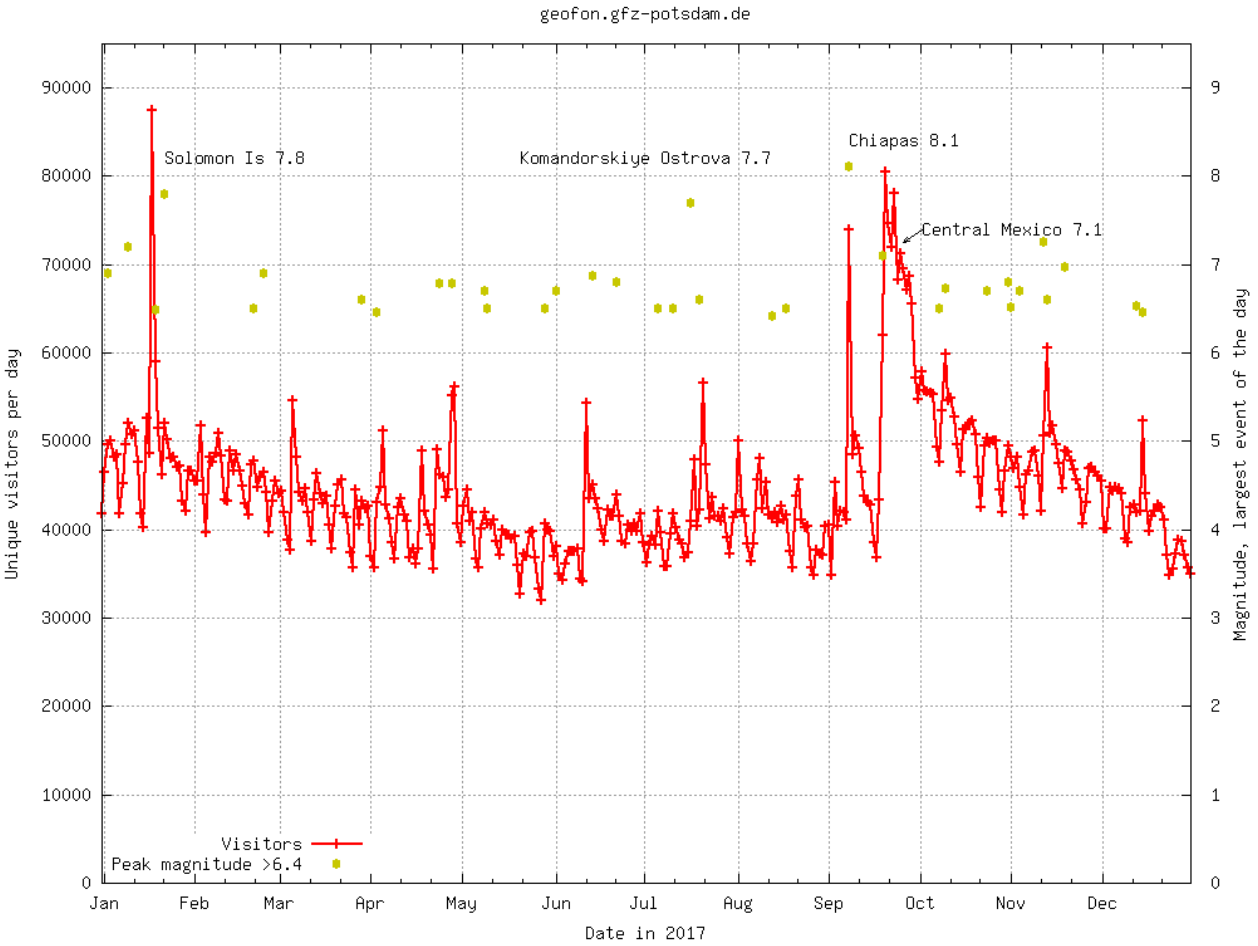


Fig. 9: Daily distinct visitors to geofon.gfz-potsdam.de during 2017 (unique IP + user application which is dominated by automatic applications including mobile devices apps). Also shown is the magnitude of the *largest* event recorded on each day, when this exceeds 6.4. (The threshold for 'xxl' alerts is 6.5 in most of the world).

given at the following events:

- BMKG Jakarta, Indonesia.
- GFZ International Training Course, Potsdam, Germany.
- EGU Vienna, Austria
- Tailor made SeisComP 3 training for Tajik colleagues, who later restarted an old station in Dushanbe with real-time streaming, Potsdam, Germany.

8 Publications by GEOFON staff

Cesca, S., Zhang, Y., Mouslopoulou, V., Wang, R., **Saul, J.**, Savage, M., Heimann, S., Kufner, S., Oncken, O., Dahm, T. (2017): Complex rupture process of the Mw 7.8, 2016, Kaikoura earthquake, New Zealand, and its aftershock sequence. - Earth and Planetary Science Letters, 478, pp. 110-120. DOI: http://doi.org/10.1016/j.epsl.2017.08.024

Cesca, S., Heimann, S., Kriegerowski, M., **Saul, J.**, Dahm, T. (2017): Moment Tensor Inversion for Nuclear Explosions: What can we learn from the 6 January and 9 September 2016 Nuclear Tests,

North Korea?. - Seismological Research Letters, 88, 2, pp. 300-310. DOI: http://doi.org/10.1785/0220160139

Kufner, S., Schurr, B., Haberland, C., Zhang, Y., **Saul, J.**, Ischuk, A., Oimahmadov, I. (2017): Zooming into the Hindu Kush slab break-off: A rare glimpse on the terminal stage of subduction. - Earth and Planetary Science Letters, 461, pp. 127-140. DOI: http://doi.org/10.1016/j.epsl.2016.12.043

Lauterjung, J., Rudloff, A., Münch, U., Acksel, D., **Hanka, W.**, Falck, C., Ramatschi, M., Letz, H., Babeyko, A. Y., **Strollo, A.**, Wächter, J., Schöne, T., Merx, A., Illigner, J., Zech, C., Rakowsky, N., Schröter, J., Hiller, W., Dech, S., Strunz, G., Riedlinger, T., Raape, U., Post, J., Schöckel, T., Behrens, J., Flueh, E., Gayer, G., Günther, H., Nöhren, I., Schlurmann, T., Goseberg, N., Eka Sakya, A., Masturyono, Fauzi, F., Pariatmono, Harjono, H., Raflina, I., Syafii, M., Sofian, I., Efendi, J., Harijono, Sri Woro, B., Harjadi, Prih, P. J., Suhardjono, Subarya, C., Spahn, H., Vidiarina, H. (Eds.) (2017): 10 Years Indonesian Tsunami Early Warning System: Experiences, Lessons Learned and Outlook, GFZ German Research Centre for Geosciences : Potsdam, 69 p. DOI: http://doi.org/10.2312/GFZ.7.1.2017.001

9 GEOFON Team (Human Resources)

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/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

[*] Only until June 2017 [**] Not working full time for GEOFON.

10 GEOFON Advisory Committee Members

- 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

11 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.

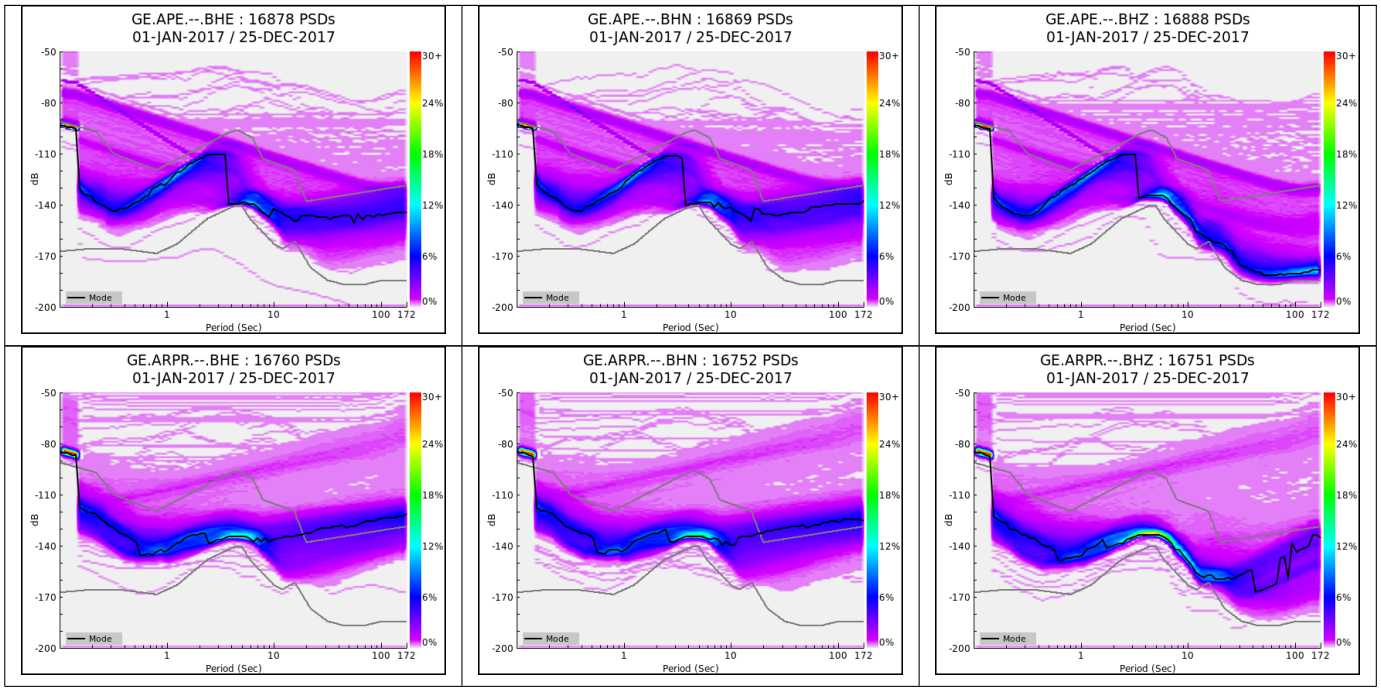
12 References

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.

