Research Networking Programmes

Short Visit Grant

Proposal Title: Seismic signal analytical procedures applied to Fogo Volcano

Application Reference Nº: 6433

Participant Name: Rita Silva Marques

Period: February 18th to March 4th, 2015.

1) Purpose of the visit

The Azores archipelago is located in a peculiar region, in close proximity to the triple junction between the Eurasian (EU), African (AF) and North-American (NA) plates. Important tectonic structures, such as the Mid-Atlantic Ridge and Terceira Rift (*s.l.*), assign particular geodynamic and tectonic settings, which result in an intense seismic and volcanic activity. In the Azores archipelago, an integrated network of seismometers is deployed in various volcanoes and data are continuously sent to the CVARG/CIVISA (Centro de Vulcanologia e Avaliação de Riscos Geológicos and Centro de Informação Sismovulcânica dos Açores, respectively) data acquisition centre. During the next two years, 12 broadband stations will be installed to improve the detection of low frequency seismic events. The seismic data are the raw material for further analysis, whether be daily routine analyses or for improving knowledge, being an important tool for seismic and/or volcanic forecasting. It is also essential the integration of the information obtained by seismology with other monitoring techniques, in order to understand the state of activity of the volcanic systems and to identify possible unrest precursors.

Considering the geodynamic setting similarity found out between the Azores archipelago and Iceland, a straight cooperation between CVARG/CIVISA and IMO is quite promising in order to compare analytical methodologies, as well as to compare characteristic seismic signals and acquire the “know how” to analyse them.

The exchange of experience favoured by this short visit allowed comparing seismic monitoring strategies used by the two observatories, including seismic stations deployment, data transmission and acquisition systems, as well as automatic detection and location of seismic events. It also contributed for the improvement of analytical methodologies applied currently in the CVARG/CIVISA. The possibility to compare data from different volcanoes can help in the recognition of future signals of volcanic unrest, particularly in the Azorean dormant volcanoes, helping to strengthen the capacities of the observatory.

2) Description of the work carried out during the visit

The work started some days before the travel with the selection of specific seismic events recorded by the CVARG/CIVISA seismic permanent network. The selected events present shapes and spectral content slightly different from the typical VT earthquakes that are usually recorded by the network. Therefore, it was of truly interest that different methodologies were applied to these events, in an attempt to understand their location/origin.

During the visit, the researcher was received in the Icelandic Meteorological Office (IMO) by Dr. Kristín Vogfjord, and all the activities were carried out there. In the first days the researcher was introduced to the IMO facilities in what concerns the daily routine of the seismic monitoring group, highlighting the fact that they were still monitoring the volcanic eruption in Bardarbunga Volcano. The way of working, the IMO seismic network configuration, as well as the type of seismic equipment deployed in Iceland, was also discussed. All these discussions were essential and can contribute, not only to interpret the seismicity recorded at Azores islands but also to improve the analytical methodologies applied in the CIVISA data acquisition centre (CAD).

During this period, the researcher was introduced to the prerequisites for implementing the ShakeMap software (Wald *et al*., 1999), reading IMO reports and related papers. Despite this task will not be completely overviewed during this visit, a first approach to the methodology was made.

In the next days, the tasks were based mainly on the noise analysis of some CIVISA stations. To accomplish these tasks, the researcher had to become familiar with the Seismic Analysis Software package, SAC (Goldstein and Snoke, 2005).

The noise analysis was carried out for all stations with 3 component sensors installed in São Miguel Island (7 stations in total). The sensors are LE (Lennartz) 1s. The analysis consisted in the determination of noise spectrum for a 350 second length window for each station and each component (figure 1), after removing the instrument responses from the traces. For this, Dr. Vogfjord created the response files for the LE 1s sensors.

