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Feedback on the Installation of a Borehole Broadband Seismometer at Station BOUF

S11D-2494

French Permanent Broadband Network (RLBP)



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I. Introduction

We present here tests we performed at a new French permanent broadband station in western France, BOUF (Fig. 1). The sensor (T120PH) is installed in a 10 m deep cased borehole and surrounded by sand (Fig. 2). The aim of our tests is to infer the improvement of a borehole installation with respect to the temporary deployments used to validate a new site. A T120PA sensor has been installed for a month at the surface of the well in a pipe, at first without isolation and, after 4 days, with a Trillium cover and sheep wool

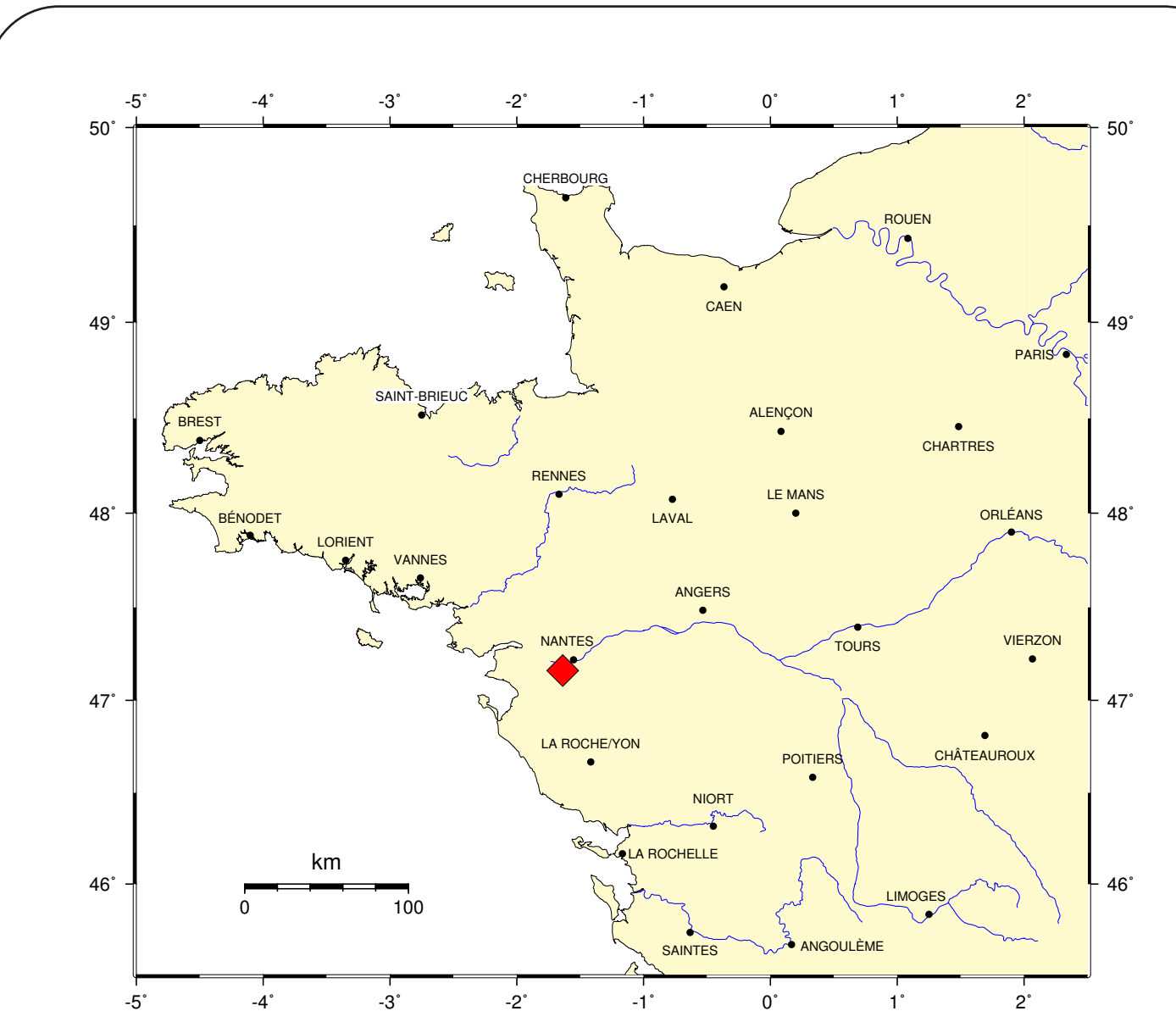


Figure 1: Location of the BOUF station in western France, at less than 10 km of Nantes. It is settled in a 10m deep cased borehole.

