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The Iquique Local Network and PicArray

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Abstract

The Iquique Local Network (ILN), a temporal network of broadband and short period seismic stations has been operating in Northern Chile since 2009. The aim of this installation was to locally densify the permanent seismic installation of the Integrated Plate Boundary Observatory in Chile (IPOC), with the main goal to decrease the magnitude of detected earthquake, to improve the hypocentral location accuracy, to allow a more accurate investigation of seismic source parameters, and to analyse proposed seismogenic structures of the Northern Chile seismic gap. The network setup evolved with time, with different geometries at different installation phases, aiming to study different seismicity features. In the first phase, started in 2009 and operational since 2010 until autumn 2013, the network had a sparse configuration, targeting a broad region extending from 19.5° S in the North to approximately 21.3° S South of Iquique. In the following stage, operational until fall 2017, most broadband stations were rearranged into a small aperture seismic array (PicArray) close to the village of Pica, to monitor with array techniques the shallow seismicity at the plate interfacer, intermediate and deep focus seismicity.

1 Introduction

The Iquique Local Network (ILN) as one component of the International Plate boundary Observatory Chile (IPOC; GFZ and CNRS 2006) is a seismological network installed around the North Chilean harbour city of Iquique. With its average station spacing of approximately 25 km, the network aims at recording small to moderate seismic events to verify the crustal structure and seismic behaviour of the subduction interface in this region. Since the general task of the IPOC is to monitor the deformation signal before a large earthquake in a brought frequency range, the data of the ILN should provide insight in processes along material boundaries and geometrical features to investigate such an 'earthquake preparation phase' on a local scale. The ILN was originally built as a long term temporal deployment, also supporting hazard analysis for Iquique and the surrounding region. It hosts the nearest station to the coast which is especially important for investigating tsunamigenic earthquakes and their related hazard. An important scientific aim of the ILN was to verify the assumed hypothesis that seismogenic features in the area of the network identified by pronounced gravity anomalies suggested that the area could play a major role in a future earthquake. This earthquake occurred on April 1st, 2014 with a magnitude of Mw 8.2. Although the rupture was located off-shore, the ILN had the exact N-S extension of the rupture length parallel to the off-shore rupture (Schaller et al., 2015).

The PicArray was deployed in November 2013 in the vicinity of the village of Pica. The site was chosen as a central spot with respect to the former Northern Chile seismic gap, the availability of a very quiet station from the ILN, the lack of significant noise sources, and the ground conformation, well suited to host a small scale array. The seismic array, originally composed of 9 broadband stations, had an aperture of about 3 km. The PicArray installation aimed to enhance the seismological target of the former ILN configuration, allowing the application of beamforming and array based techniques to analyse the shallow seismicity at the plate interface, the intermediate and deep focus seismicity below Northern Chile and neighbouring regions and to analyse microseismicity and seismicity in the vicinity of the Pica village.

In November 2017, the PicArray setup was further modified, redeploying some of the PicArray installation to build a small network at about Lat 21°S, aiming to better monitor the slab at the southern edge of the 2014 Mw 8.2 Iquique earthquake rupture area.

2 Data Acquisition

2.1 Experimental Design and Schedule

The installation of ILN and PicArray comprised different deployment stages.

2.2 Iquique Local Network, stage 1 (2009-2013)

The first stage took place in the period 2009-2013. The installation developed with time, due to availability of the instruments and advancement of construction work at each station site. The very first stage just had two GURALP stations installed, one in a mining gallery (NEUQ) and the second one at the basement of a building of the Arturo Prat University in Iquique (UNAP). This first stage also had an antenna configuration with four REFTEK stations around the French PBO site at Humberstone. During the following deployment phases more GURALP stations were installed in their vaults. The REFTEK stations changed their locations several times to fill voids in the deployment scheme until filled by GURALP stations on important network sites. The ILN layout at April 27, 2011, covered a total area of 150 km in N-S and about 120 km in E-W direction (Fig. 1).

2.3 Iquique Local Network and PicArray, stage 2 (2013-2017)

A full station redeployment was performed in November 2013. All seismic broadband stations of the former ILN sites were removed, except stations UNAP, PATA and CHOM. Some of the former installation sites were later reinstrumented by the National Seismological Centre of Chile (CSN). At the time of the redeployment, many sensors and acquisition systems were not working correctly, a few instruments were damaged, also due to vandalism to the station sites. Using the available working instrumentation, the PicArray could be built.

The PicArray was deployed in November 2013, close to the village of Pica. Originally composed of 9 broadband stations, it was planned and built around the station PICL. The array location was chosen due to the low noise of the site, its accessibility and the geographical locations, which is optimal to target the central part of the former Northern Chile seismic gap, as well as local seismicity clusters. The array has a slight elongation along an EW direction, due to the topography of the site, and an aperture of about 3 km. The array was instrumented with broadband stations, and only at a later stage one additional short period seismic sensor was installed (station PICLA)

The station distribution at January 1, 2017, is shown in Fig. 5, and Table 1 summarises the most important information about each station.

2.4 Recent configuration and future plans

In May 2017, upon the failure of some sensors and dataloggers, and the stolen equipement at PICL8, the PicArray configuration was reduced to 5 stations. The remaining working instrumentation was used to build 3 new broadband installations, named PATS, SECO and SALG. The main motivation for the new setup was to better monitor the slab at the southern edge of the Iquique earthquake rupture region. The same region has been target of a denser GPS installation within IPOC.