13 Appendices

13.1 Probability Density Functions (PDF) for operational GEOFON stations 01.2017 - 12.2017

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 Broad-Band 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.



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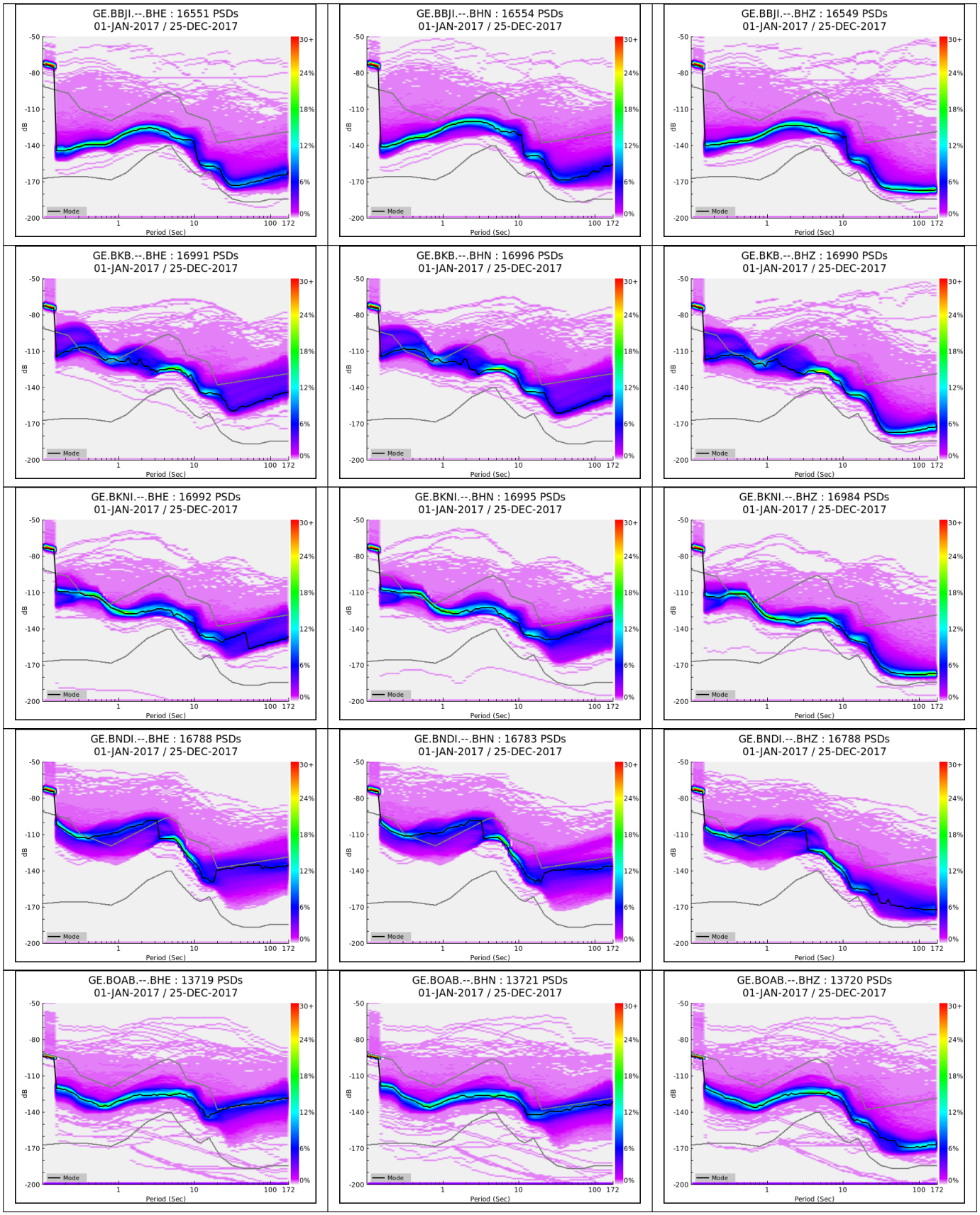

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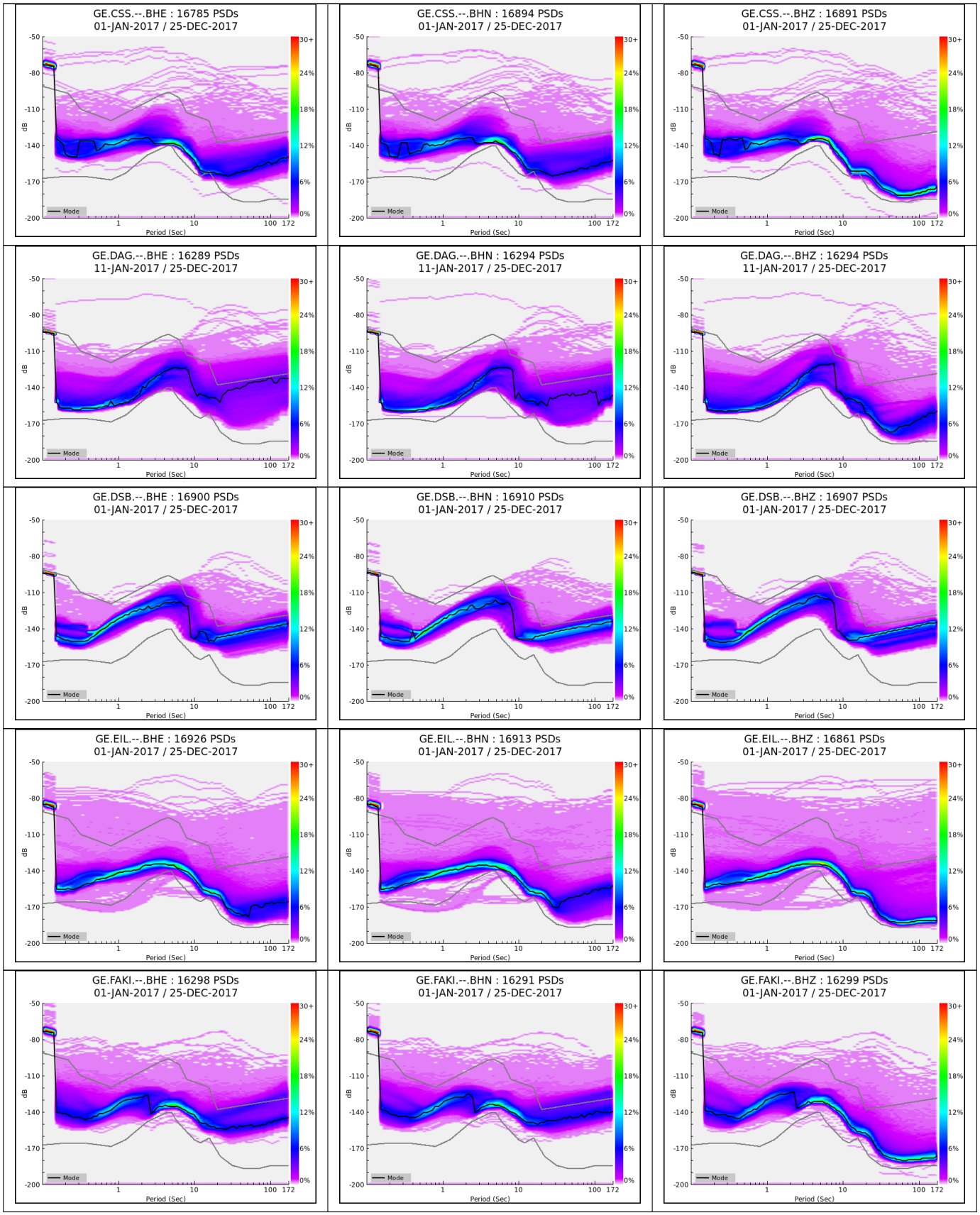