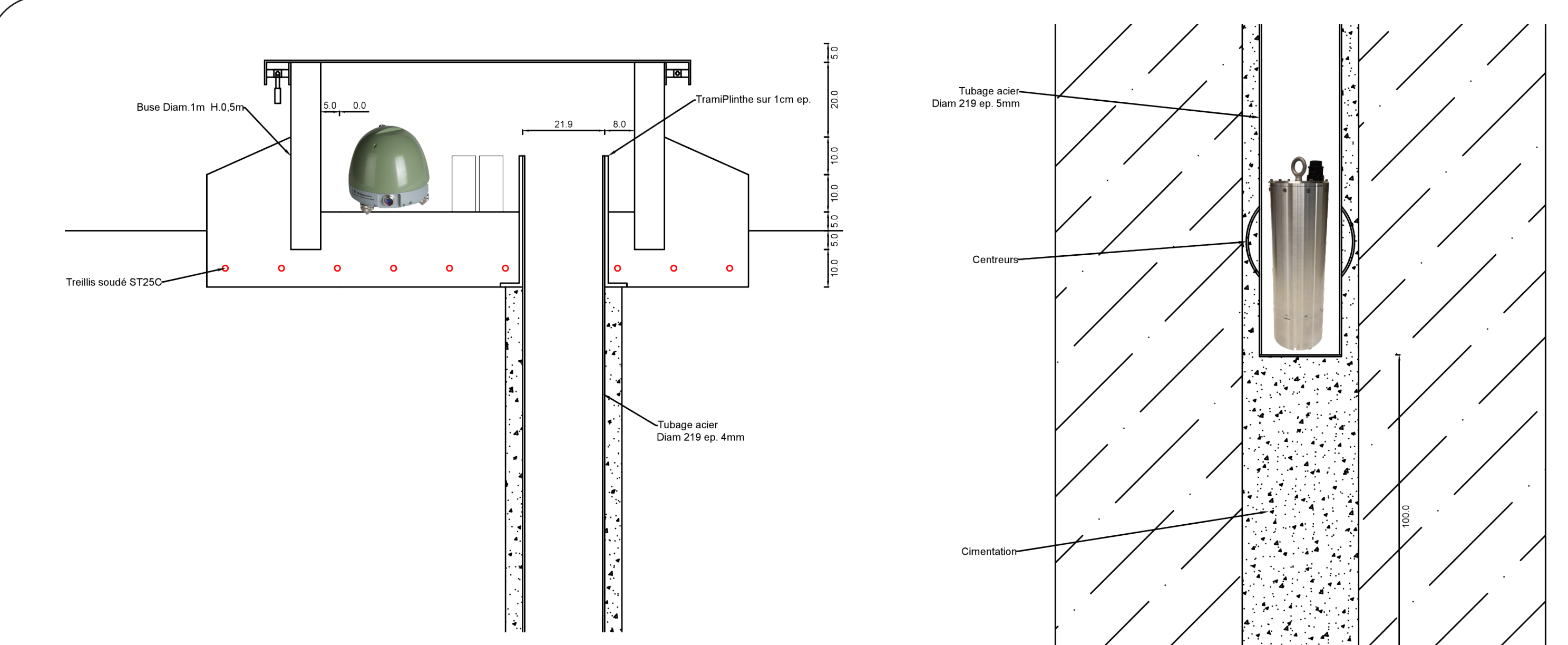


Figure 2: Borehole is instrumented with a T120PH (BOUF) surrounded by sand (right). A T120PA (BOUF1) was installed at the surface in the concrete pipe that covers the well (left).



Figure 3: Pictures of the site (left), of the well head (center) and of BOUF1 installation in the well head with wool (right).

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II. Noise Analysis

We compute probabilities of power spectral densities (PPSD) with a code used by the French community to check the noise level at potential sites of new RLBP stations (author J. Vergne). PPSD give an estimation of the signal quality one could expect at a given site with respect to the noise models from Peterson [USGS, 1993] (black curves on Fig. 4-6). We show that a well installation dramatically improve the long period signal with respect to light temporary installation generally used to propect new stations. The improvement is particularly dramatic on the horizontal components (Fig. 5, no more dispersion). The noise level at long period in the well can be as good (even better) as installations in caves or tunnels (e.g. SSB station on Fig. 6).

