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Dead Sea Seismic Array, Jordan for DESERVE Project (Feb. 2014 - Feb. 2015) - Report

Scientific Technical Report STR16/01 – Data
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Friederike Lott[1*], Mahmoud Al-Qaryouti[2], Ulrich Corsmeier[1,] & Joachim Ritter[3]

[1] *Karlsruhe Institute of Technology KIT, Institute of Meteorology and Climate Research IMK. Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany*

[2] *Jordan Seismology Observatory JSO. Ministry of Energy and Mineral Resources, P.O.Box 140027, Amman11814, Jordan*

[3] *Karlsruhe Institute of Technology KIT, Geophysical Institute GPI. Hertzstraße 16, 76187 Karlsruhe, Germany*

[*]*corresponding author*

Abstract

A temporary seismic array was installed in combination with a meteorological station in the Dead Sea valley, Jordan. Within the scope of the HGF virtual institute DESERVE we operated 15 temporary seismic stations between February 2014 and February 2015 together with a nearby meteorological station close to the east coast of the Dead Sea. The main aim was to acquire data to study the influence of wind on seismic records and retrieve related meteorological parameters. The study area is scarcely populated and has ideal meteorological conditions to study periodically occurring winds.

Coordinates: 31.65°N / 35.58°E
Supplementary data: http://doi.org/10.5880/GIPP.201001.1
Keywords: Seismology, Array, Noise, Wind

1. Introduction

The DEad SEa Research VEnue (DESERVE) programme, funded by the Helmholtz Association, focuses on multiple geoscientific disciplines addressing natural risks such as weather and climate aspects, seismic hazards and changes in water cycle in the environment of the Dead Sea region. Taking advantage of the interdisciplinary character of the project, an experiment on the influence of meteorological parameters on ground motion was realized, given that the topography and wind systems in the region provide ideal conditions.

There have been several studies on correlations between seismic noise and wind speed (Withers et al., 1998), and the investigations on storms by Holub et al. (2008, 2009). However, hitherto investigations on the influence of wind on seismological data were secondary results in experiments that were not purpose-built and therefore limited in the comparability of meteorological and seismic data sets.

We designed a target-oriented experiment in the Dead Sea valley conducting seismological and meteorological measurements in close vicinity. Quite common in the area are various local wind systems, most distinct during summer. In winter storms can occur, thus different wind conditions could be expected during the observational period. The goal of our study is to combine meteorological and seismological data sets in order to detect the influence of wind on seismic records and to find directly correlated signals in the seismological and meteorological recordings. Here we present a description of the experiment and data from the temporary seismic array installed in Jordan using instruments provided by the Geophysical Instrument Pool Potsdam (GIPP) at the GFZ German Research Centre for Geosciences (Deutsches GeoForschungsZentrum GFZ).

2. Data Acquisition

2.1 Experimental Design and Schedule

For a period of about one year beginning February, 2014 we installed 15 seismic stations including 5 broadband (120 s) and 10 short period seismometers (1 s). This observation period covers one complete weather cycle including summer wind systems and winter storms. The stations were deployed in the Dead Sea basin close to the northwestern shore of the Dead Sea in Jordan (Figure 1). The topography of the area is steep, and the stations were located outside of the sediment cover in the valley, with elevations between 374 m below and 123 m above sea level. The aperture of the array is about 3 km (Figure 1) and tuned to wavelengths of about 200-2000 m for array processing.

The seismic array was designed to consist of 3 circles of stations with very short (~90 m), medium (~300 m) and large (>700 m) radii. The individual locations of the recording sites were chosen to avoid a linear alignment when using the records for all possible back azimuths. The central recording station (DES01) and the outmost four recording stations (DES12, DES13, DES14, and DES15) have broadband sensors (NANOMETRICS Trillium compact 120 s) due to the large interstation distances. The short period seismometers (1 s) were placed between the central and the outer stations as first and second circles. Depending on the ground conditions, which was mostly rock, the sensors were buried at depths of up to 50 cm to protect them from direct wind, sunshine and vandalism.