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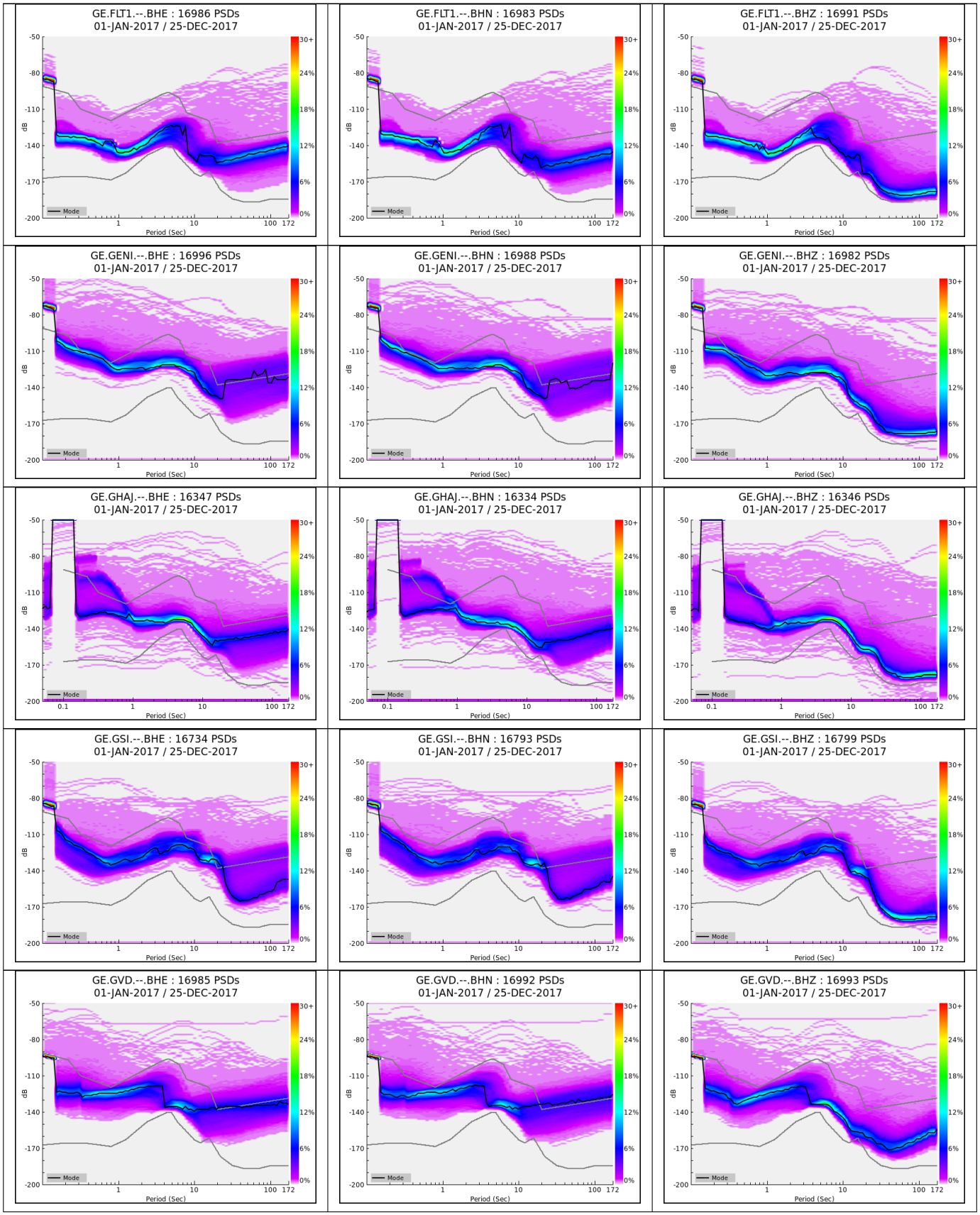

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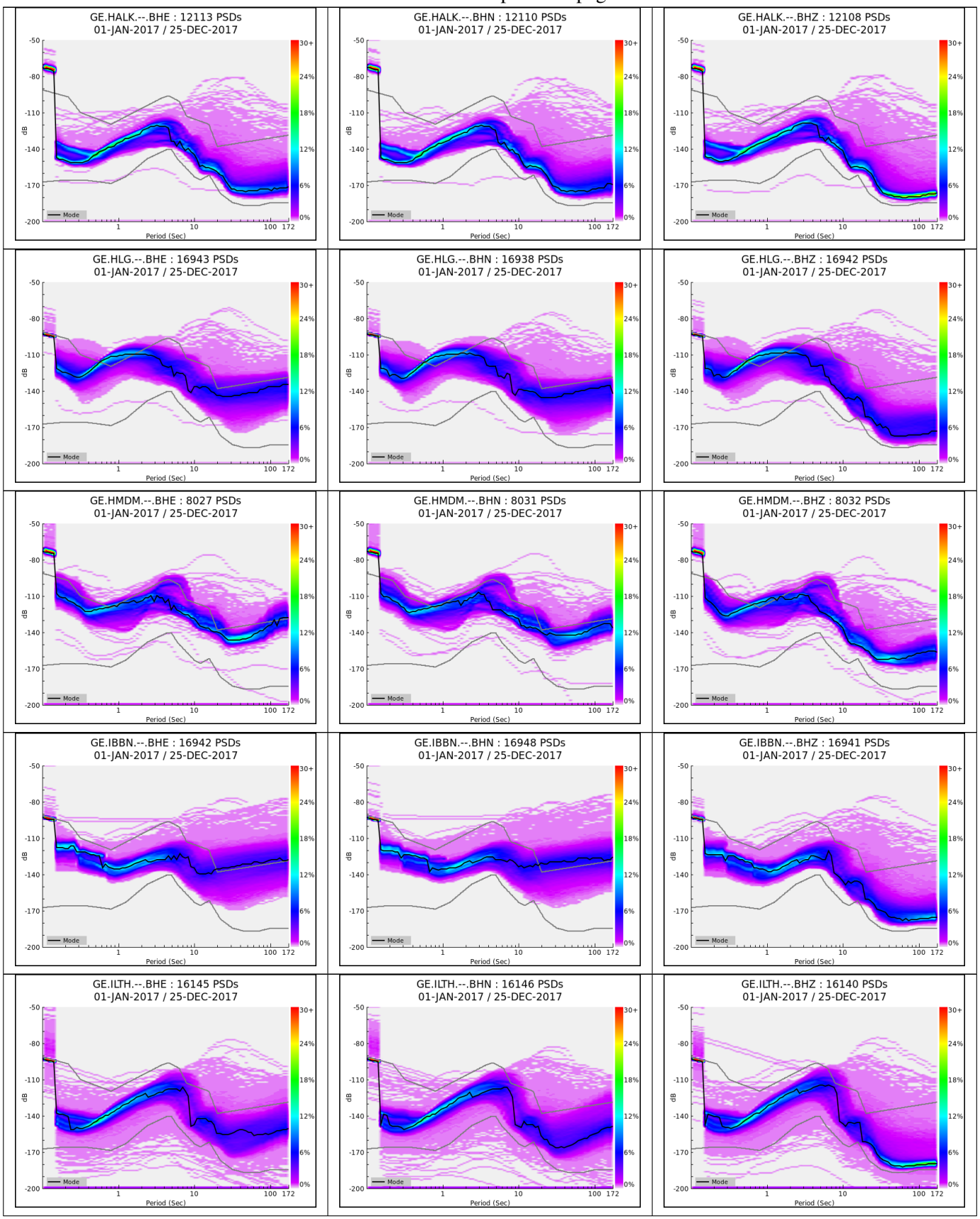

