Testing various modes of installation for permanent broadband stations in open field environment

Jérôme Vergne[1], Olivier Charade[2], Benoît Arnold[2], Thierry Louis-Xavier[2]

[1] Ecole et Observatoire des Sciences de la Terre, Institut de Physique du Globe, Strasbourg, France (jerome.vergne@unistra.fr)
[2] Division Technique de l'INSU, CNRS, Meudon, France

RESIF — EOST Ecole et Observatoire des Sciences de la Terre — CNRS INSU Division Technique

Abstract

In the framework of the **RESIF** (Réseau Sismologique et géodésique Français) project, we plan to install more than one hundred new permanent broadband stations in metropolitan France within the next 6 years. Whenever possible, the sensors will be installed in natural or artificial underground cavities that provide a stable thermal environment. However such places do not exist everywhere and we expect that about **half the future stations will have to be set up in open fields**. For such sites, we are thus looking for a standard model of hosting infrastructure for the sensors that would be easily replicated and would provide good noise level performances at long periods.
Since early 2013, we have been operating a **prototype station** at Clévilliers, a small location in the sedimentary Beauce plain, where we **test three kinds of buried seismic vaults and a downhole installation**. The cylindrical seismic vaults are 3m deep and 1m wide and only differ by the **type of coupling** between the casing and the concrete slab where we installed insulated Trillium T120PA seismometers. The downhole installation consists in a 3m deep well hosting a Trillium Posthole seismometer. For reference, another sensor has been installed in a ~50cm deep hole, similarly to the way we test every new potential site.
Here **we compare the noise level in each infrastructure** at different frequencies. We observe quite similar performances for the vertical component recorded in the different wells. Conversely, the **noise levels on the horizontal components** at periods greater than 10s **vary by more than 20dB** depending on the installation condition. The best results are obtained in the completely decoupled vault and for the downhole setting, both showing performances comparable to some of our permanent stations installed in tunnels. The amplitude of the horizontal noise also appears to be **highly correlated to wind speed** recorded on site, even at long periods. The variable response of each vault to such external forcing can partly explain the variations of the seismic noise levels.

