Introduction

The Dutch crustal architecture consists of thick sedimentary layers underlain by metamorphic basement complex (de Jager, 2007; Fig. 1). While there have been a few studies that investigated the crustal structure, information about the crustal thickness and composition is limited and poorly constrained (Duin et al., 1995; Yudistira et al., 2017). The knowledge of the crustal structure is crucial for understanding the tectonics and constraining ongoing geodynamics modeling efforts.

Figure 1: (a) Tectonic map of the Netherlands (b) Topographic map with the distribution of broadband seismological stations.

Our earliest comprehensive knowledge of Moho depths was provided by deep seismic reflection surveys and the latest model was derived from ambient seismic noise (Duin et al., 1995; Yudistira et al., 2017; Fig. 2). The two models show significant inconsistencies, hence the need to resolve the Moho depth and understand its relationship with tectonics. In this study, we estimate crustal thicknesses and bulk composition of the Netherlands to resolve existing inconsistencies in the available models using receiver functions (RFs).

Further Works

Most RFs in the Netherlands are affected by sediment reverberation (Fig. 7). To solve the challenge, this study will explore:
- RF resonance removal filter approach
- Sequential (sediment and sub-basin) H-K stacking of the RFs
- Probabilistic inversion of the RFs

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References

- de Jager, J. (2007). In Geography of the Netherlands (pp. 5-26).

H-K Stacking Analysis

H-K stacking is an established technique for estimating Moho depth (H) and Vp/Vs ratio (K); it uses stacked P-S converted phase arrivals and a grid search in the H-K space to constrain the most likely H-K combination (Zhu & Kanamori, 2000).

Receiver Function Analysis in the Netherlands

Here, we show results from two seismic stations (HGN – without sediment effect and NE002 that highlights the strong influence of the sedimentary cover on the RFs and the Moho results) in the Netherlands.

Sediment Effects in Receiver Function

The Moho is a major interface that RFs are sensitive to; however, the presence of sediments makes Moho retrieval from RFs a challenging task (e.g., Fig. 4) because:
- Sediments introduce intra-crustal P-S conversions.
- These conversions mask direct P arrival (Yeck et al., 2013).
- Sub-basin P-S are delayed due to slow velocity sediments.

These result in erroneous Moho depth estimations.

Figure 4: RF forward models for 33 km thick crust for station (a) on hard-rock showing clear Moho phases (b) on 5 km thick sedimentary layers showing sub-basin phases masked by sediment reverberations.

Figure 7: Sediment sequence thickness map with examples of RFs and Moho depth estimations (Kalkman et al. 2016)

Receiver Functions

RFs are P to S (PRF) or S to P (SRF) wave conversions from subsurface discontinuities, which are isolated from 3-components teleseismic earthquake records. Here, we used PRFs for estimating crustal thickness and bulk composition (Vp/Vs) (e.g., Fadel et al., 2018; Fig. 3).

Figure 3: Schematic showing ray paths of P to S wave conversion phase (Ps) and the multiples (PsPs, PpSs, PpPs) at velocity contrast.

Station Without Sediment - HGN

- HGN is located on hard Carboniferous rock.
- RFs not affected by sediment reverberation (Fig. 5).
- Estimated crustal thickness of 33 km.

Station With Sediment - NE002

- NE002 is on top of sedimentary sequence up to 5 km thick.
- RFs affected by sediment reverberation (Fig. 6).
- Estimated crustal thickness of 20 km.