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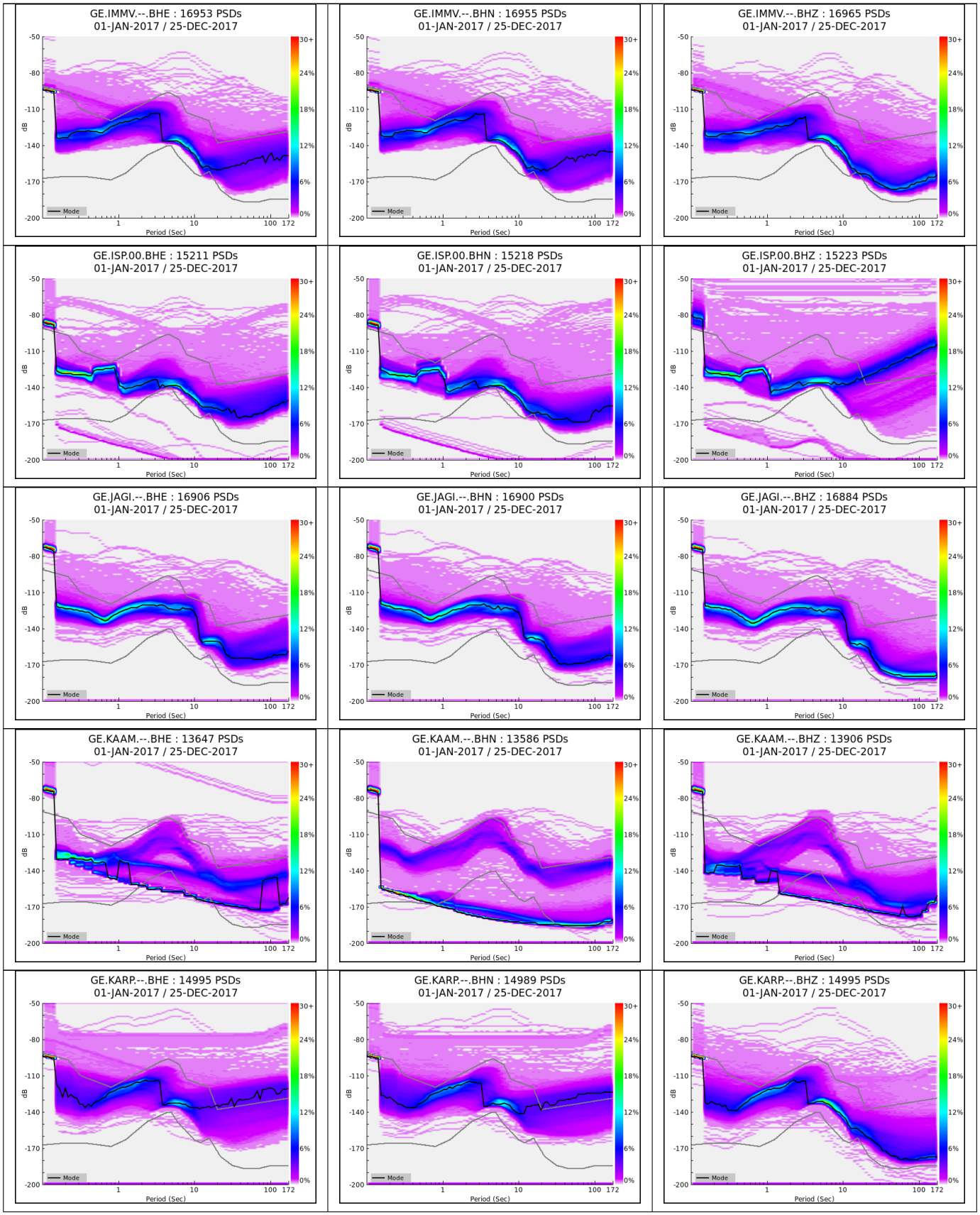

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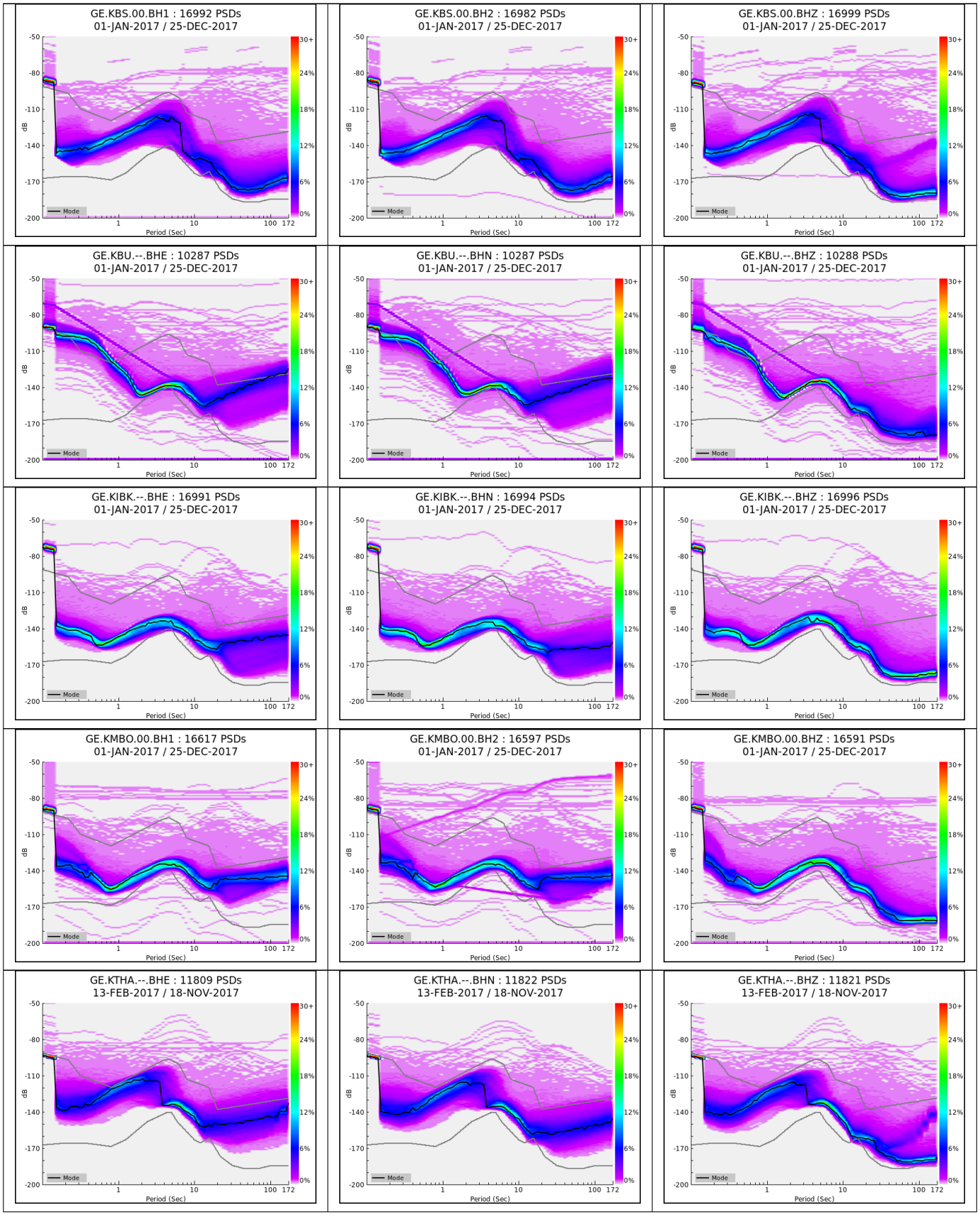

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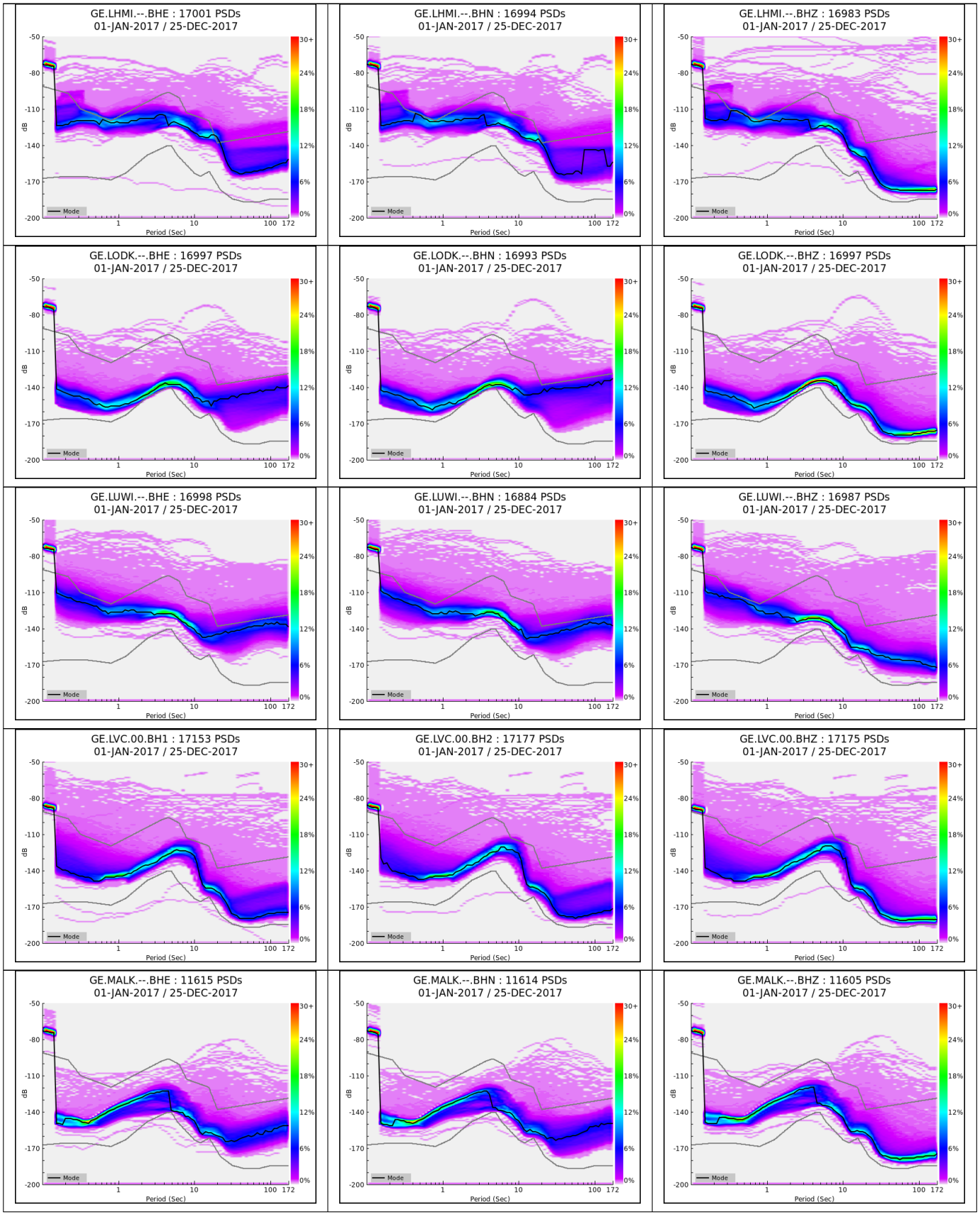