1. Noise power spectral densities differ at long period

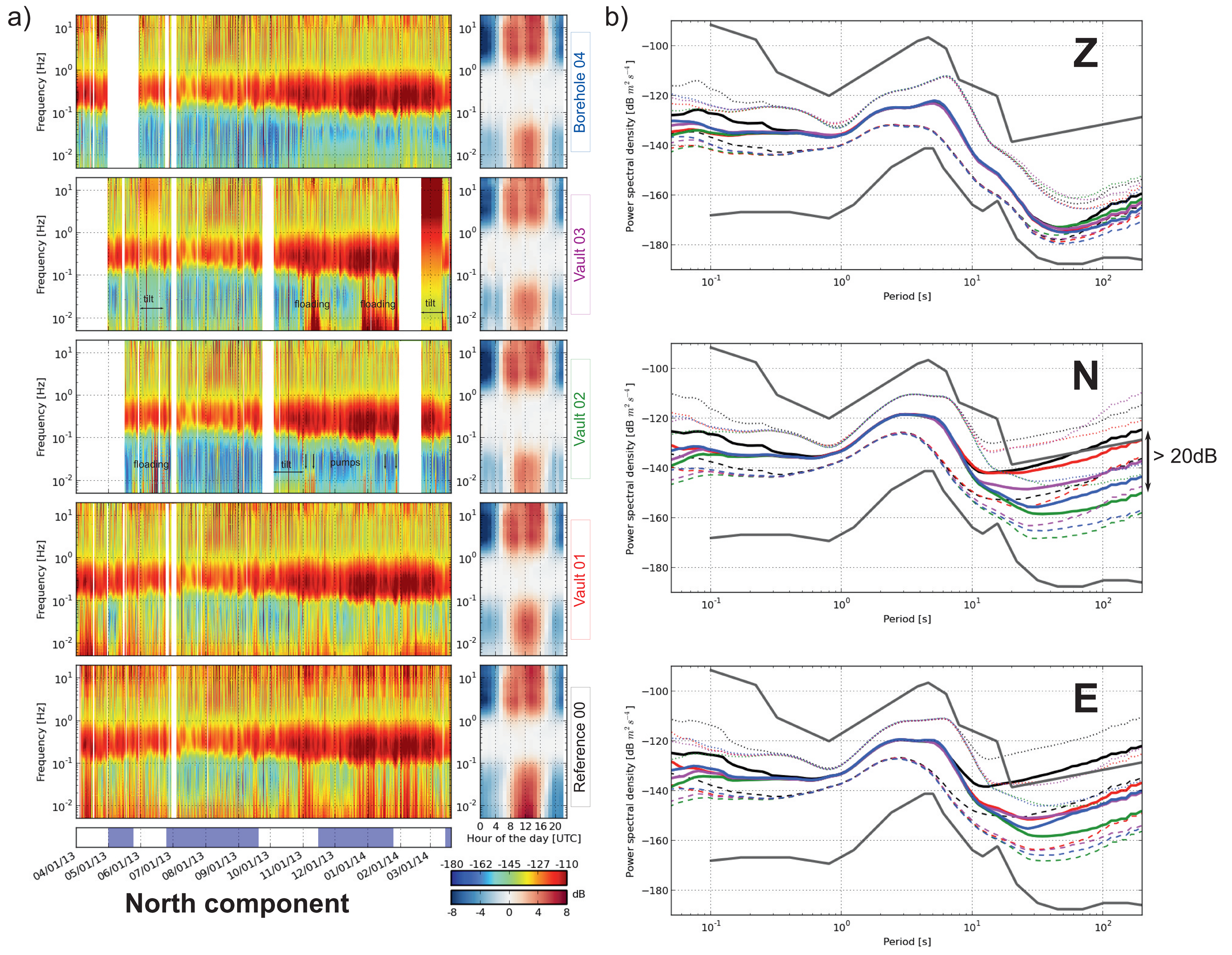
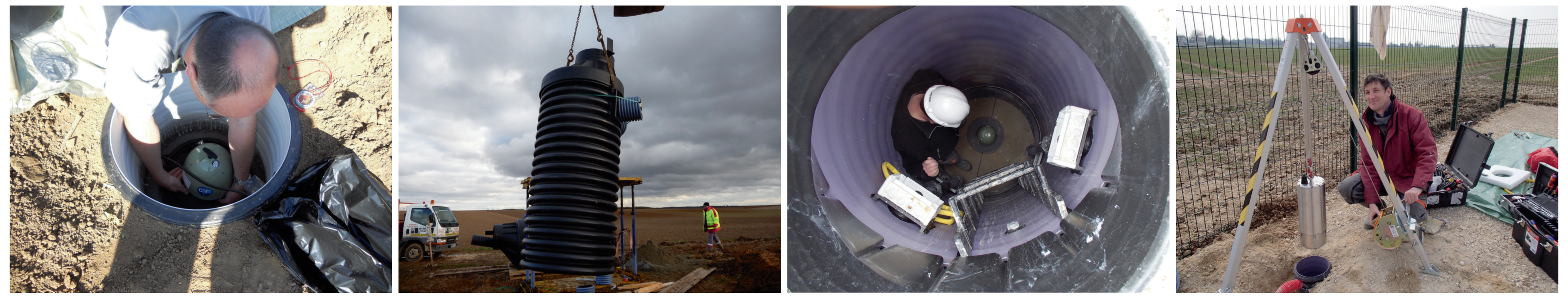
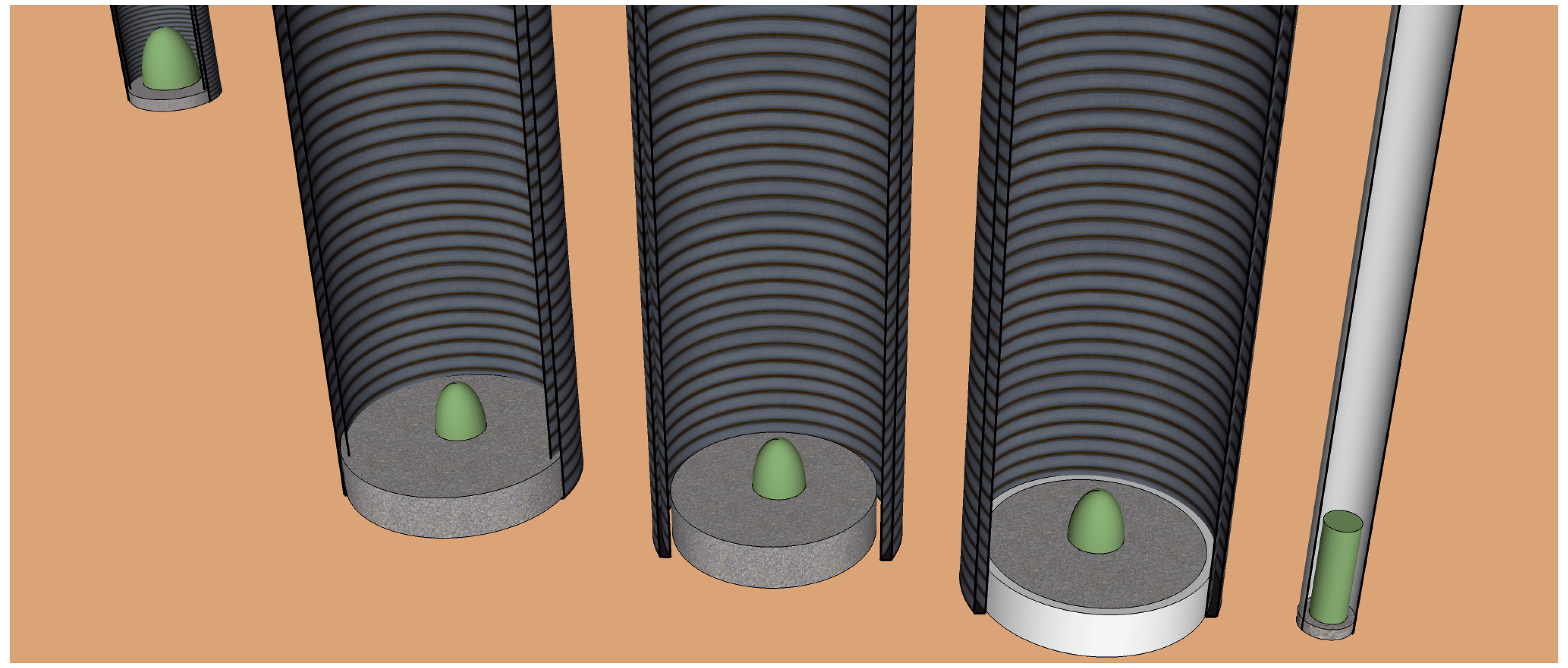