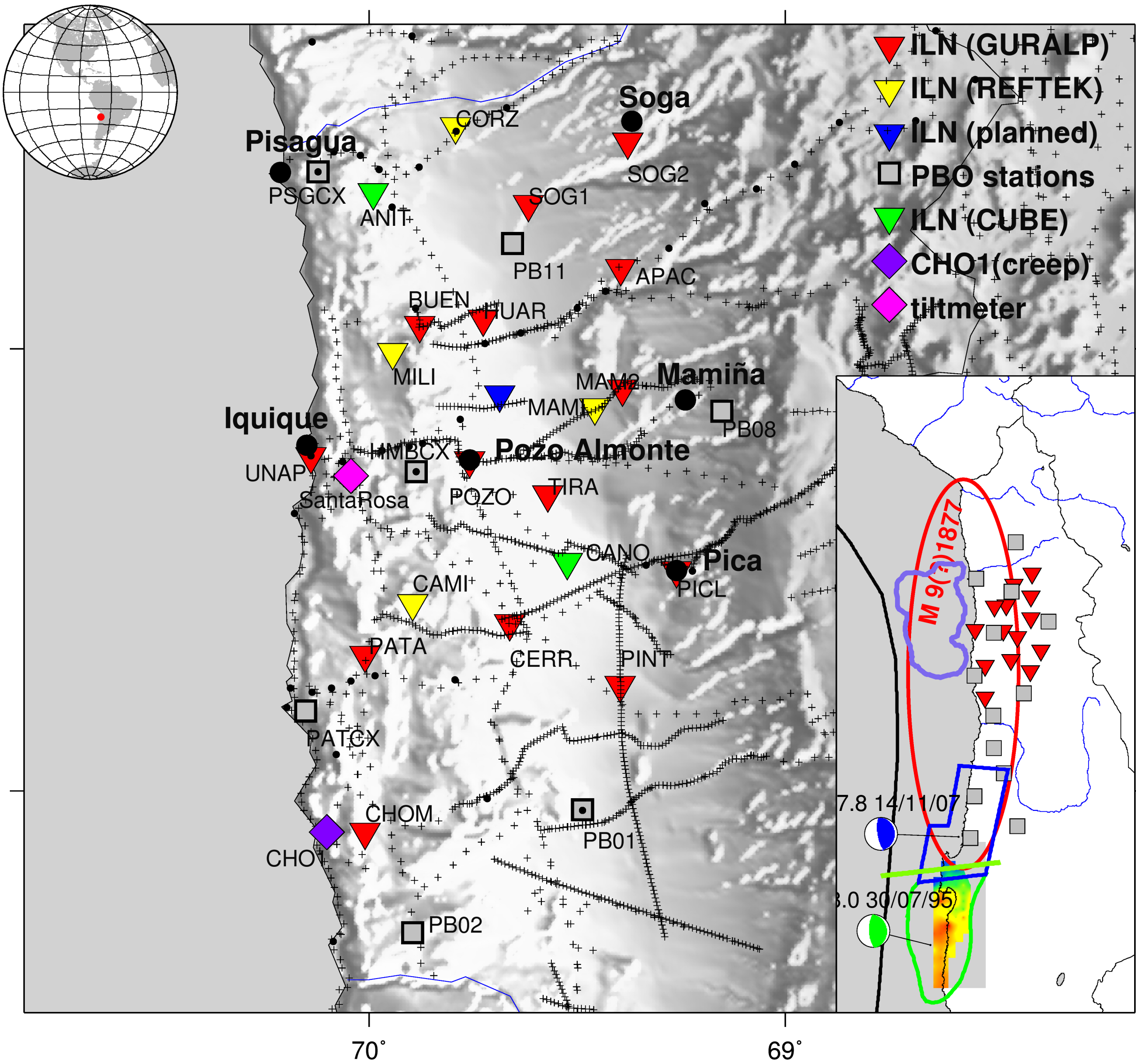

Fig. 1: Instrumentation and field campaigns in the area of the Iquique Local Network (ILN). The colored triangles represent the respective station sites, for color code see legend in the upper right corner. The blue diamond at the southern end of the network marks the creepmeter station on the Chomache fault and the magenta diamond denotes the long base line tiltmeter in the mine of Santa Rosa. The small black crosses capture the tracks and stations of the gravity field campaign in 2011 and small black dots show GPS sites either measured as campaign data or at permanent sites. The small inlay in the right lower corner gives an overview on the entire seismo-tectonic situation in the North Chilean Seismic Gap (NCSG) with coarse approximations for the rupture planes of the Mw 8.1, 1995, Antofagasta (green), the Mw 7.8, 2007, Tocopilla and Mw 8.2, 2014, Iquique

2.5 Site Descriptions

With the exception of the UNAP (Iquique city) and AERO (at the base of the Iquique Airport tower) installations, station sites are remotely located in unpopulated areas, with no relevant anthropogenic seismic noise sources (e.g. as at station PATA, Fig. 2). As for the station installation, the sites have been prepared at different times and with different installation setups. For all stations equipped with GURALP CMG-3EPSC broadband seismometers, underground vaults were constructed where the seismometers were installed on concrete basis reaching ~ 1m into the ground (Fig. 3). This concept fostered a better coupling in the overall sandy soil conditions in the network area and resulted in excellent signal to noise ratios. The concrete basis was also used at station APACa, PicArray stations and later installations, although it was not possible to construct an underground vault (Fig. 4). Stations equipped with short period sensors were installed in holes in the ground. All installation included insulation and protection of the equipment against strong temperature variations and weather conditions.

Fig. 2: View of station PATA during maintenance in November 2013 (Photo S. Cesca). The station is located in a remote site, far from any anthropogenic source of seismic noise. The installation vault is protected by a fence and a trap-door.

2.6 Instrumentation and sensor orientation

The ILN and PicArray operated up to 20 seismological stations. Out of these, 14 corresponded to broadband stations, equipped with GURALP instruments, each station including a CMG-3ESPC seismometer with 60s to 50 Hz frequency response, a CMG-DM24 S3 digitiser with 3 24-bit channels, 64Mb flash memory and GPS antenna, and a CMG-DCM Data Communications Module with removable data storage device. The remaining 7 stations were equipped with REFTEK stations connected to a 1Hz Mark L 3D seismometer. As power supply we used solar panels and car batteries (in most cases 35 Ah), which were checked, recharged or exchanged on a regular schedule approximately every year. During station maintenance the stations were in most cases recording, to reduce as possible data gaps. Sensor orientation has been adjusted using a magnetic compass during installation.

Fig. 3: Vault at station PATA, hosting a broadband seismometer, acquisition system and battery (Photo S. Cesca, November 2013).

3 Data Description

3.1 Data Completeness

Data cover a long installation period and different installation setups. Data are incomplete, due to discontinuous station maintenance, vandalism episodes (e.g. removing solar panels and/or batteries), temporally reduced power supply (e.g. sand partially covering the solar panels), as well as degradation of power supply (i.e. batteries).

Fig. 7 shows the uptime of each stations.

3.2 Data Processing

Available data is raw data in miniSEED format (recorded in GCF format and converted to miniSEED). The miniSEED data on hand is in units of counts, not filtered and not resampled. Sampling is either 100 or 200 Hz, varying for different station sites and installation phases. Station metadata, including restitution information and characteristics of the sensors, are provided in stationXML format. Data and metadata can be downloaded from the GEOFON repository.

Fig. 4: View of PICL4 site, during the installation phase (November 2013, Photo S. Cesca). Sensors and acquisition system were protected and insulated within half metal barrels, digged into the ground at about 1 m depth. A thin layer of stones and concrete was built within the barrels, to provide a flat and rigid basement for the seismic sensor.

3.3 Data quality and Noise Estimation

Antropogenic noise is low at most stations, since sites were chosen in unpopulated areas and far from any infrastructure. Some, spatially distributed mining sites are present in the region. Most relevant natural noise sources can be wind, affecting high frequency records, and the ocean, affecting the amplitude of microseismic noise, higher for coastal stations. Transient, human noise sources can be present at the PicArray due to the vicinity of a small rubbish dump site and the construction of a small road, completed between 2015 and 2017.

Fig. 6 shows noise probability density functions for all channels.

3.4 Timing Accuracy

Seismic data consist of digital data with a sample rate of 100 or 200 samples per second.