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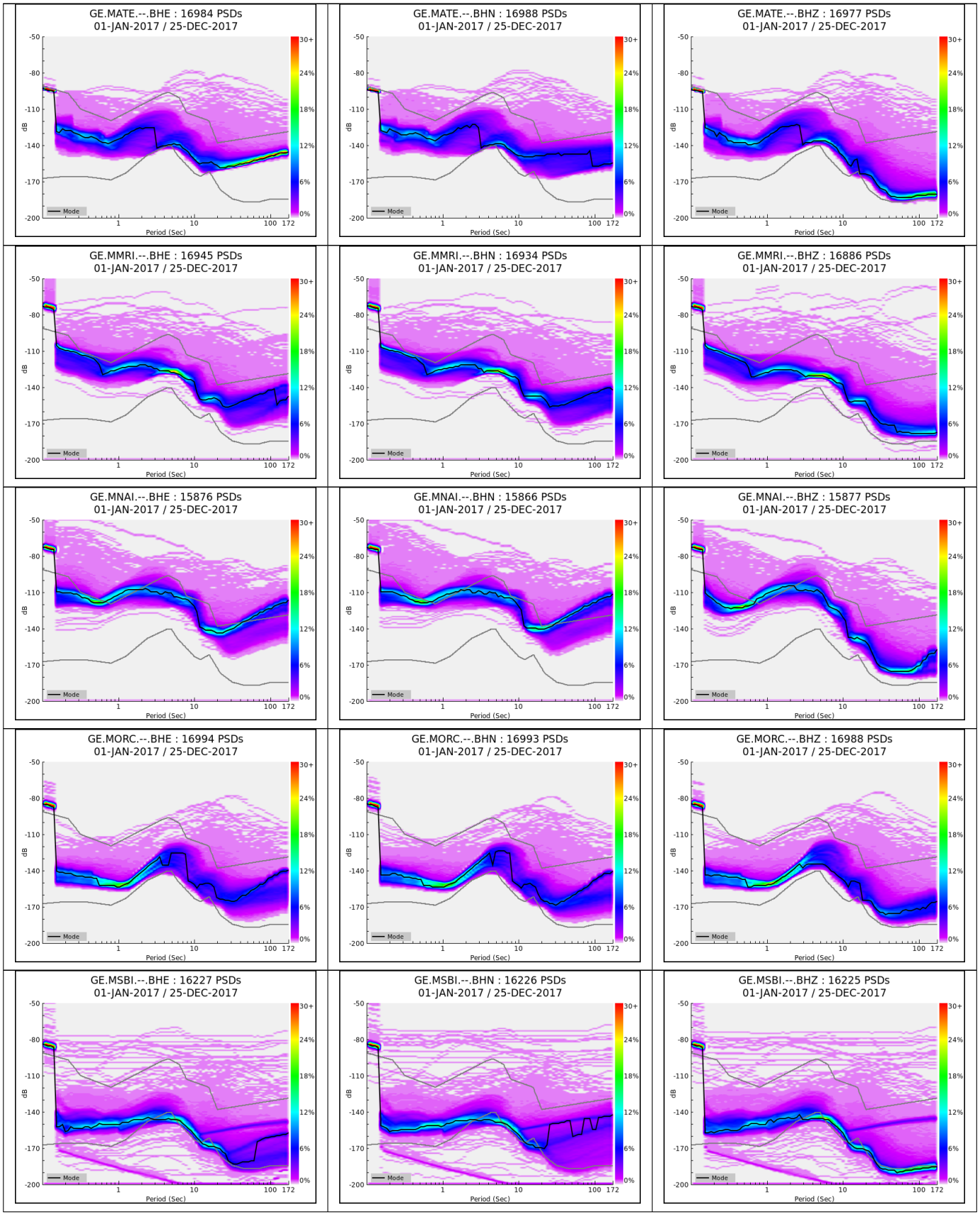

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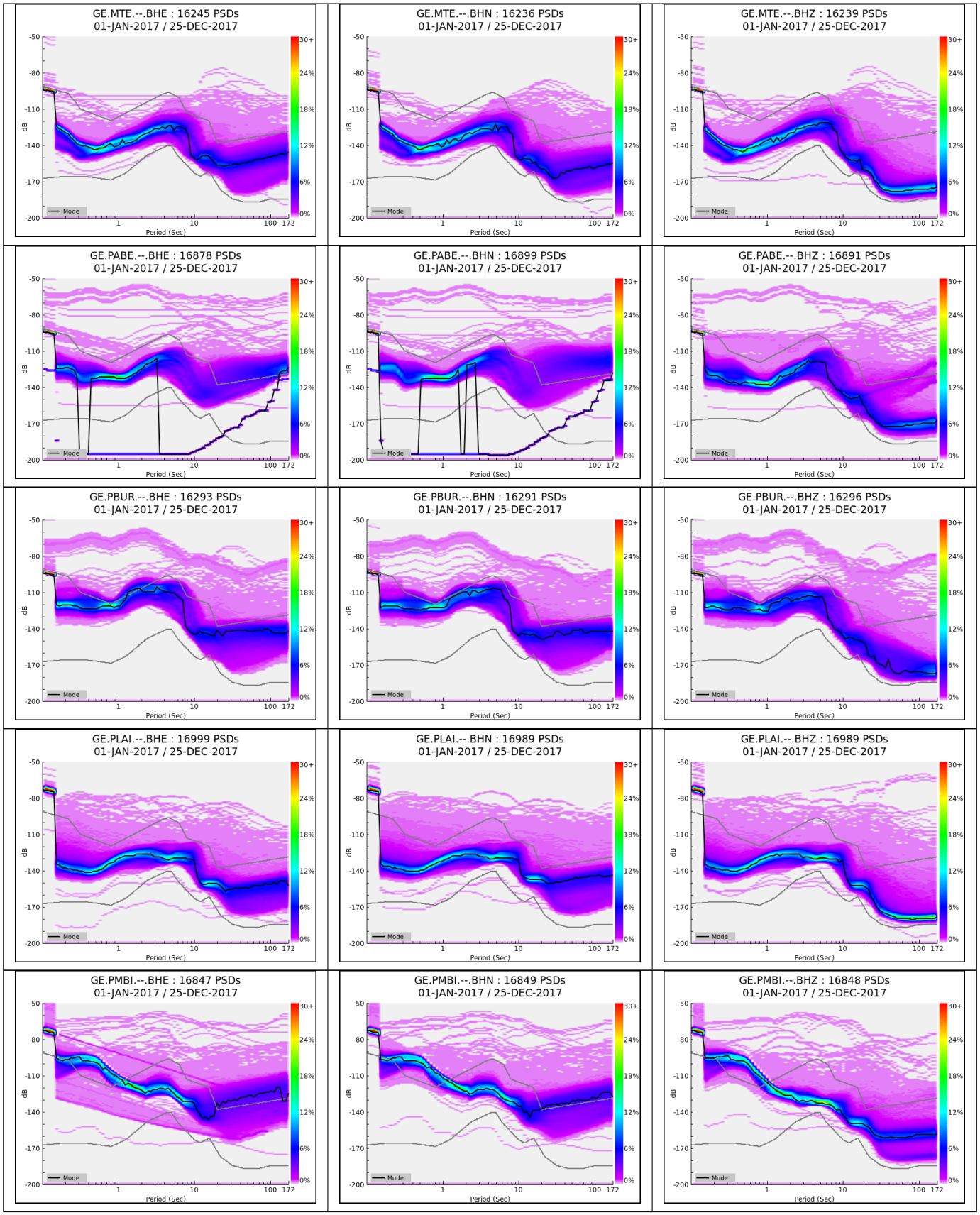