Figure 1: a) Spectrogram of the North component data in each vault obtained by appending hour-long Power Spectral Density (PSD) functions. For each complete hour of data, the PSD is computed using the method of McNamara and Buland (2004) averaging the acceleration energy spectra over one octave bandwidth. White vertical strips indicate a lack of data. Right insets represent the relative variations of the PSDs with the hour of the day and over the frequency band. A clear diurnal variation is observed except in the north component. Anthropogenic origin of noise at high frequencies explains the decrease of energy around noon. At low frequencies, the increase of noise during the day is probably due to temperature or wind. b) Median (bold line), 10th and 90th percentiles (dashed and dotted lines respectively) of the PSDs for the three components in each well (color code on central figure) computed for data during the purple periods on the bottom timeline in (a). Gray lines indicate the New Low Noise Model and New High Noise Model of Peterson (1993).

Setting

The prototype site is located in the Beauce plain, ~500m north of the small town of Clévilliers (Eure-et-Loir) and 14km from the major city of Chartres. The nearest highway is ~4km away. The rented 180m2 parcel is surrounded by farmed fields and protected by a 1m high fence. Near surface geology consists in arable soil and unconsolidated clastic sediments. Water table oscillates from 1 to 5m depth.
The vaults and the borehole tube have been installed in 3m deep excavations, backfilled and covered with on-site soil and sand. Pressure, temperature and humidity sensors are installed within each vault and report stable conditions. All sensors are connected through buried cable paths to Q330 digitizers installed in a 1m tall outdoor box.





