Long Term Seismic Noise Measurement in Sos Enattos Mine (Sardinia): experiment's status of the art and preliminary results

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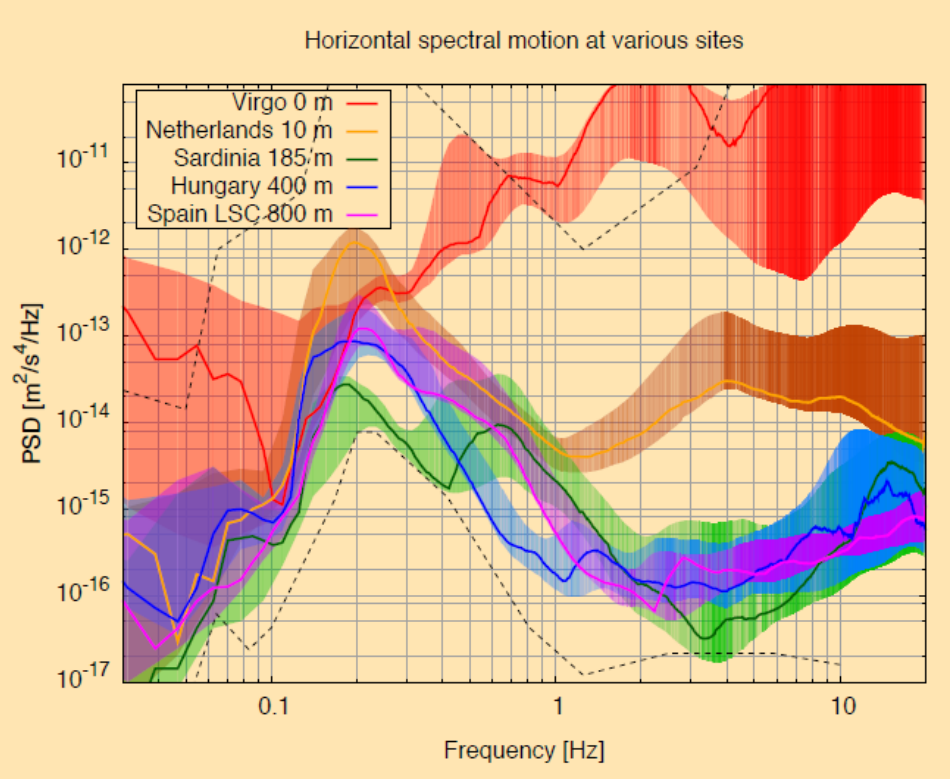
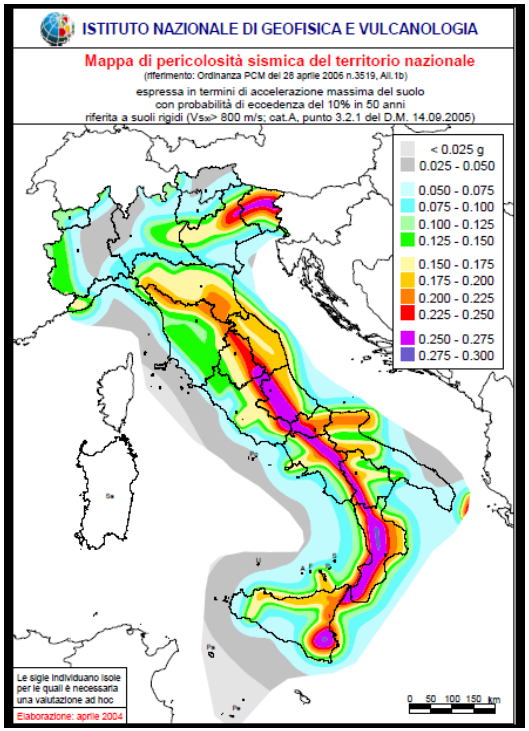
Introduction

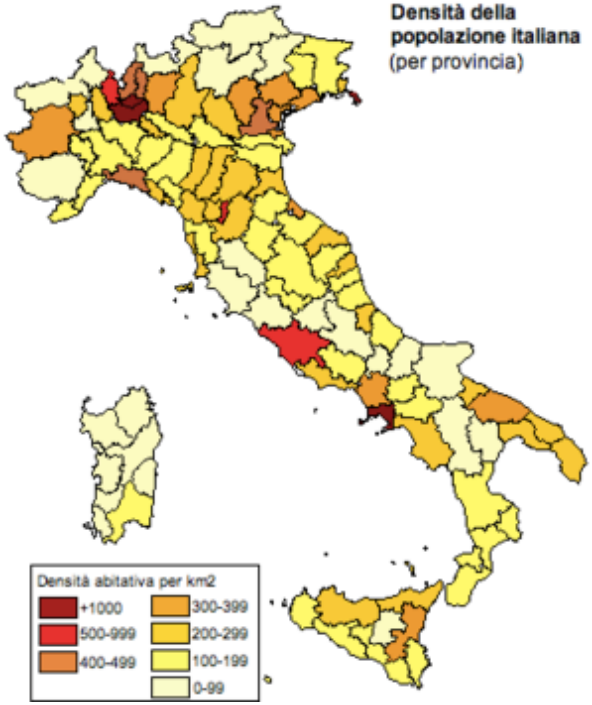


From previous analysis (ET – Design study ET-0106C-10), Sos Enattos Mine, in Sardinia, shows an interesting very low seismic noise.