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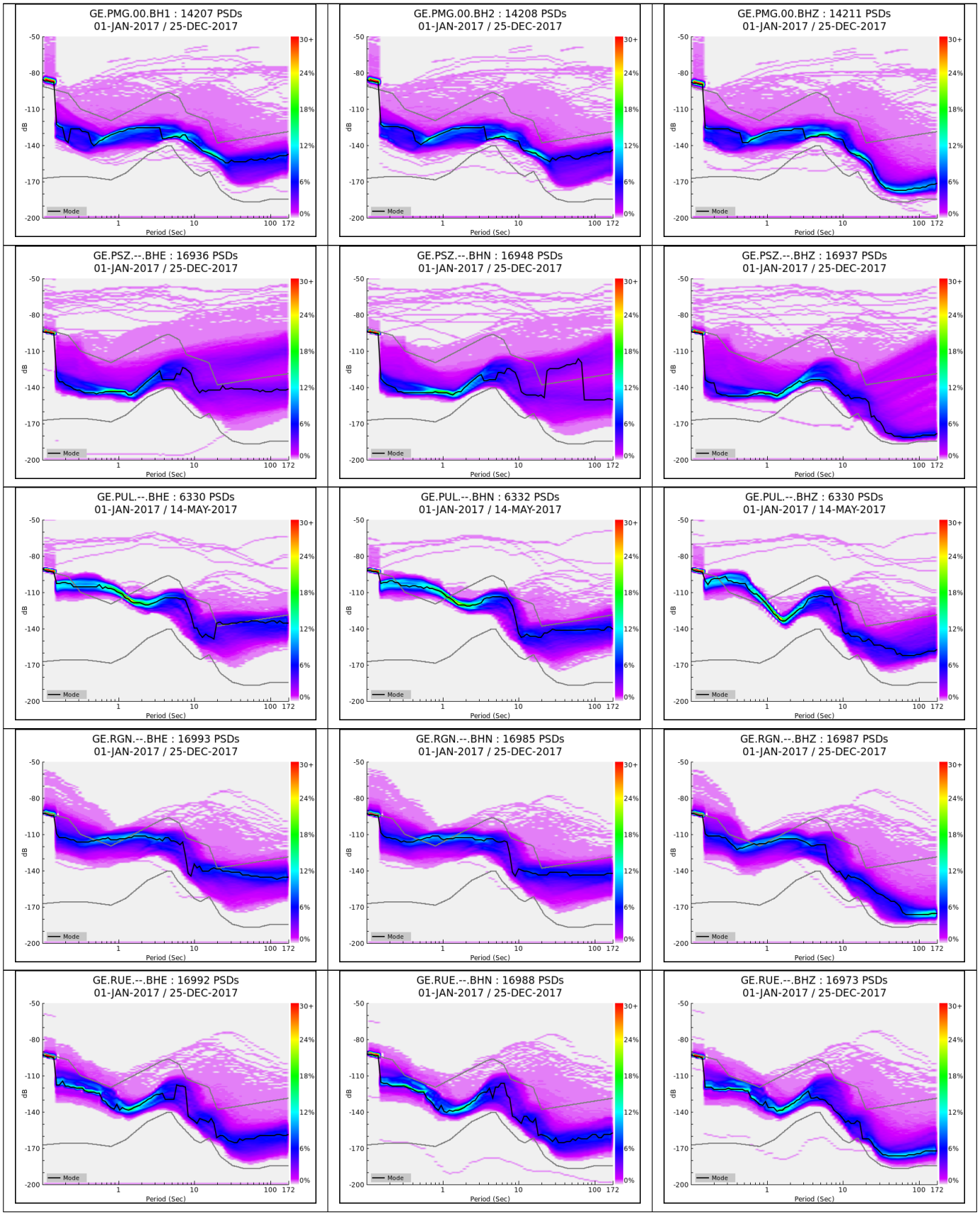

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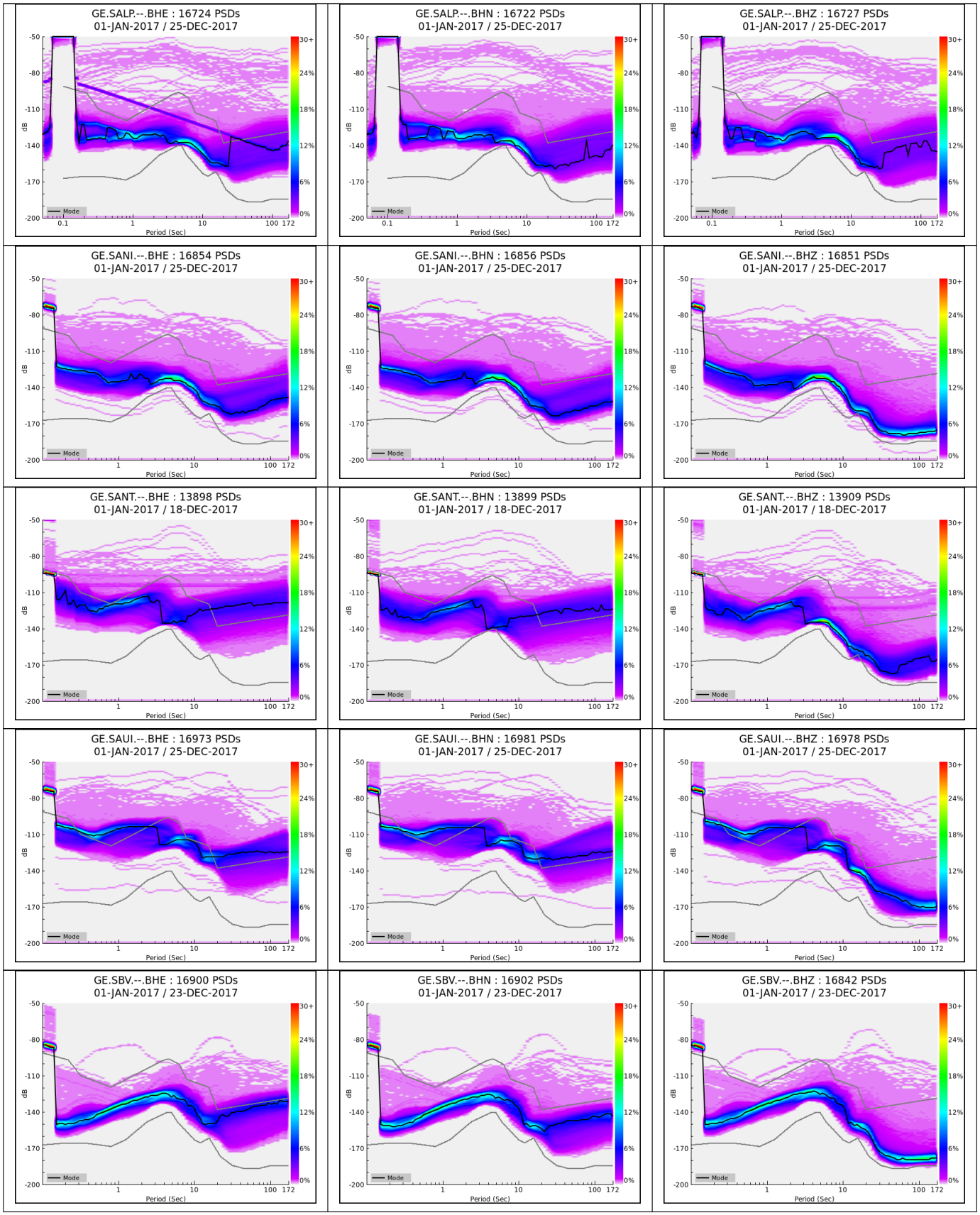

