Reduction of Noise in Horizontal Long Period Seismograms Using Local Atmospheric Pressure

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1 Introduction

It is well known that the noise level of the horizontal components of seismic sensors is much higher than the level of the vertical ones. It is often assumed that the tilt of the seismometer's monument due to local pressure variation – besides other meteorological effects – is responsible for that effect, mainly in the frequency range below 10 mHz.

To improve the signal-to-noise ratio we try to find correlations between the seismic noise and pressure seismograms by using regressions that are based on simplistic physical models (ZÜRN & NEUMANN, 2002) and calculated by application of the seismometer's transfer function. The resulting pressure seismogram can be used to reduce the noise by substraction from the observed seismogram. The general plausibility of the models is demonstrated by numerical computation using the finite element method (FISCHER, 2002). Models will be modified according to results. We test our models for the geodynamic observatories BFO and MOX.

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2 Physical Models

Two different physical models (Zürn & Neumann, 2002) are used which describe the response of the horizontal seismometer to local pressure variations.

1) Local Deformation Tilt (LDT). Tilt caused by quasistatic pressure changes.

2) Travelling Wave Tilt (TWT). Horizontal wave in atmosphere above elastic half space with attraction, tilt and inertial effect. See Zürn & Neumann (2002) for details.

3 Examples

3.1 Example 1: MOX

The first example is taken from a Moxa record in July of 2001, with a length of only 24 hours. Figure 1-a shows the original seimic data of the EW STS-1 seismograph of station MOX. There is an unusual signal which doesn't seem to be caused by seismic motion of the ground. Additionally, the pressure signal is shown in Figure 1-b. To

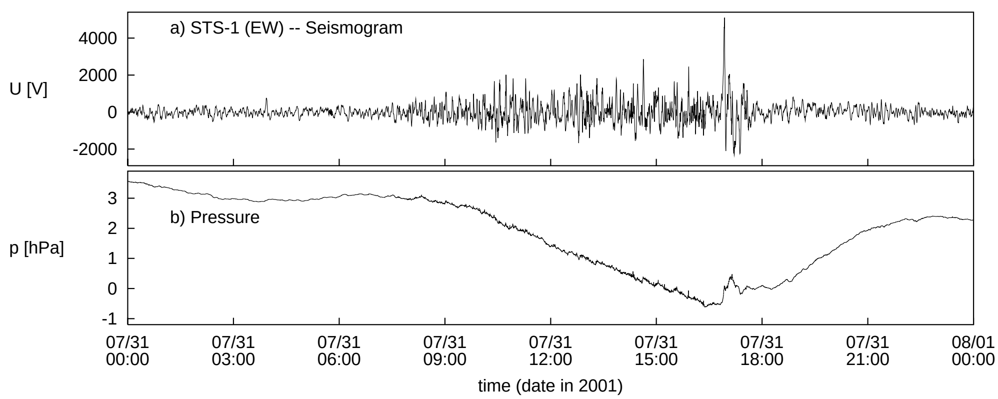

Figure 1: Example 1 – MOX. Original seismic and pressure data (EW)

reduce the noise of the seismic record, both models LDT and TWT are used to calculate pressure seimograms, which represent the motion of the seismometer's monument according to local pressure changes, correctness of the theoretical models assumed. These are then fit simultaneously to the data using least squares. The resulting model seismogram is shown in Figure 2-a. Figure 2-b shows the residual seismogram after subtraction of the model from the observed data. This method clearly reduces the noise of the seismic record.