The data taking lasted only six days (from June 31, to July 5, 2010). Therefore for a better characterization of the site, a long term acquisition is necessary (a least one year) to seasonal changes, long term stability and Geo-Hydrological studies.

Sos Enattos Mine – Lula (Sardinia)





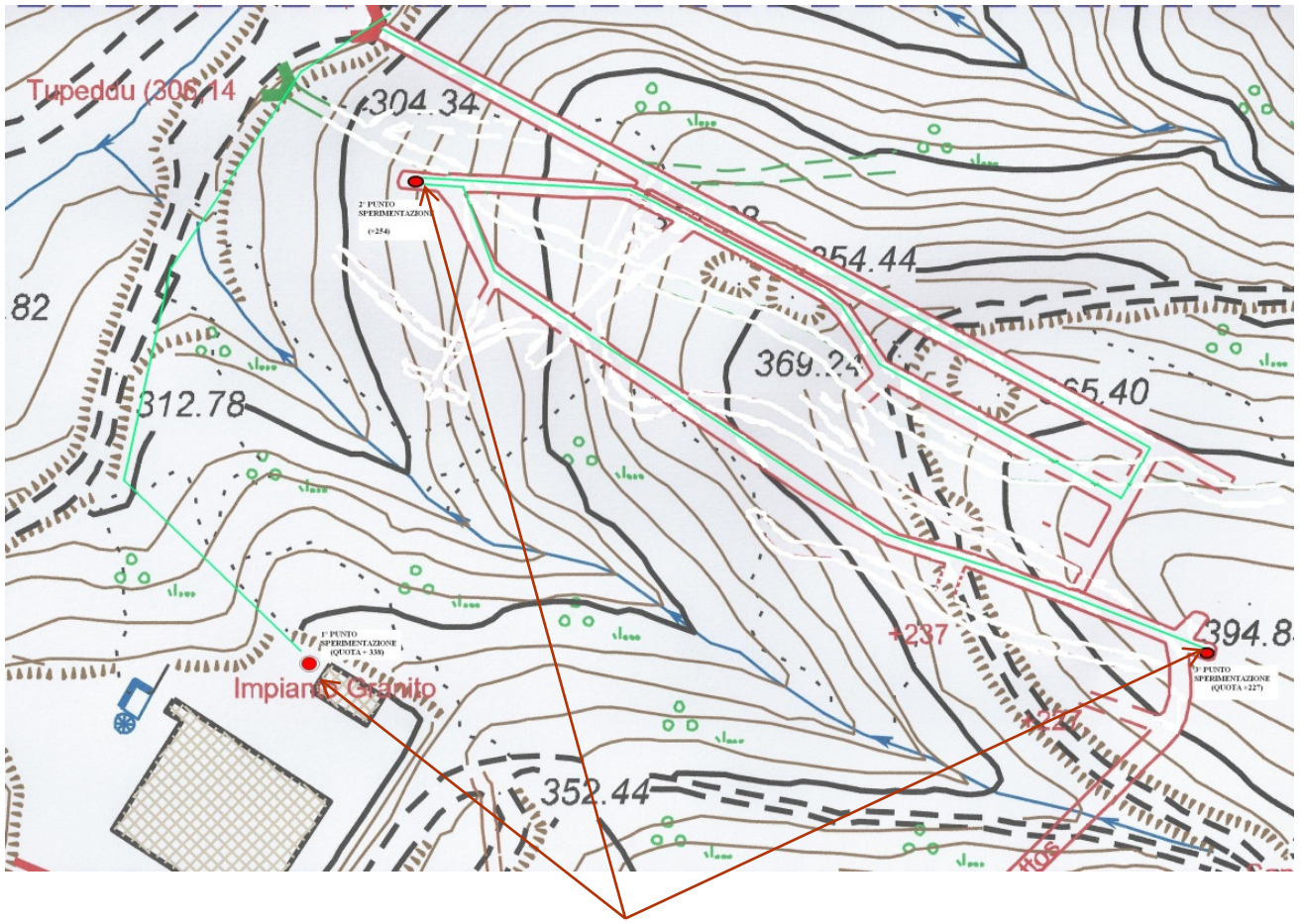
The mine is preserved by the I.G.E.A. s.p.a. company and it is located near the village of Lula (Nu) in Sardinia: its a former mine of schist rocks composed of sphalerite ([Zn,Fe]S) and galena (PbS).

- Pros: the site has low population density and low earthquake activity.
- Cons: the site is near sea and there is a high wind activity.

Aim of the experiment

- Measurement of the site seismic activity in the frequency band 0.01:20 Hz.
- Study of the correlation between the increase of seismic noise in the microseismic band and the weather conditions.
- Estimation of the influence of sea activity and of human activity on seismic noise.
- Measurement of the seismic activity at different underground levels for testing out the analytic model of Newtonian noise reduction due to depth.