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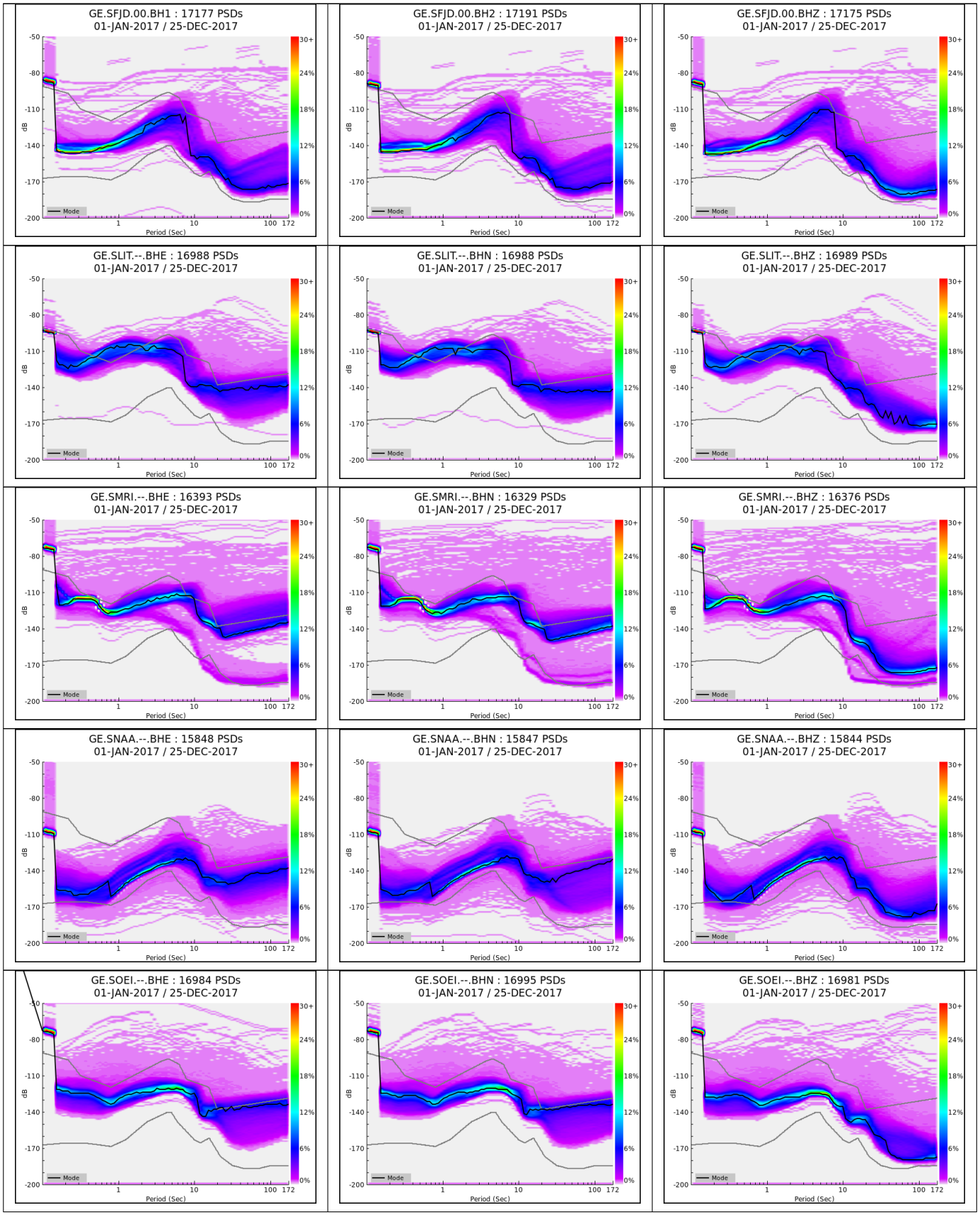

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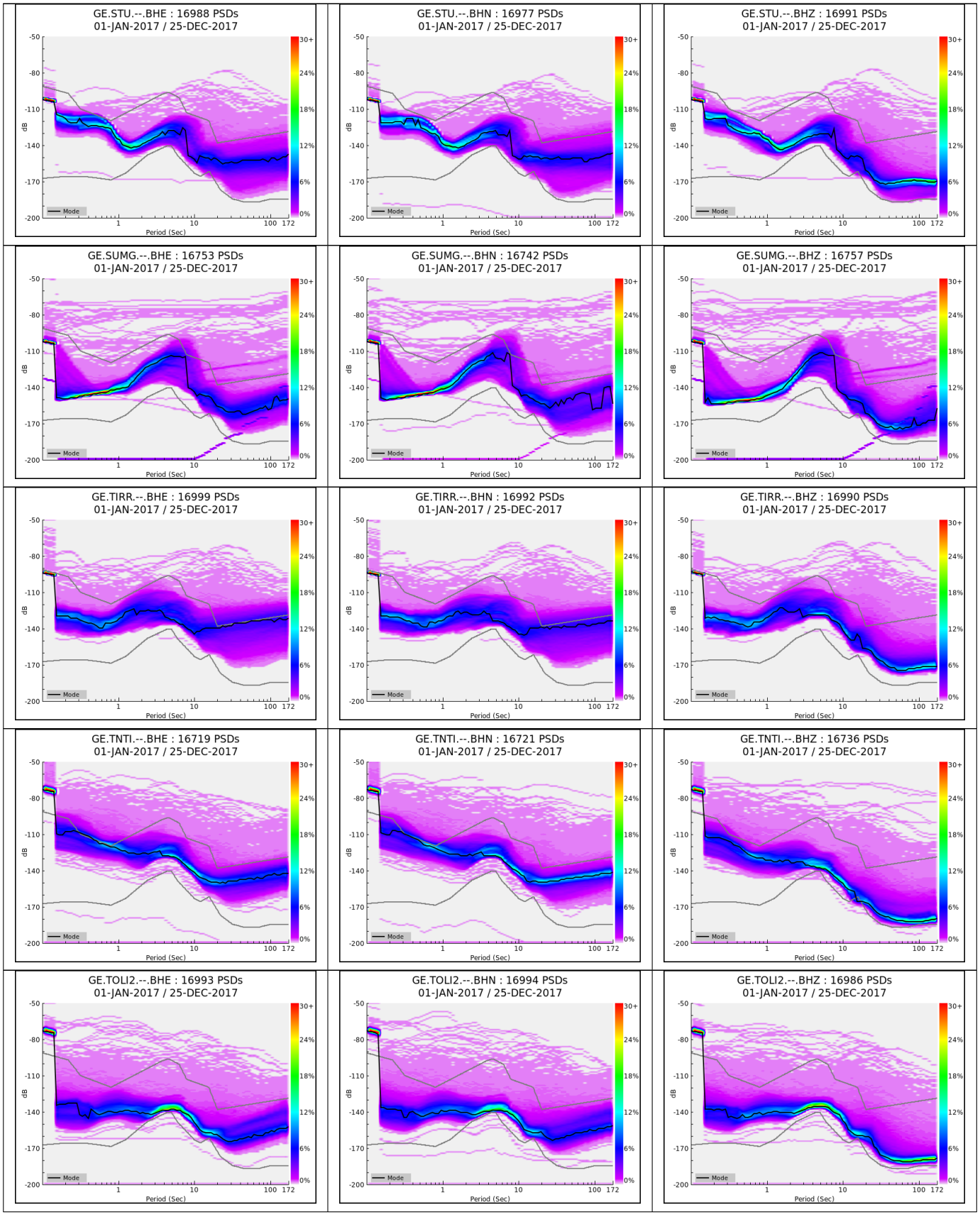

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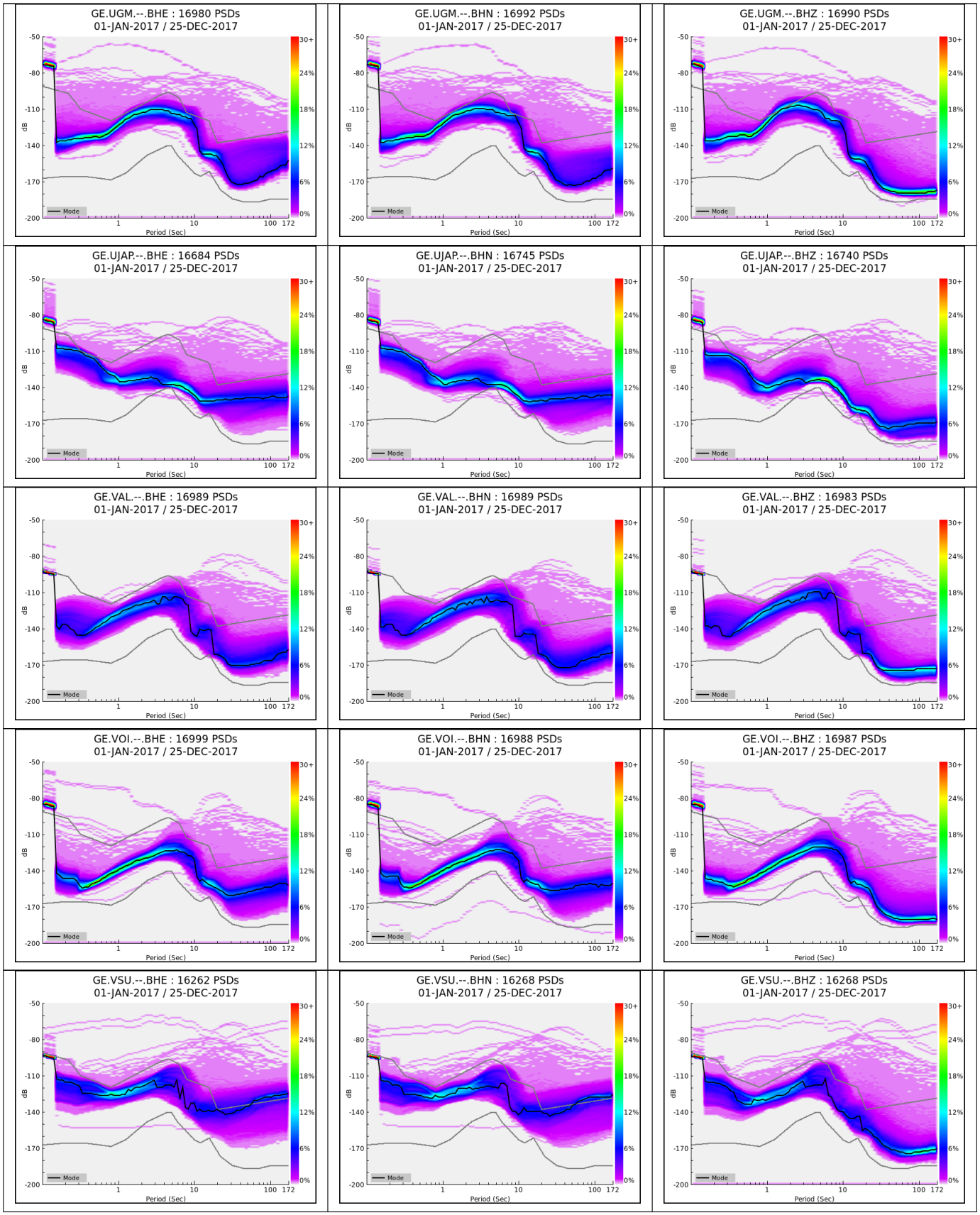