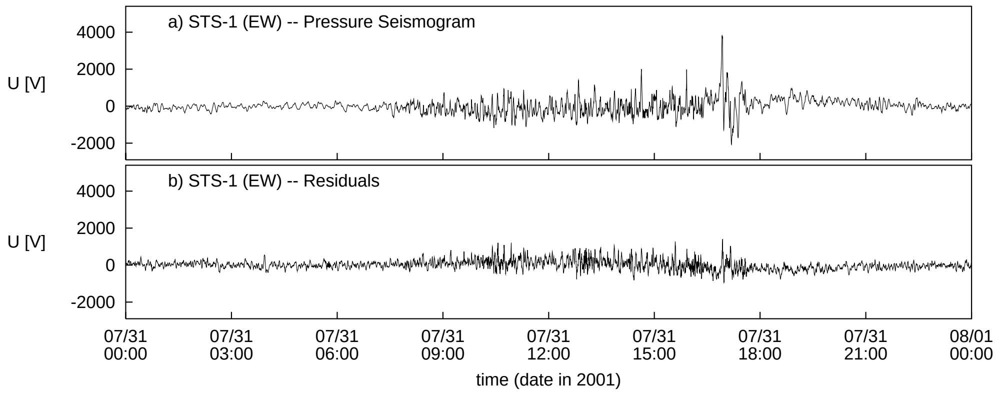

Figure 2: Example 1 – MOX. Calculated pressure seimogram and residuals (EW)

3.2 Example 2: BFO

As an example for more typical seismic signals, Figure 3 is showing a ten days record from BFO (Schiltach). Earthquake activity was very low in that period of time. Therefore, a lot of the energy forming the seismogram is produced by local air pressure rather than by earthquakes or other seismic signals, such as microseismic noise. There

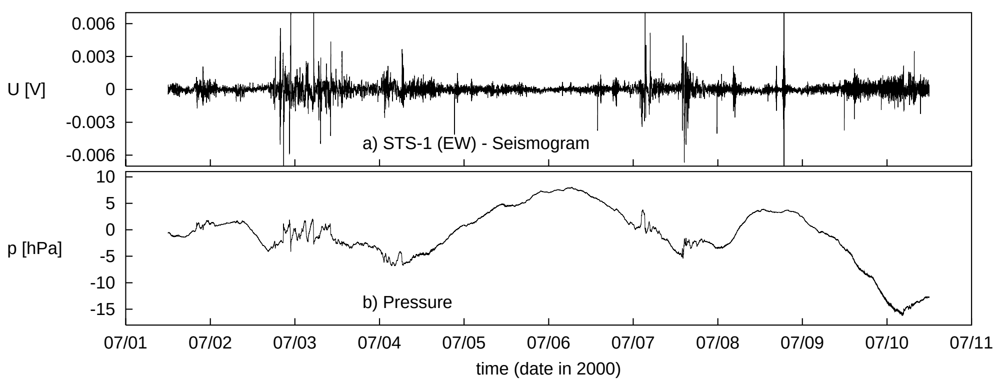

Figure 3: Example 2 – BFO. Original seismic and pressure data (EW)

are several obvious disturbances by pressure changes to the seismic sensor's output, especially on the 3rd and 7th of July. On the other hand there are signals that are most likely caused by real seismic motion, for example the earthquake in the second half of the 8th of July. We applied the same method as above to find the optimal pressure seimogram (Figure 4-a) and subtracted this from the observed data (Figure 4-b). Whereas the earthquake signals are taken over with no change, the signals that had been evoked by local tilts of the monument are clearly reduced.

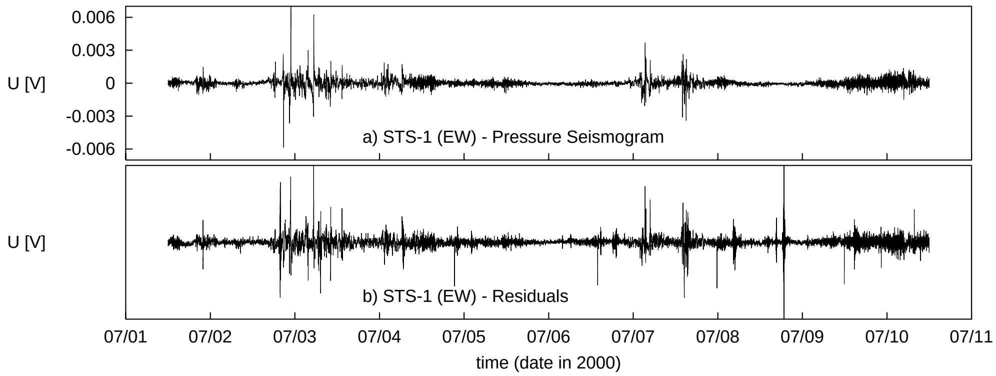

Figure 4: Example 2 – BFO. Pressure seismogram and residuals (EW)