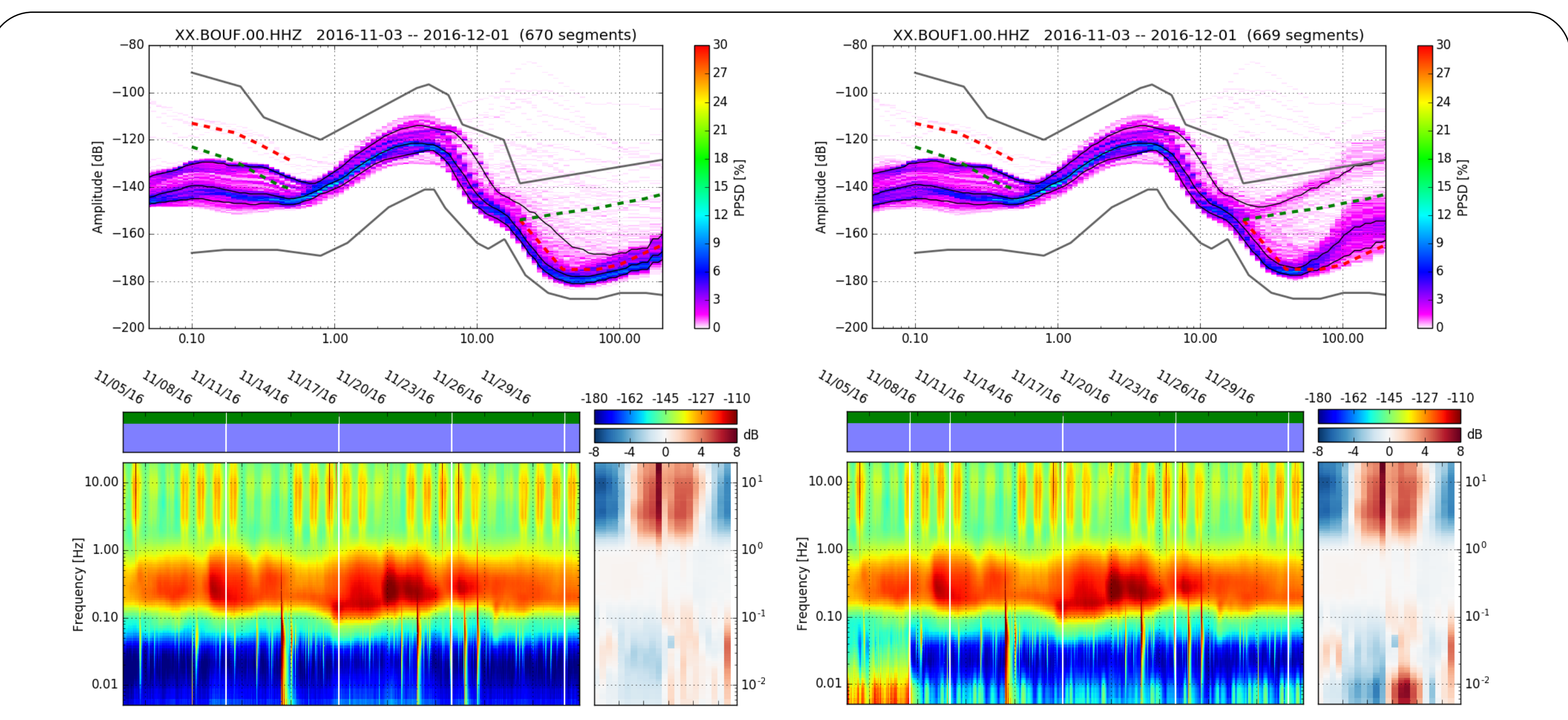


Figure 4: Top: PPSD for HHZ components at BOUF (left) and BOUF1 (right). Bottom: daily variations of the HHZ spectrum (amplitude in dB).