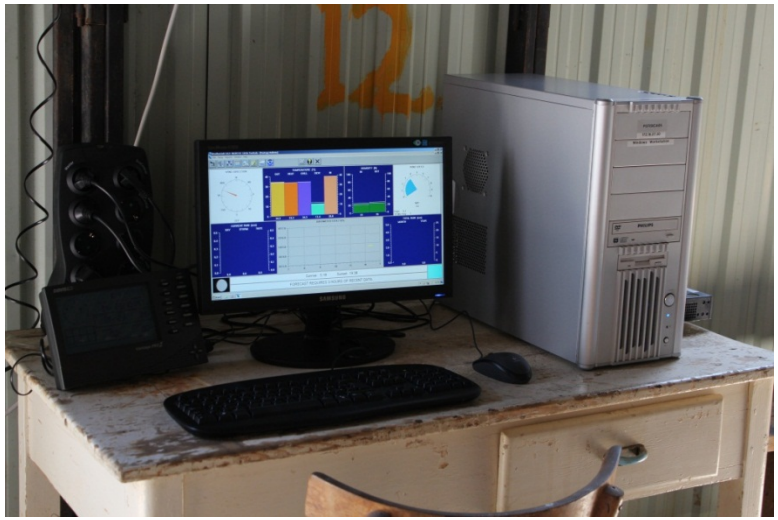
Seismic Stations



The monitoring system is presently composed by **three stations**: the first one is at ground level (338m above sea level); the second one at about -84m level underground, and the third one at about -111m level underground.

The three stations are connected together through optical fiber link (gigabit Ethernet switch).

Monitoring Station at ground level

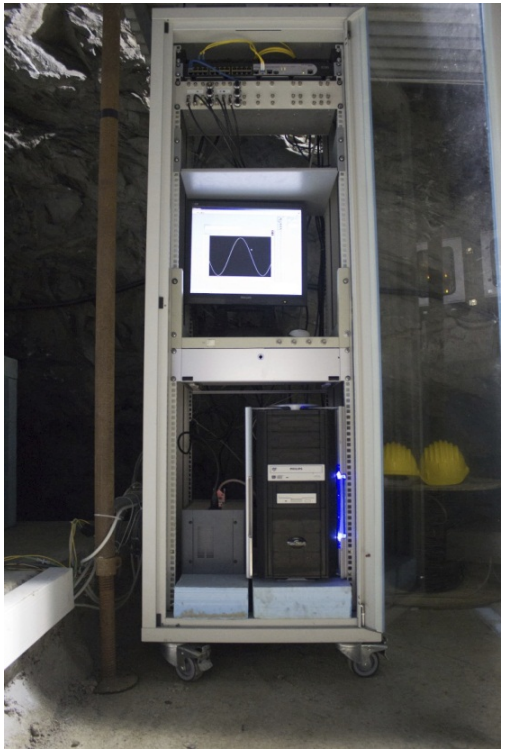


- PC desktop with Windows 7 operating system
- National Instrument NI-6289 DAQ board (18bit, 32 channels, highest sampling frequency 500kHz)
- DAQ software developed on Labview 6.5
- Weather Station Vantage Pro II by Davis equipped with sensors of
  - Temperature
  - Barometric pressure
  - Rain
  - Wind speed and direction
- Environmental data are acquired at 1 sample/minute

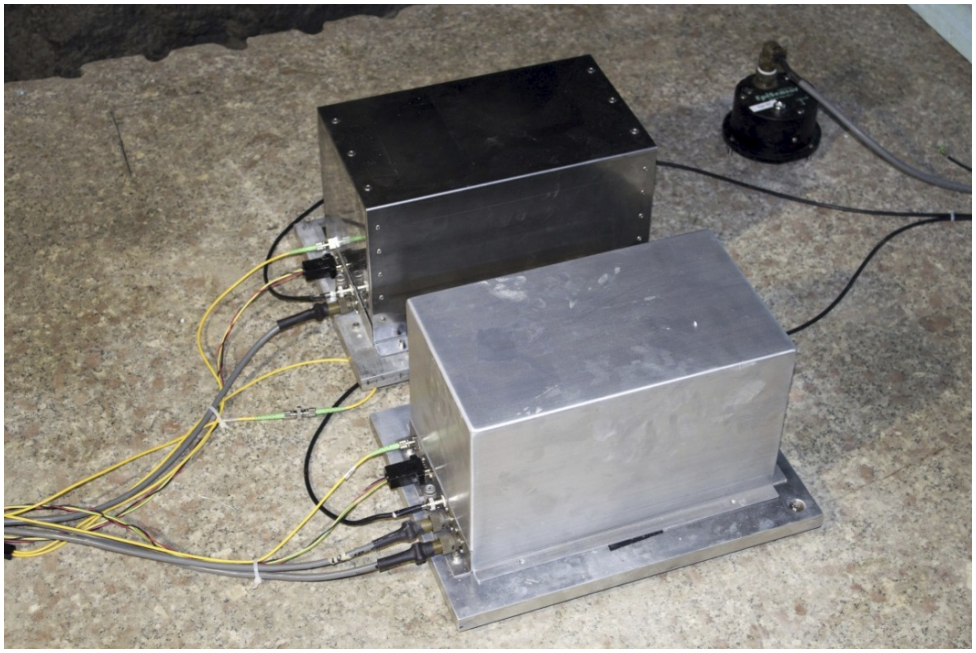
Monitoring Station at level -84m

- The tunnel entrance has been closed using a thermal isolating rigid wall
- A granite basement (320x175x23 cm) has been fixed to the ground.
- Two thermal and acoustic isolating box of dimension 120x120x60 cm has been realized to cover the seismic sensors
- All the electronics are connected to UPS or batteries system

- Environmental monitoring system:
  - One temperature and one humidity sensor
  - two temperature sensors (one inside each thermal insulating box)
  - Four temperature sensors (one inside each seismometer)