4 Data Access

4.1 File format and access tools

The data are stored in the GEOFON database, and selected time windows can be requested by EIDA access tools as documented on http://geofon.gfz-potsdam.de/waveform/. Normally the data are delivered in miniseed format. The current data access possibilities can always be found by resolving the DOI of the dataset.

4.2 Availability

When using the data please cite: Cesca, Simone; Sobiesiak, Monika; Tassara, Arturo; Olcay, Manuel; Günther, Erwin; Mikulla, Stefan; Dahm, Torsten (2009): The Iquique Local Network and PicArray. GFZ Data Services. Other/Seismic Network. DOI: http://doi.org/10.14470/VD070092

5 Conclusions and recommendations

The data of the network densified the IPOC permanent installation in Northern Chile with different configurations at different installation stages.

The seismic installation started in 2009 and seismic data include records of the Mw 9.0 Maule Earthquake in 2010, the large Mw 8.2 Iquique earthquake of April 1, 2014 (Schurr et al. 2014, Cesca et al. 2016), as well as its foreshocks and aftershocks sequences.

Future installation in the region may rely on the low anthropogenic noise, except in the vicinity of towns, mines and a few major communication roads. The presence of strong winds and sandy soil can temporally affect the functionality of solar panels and reduce the power supply.

6 Acknowledgments

We are thankful to UNAP Iquique and the Pica municipality to help installation and maintenance operations and to the Departamento de Geofísica, University of Chile, Santiago, for technical and administrative support. The Plate Boundary Project Iquique Local Network and PicArray are part of the IPOC Integrated Plate boundary Observatory Chile seismic network (GFZ et al., 2006)

7 References

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Table 1: Station table. Note that start and end times represent the maximum validity of the corresponding configurations, not the actual data availability or time in the field. Azi: Azimuth of north or '1' component.

Label	Lat	Lon	Ele	Azi	Rate	Sensor	ID	Logger	Id	Start	End	Channels
AERO	-20.53991	-70.17818	20	90	100	CMG-3ESP/60	T35739	DM24	A1388	2010-11-24	2011-04-20	HHZ HHN HHE
APAC	-19.81656	-69.39541	2196	90	100	CMG-3ESP/60	xxxx	DM24	yyyy	2011-11-25	2013-11-07	HHZ HHN HHE
BUEN	-19.95618	-69.90733	1120	90	100	CMG-3ESP/60	T34776	DM24	C622	2010-12-09		HHZ HHN HHE
CERR	-20.62221	-69.66251	987	90	100	L4-3D	4956	REFTEK-72A	7692	2010-12-07		HHZ HHN HHE
CHOM	-21.09404	-70.0102	1200	90	100	CMG-3ESP/60	xxxx	DM24	C623	2011-04-27	2013-11-19	HHZ HHN HHE
CHOM	-21.09404	-70.0102	1200	90	200	CMG-3ESP/60	xxxx	DM24	C623	2013-11-20		HHZ HHN HHE
CORZ	-19.4945	-69.79348	0	90	100	L4-3D	xxxx	REFTEK-72A	yyyy	2010-01-01		HHZ HHN HHE
HUAR	-19.93203	-69.72611	1135	90	100	CMG-3ESP/60	T35732	DM24	C620	2009-12-03		HHZ HHN HHE
MAM1	-20.13347	-69.45546	1426	90	100	CMG-3ESP/60	T35808	DM24	A1389	2010-12-03		HHZ HHN HHE
MAM2	-20.09217	-69.395	1426	90	100	L4-3D	4954	REFTEK-72A	7682	2010-12-06		HHZ HHN HHE
NEUQ	-20.1722	-70.07323	1043	90	100	CMG-3ESP/60	T34639	DM24	C617	2009-05-17		HHZ HHN HHE
PATA	-20.6918	-70.00257	780	90	100	CMG-3ESP/60	T35738	DM24	A1387	2010-11-24	2013-11-19	HHZ HHN HHE
PATA	-20.6918	-70.00257	780	90	200	CMG-3ESP/60	T35738	DM24	A1387	2013-11-20		HHZ HHN HHE
PICL	-20.50209	-69.26111	1773	90	100	CMG-3ESP/60	T34777	DM24	C618	2009-12-01	2013-11-07	HHZ HHN HHE
PICL	-20.50209	-69.26111	1773	90	200	CMG-3ESP/60	T34777	DM24	C618	2013-11-08		HHZ HHN HHE
PICL2	-20.4995	-69.26623	1744	90	200	CMG-3ESP/60	T34776	DM24	C622	2013-11-12		HHZ HHN HHE
PICL3	-20.5015	-69.27381	1708	90	200	CMG-3ESP/60	T35808	DM24	1389	2013-11-13		HHZ HHN HHE
PICL4	-20.50238	-69.28196	1654	90	200	CMG-3ESP/60		DM24	C617	2013-11-13		HHZ HHN HHE
PICL5	-20.4897	-69.28003	1656	90	200	CMG-3ESP/60	T35467	DM24	C624	2013-11-14		HHZ HHN HHE
PICL6	-20.48641	-69.26605	1748	90	200	CMG-3ESP/60	T35461	DM24	C614	2013-11-14		HHZ HHN HHE
PICL7	-20.49121	-69.25018	1827	90	200	CMG-3ESP/60	T35733	DM24	1384	2013-11-15		HHZ HHN HHE
PICL8	-20.51208	-69.27737	1612	90	200	CMG-3ESP/60	T35732	DM24	1385	2013-11-15		HHZ HHN HHE
PICL9	-20.49152	-69.26118	1749	90	200	CMG-3ESP/60	T34782	DM24	C620	2013-11-14		HHZ HHN HHE
PICLA	-20.50773	-69.25383	1947	90	200	L4-3D	4955	DM24	A2386	2014-11-19		HHZ HHN HHE
PINT	-20.76133	-69.39726	1146	90	100	CMG-3ESP/60	T34782	DM24	A1386	2009-12-05		HHZ HHN HHE
POZO	-20.25246	-69.75943	1024	90	100	CMG-3ESP/60	T35733	DM24	A1384	2009-12-04		HHZ HHN HHE
SOG1	-19.67028	-69.61834	1590	90	100	CMG-3ESP/60	T35467	DM24	C624	2010-11-29		HHZ HHN HHE
SOG2	-19.52838	-69.37863	2722	90	100	CMG-3ESP/60	T35461	DM24	C614	2011-04-26		HHZ HHN HHE
TIRA	-20.32991	-69.57166	1020	90	100	CMG-3ESP/60	T35734	DM24	A1385	2009-12-05		HHZ HHN HHE
UNAP	-20.24393	-70.14041	0	90	100	CMG-3ESP/60	T34622	DM24	A1383	2009-05-14		HHZ HHN HHE