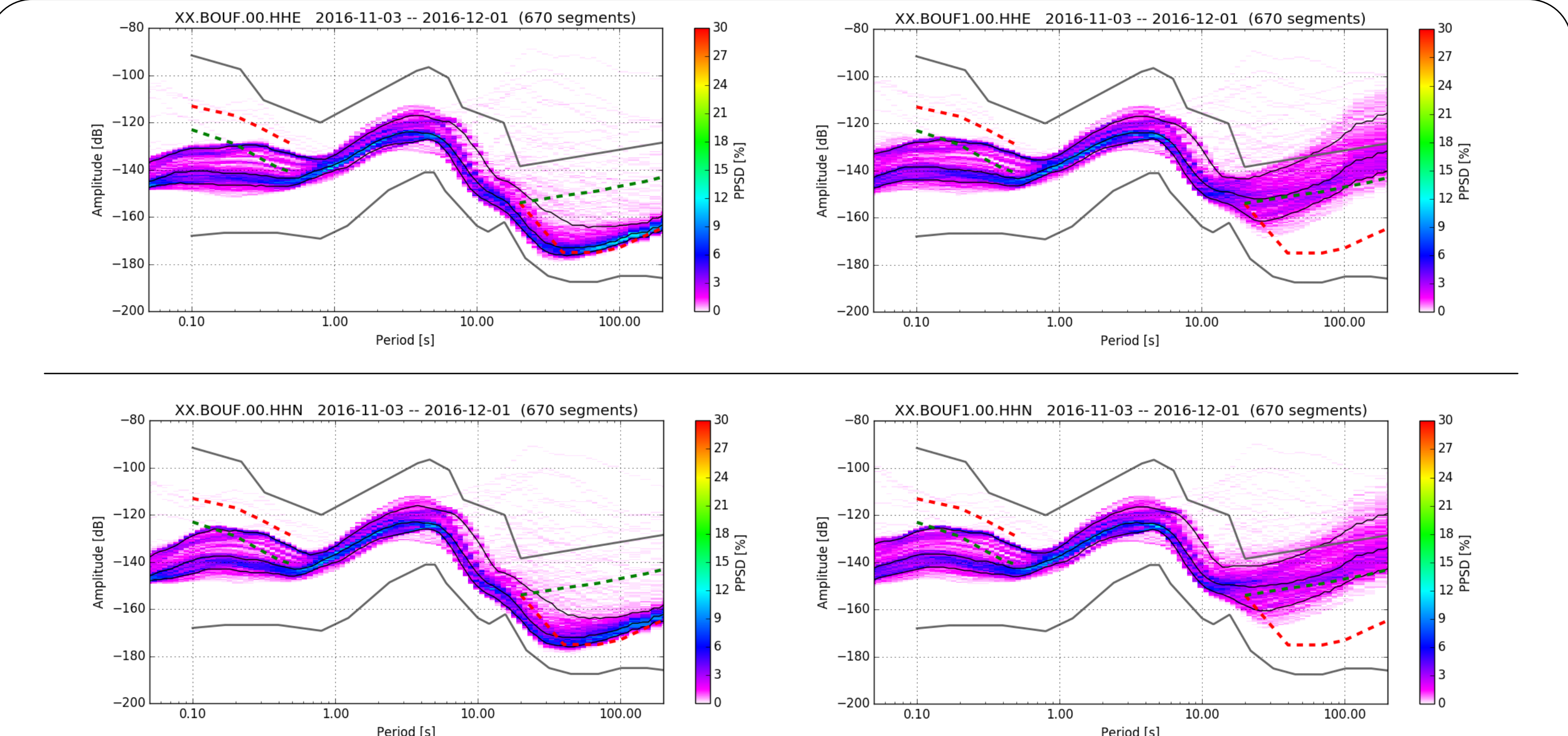


Figure 5: PPSD of the horizontal components (top HHE; bottom HHN) at BOUF (left) and BOUF1 (right).

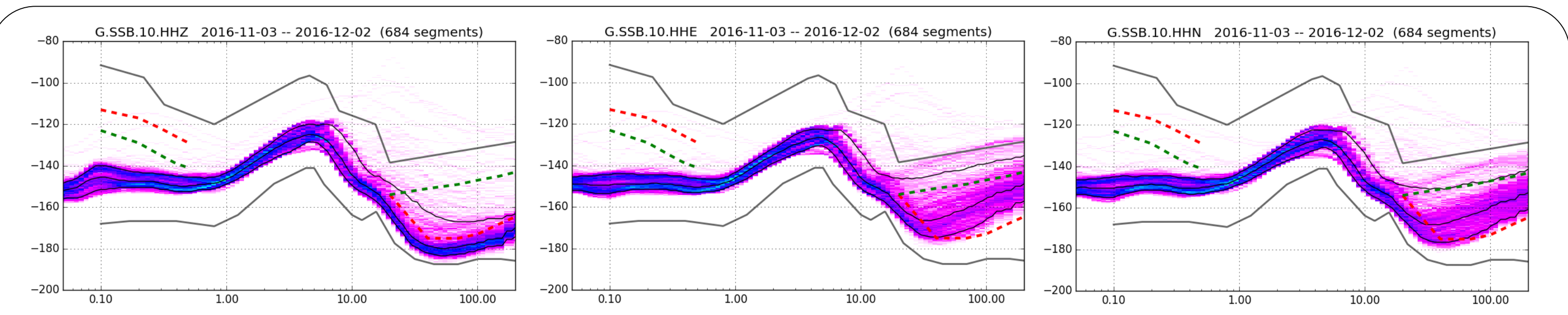


Figure 6: PPSD at station SSB from the Geoscope network (code G, sensor: STS-2). This station is located in a tunnel in the French Massif Central. Note the dispersion of the traces on the horizontal components.