Reference 00	Vault 01 coupled	Vault 02 decoupled	Vault 03 sealed	Borehole 04
- 50cm deep / 40cm wide - HDPE casing - Thin concrete slab coupled with casing - T120 sensor with insulation cover	- 3m deep / 1m wide - HDPE casing - 20cm thick concrete slab coupled with casing - T120 sensor with insulation cover	- 3m deep / 1m wide - HDPE casing - 20cm thick concrete slab decoupled from casing - T120 sensor with insulation cover - Pump against flooding	- 3m deep / 1m wide - HDPE casing - 20cm thick concrete slab separated from casing with EPDM seal - T120 sensor with insulation cover - Pump against flooding	- 3m deep / 21.5cm wide - HDPE tube put in the excavation of vault 03 - Small concrete base coupled with tubing - T120PH downhole sensor surrounded and covered with sand

Summary

Properly building the sensor's hosting infrastructure is crucial to record long period-low amplitude signals on the horizontal components

Downhole installation and seismic vault with a decoupled concrete slab produce the best results

Wavefield coherency between the wells strongly decreases for periods greater than 20s

Site testing performed with a sensor buried at shallow depth provides a good estimate of the site's quality for the vertical component but overestimates the long period noise on the horizontal components

Appart from the frequency bands of microseismic peaks and anthropic activities, background seismic noise amplitude is related to wind speed. Wind-induced tilting is observed at periods greater than 10s

McNamara, D., and R. Buland (2004), Ambient Noise Levels in the Continental United States, Bulletin of the Seismological Society of America 94, no. 4, p.1517–27
Peterson J. (1993), Observation and modeling of seismic background noise. U.S. Geological Survey Technical Report 93-322, p. 1–95