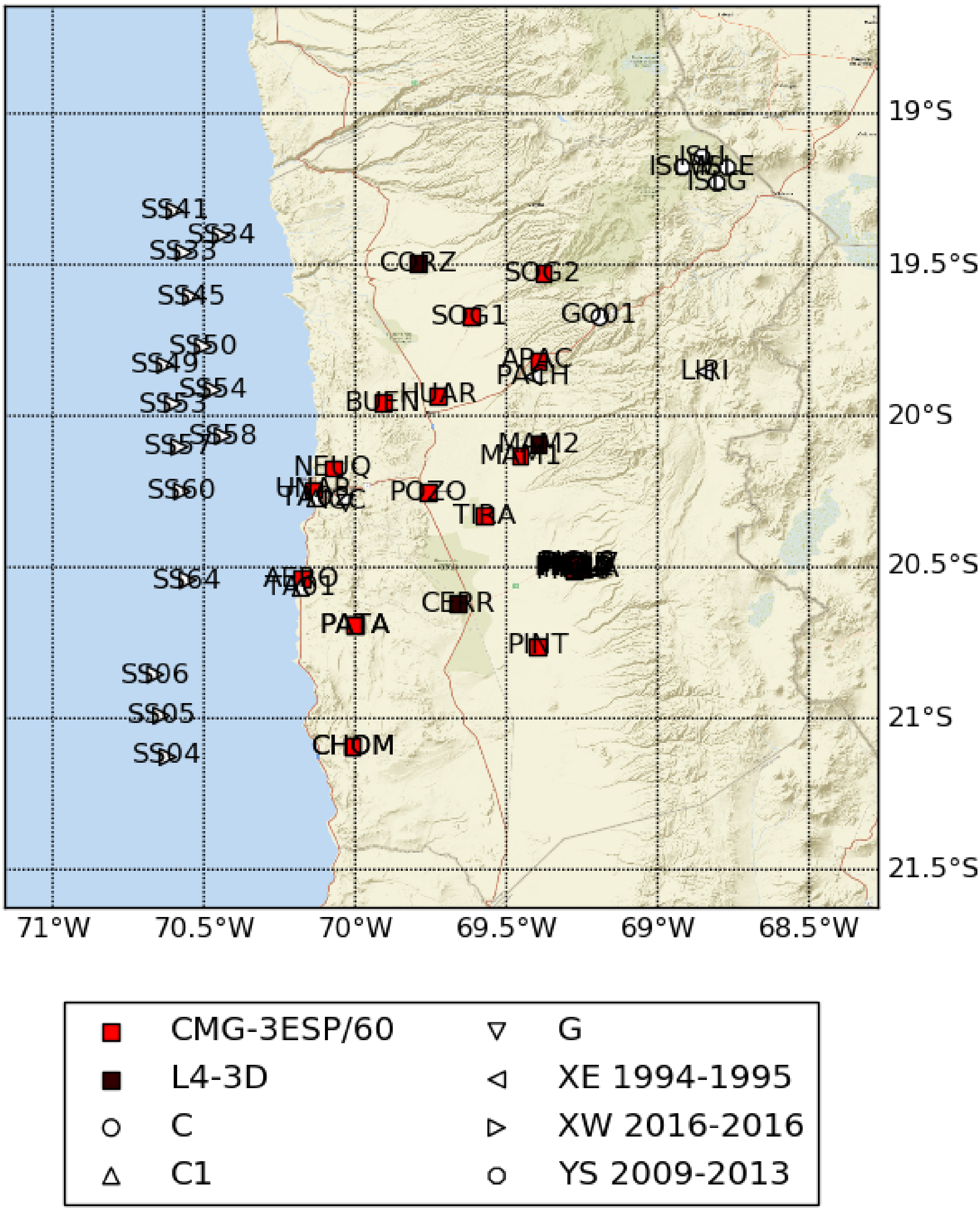
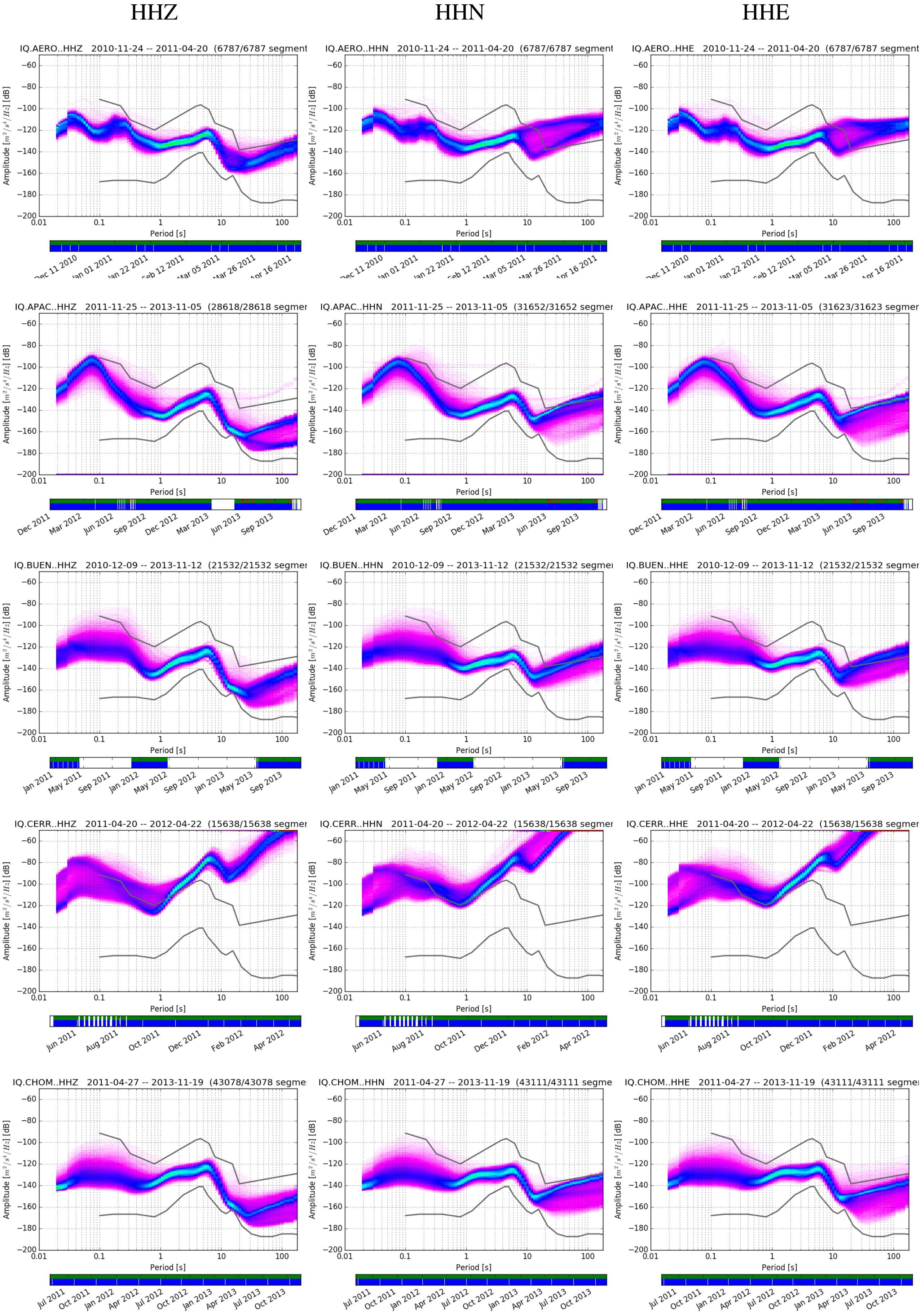