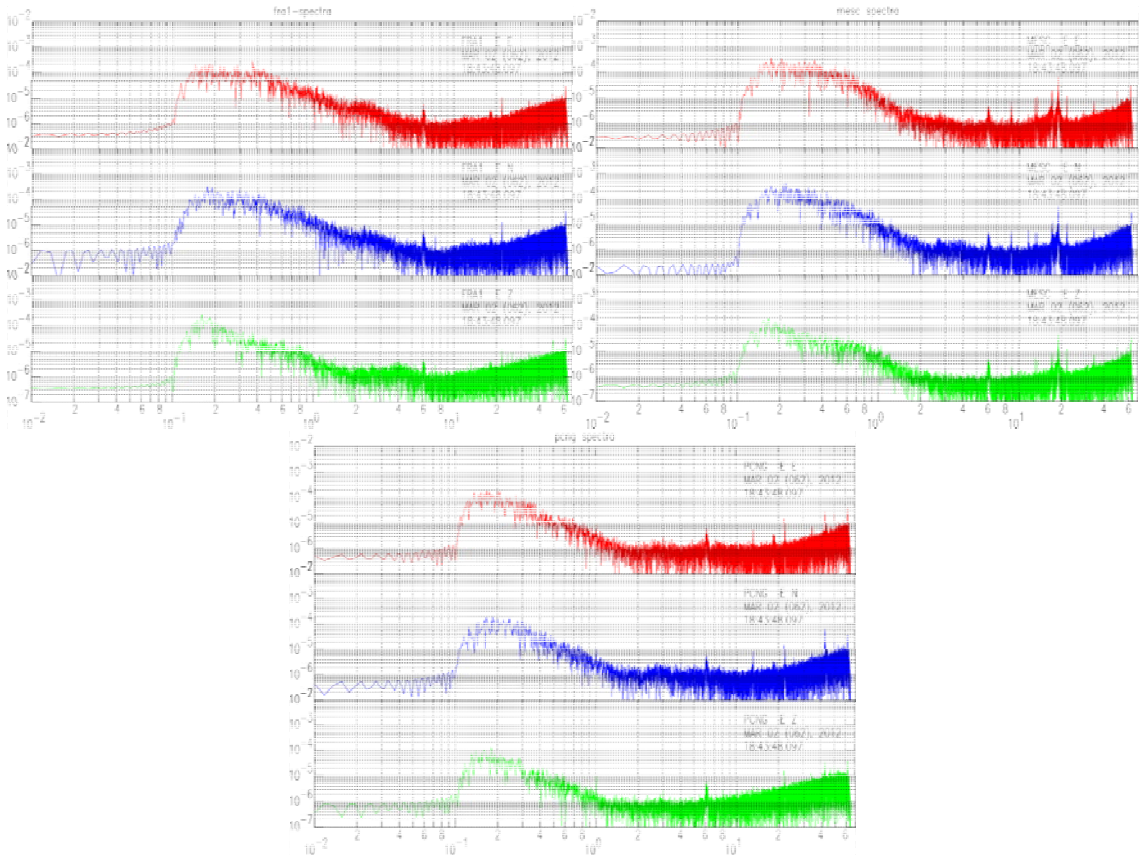

Figure 1 - Examples of noise spectrum for three short-period stations (LE 1s) from CIVISA permanent network. The *xx* axis represents frequency (Hz) and the *yy* axis amplitude.

The seismic noise was synthesized by velocity power spectral density (PSD) curves (figure 2). The velocity PSD curves are here represented as a function of the frequency, and they are compared with the new low-noise model (NLNM) and the new high-noise model (NHNM) models of Peterson (1993). These models are currently assumed as the acceptable limits for the seismic noise at permanent inland stations (Bormann, 2002).

The majority of the velocity PSD curves do not quite fall within the NLNM and NHNM levels, especially from 0.3 to 1 Hz, with exception to the PCNG station that shows a reasonable behaviour. At frequencies higher than 10 Hz, the signal shows an increase of amplitude, which is also visible in the spectra represented in figure 1.