The stations were maintained every 4-8 weeks by staff from the Jordan Seismology Observatory. Maintenance included changing batteries and data media as well as controlling the proper functioning of the recordings units (see section 2.3).

In direct vicinity (100 m) of recording station DES15, in about 2 km distance from the central seismic station DES01, a meteorological station was located recording 3-component wind speed, temperature, precipitation, barometric pressure, relative humidity, short and long wave radiation.

2.2 Site Descriptions and Possible Noise Sources

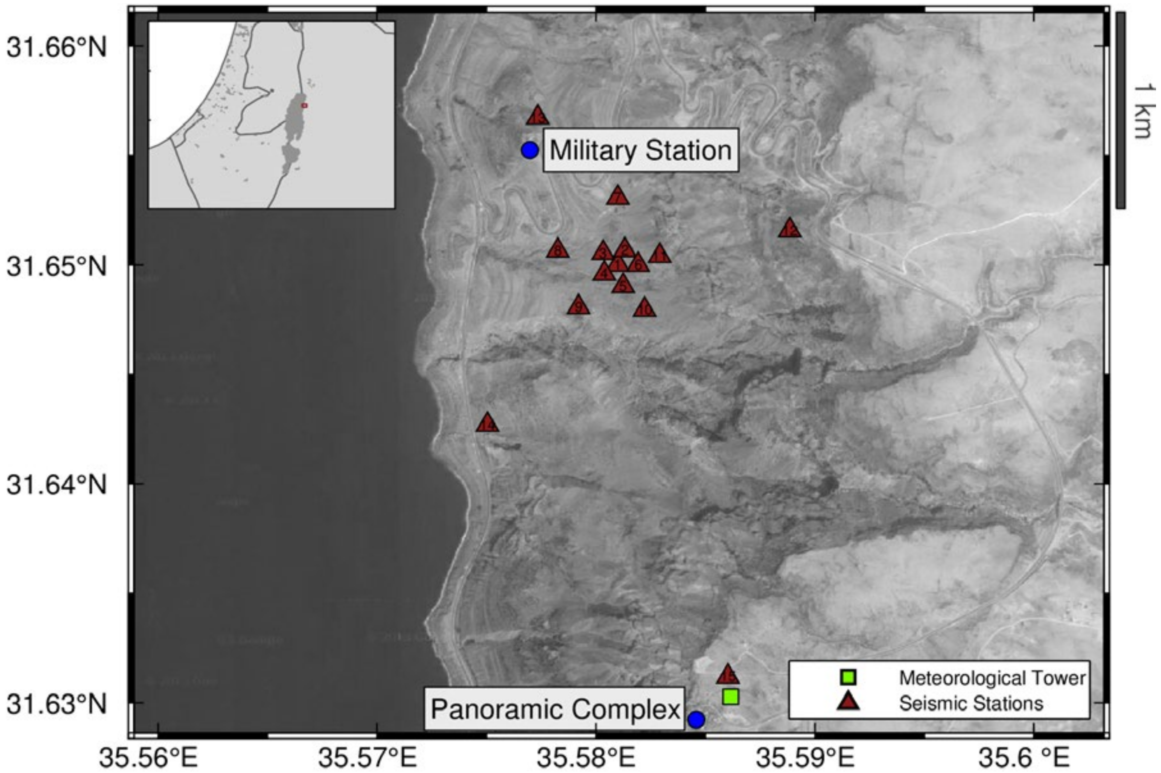

Figure 1: Map of the array with the seismic recording stations and other reference points. Satellite image: Bilder@CNS2015 / Astrium,DigitalGlobe

The array was located at the edge of the Dead Sea basin and therefore the single recording stations were placed at very different elevations (Table 1). The stations were deployed in stony and/or sandy soil with no or scarce vegetation. Two streets (potential noise sources) are close to the array: the heavily used Dead Sea highway along the eastern Dead Sea coast and the road from the Dead Sea to the city of Madaba with only rare traffic. Apart from a small military station consisting of one building and the Panoramic Complex (comprising a museum, a restaurant, and a solar power plant) there are no other buildings within a 2.5 km radius.