2. Waveform coherency decreases at short and long periods

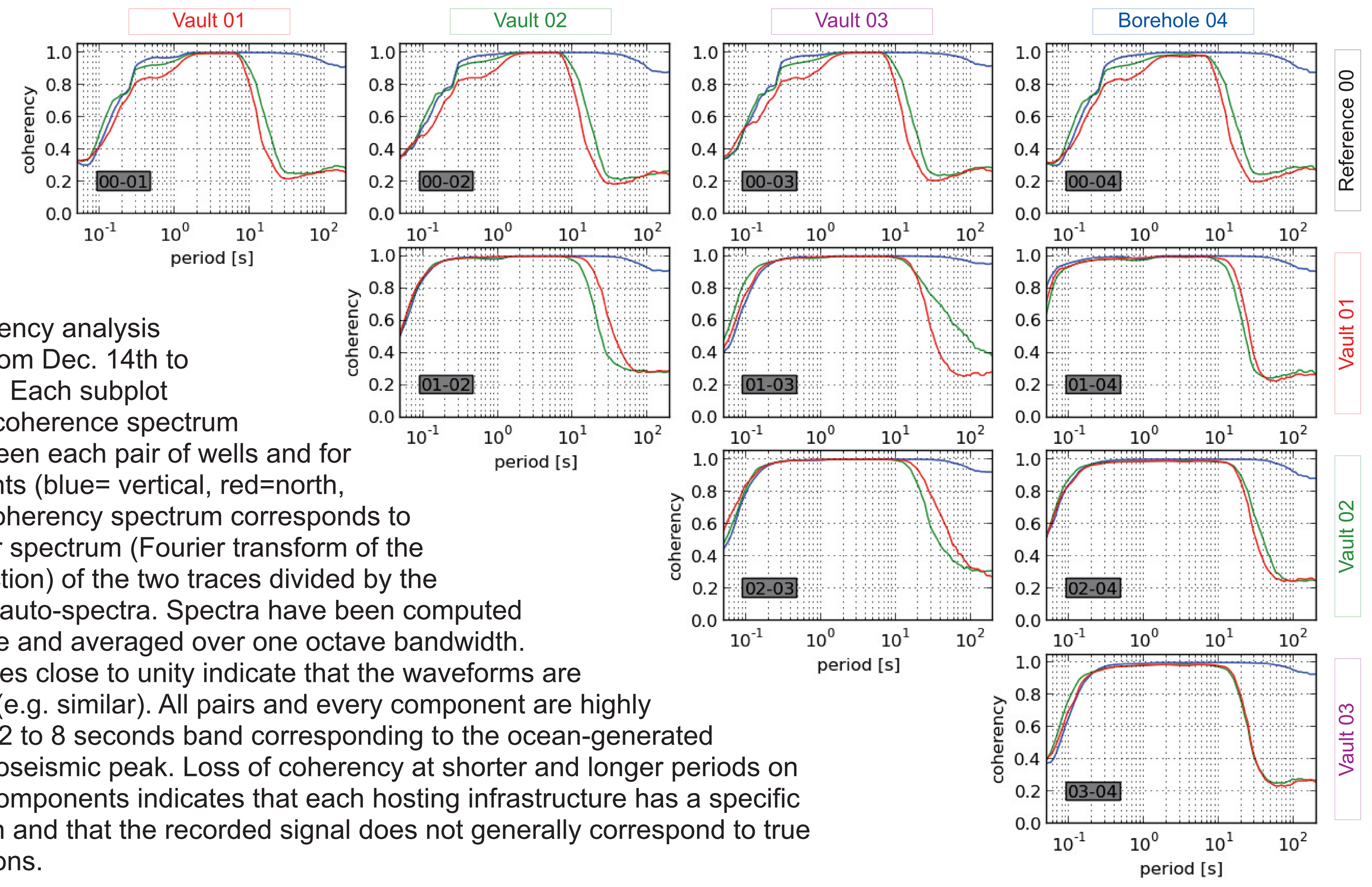
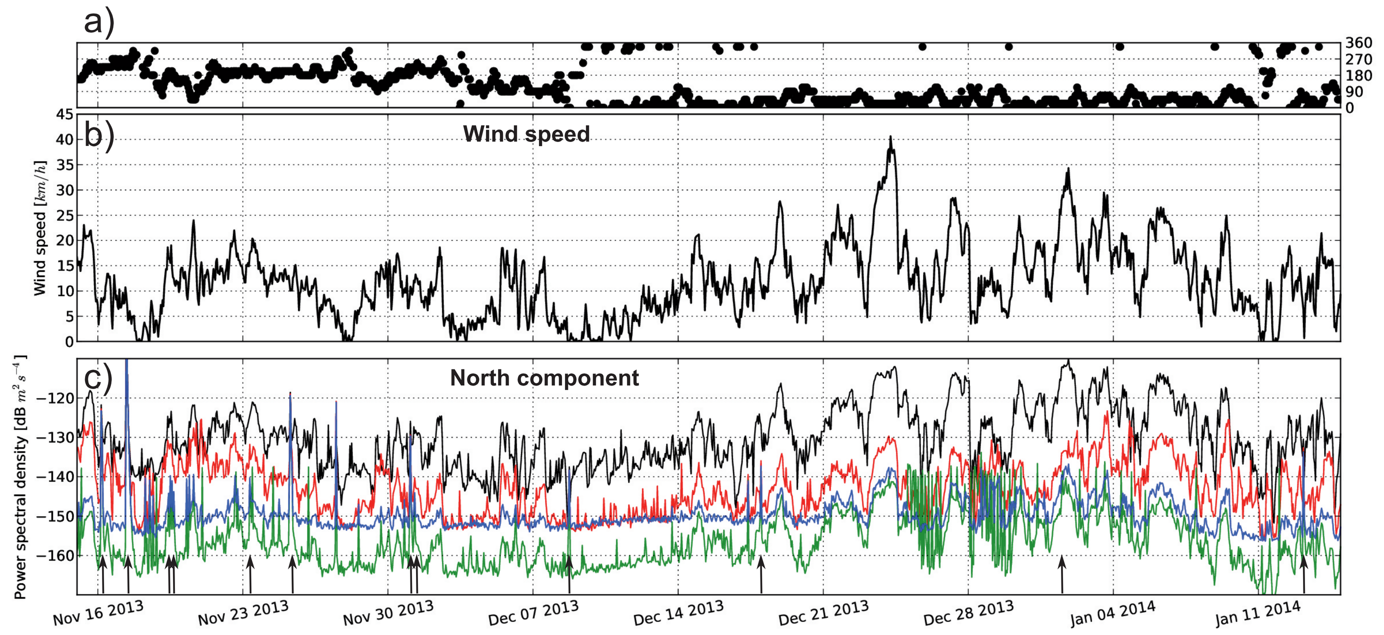