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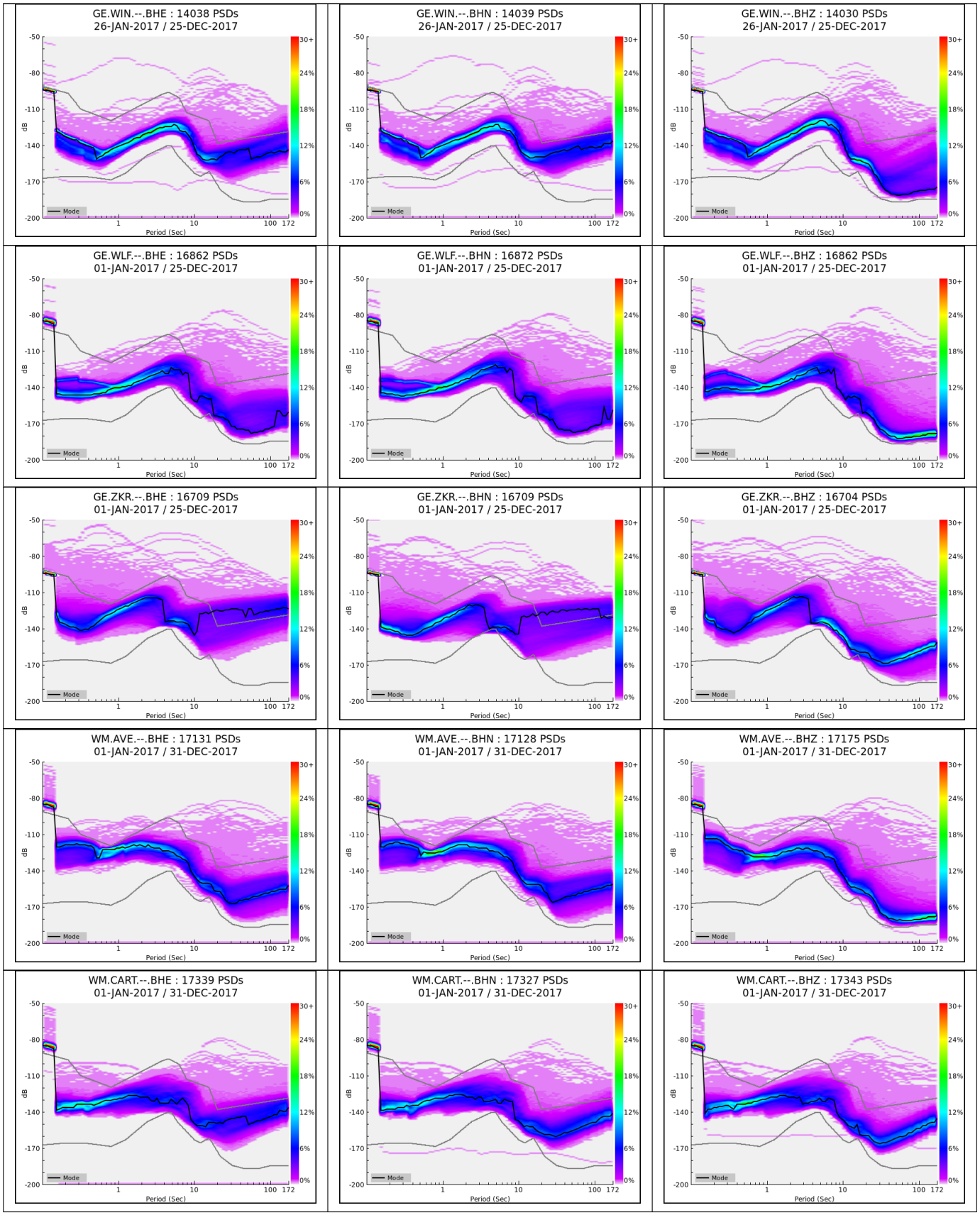

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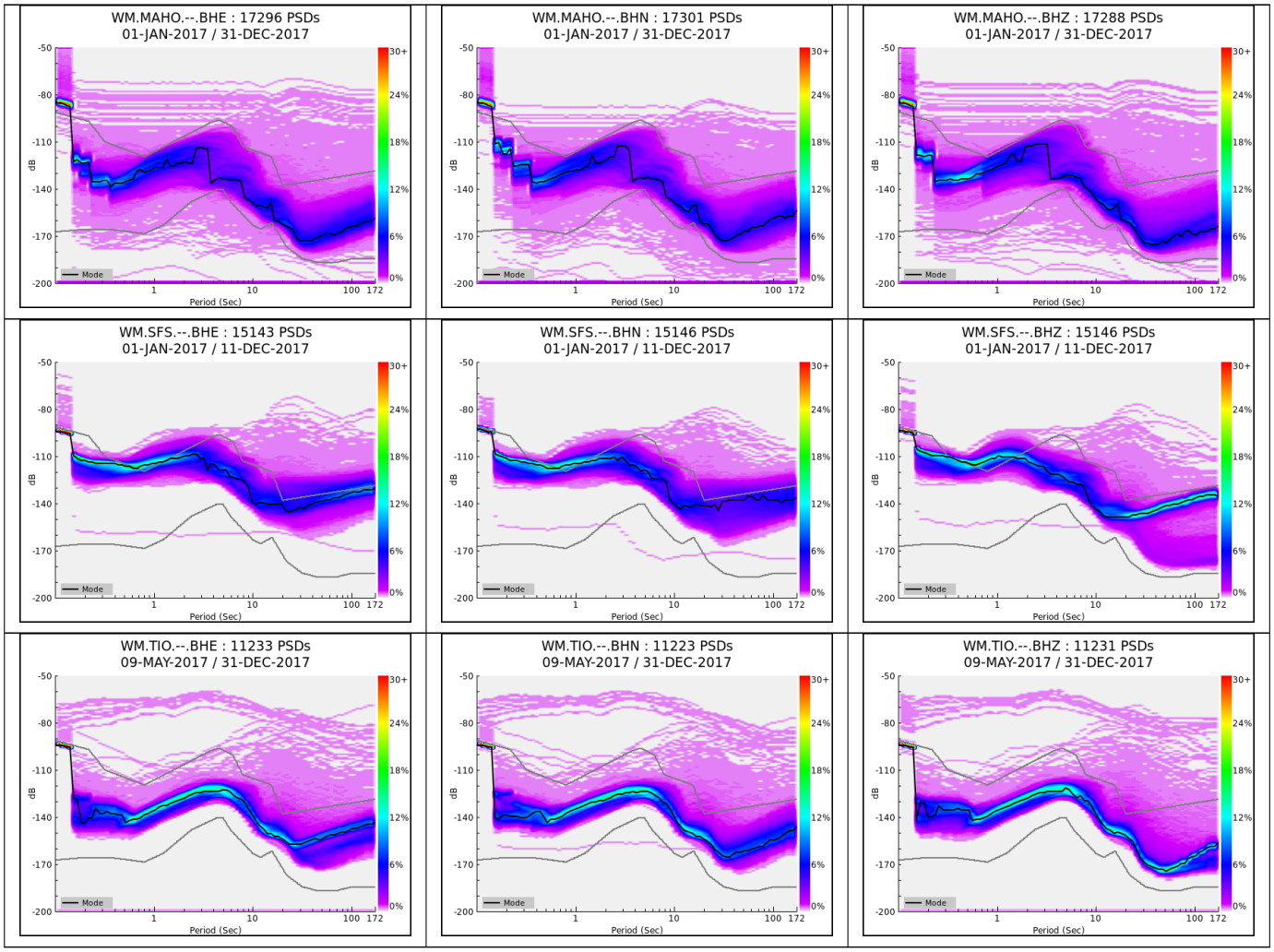

Fig. 10: GE Network PSDs (2017)

14 Annexes

14.1 Summary of GE maintenance team activities

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.

1. GE Network maintenance report (2017)

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ISSN 2190-7110