Recording station DES15 has the highest elevation and is located within the area of Panoramic Complex. In about 200 m distance from the sensor the museum and restaurant are places for excursions and therefore we anticipate occurrence of anthropogenic noise during day times. A meteorological station consisting of a mast of 10 m height is installed in 100 m distance from DES15. Station DES13 is located close to a military station with some traffic. DES14 stands close to the Dead Sea highway with a high volume of traffic affecting the data quality.

At the end of the experiment broad band stations DES13 and DES14 were reinstalled as stations DES20 and DES21 for a period of 6 days close to the meteorological tower for reference measurements. Table 1 lists all station names, locations, elevations, sensors, loggers, and runtime dates.

Station	***Location***	***Alt. /m***	***Sensor, ID***	***Logger, ID***	***Runtime***
DES01	*31.65002N,35.58100E*	*-292*	*Trillium Compact 015*	*CUBE 710*	*2014/02/22-2014/11/30* *2014/12/09-2015/02/12*
DES02	*31.65068N,35.58132E*	*-189*	*Mark Products 1357*	*CUBE 645*	*2014/02/25-2015/02/12*
DES03	*31.65055N,35.58033E*	*-209*	*Mark Products 1824*	*CUBE 641*	*2014/02/25-2015/02/11*
DES04	*31.64960N,35.58038E*	*-232*	*Mark Products 1885*	*CUBE 642*	*2014/02/27-2015/02/11*
DES05	*31.64904N,35.58124E*	*-276*	*Mark Products 1871*	*CUBE 643*	*2014/02/27-2015/02/11*
DES06	*31.65001N,35.58192E*	*-263*	*Mark Products 1354A*	*CUBE 644*	*2014/02/27-2015/01/05*
DES07	*31.65307N,35.58100E*	*-190*	*Mark Products 1879*	*CUBE 640*	*2014/02/22-2015/02/12*
DES08	*31.65066N,35.57826E*	*-280*	*Mark Products 1823*	*CUBE 646*	*2014/02/24-2014/10/18* *2014/10/31-2015/02/11*
DES09	*31.64807N,35.57920E*	*-257*	*Mark Products 1355A*	*CUBE 647*	*2014/02/24-2014/06/20* *2014/08/08-2015/02/11*
DES10	*31.64796N,35.58222E*	*-195*	*Mark Products 2831*	*CUBE 648*	*2014/02/24-2015/01/05*
DES11	*31.65041N,35.58291E*	*-162*	*Mark Products 1898*	*CUBE 649*	*2014/02/24-2015/01/30*
DES12	*31.65158N,35.58886E*	*90*	*Trillium Compact 013*	*CUBE 711*	*2014/02/26-2015/02/12*
DES13	*31.65673N,35.57734E*	*-248*	*Trillium Compact 016*	*CUBE 712*	*2014/02/26-2015/02/11*
DES14	*31.64270N,35.57505E*	*-374*	*Trillium Compact 014*	*CUBE 713*	*2014/02/26-2015/01/05*
DES15	*31.63120N,35.58603E*	*123*	*Trillium Compact 007*	*CUBE 650*	*2014/02/23-2015/02/17*
DES20	*31.63028N,35.58616E*	*123*	*Trillium Compact 016*	*CUBE 712*	*2015/02/11-2015/02/17*
DES21	*31.63028N,35.58616E*	*123*	*Trillium Compact 014*	*CUBE 713*	*2015/02/11-2015/02/17*

Table 1: Station instrumentation information including serial numbers. Note the negative altitude values due to the deep depression of the Dead Sea valley.