- PC desktop with Windows 7 operating system
- National Instrument NI-6289 DAQ PCI board
- DAQ software is developed on Labview 6.5
- The sampling frequency is fixed to 200Hz for seismic channels and 1 Hz for environmental monitoring channels
- Ethernet gigabit switch with optical fiber port



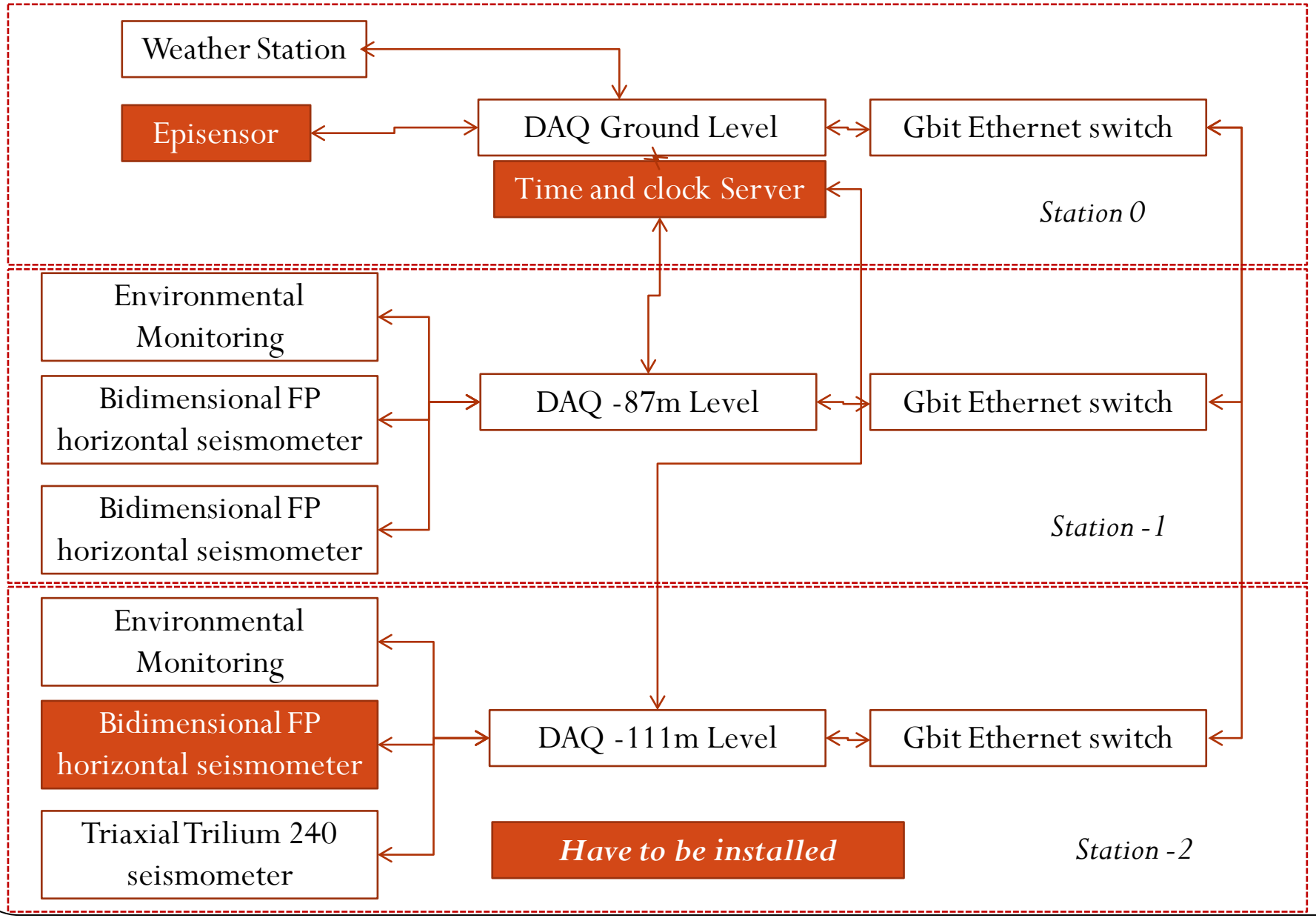
- Four horizontal seismometers developed in 2009 at University of Salerno based on FP mechanical scheme and with optical lever readout system, configured without force feedback control.
- The seismometers has been successfully tested and actually in acquisition at LNGS with a measurement band from 1μHz to 10 Hz.

- Two seismometers, oriented in N-S and E-W direction, are calibrated at resonant frequency of about 1Hz. The other two seismometers, oriented parallel respect to the previous one for correlation analysis, are calibrated at resonant frequency of about 0.4Hz.
- The optical readout is realized to reach a sensitivity of about 10^{-9} m/√Hz at 1 Hz. In this configuration the seismometers have a sensitivity of about 10^{-18} $m^2/s^4/Hz$ at 1 Hz.
- Two accelerometers, model Episensor by Kinemetrics, are fixed in the same thermal and acoustic isolating box of two FP seismometers in parallel configuration.