Fig. 5: Station distribution in experiment (red symbols). If present, white-filled symbols show permanent stations and other temporary experiments archived at EIDA or IRIS-DMC, whose activity period overlapped at least partially with the time of the experiment. If present, open symbols show station sites which were no longer active at the time of the experiment, e.g. prior temporary experiments.



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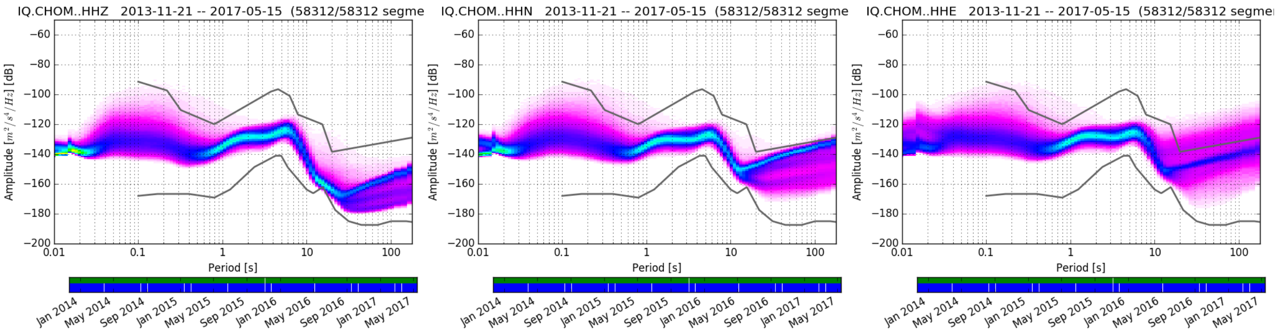
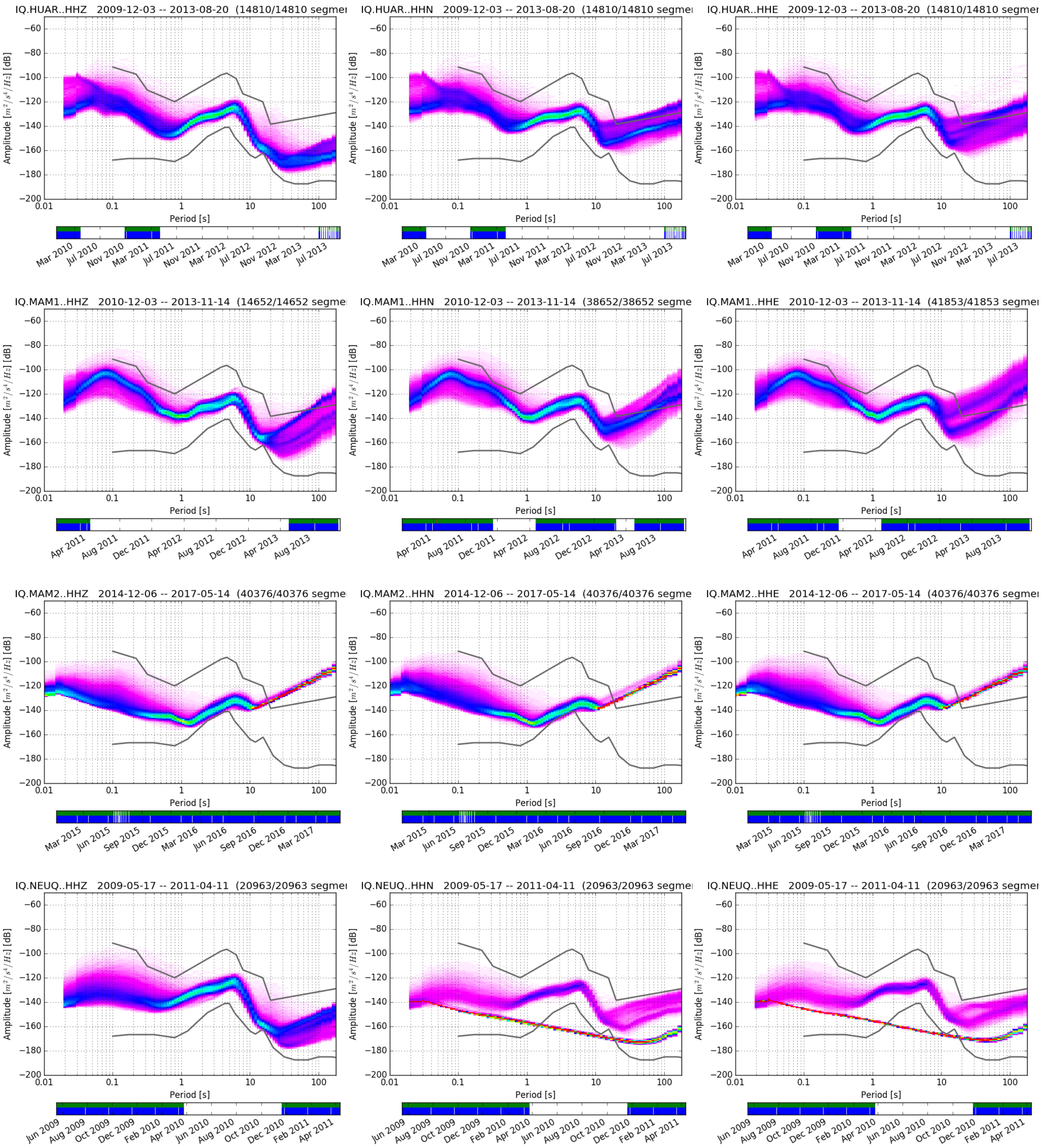
HHZ HHN HHE