2.3 Instrumentation

We obtained 15 sensors and data loggers from the GIPP. All of the seismic stations were equipped with CUBE³ data loggers and ran on external batteries. All stations recorded 3 components (vertical, N-S and E-W) of data with a 200 Hz sampling rate. Sensors were oriented with a compass whereas uncertainties of up to +/- 5° can be expected. Note, that the horizontal components are oriented with respect to the magnetic field and a declination of about 4° to the geographic North and should be corrected. Table 1 lists the individual station instrumentation.

Sensors:

- 5 Trillium Compact 120 s seismometers
- 10 Mark L4-3D 1 s seismometers

Loggers:

All seismic stations were equipped with CUBE³ data loggers. The time series were stored locally on internal memory cards. Due to limited internal storage capacity of the loggers, data was downloaded manually every 4-8 weeks during the station maintenance when batteries were changed as well.

Power supply

As power supply 35 Ah calcium car batteries were used that were exchanged and recharged on a regular schedule every 4-8 weeks. During station maintenance the stations were unplugged from power and thus not recording. Figure 3 outlines the run time of each station. Grey squares mark station maintenances when data has gaps and higher noise levels.

3. Instrument Properties and Data Processing

Available data is raw data (recorded in CUBE format and converted to MSEED) using the script cube2mseed from the GIPP toolbox (Release 2013.268) in Linux. The data on hand is in units of counts, not filtered and not resampled. Table 2 lists the required logger settings and sensor characteristics of the instruments. The logger settings such as gain and A-D conversion factor are the same for all instruments. Sensitivity and normalization factor depend on the sensor type. For the 1 s sensors, normalization factor, sensitivity, and poles and zeros are individual for each instrument and component. Note, that values listed in table 2 are average values. For exact values, please contact GIPP staff. Figure 2 displays instrument responses calculated for stations DES01 and DES02 (Z - vertical, N-S, and E-W components) exemplarily.

Sensor	Logger gain	A-D conversion	Sensitivity /V/(m/s)	Normalization factor	Poles	Zeros
Trillium Compact	*1*	*0.244*	*750/10*	*8.184e+11*	*-0.0369 + 0.0371i;*	*0;*
					-0.0369 - 0.0371i;	*0;*
					-3.7120e+02 + 0.0000i;	*-434.1*
					-3.7390e+02 + 4.7550e+02i;	
					-3.7390e+02 - 4.7550e+02i;	
					-5.8840e+02 + 1.5080e+03i;	
					-5.8840e+02 - 1.5080e+03i	
Mark Products	*1*	*0.244*	*170*	*1.414*	*-4.443 + 4.443i;*	*0;*
					-4.443 - 4.443i	*0*

Table 2: Sensor and logger properties for recording stations with Nanometrics Trillium Compact and Mark Products sensors. Note: sensitivity, normalization factor, and poles and zeros in this table are average values for Mark Products instruments. The sensitivity of the Trillium Compact instrument is divided by 10 due to a divisor in the break-out box of the instrument.