4 Variance Reduction

Processing seismic records using our simplified models results in a considerable noise reduction. Figure 5 depicts the acceleration power spectral density of STS-1 EW-component at BFO for the same period of time as used in Section 3.2. The dotted line is the spectral density of the original record, the solid line the residuals. For comparison, Peterson's New Low Noise Model (PETERSON, 1993) for vertical seismic noise is also shown (labeled NLNM). The variance reduction is more than 50 percent, half of an order of magnitude.

The present focus of our interests is on testing the procedure's stability. Dependent on the length of the analyzed record and on the presence of small teleseismic signals the average variance reduction is about 40 percent for the NS-component and more than 50 percent for EW. For the station MOX we get variance reductions of more than 20 percent for the EW-component, whereas the NS-sensor appears to be insensitive to pressure. That might be due to a lower dependency of that component on local pressue changes or it could mean that there is a need to measure the air pressure in a different location than we did in the past.

When the second data example (the 10 days BFO record of July 2000) is analyzed for different time windows, we get variance reductions as shown in Figure 6. Parts a) and b) give the pressure seismogram and the residuals as a reference, while Figure 6-c) and d) document the regression coefficient's dependence on the window length and on the seismic signal, respectively. For a time window length of 2 days, as in Figure 6-c), the variance reduction is very high for signals induced by local pressure variation only, as on the 3rd of July and on the 7th, respectively. Teleseismic signals like the ones on the 5th and 9th of July 2000 lower the variance reduction to nearly zero, as espected. Usually, time windows of at least 4 days give reasonable results, i. e. the the variance reduction is stable, as shown in Figure 6-d).

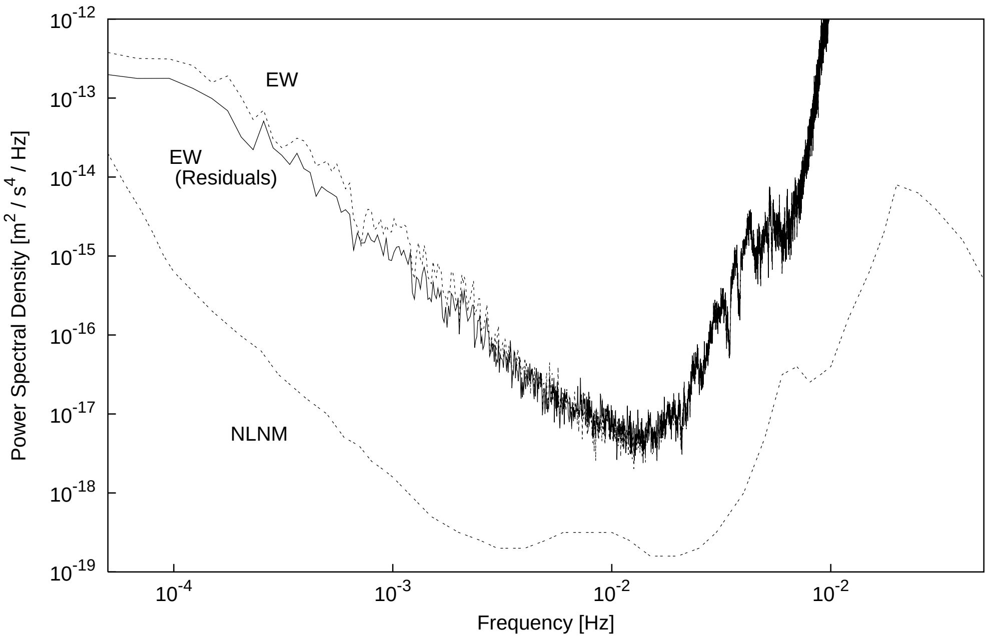

Figure 5: PSD-reduction for one horizontal seismic sensor when using both models LDT and TWT. Computed for 10 day record from BFO (EW-component)