CORZ-HHZ.png CORZ-HHN.png CORZ-HHE.png



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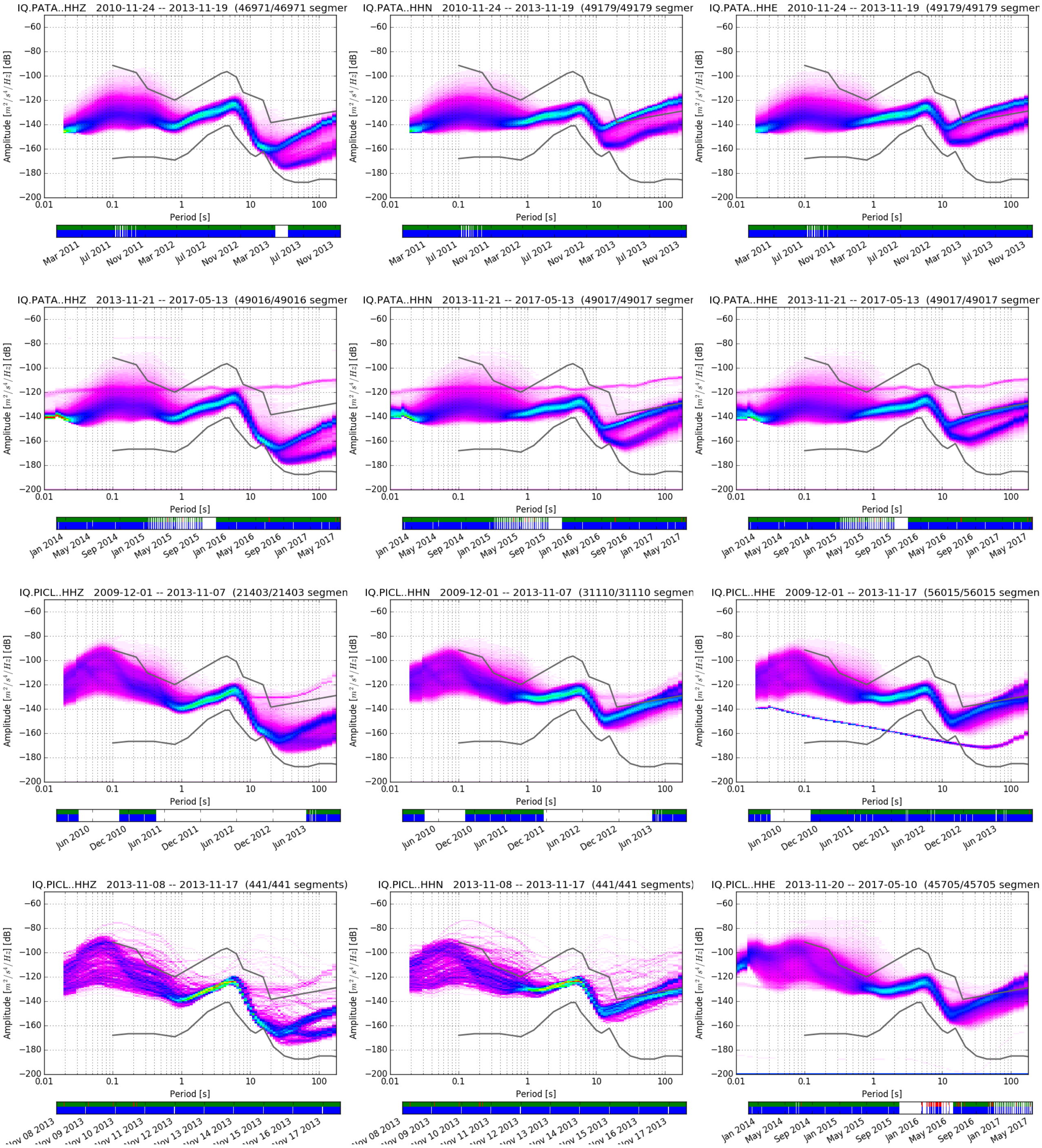
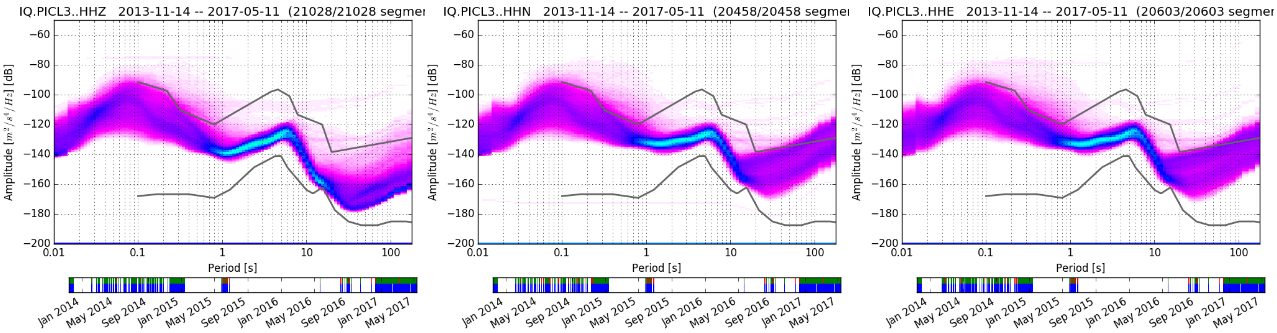
HHZ HHN HHE