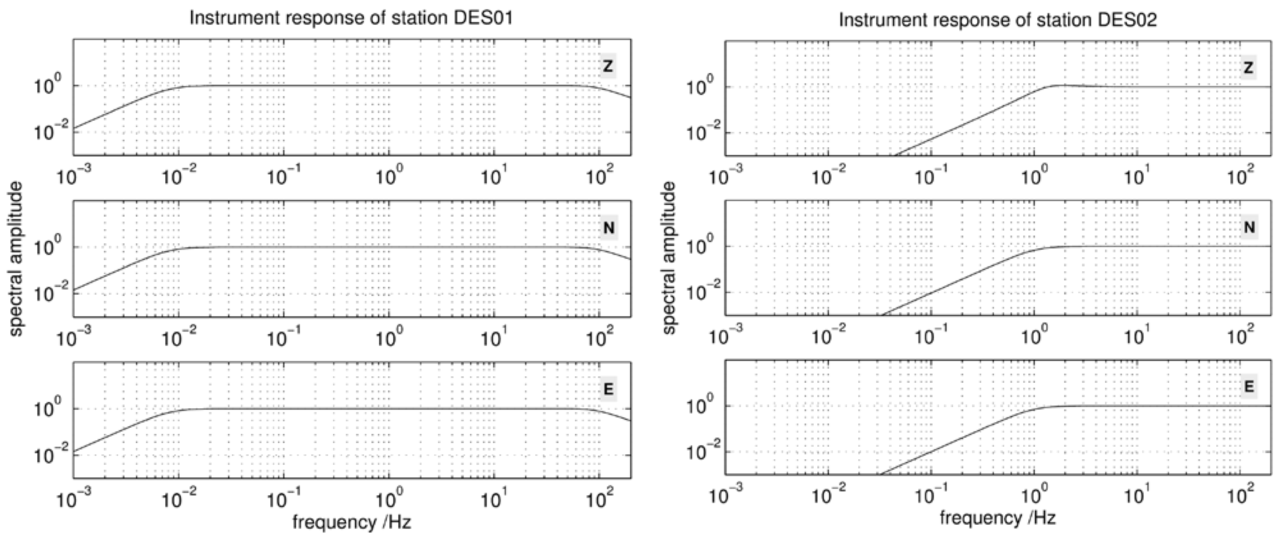

Figure 2: *Instrument responses of Trillium Compact 015 at station DES01 (left panel) and Mark L4-3D 1357 at station DES02 (right panel).*

4. Data Description

Data is digital data with a sample rate of 200 samples per second.

4.1 Data Completeness

Data from the seismic array is available from end of February 2014 to the middle of February 2015. Additionally, data from recording stations DES20 and DES21 is available for one week in February 2015 (see Table 1, Figure 3).

The seismic stations were deployed in an unguarded, open area. Thus continuous power supply by solar panels was not possible due to safety reasons. Therefore, during station maintenance on a regular schedule batteries were exchanged, data saved, and internal memory cards emptied at the CUBE loggers. During station maintenance, data recording was interrupted, leaving short gaps in the data. Apart from that and from subsequently discussed cases, data recording was continuous for the period of about one year with a data retrieval of 96%.

Figure 3 illustrates the run time of all recording stations including marks for station maintenances. Three stations have data gaps of between 9 days and more than a month: DES01, DES08, and DES09. Three other stations, DES06, DES10, and DES14, were discovered by locals and collected by the local police in January 2015, therefore data acquisition stopped earlier at these stations.