5 Outlook

To improve the reduction of noise in horizontal seismograms we will try to continue with the following items:

- Stability: We need to process more data sets to check the stability of the procedure. Checks with very long time series need to be done as well.
- Models: We need to tune the simple physical models according to the results of the numeric modeling.
- MOX: Concerning the present lack of pressure resistent doors we might have to use pressure sensors inside the station as as well as outside.
- BFO: To learn more about effects of a travelling pressure wave we want to establish a small pressure sensor array around the station.

References

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Peterson, J., 1993: *Observations and Modeling of Seismic Background Noise*, U. S. Geol. Survey,Open-File Rep. **93-322**: 1–45.

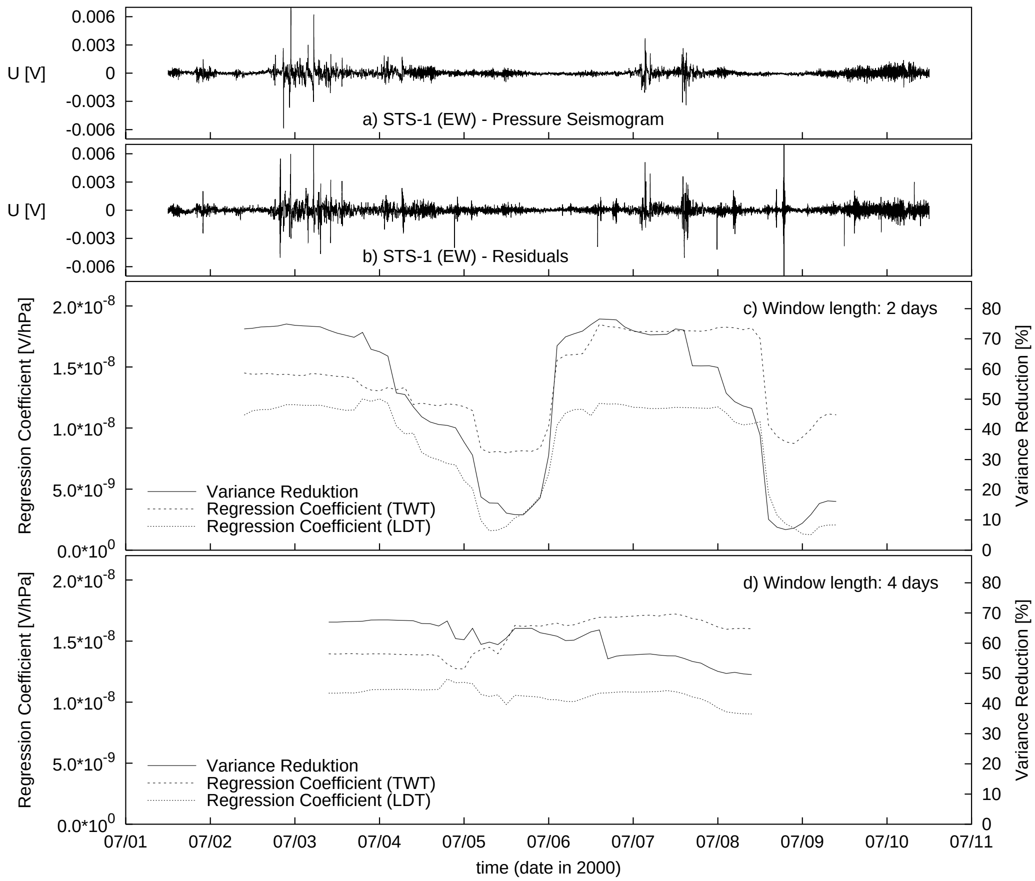

Figure 6: Stability of regression coefficients and variance reduction vs. time and for different window lengths.

Zürn, W. & Neumann, U., 2002: *Simplistic models of atmospheric effects in horizontal seismograms*, Bulletin d'Information des Marées Terestres **this issue**.