Figure 2 : Coherency analysis of waveforms from Dec. 14th to Dec. 21th 2013. Each subplot represents the coherence spectrum computed between each pair of wells and for the 3 components (blue= vertical, red=north, green=east). Coherency spectrum corresponds to the cross power spectrum (Fourier transform of the covariance function) of the two traces divided by the product of their auto-spectra. Spectra have been computed every 1/8 octave and averaged over one octave bandwidth. Coherency values close to unity indicate that the waveforms are linearly related (e.g. similar). All pairs and every component are highly coherent in the 2 to 8 seconds band corresponding to the ocean-generated secondary microseismic peak. Loss of coherency at shorter and longer periods on the horizontal components indicates that each hosting infrastructure has a specific transfer function and that the recorded signal does not generally correspond to true ground oscillations.

3. Wind speed is highly correlated to seismic noise

Figure 3.1: Comparison between wind speed and temporal evolution of seismic-noise amplitude in the different wells. Wind data are recorded on site every 5 minutes with a ProVantage 2 meteorological station. a) Wind direction relative to north. b) Wind speed averaged every hour. c) Seismic noise amplitude on the north component at ~50s period. Colors refer to the different wells. Note the overall correlation with wind speed. Black arrows highlights M>6 teleseismic earthquakes.



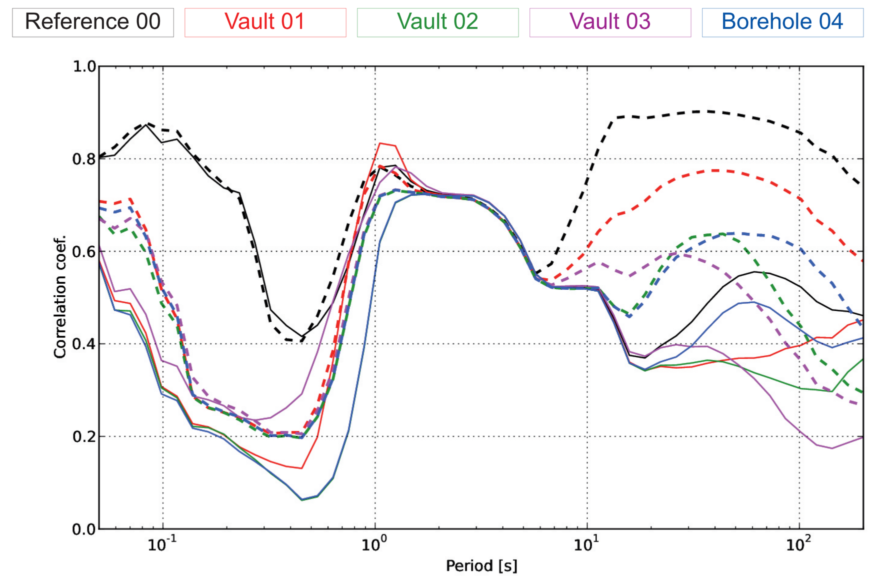


Figure 3.2: Correlation coefficient between wind speed and amplitude of seismic noise at various frequencies. Seismic noise levels are taken from the hourly PSDs (see Fig. 1a) between Nov. 15th 2013 and Jan. 15th 2014 (similar to Fig. 3.1). Continuous/dashed lines refer to the vertical/horizontal components (mean value of east and north component). Colors indicate the different wells. At short periods, similar correlation for the vertical and horizontal components indicates that wind-induced seismic noise is probably caused by vibrations of local elements (fence, outdoor box, ...). At periods longer than ~10s, tilting induced by infra-gravity waves is speculated to explain the higher correlation with the horizontal components. Decreases of correlation at some periods can be explained by other preponderant source of seismic noise such as anthropogenic sources from 0.1s to 1s or microseismic peaks around 7s and 14s.