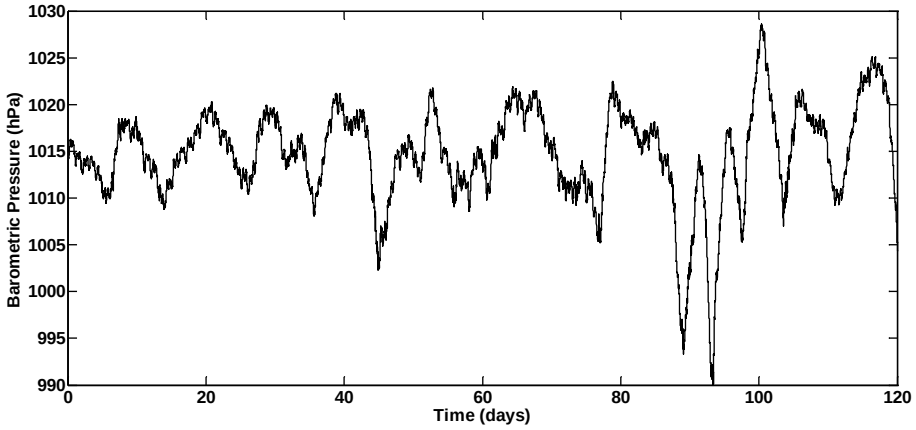
Monitoring Station at level -111m

- DAQ based on standard pc desktop with National Instrument NI-6289 board, software developed in Labview 6.5
- Three temperature and one humidity sensors inside the tunnel, closed using thermal and acoustic isolating panels. The environmental monitoring channels are acquired at sampling frequency of 1 Hz.
- One tri-axial seismometer Trillium 240 by Nanometrics, connected to a Taurus acquisition system. The sensor is placed on granite tile, and enclosed in a thermal and acoustic isolating box. The sampling frequency is 40Hz.
- Two granite tile of about 120x100 cm covered with isolating box are ready for the installation of other FP seismic sensors (January).