III. Signal Comparison

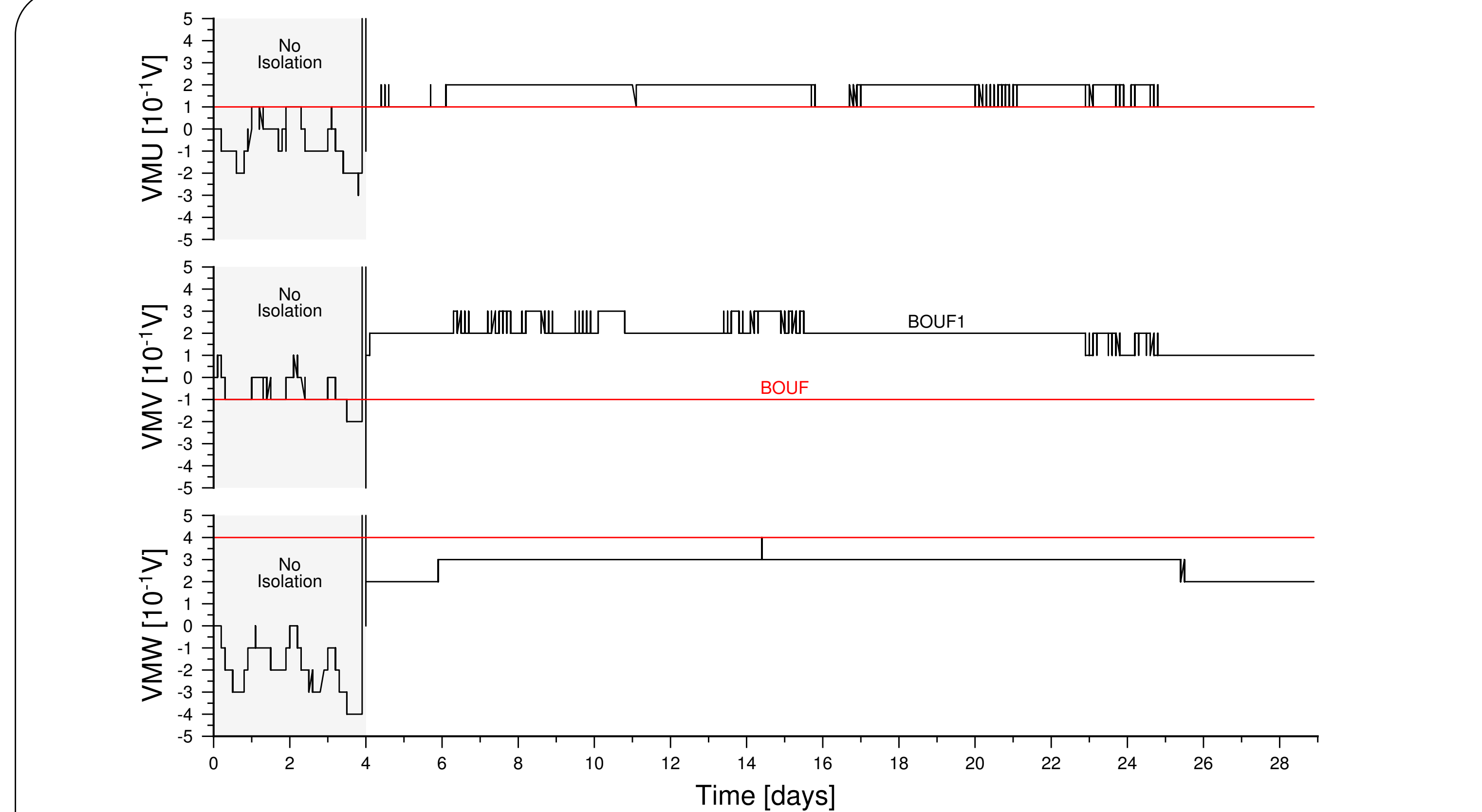


Figure 7: Comparison of the mass position of the T120PA (black) and T120PH (red) sensors on 29 days. Note that T120PA was not isolated for the first 4 days (gray shaded time period).

Comparison of the mass positions between the 2 sensors evidences the stability of the T120PH installed in the well (Fig. 7). On the other side, mass positions dramatically vary when the T120PA is not isolated. The addition of a Trillium cover and sheep wool considerably improve the stability of the T120PA masses (and thus its noise level). Fig. 8 and 9 show a one day trace for the LH components of BOUF and BOUF1. They clearly demonstrate the impact of the temperature variations on the seismological signal. In the case with no isolation, the signal is strongly altered and glitches appear. With isolation, the difference between BOUF and BOUF1 is reduced and noise can be efficiently removed with a highpass filter.