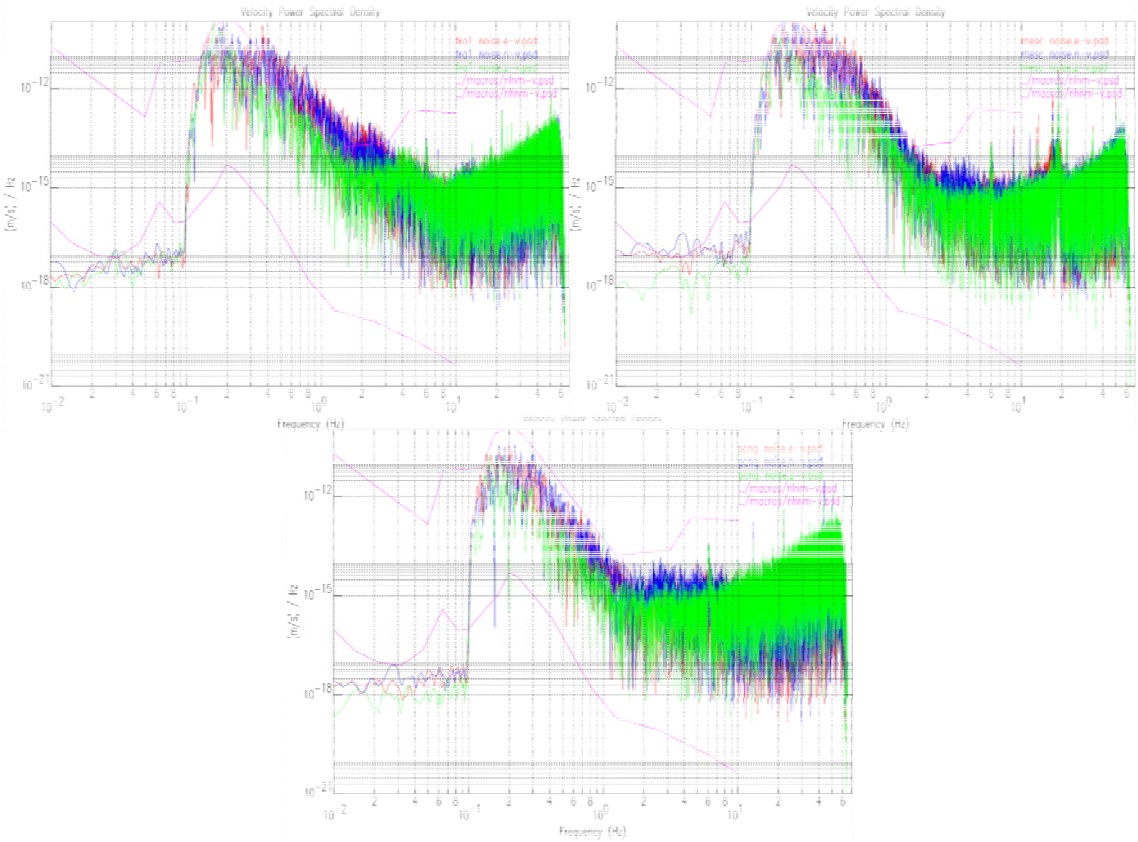

Figure 2 - Examples of velocity power spectral density curves for three short-period stations (LE 1s) from CIVISA permanent network. The new low-noise model (NLNM) and new high-noise model (NHNM) levels are superimposed on the figure. The PSD curves generally lie within these curves, which are representative of good and poor quality sites, respectively.

During the visit to the IMO, the researcher was invited to attend the Scientific Boarder Meeting regarding the volcanic activity in the Bardarbunga system, which usually occurs twice a week at the Civil Protection headquarters. The meeting was attended by scientists from Icelandic Met Office and the Institute of Earth Sciences University of Iceland along with representatives from the Icelandic Civil Protection and The Environmental Agency of Iceland. It was a great opportunity to see how the different parts interact, and how they follow the evolution of the eruption.

The last days of the visit were spent working on the Azorean seismic events. Dr. Vogfjord setup a gradient velocity model for S. Miguel Island based on the 1D velocity model used in the CIVISA daily routine, to be introduced in the SIL system (IMO system).

The original data were converted to SAC format and picked in SAC (figure 3). Not all data were used, since a selection of events was performed based on the SNR. This quality selection was made considering a broadband vertical channel from the IRIS-GSN station, CMLA. This station is also located on the island of São Miguel and was used as reference to evaluate the quality of the signal acquired through the stations of the CVARG/CIVISA network.

The picked arrival times from the selected events were used to create the *ana* files (phase readings files used in the SIL system) to allow the event location in the SIL system without using waveforms. Files with the velocity model and the station locations were also created, in order to run the SIL location programme.