PICL2-HHZ.png PICL2-HHN.png PICL2-HHE.png



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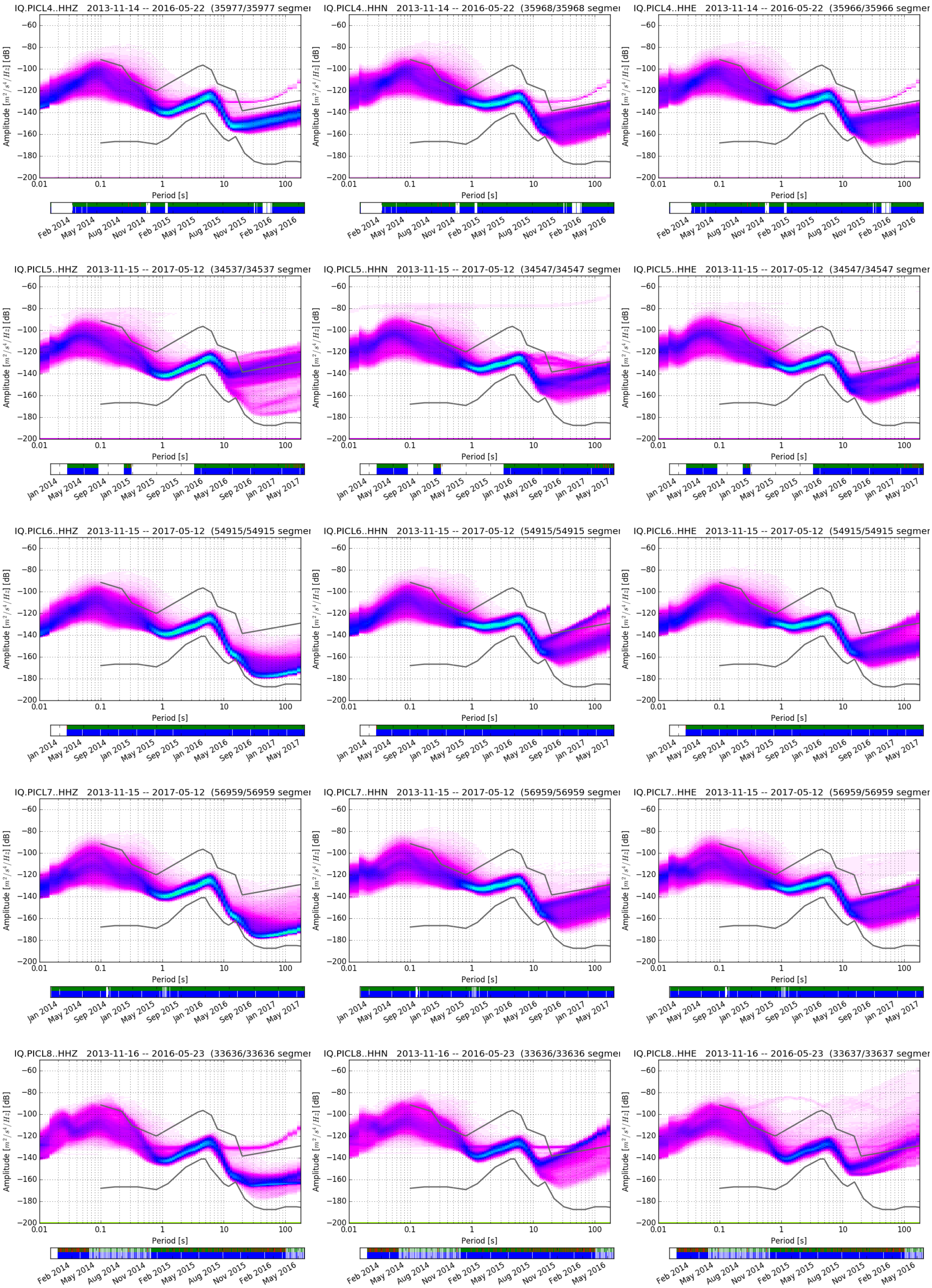
HHZ HHN HHE



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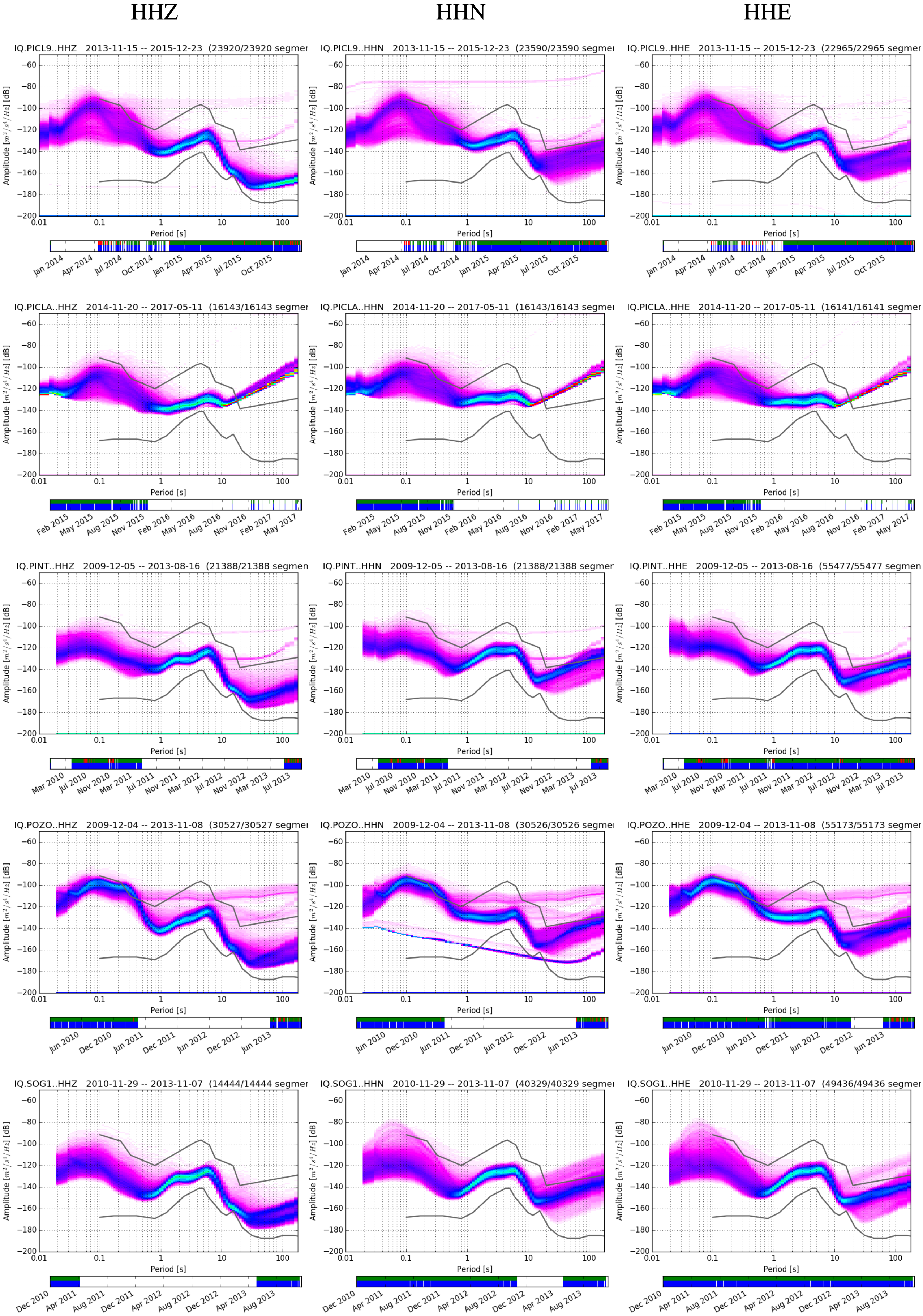

