A. Introduction

While the sediment and the uppermost crustal structures beneath The Netherlands are relatively well known from seismic reflection and borehole data, the deeper crustal and upper mantle structures are not much investigated. Using a new temporary deployment of broadband seismometers in The Netherlands we aim to investigate the crustal structure and upper part of the mantle using an integrated surface wave analysis.

The current focus is to determine Rayleigh wave group velocities based on cross-correlations of ambient seismic noise data.

B. Basic Theory and Practical Measurement Technique

Seismic noise interferometry is increasingly used to study the substructure surface, from very local to global scales. The method provides the observational Green’s function between two points by cross-correlating long records of noise wavefields recorded at those points (Lobkis & Weaver 2001; Wapenaar 2004; Snieder 2004).

The empirical Green’s function between two receivers at position $\mathbf{x}_1$ and $\mathbf{x}_2$ is given by the cross-correlation of two wavefields $u_1$ and $u_2$ recorded at station $\Lambda$ and $\Lambda'$ (Wapenaar, et. al., 2010):

$$G_{\mathbf{x}_1\mathbf{x}_2}(t)\triangleq \mathbb{E}(u_1(t)u_2^*(-t))$$

where $G_{\mathbf{x}_1\mathbf{x}_2}$ are the Green’s functions corresponding to the response at location $\mathbf{x}_1$ due to an impulsive source at location $\mathbf{x}_2$ and vice-versa $\mathbb{E}$ is the auto-correlation of the source signal.

We determine Rayleigh wave group velocity curves between station pairs based on the cross-correlation of daily seismic records. We use the following steps as described in detail by Bensen, et al. (2007):

1. Time domain 1-bit normalization and spectral equalization; the aim of this step is to reduce the dominant effect of earthquakes and to equalize the signals spectrally.
2. Cross-correlation of daily normalized records.
3. Temporal stacking, this enhances coherent signals and suppresses incoherent ones.
4. Dispersion curve measurement.

The group velocity is measured using a frequency time analysis (FTAN) (Dziewonski, et al., 1981). Instead of the stacked cross-correlation function (CCF), to enhance the energy distribution of the fundamental mode in the frequency-time map (FT-map), time-variable filtering is applied using a reference group velocity curve. The reference group velocity is determined from the average of selected good quality group velocity curves.

C. Data and Data Analysis

Data are from the NARS-Netherlands project, a temporary deployment of 20 broadband seismometers in The Netherlands (red). To cover the entire area of The Netherlands we also used data from 9 permanent KNPB stations (blue), 2 German stations (GRSN, yellow) and 2 Belgium stations (BSN, brown).

141 station pairs were manually selected from all of the possible pairs based on the signal-to-noise ratio of the CCFs. We obtained good quality CCFs for inter-station distances of more than 75 km constructed from noise time series longer than three months. The causal and acausal parts of the CCFs are not similar, due to the inhomogeneous distribution of noise sources. We also discarded the unphysical part of the CCFs rather then use the average CCF.

D. Rayleigh Wave Group Velocity Inversion

We used a regularized least-squares inversion to create group velocity maps

$$\Delta = A'W_A\Lambda + \lambda(SL^TL)^{-1}A'W_I(\Delta_{m0} - A_m)$$

where $\Delta$ is the model perturbation from a reference group velocity, $A$ is the forward operator matrix, $W_I$ the data weighting matrix, $\lambda$ the smoothing matrix, $\Lambda$, and $\Delta_{m0}$ are norm-damping and smoothing strength. Regularization parameters were chosen based on criteria of the misfit value and stability of the model solution.

E. Conclusion and Outlook

We have obtained Rayleigh wave group velocity maps of The Netherlands for periods between 10 and 30 s, with a good agreement with gravity anomaly data. The shear wave velocity structure beneath The Netherlands will be determined by inversion of these group velocity maps. Furthermore, together with Love wave group velocity maps it will be possible to explore the anisotropic shear velocity structure.

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References


