AMBIENT SEISMIC NOISE CORRELATION IN TWO DIMENSIONS

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Abstract

Ambient Seismic Noise Tomography (ASNT) has become a popular analysis method to study earth structure in recent years. The method is based on correlation analyses of ambient seismic noise measured at two seismographs (Shapiro *et al.*, 2005). The correlation enhances from the stochastic noise those components which travel in line with the two stations. The correlogram can be used as a deterministic seismogram and measures of seismic velocity drawn from it.

The method was recently applied by Gudmundsson *et al.* (2007) to data from the HotSpot experiment to study crustal structure in Iceland. The results prove the methods potential as they show a strong correlation with surface geology. However, the full potential is not exploited since more data can be incorporated, e.g. from the SIL network. The results are presented below as group velocity maps at three periods sensitive to the upper and middle crust in Iceland.

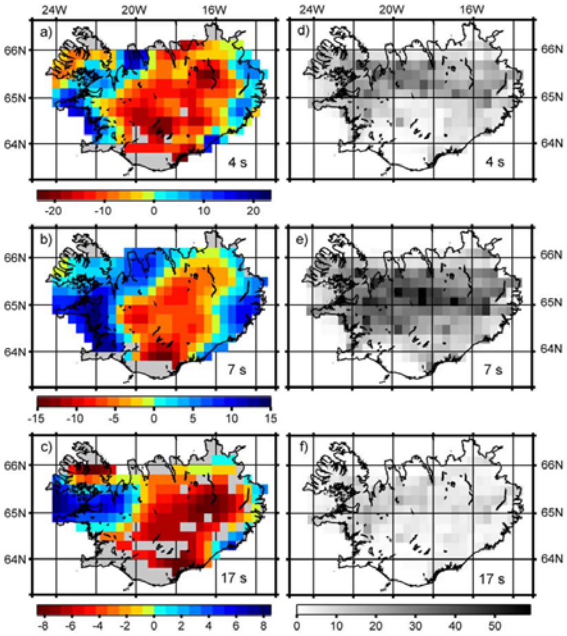

Figure 1. (a)–(c) Group velocity maps (percentile variation from reference velocity) and (d)–(f) maps of hitcounts for the three frequency bands used.

In ASNT it is usually assumed that the derivative of the cross-correlation function between simultaneous noise records at two stations provides an estimate of the Green's function between the stations. This result (Roux *et al.*, 2005) is based on a body-wave approximation and assumes a wavefield, which is fully diffuse, i.e. isotropic, in all three dimensions. However, seismic noise is usually dominated by surface waves that are two-dimensional phenomena and do not propagate equally in all three dimensions. The correlation of randomly orientated surface-waves does concentrate energy from the in-line direction between seismographs, producing a function which resembles the Green's function, but deviates significantly from it, even for a completely homogeneous Earth.

This function can be derived by considering an even distribution of impulsive surface-wave sources on a two-dimensional surface, or parts of it, randomly distributed in time. If the outer radius of the source region exceeds several times the intra-station distance the response rapidly approaches that for an even influx of surface waves from infinity. This response can be derived from simple energy flux arguments and is:

$$C(t) = \frac{\varepsilon v}{2\pi} \cdot \frac{1}{\sqrt{a^2 - v^2 t^2}}$$

where $C(t)$ stands for the correlation, t for time, v for velocity and a for the intra-station distance. ε stands for the even energy flux.

The band-passed undifferentiated (or differentiated) correlation has a frequency dependent peak at a lag which systematically deviates from that of the corresponding Green's function, and thus introduces a bias to phase determination. This bias is proportional to period. The broadband noise correlogram is singular at the time corresponding to direct intra-station propagation and is therefore better suited for estimation of phase or group time than its derivative. This singularity renders the correlogram relatively insensitive to concentrations of sources that are not in line with the station pair being used. While the phase velocity estimated from the peak of the correlation function is always biased the estimated group velocity is not, in those idealised cases we have examined. This follows analytically from the fact that the phase bias is proportional to period.

References

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