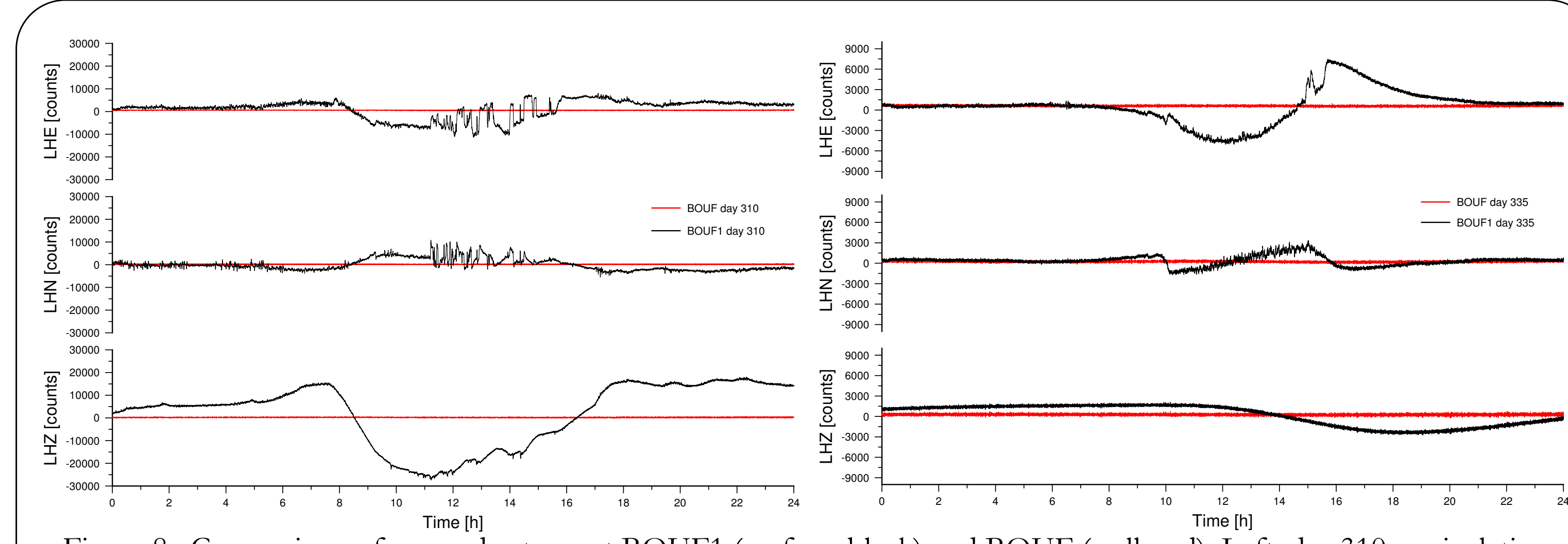


Figure 8: Comparison of a one day trace at BOUF1 (surface, black) and BOUF (well, red). Left: day 310, no isolation for BOUF1. Right: day 335, Trillium cover + wool for BOUF1. Note the stability of the trace at BOUF.

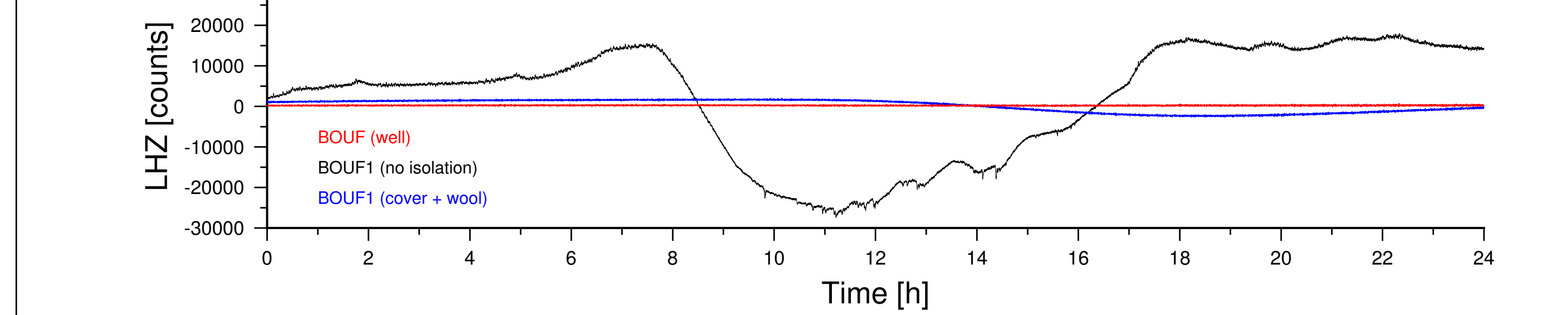


Figure 9: Effects of the isolation of the sensor on the LHZ components at BOUF (red) and BOUF1 (black = no isolation; blue = isolation).

IV. Orientation and Local Events

The price one has to pay with borehole installations is the difficulty of knowing the exact orientation of the seismometer. An efficient way to obtain the misorientation of the sensor is to use a second apparatus whose orientation is known (Tasic & Runovc, *J. Seismol.*, 2013). The T120PA was oriented at the surface with a gyrocompas. The traces are filtered between 0.1 and 10Hz to seek for an optimal coherence in the signal between the sensor (microseismic peak) and rotation matrix is returned from least-squares inversion (code written by M. Bès de Berc, EOST). We find a 33° difference between the sensors. A comparison between BOUF and BOUF1 traces for a local event validates this value (Fig. 10).