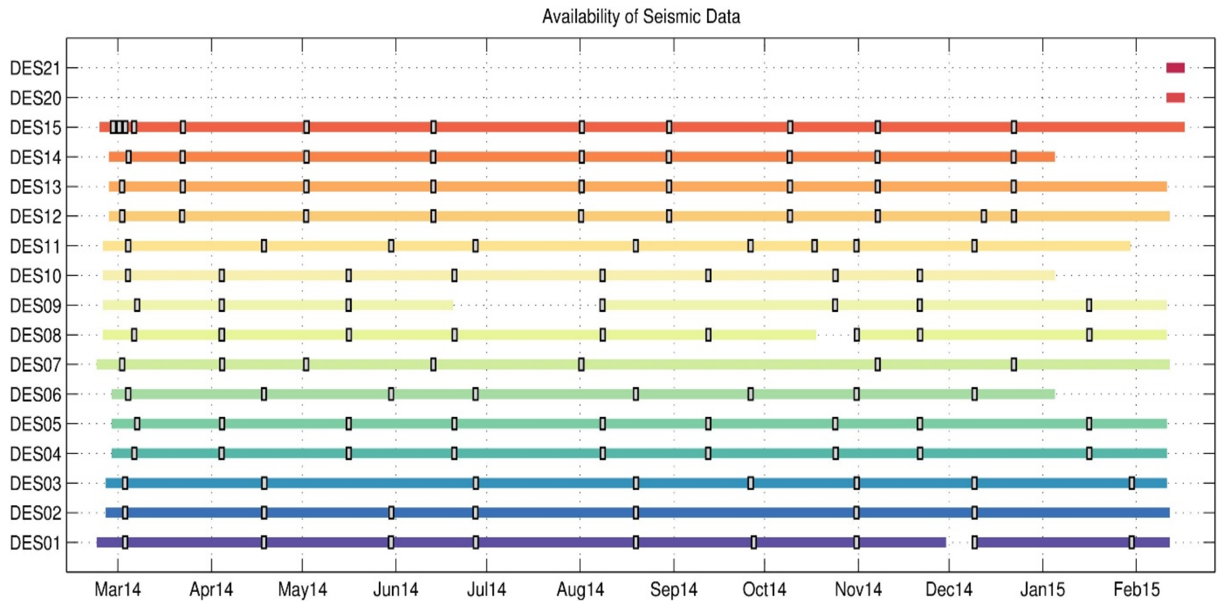

Figure 3: Availability of seismic data. Grey squares mark small data gaps when station maintenance was done.

4.2 File Format

Data is in CUBE proprietary data format (http://www.omnirecs.de/; see below). The CUBE file format is an intermediate data format that cannot be used directly. Instead, it should be converted to mseed (or ASCII or SEG-Y etc.) first for example by using the respective utility from the *GIPPtools* (by Christoph Lendl, http://www.gfz-potsdam.de/sektion/geophysikalische-tiefen-sondierung/infrastruktur/geophysikalischer-geraetepool-potsdam-gipp/software/gipptools/).

The header of CUBE data can be obtained using the utility *cubeinfo* from the *GIPPtools* toolbox. The header includes information about the used CUBE unit, configured digitizer settings and the GPS mode used during recording.

4.3 Data Content and Structure

The CUBE data archive is arranged in a folder structure as follows:

yyyy/xxx/

Whereas:

- yyyy: Directory named by four-digit year
- xxx: Directory named by three-digit CUBE number (see Table 1)

The directories ***xxx*** contain the raw CUBE data files. Each CUBE file contains data of 24h length, starting 00 UTC each day. In case of data gaps (see Figure 3) there may be multiple files for one day with later starting times. One file contains data of one logger including all three components and header information. The files are named according to the start time of the records:

mmddHHMM.xxx

Whereas:

- mm: two-digits number month
- dd: two-digits number day
- HH: two-digits number hour
- MM: two-digits number minute
- xxx: three-digit CUBE number

5. Data Quality and Timing Accuracy

5.1. Noise Estimation

Data at hand is raw data that wasn't subjected to any corrections. However, to give an estimate of the data quality, below an example is presented with the noise level of processed data. Seismic stations in this experiment were temporary stations deployed at a maximum depth of 50 cm in the ground and thermally isolated and covered by plastic buckets. Due to the site location (see section 2.2) we presume there is only little anthropogenic noise in the data. As an estimation of the data quality, Figure 4 displays the power spectral density of the recorded ground motion velocity at all recording stations for a period of 6 hours at night on 15th March 2014 for the vertical component. In this example, data is converted to units of ground motion velocity in nm/s, processed by removing mean and trend, tapered, band-pass filtered at 1-100 Hz, and the instrument response functions are removed. Power spectral density is calculated using the Thomson multitaper method (Thomson, 1982).

The traces in Figure 4 are placed between below 0 dB/Hz and 40 dB/Hz. Note the power spectral density of station DES14 which was located close to the Dead Sea highway, with a level higher than 30 dB/Hz for a wide frequency range. However, most other stations have significantly lower noise levels with power spectral density values less than 10 dB/Hz above 20 Hz.

