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▶ **To cite this version:**

Jerôme Vergne, Hélène Pauchet, Mickael Bonnin, El-Madani Aissaoui, Luigi Ardito, et al.. Quality Improvement of the French Permanent Broadband Stations with Shallow Posthole Installations. EGU General Assembly 2019, Apr 2019, Vienne, Austria. 2019. hal-02275873

HAL Id: hal-02275873
https://hal.science/hal-02275873

Submitted on 3 Sep 2019

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Quality Improvement of the French Permanent Broadband Stations with Shallow Posthole Installations

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1) The French permanent broadband network (RESIF-RLBP)

Within the framework of the RESIF (Réseau sismologique et géodésique français) research infrastructure, a major extension of the French permanent broadband network (RLBP) has been initiated in 2011 with the objective to reach ~190 stations by 2020. This network will allow a more homogeneous covering of metropolitan France, encompassing a wide variety of tectonic and geological units. Presently the RLBP network consists in 124 operating stations (Fig. 1.1).
For each new potential site a test was conducted for ~3 weeks, usually burying the broadband sensor at 50-80 cm depth directly in the ground or within a light temporary vault (Fig. 1.2).
For the final set-up, we tested various hosting infrastructures at three prototype sites and decided to promote the installation of a posthole sensor in a steel-cased shallow borehole, 5-20m deep, for all the sites in open areas (Fig. 1.3). 43 stations have already been installed this way and have been operated for 5 to 20 months.
Here we compare the ambient noise level for these **43 shallow borehole installations** with the one recorded during the test period (section 2) and at other permanent stations installed in other kind of infrastructures (shallow vault, tunnel, caves, …) (section 3).

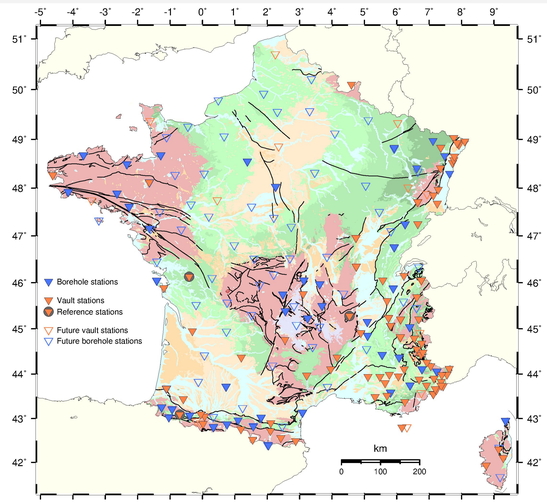


Figure 1.1 : *Map of the RLBP network above the geologic map of France. Solid triangles represent the operating stations (used in the present study). Open triangles represent stations that will be installed by the end of 2020. Borehole stations are plotted in blue while "classical vault" installation are plotted in orange. Geology map legend is presented to the left.*



Figure 1.2 : *Examples of installation of typical RESIF test sites : DAUF (left) - REYF (middle) - CRAS (right)*



Figure 1.3 : *Left: Drilling of a 6 m borehole by the BRGM at Gruissan (CLAF). Middle: Installation of a Nanometrics T120-PH in a 10 m borehole at Île d'Oléron (SDOF). Right : Final configuration of an operating posthole station of the french broadband network (OLIV, Brittany).*

2) Shallow borehole installation much better than site testing !

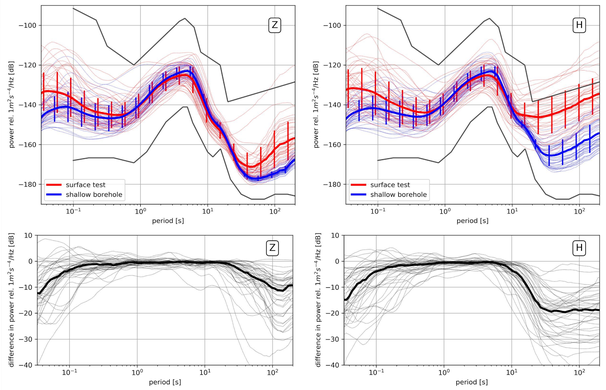


Figure 2.1 : *(top) Median of the probability density function of the power spectral density functions (mPDF-PSD) of continuous records (dotted lines), following McNamara and Bulland (2004), for each of the 43 sites during their testing period (red) and in their final shallow borehole configuration (blue) for the vertical component (left) and the mean of the two horizontal components (right). Thick curves indicate the mean and standard deviation of the 43 mPDF-PSD for each configuration. (bottom) difference between the test and shallow borehole mPDF-PSD for each site (dotted black lines) after correcting from the mPDF-PSD difference at a reference station (SSB, MLS, ATE or CHIF - see Fig. 1.1) computed for the two corresponding measuring periods. Thick thick lines correspond to the median of the individual differences. Note that the vertical scale goes from -40dB to +10dB.*