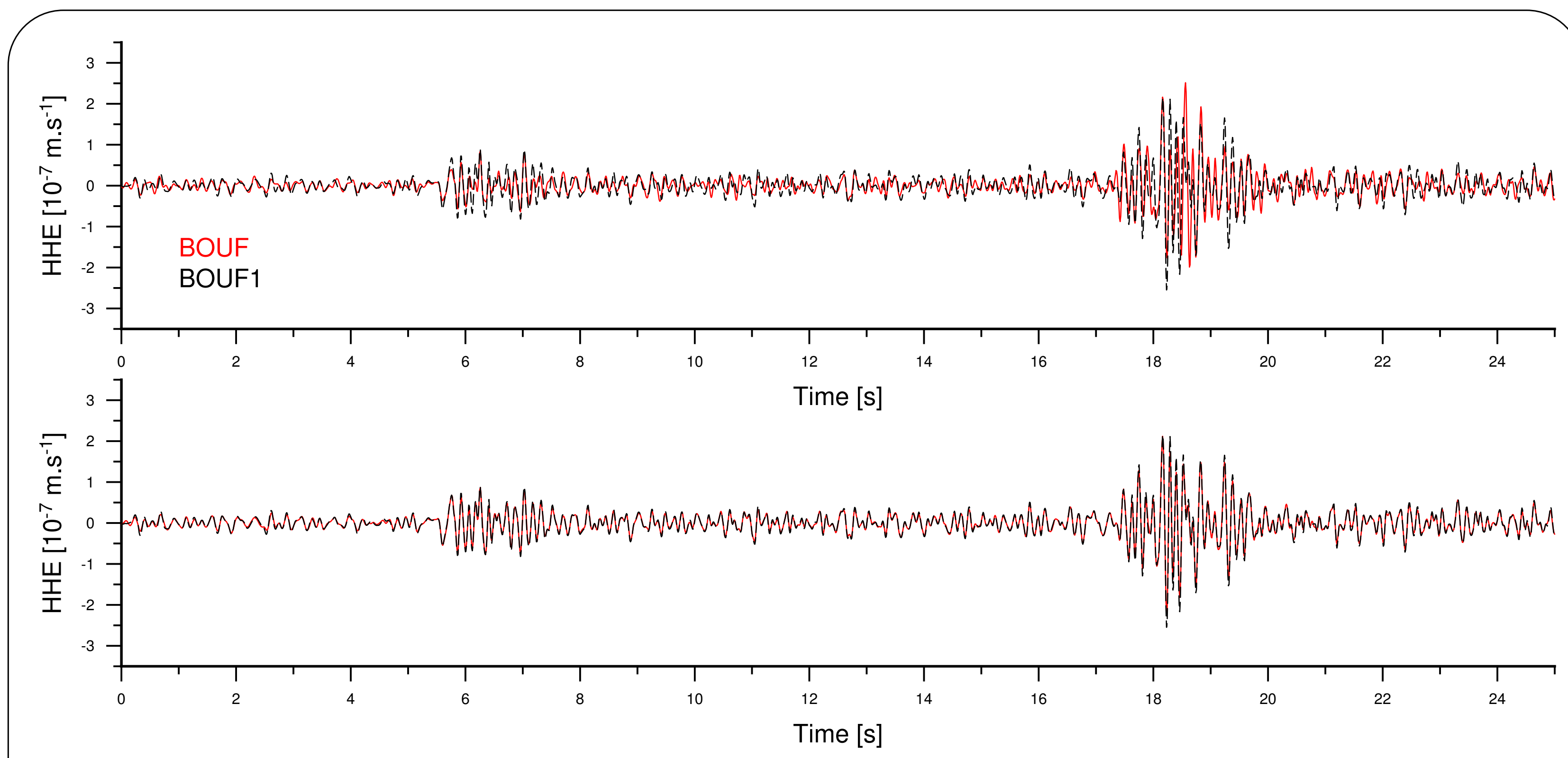


Figure 10: Top: Sismogram of a M=2.1 event at 95 km of the stations (source CEA-LDG); BOUF sensor in the well (red) is not oriented with respect to geographical coordinates. Instrument response was remove from the signal (velocity) and a zerophase bandpass filter (2-10Hz, poles=2) was applied. Bottom: same signal but the horizontal components of BOUF were rotated of 33° toward the east.