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HHZ HHN HHE

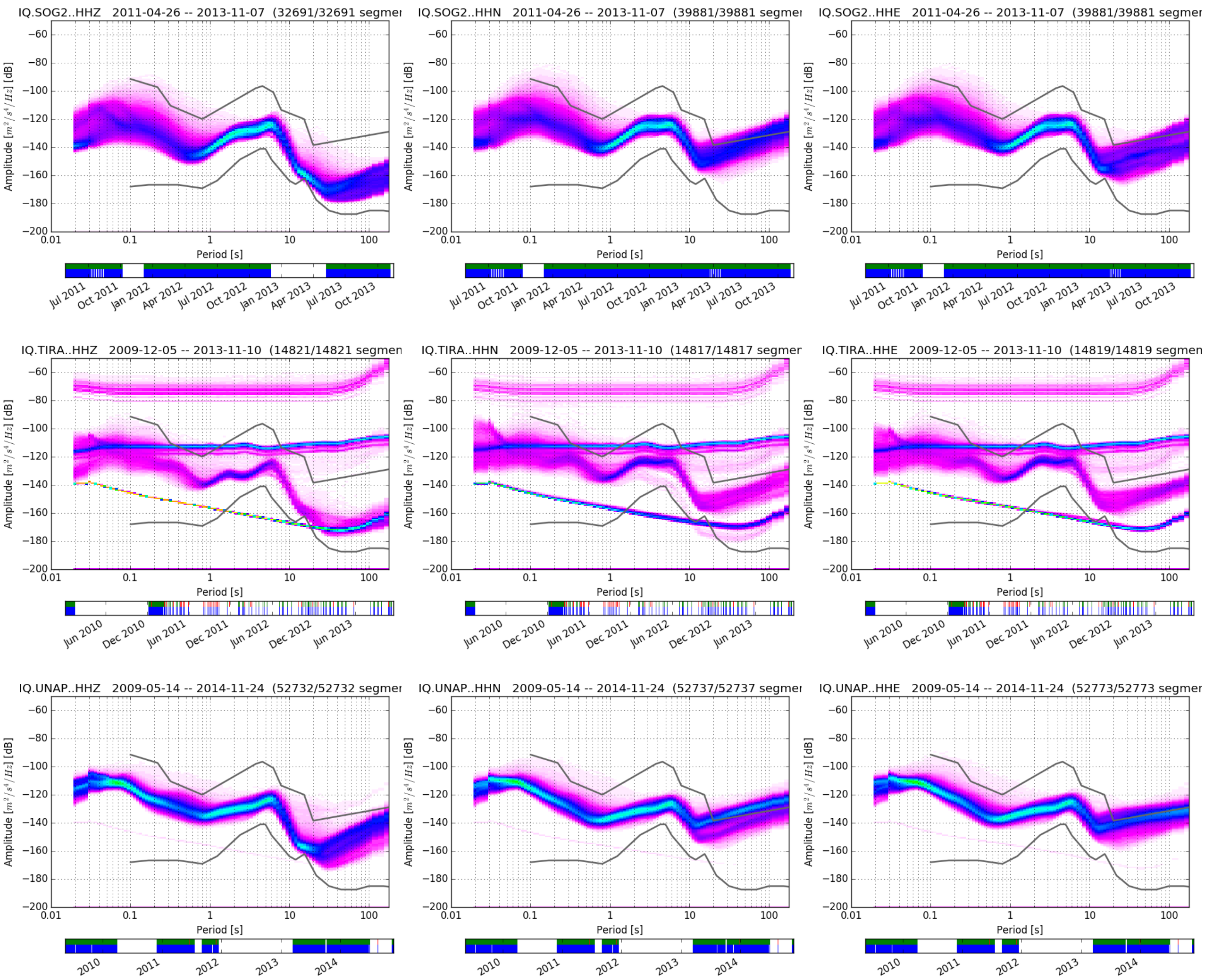

Fig. 6: Noise probability density functions for all stations for database holdings

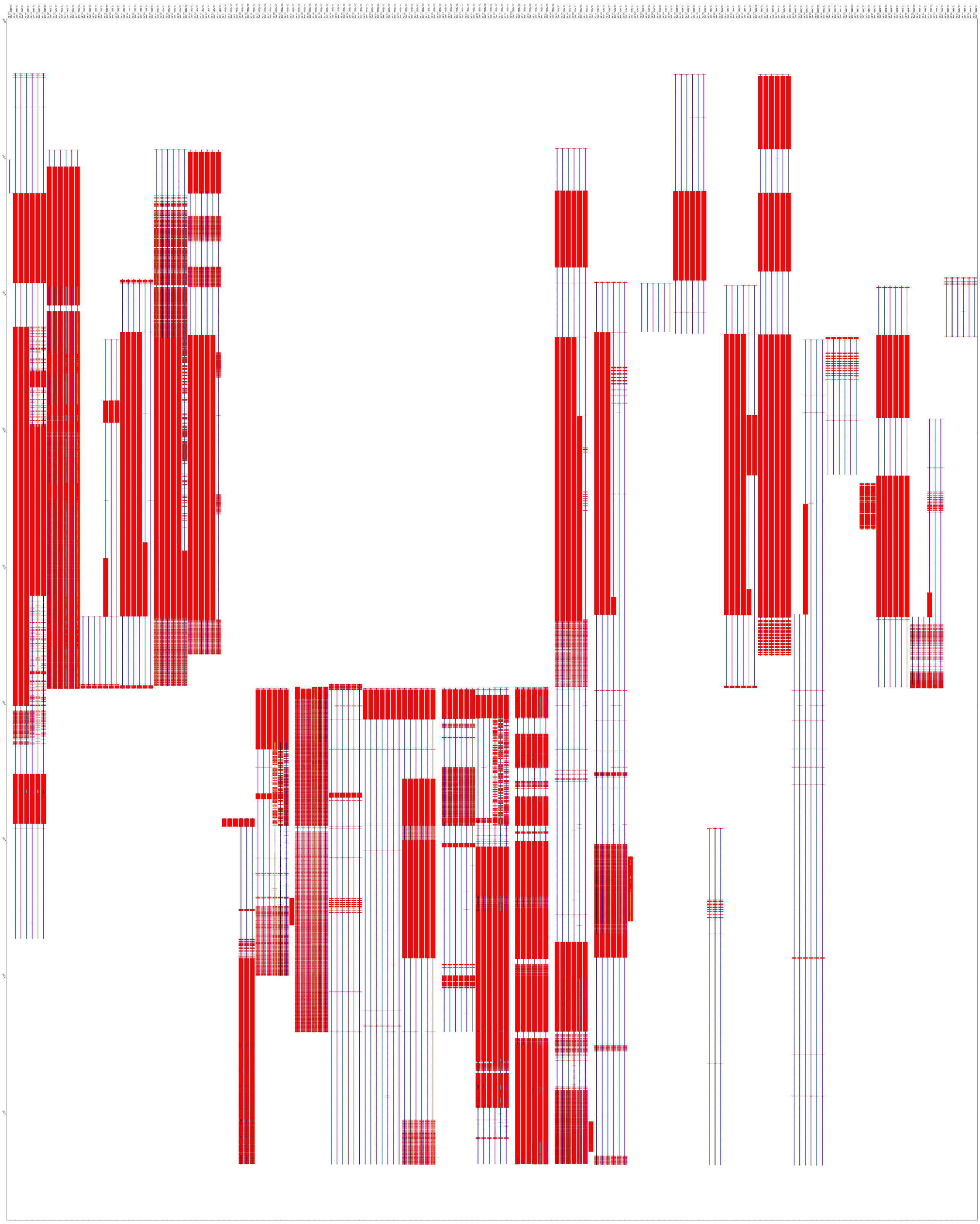

Fig. 7: Overview of uptimes of all stations generated with *obspy-scan*

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