On the origin of ambient seismic noise in northern-Chile: insights from numerical modeling

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1) Context and objectives:
Analysis of one-year crosscorrelations of ambient seismic noise recorded by the broadband stations of the International Plate Boundary Observatory Chile (IPOC) project in northern Chile showed some intriguing features that motivated this study: 1) stable information up to 2 Hz maximum frequency, 2) asymmetric waveforms between positive-negative lags both in amplitude and frequency content, and 3) small (if any) seasonal variation specifically at high frequencies (> 0.1 Hz). In order to understand the physical processes that could give rise to these observations, numerical modeling of noise propagation appears to be an adequate tool. A simplified Earth’s model of the study area is used to generate Green functions from random noise sources located near coastal regions.

Our main objective is to determine the location and stability of ambient seismic noise sources. This information will be highly valuable to make inferences about variations in Earth’s properties and/or passive seismic tomography in the study area.

3) Data analysis
- Selection of 4 three component stations PB04, PB05, PB06, PB07 (year 2007)
- Clipping of strong events, whitening between 0.02 Hz - 2 Hz, one-bit auto/cross-correlations (78 in total)
- Stacking of one-month length time duration

4) Numerical modeling
Green’s functions are calculated via the discrete frequency-wavenumber method (Buchon, 1979; Favreau, 2009) from vertical/horizontal point forces located at the surface of the model following the coastline and at two parallel lines within the ocean around 50 km from the coast (almost parallel to the trench). The 1D velocity model comes from previous seismological studies in the region (Husen et al, 1999; Peyrat et al, 2009).

Synthetic noise recordings of one-day long duration are created simply by adding Green’s functions from the database at random ‘initial’ (trigger) times in order to create sufficient disorder: each of the 1144 sources (in coastline) triggers 1000 times for a one-day long noise seismogram. For some cases, a constant Q quality factor is applied to take into account wave attenuation within the lithosphere. After that, the correlations are calculated following the same procedure as for real ambient noise data.

2) Study area: Tocopilla earthquake (2007, Nov 14; Mw=7.7)
Occured in the northern-Chile seismic gap at around 46 km depth, this interplate earthquake offers a unique opportunity to understand issues connected with the rupture of the locked interplate interface in Chile (Delouis et al, 2009; Peyrat et al, 2010). We may expect some variations in physical properties of the lower crust, and therefore noise correlation techniques could be very informative. The first step was to estimate Green’s functions between nearby IPOC seismological stations (red triangles on the left).

5) Preliminary conclusions
- Velocity model slightly slower than reality
- Best match with sources near the coastline (two parallel lines)
- Rotation of synthetic correlations indicate similar behavior as real data (no preferential orientation)
- Some high-frequency (> 1 Hz) arrivals caused by coherent Green’s functions summation → need of more disorder in the model (more diffusive Earth crust) ?

From figures on the left (top-bottom), we obtain incoming noise directions (green-red) arrows on the figure on the right.

No preferential orientation for incoming ambient noise → near-coastal source locations (confirmed by numerical modeling results).

On-going work: angles as a proxy of seasonal variations in source locations.

Synthetics (blue) vs real (red) cross-correlations (March 2007) from station pairs PB04-PB05 (left) and PB04-PB06 (right). Noise synthetics were generated by combining horizontal and vertical point force excitations on two parallel lines near the coastline (shown in the location map).