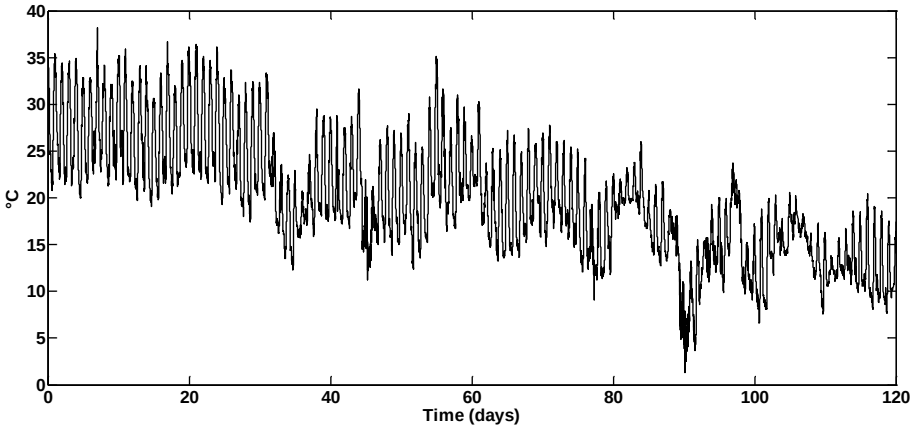
Seismic Monitoring Schema



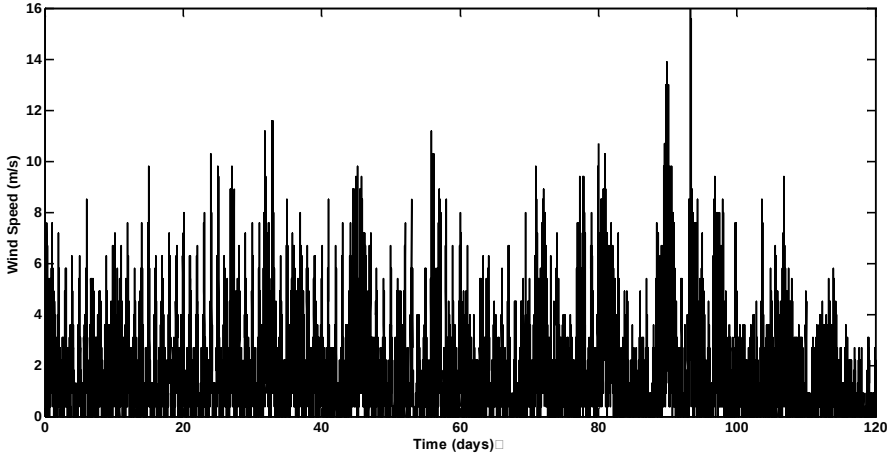
Weather Station Measurements



Barometric Pressure



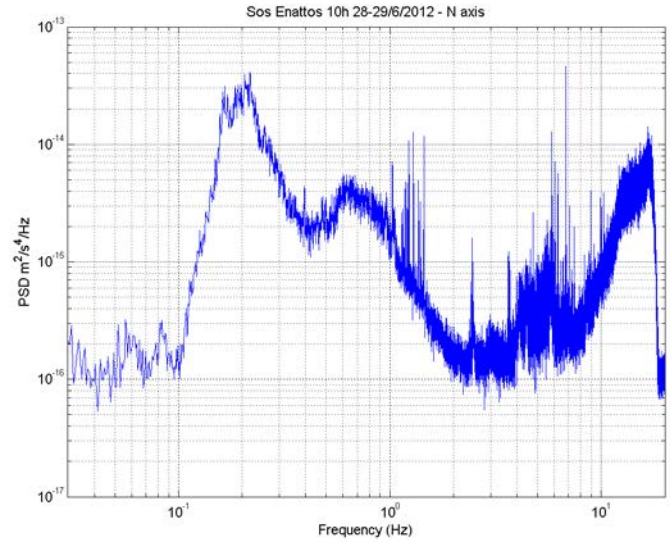
Outside Temperature

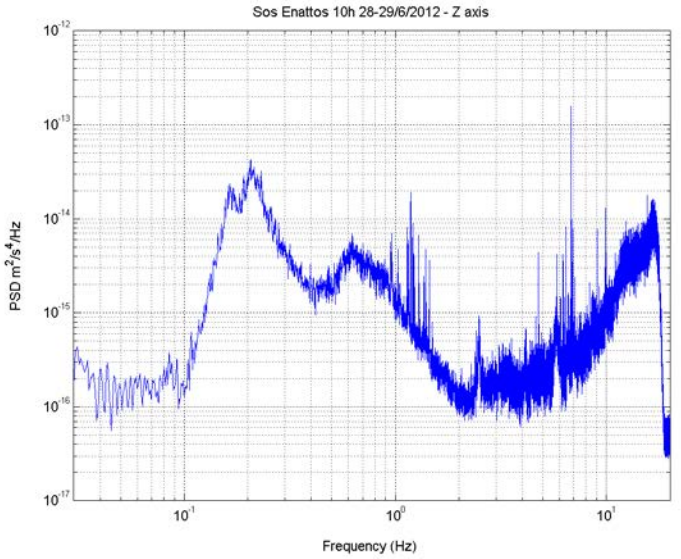


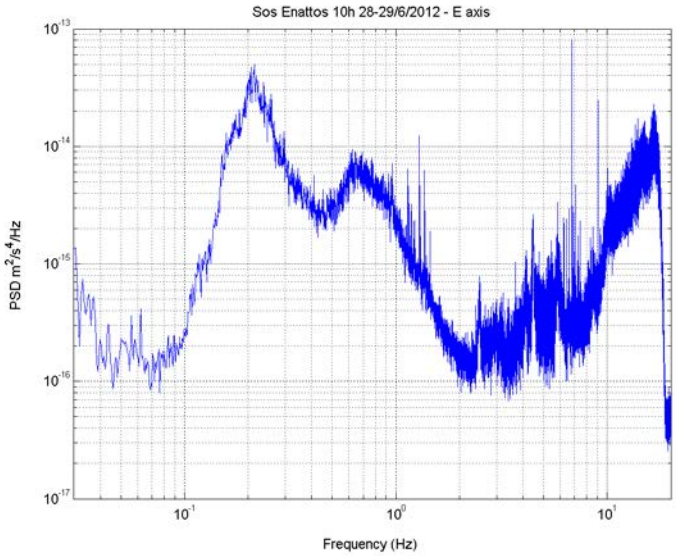
Wind Speed

- Data acquisition started at the end of July 2012 without interruptions.
- At the moment the station is fully operational.