Comparing the median value of the noise power spectral density (PSD) between the surface test and the final posthole installation shows a general improvement on both vertical and horizontal components and for frequencies higher than 5Hz and periods longer than 10s (H comp.) - 20s (Z comp). On average, the improvement brought by a shallow posthole installation is ~10dB for high frequencies and 10 (Z comp.) to 20 (H comp.) dB at long periods but can sometimes reach more than 40dB. Note that on the Z comp. we observe almost no dispersion among the 43 sites of the median PSD at periods longer than 10s.

Long-period improvement

On average, at periods longer than 10s, surface tests show a clear daily variability of the ambient noise level with higher noise around 12:00 UTC. These diurnal effects are usually linked to daily temperature variations mostly seen on the Z comp. [Doody et al., 2018] and daily local wind/pressure variations, inducing tilt at sensor depth, mostly seen on the H comp. [De Angelis and Bodin, 2012].
After the shallow borehole installation, theses diurnal effects have been strongly reduced on the H. comp and almost completely removed on the Z comp.

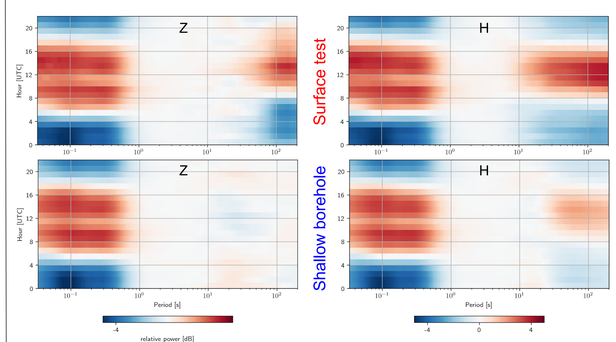


Figure 2.2 : *Daily variation of ambient noise with frequency. Each of the 4 panels represents spectrograms binned by the hour of the day in UTC (local time is +1 or +2H) and after removing the mean value at each frequency. Top panels show the mean of such daily-averaged spectrograms for the 43 sites in their test configuration (left = vertical component; right = mean of the two horizontal components) and bottom panels for the shallow borehole configuration.*

3) Shallow borehole stations better than most other permanent stations !

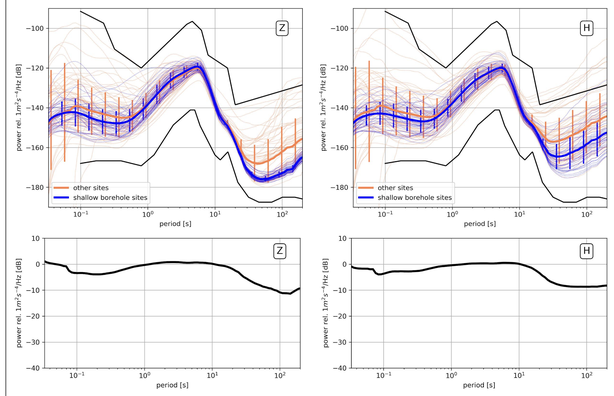


Figure 3.1 : *(top) Similar to Fig 2.1 but comparing the mPDF-PSD of one month (Jan. 2019) of continuous records at RLBP operating stations installed in a shallow borehole (blue) or in other kind of "vault-like" infrastructure (orange). (bottom) Difference between the mean of the mPDF-PSD for these two kind of configuration (blue - orange curves shown on top).*

Permanent stations installed in steel-cased boreholes present, in average, lower noise levels at HF and LF on the vertical and horizontal components than other "vault-like" stations. Noise standard deviations are dramatically lower for borehole stations than for other stations for the Z component at LF and generally significantly lower at HF and LF for all the components.
The difference in standard deviation at HF however mostly originates from the site selection procedure organized at the national level.

High-frequency improvement

Final installation inside steel-cased boreholes does also improve the high frequency noise level.
Two observations illustrate this improvement :
1. we notice a change in the detection distribution (via STA-LTA between 2-8 Hz) at surface tests and shallow boreholes. The distribution of shallow boreholes is generally sharper and slightly switched toward higher detections rates;
2. we generally measure a ~5 dB decrease of the seismic energy between 5 and 20 Hz on Z, E and N components. This decrease is more significant for sites located on sedimentary geological zones.