V. Conclusion

The tests performed at BOUF demonstrate the efficiency of small depth boreholes to obtain good but affordable long period permanent broadband stations. It is however to note that no improvement of the short periods is to be expected from such installations (Fig. 4 & 5). Installation of a sensor in a 10m cased borehole is relatively easy. However the sensor should be covered (e.g. sand) and cables should be carefully settled. If not, one could experience disappointing results on the horizontal components caused by glitches and long period noise (Fig. 11). True orientation of the sensor can be efficiently recovered from an other sensor at the surface (Fig. 10).

Peterson, J., 1993. Observations and modelling of seismic background noise. *U. S. Geol. Surv. Open File Rep.*, 93-322.
Tasic, I. and F. Runovc, 2013. Determination of a seismometer's generator constant, azimuth, and orthogonality in three-dimensional space using a reference seismometer. *J. Seismol.*, 17(2), 807-817, doi: 10.1007/s10950-012-9355-y.

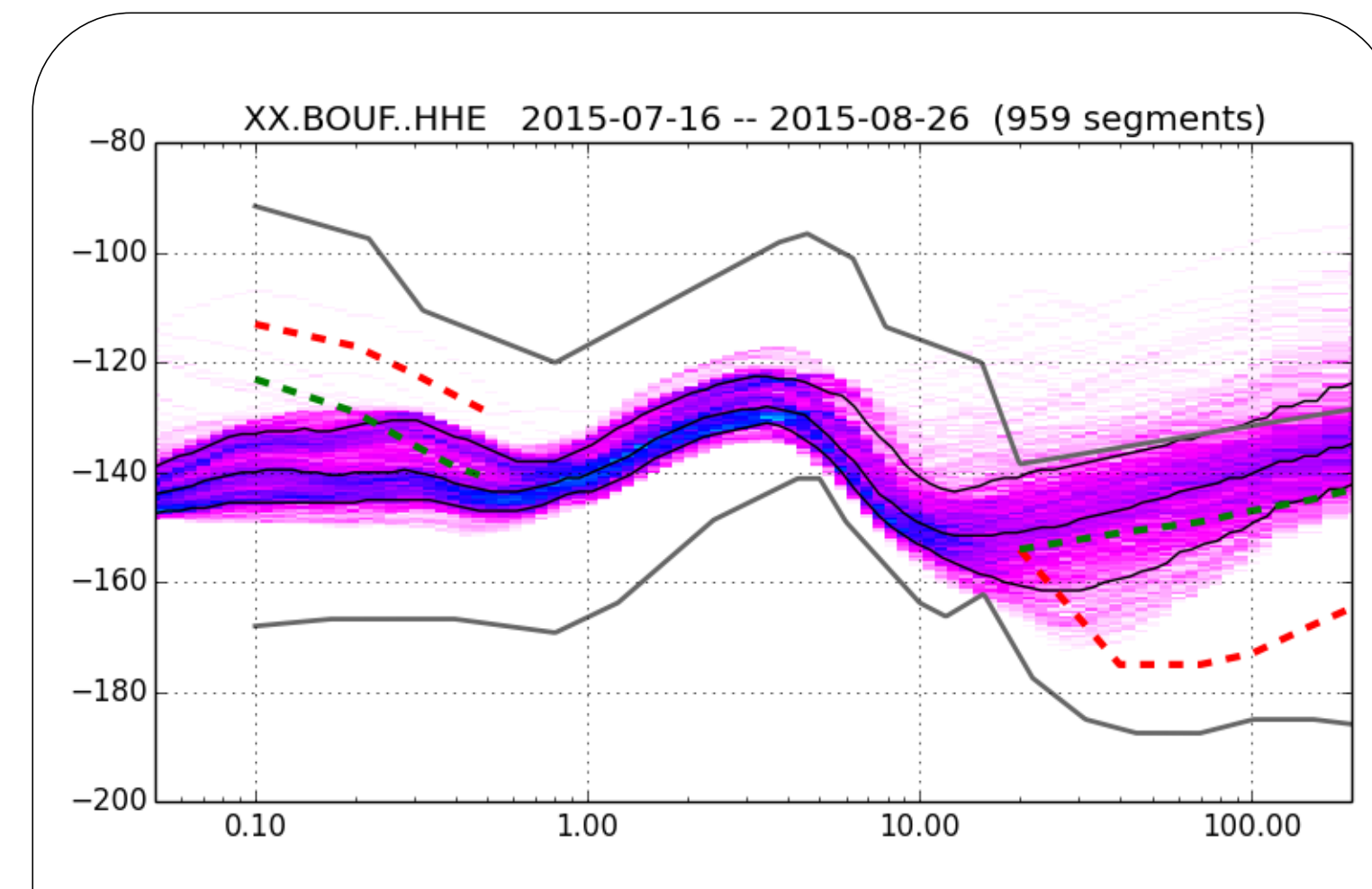


Figure 11: HHE PPSD of BOUF station without sand and without a careful installation of the sensor cables.