Examples of Trillium measurement during a quiet day in summer

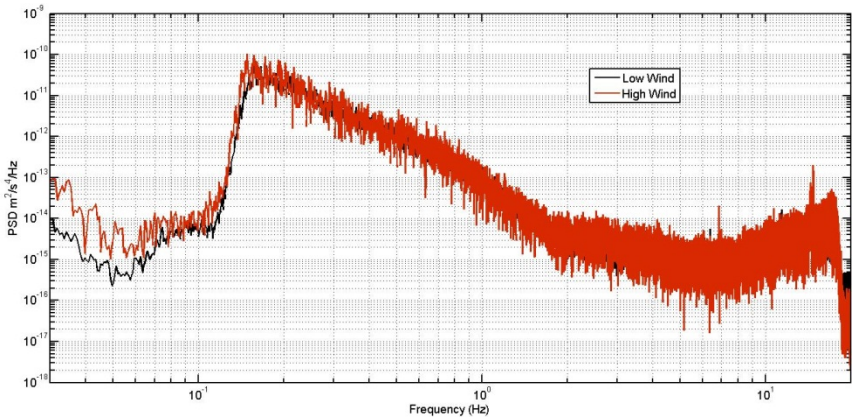


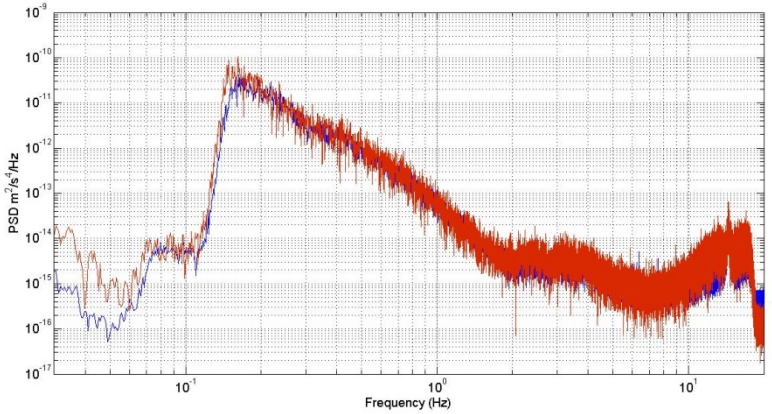


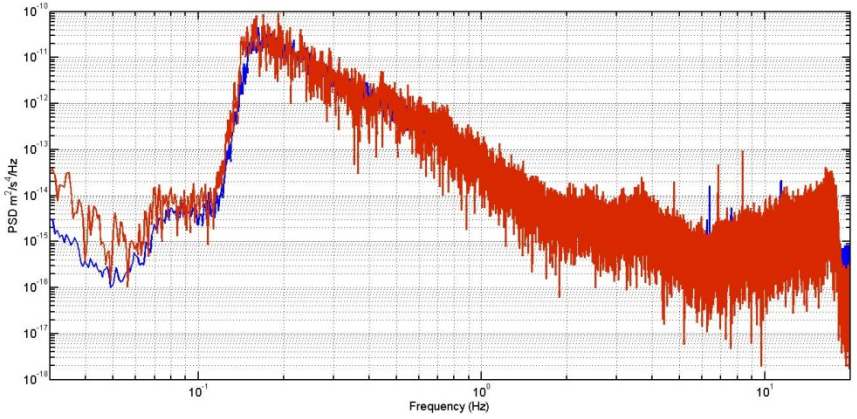


- DAQ started at the end of June
- The PSD shows a minimum seismic noise of about 10^{-16} (100mHz) to a maximum of $5x10^{-14}$ $m^2/s^4/Hz$ (200mHz) during quite days in summer.
- After some interruptions due to station upgrade, at the moment the sensor is fully operational.

Examples two set of Trillium measurements during a rough day in winter

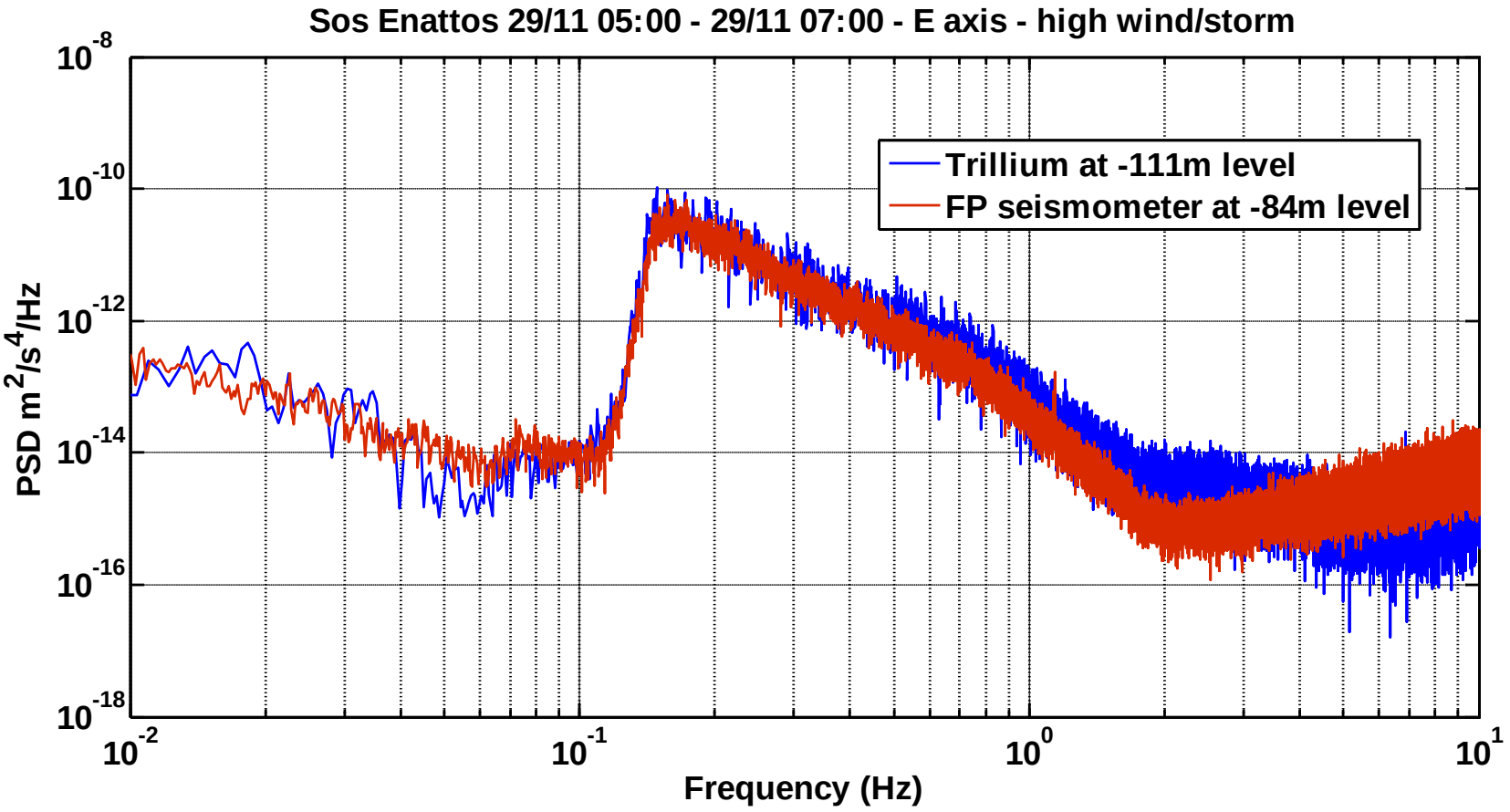






- The PSD shows a seismic noise of about 10^{-14} (100mHz) to 10^{-11} $m^2/s^4/Hz$ (200mHz) in rough days.
- From a first analysis, it seems to be an increase of three order of magnitude (at 200mHz) and one order of magnitude (at 4Hz) in rough day respect to quit day.