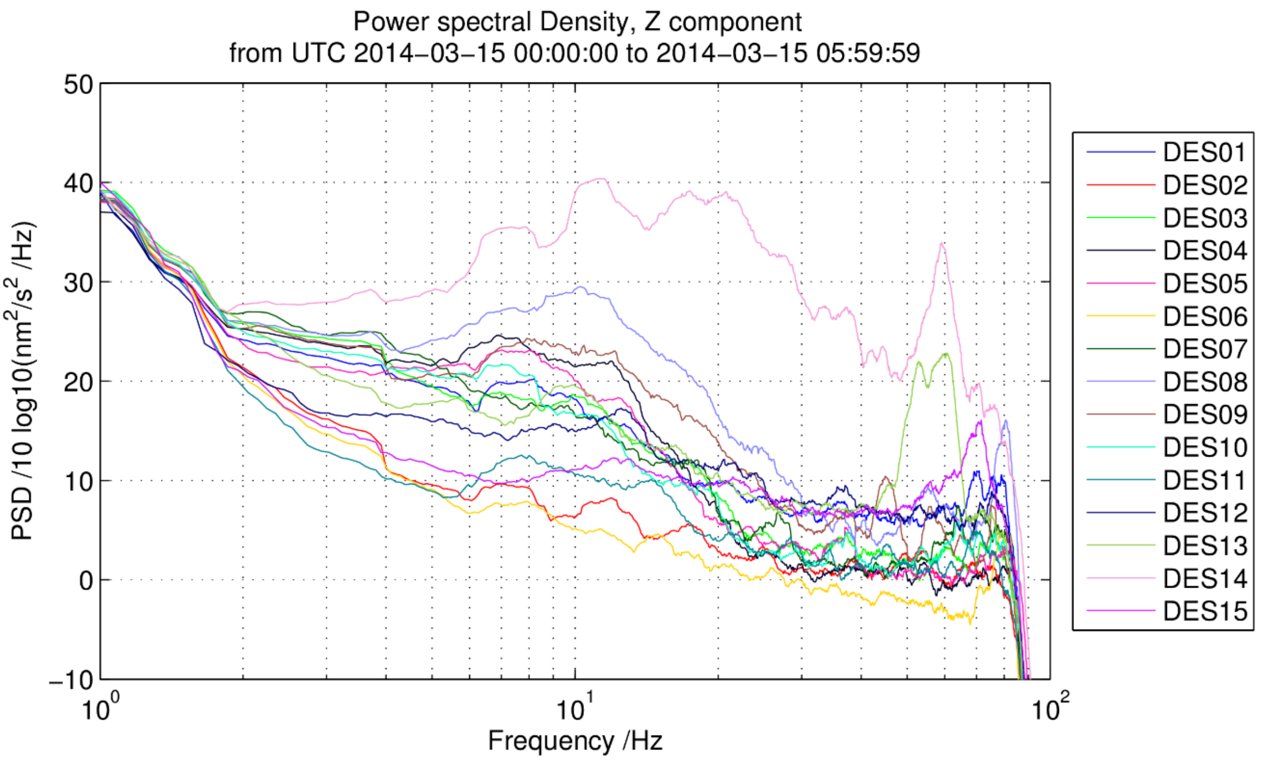

Figure 4*: Power spectral density estimate of seismic velocity at stations DES01 to DES15 (vertical component) between 1 Hz and 100 Hz. For better visibility all traces are smoothed.*

5.2 Timing Accuracy

All CUBE³ loggers were connected to GPS every 30 minutes. In order to work with correct data, the CUBE-formatted data has to be converted and resampled using e.g. the respective utility from the *GIPPtools* (see also above). After conversion (to mseed) and resampling the timing accuracy is expected to be in the order of 10 to 20 micro seconds (Ryberg, pers. Communication, 2016).

6. Data Availability/Access

The data is archived at the GIPP Experiment and Data Archive where it will be made freely available for further use on March 1, 2019 under a “Creative Commons Attribution-ShareAlike 4.0 International License” (CC BY-SA). When using the data, please give reference to this data publication. Recommended citation for this publication is:

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