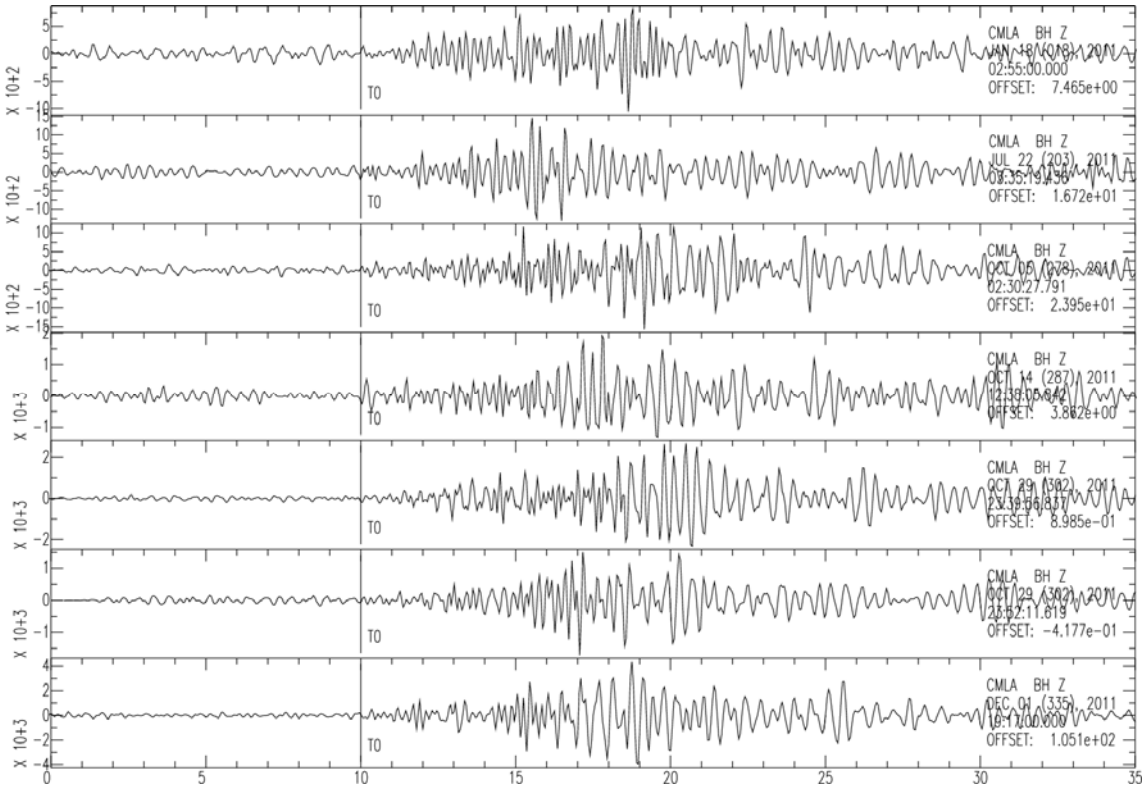

Figure 3 - Examples of seismic events recorded in CMLA station (IRIS network).

The seismic events shape does not show clear P-onsets, and the S-phases are also not reliable. The original location of these events seems to point to unrealistic deeps. Tests were made in the SIL system to confirm (or not) these results, as well with other programmes, with the help and collaboration of Dr. Martin Hensch (from IMO).

The researcher spent also some time with Dr. Matthew Roberts, from the hydrologic/floods monitoring group, and with Dra. Sara Barsotti, from the volcanic monitoring group. Each one presented the activities of the group, focusing the early warning systems developed in each area.

During the stay, the researcher also attended the weekly monitoring meeting, where the staff involved in the different monitoring areas meet and discuss the activity that occurred during the week.

3) Description of the main results obtained

The noise analysis showed a high noise in almost all stations, and also showed that components from a same station do not respond in the same way. The frequency range in which the microseismic noise is resolved is thus 0.2 to 6 Hz. The increase of amplitude at frequencies higher than 10 Hz seems to be due to electrical issues, which can, probably, be fixed with the right approach.

These results emphasize the fact that it is necessary to take in consideration noise analysis procedures before install seismic stations into the field. This type of analysis will help improving/reducing the SNR existent in the majority of the stations nowadays.

Moreover, the seismic stations are housed in shelters and equipped with masts to fixe the GPS and transmission antennas, which induce additional vibrations to the seismic noise. Thus, the actual construction of shelters should be reviewed and an attempt to improve this aspect must be considered.

Concerning the location of the “deep” events, no conclusive results were obtained due to the lack of data quality, whereby there is no certainty in the picked phases, neither in the phase type. Nevertheless, some assumptions were considered, and the events, in reality, may not be as deep as initially thought.

Therefore, the main result obtained during this visit was to realize the need to improve the seismic network, both the stations/sensors as well as its geometry, in order to get a better seismic coverage. With these improvements it is expected an increase in the data quality, and further analysis of the “deep” events may provide more conclusive results in future.

4) Future collaboration with host institution (if applicable)

Future collaborations with the host institution are entirely desirable. In fact, Dr. Vogfjord has provided to help in improving the methodologies existing in the CVARG/CIVISA in what concerns the installation of new seismic equipments. In addition, the noise analysis performed in the IMO was the first step, and an introduction to the subject. More detailed studies, with longer time length windows and with different day periods (quite periods) are needed to be done, and for that a close collaboration with the host institution is considered necessary.

5) Projected publications/articles resulting or to result from the grant

Due to the lack of results regarding the dataset taken from the CVARG/CIVISA, no paper is planned. Nevertheless, if some interesting results appear during the work that still has to be done in the behalf of this grant, the ESF will be duly acknowledged.

References

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