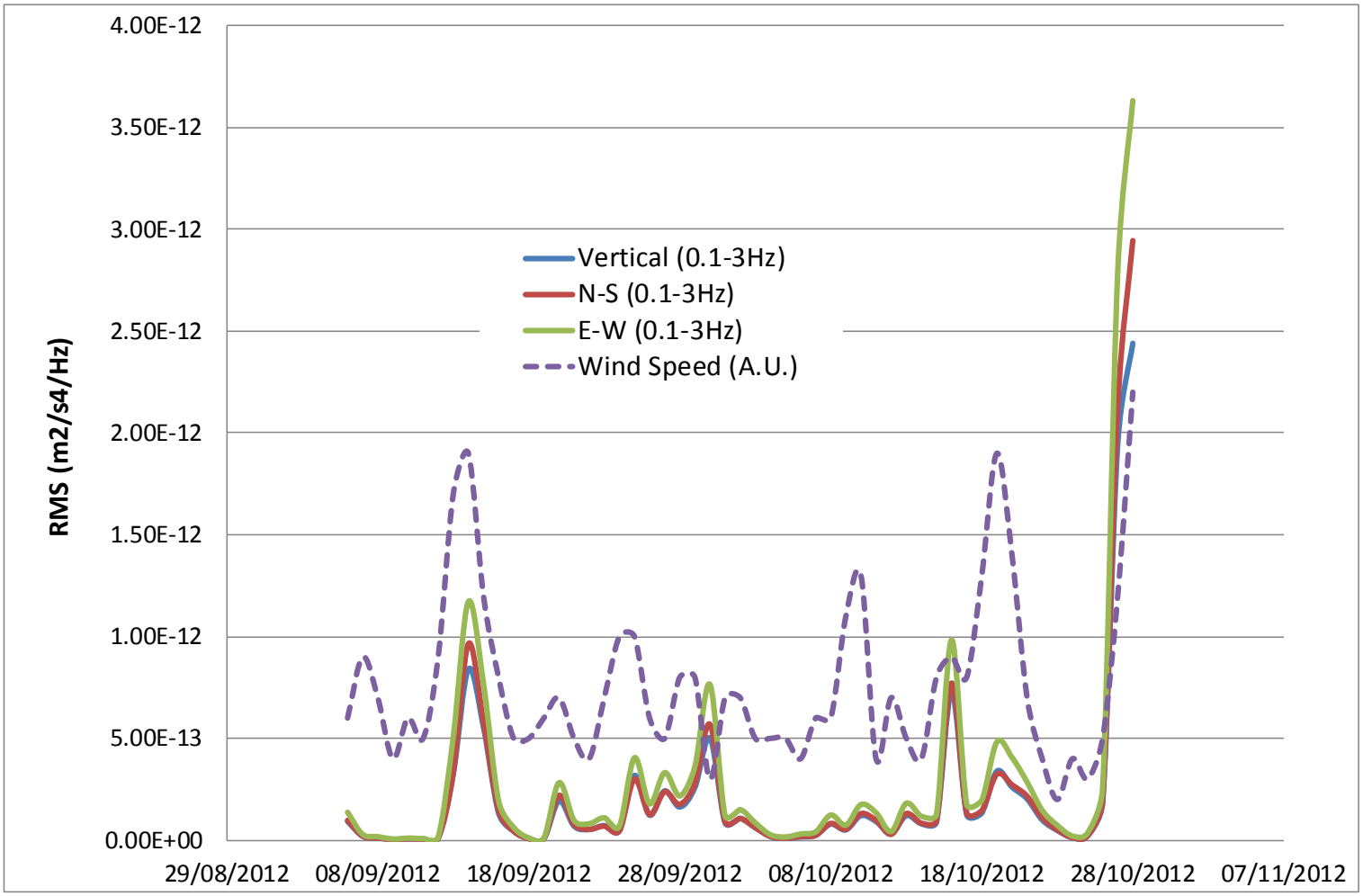
Preliminary Results of FP seismometer at level -84m



Data Acquisition of FP seismometers started in November 28.

By preliminary tests, the FP seismometers (model of 2009) have enough sensitivity to measure microseismic activity.

Example results about correlation between microseismic noise and wind speed



Summary

- Three monitoring stations have been installed in the Sos Enattos mine for long term seismic monitoring.
- At the moment the first station (ground level) is used for weather conditions monitoring, the second one (-84m level underground) and the third one (-111m level underground) are configured for seismic noise monitoring.
- Each underground station is equipped with environment monitoring system with temperature and humidity sensors.
- Each sensor (Trillim 240 and FP seismometers) has enough sensitivity to measure seismic noise in the frequency band (0.02 – 20 Hz) and they can be used for seismic characterization of the site.
- At the moment all the sensor are in data taking state
- Preliminary results show in reasonable increase of seismic noise in the microseismic noise during rough day.

Future developments

- Installing of a Time and clock server to synchronize the acquisition at the three stations and to perform an accurate correlation analysis.
- Installing infrasound microphone for acoustic noise monitoring in underground stations.
- Installing FP seismometers at station -111 m level underground.
- Move the Episensor accelerometers to the ground level for strong motion measurement.
- Implement a centralized data archive.
- Define an automatic data analysis procedure to extract all the information necessary to characterize the seismic activity of the site.