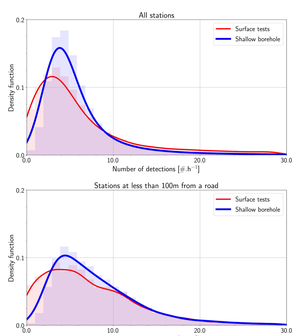


Figure 2.3 : *Distribution of the number of impulsive events detected every hour by an STA-LTA algorithm on the dataset filtered between 2 and 8 Hz.*

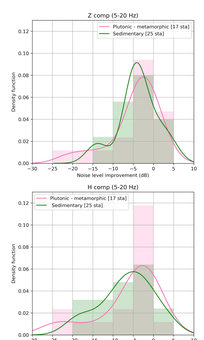


Figure 2.4 : *Distribution of the mean difference in decibels of mPDF-PSD between the test and shallow borehole in the 5-20 Hz frequency range.*

4) Put sand around your posthole sensor and take care of the cable!

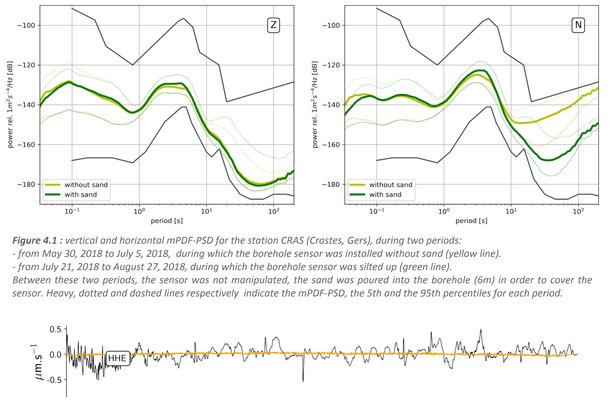


Figure 4.1 : *vertical and horizontal mPDF-PSD for the station CRAS (Crastes, Gers), during two periods:*
- from May 30, 2018 to July 5, 2018, during which the borehole sensor was installed without sand (yellow line).
- from July 21, 2018 to August 27, 2018, during which the borehole sensor was silted up (green line).
Between these two periods, the sensor was not manipulated, the sand was poured into the borehole (6m) in order to cover the sensor. Heavy, dotted and dashed lines respectively indicate the mPDF-PSD, the 5th and the 95th percentiles for each period.

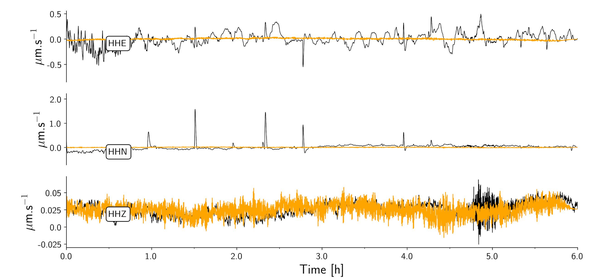


Figure 4.2 : *6 hours of filtered (lowpass at 1/20 Hz) traces at station BOUF. Solid black curves correspond to a period with no sand around the sensor and with cable issues (glitches). Solid orange curves correspond to a "well" installed sensor/cable with sand. The glitches are not detectable on the unfiltered traces but dramatically affect the noise level observed on PSD. Adding sand around the sensor has a dramatic effect of the noise level of the horizontal components at long period..*

The installation method of the downhole sensor is an important factor in signal quality. In particular, the presence of sand (Fig. 4.1) around the sensor can reduce noise by 20 dB on horizontal components for periods greater than 10 s.
Care should also be taken with the installation of instrument cable. A not suitable tension in the cable can cause LF glitches that considerably affect the station noise level (Fig. 4.2).
This phenomenon is observed at several steel-cased borehole stations and might explain the relatively large dispersion of the mPDF-PSD at long period on the horizontal components (Fig 2.1).

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RLBP stations includes 112 stations from the FR network (doi: 10.15778/RESIF.FR), 9 stations from the RD network (doi: 10.15778/RESIF.RD) and 3 stations from the G network (doi: 10.18715/GEOSCOPE.G). All data are available through the RESIF EIDA node and at seismology.resif.fr

RESIF is a national Research Infrastructure, recognised as such by the French Ministry of Higher Education and Research. RESIF is managed by the RESIF Consortium, composed of 18 Research Institutions and Universities in France. RESIF additionally supported by a public grant overseen by the French National Research Agency (ANR) as part of the "Investissements d'Avenir" program (reference: ANR-11-EQPX-0040) and the French Ministry of Ecology, Sustainable Development and Energy.