Land-Atmosphere Interaction in the low-frequency seismic band and inversion for shallow elasticity structure

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For frequencies below 0.05 Hz, except for the hum signals generated by ocean waves, the atmosphere is the main source of seismic noise. Some characteristics of atmosphere-generated seismic noise have been reported (e.g., Zürn et al., 2007; Zürn and Wielandt, 2007) but recent data from co-located pressure and seismic sensors allow us to improve our understanding of this interaction. We report our analysis of data from the EarthScope Transportable Array (TA) and some global permanent stations that are equipped with pressure and seismic sensors.

We first point out that coherence between surface pressure and vertical seismic data shows two broad peaks, a lower frequency one that rises below about 0.002 Hz and a higher frequency peak that reaches its maximum about 0.02 Hz. There is a minimum of coherence between them at about 0.003-0.004 Hz.

We noted that there is basically no phase-shift between pressure and vertical seismic displacement for the lower frequency peak while there is a 180-degree phase shift between pressure and vertical displacement for the higher frequency peak at about 0.02 Hz. Two peaks show a completely opposite relationship between pressure and vertical displacement. The zero phase-shift for the lower frequency peak is consistent with the mass-attraction effect due to density perturbations in the atmosphere and the 180-degree phase shift for the peak about 0.02 Hz is consistent with elastic deformation caused by surface pressure.

They suggest that these are two competing forces generated by the atmosphere, one that tends to attract the sensor mass upward by density perturbations in the atmosphere and the other that tends to push down the ground due to high pressure. The mass-attraction effect wins for the lower frequency peak and the ground deformation effect wins for frequencies above 0.01 Hz. The existence of the minimum between the two peaks indicates that relative size of these forces switches at about 0.003-0.004 Hz (already pointed out by Zürn and Wielandt, 2007).

The size of the higher frequency peak (at about 0.02 Hz) is strongly influenced by the elasticity of near-surface materials; at many sites with STS-1 sensors, this high frequency peak is often hard to identify as the sites are mostly at hard-rock sites, meaning there is little deformation due to atmospheric pressure. On the other hand, some EarthScope TA sites are at soft sediment sites and show a large (and dominant) peak at about 0.02 Hz. For such soft sites, we can derive shallow structure from pressure and seismic data.

We will present an inversion scheme to invert data from this higher frequency peak. Basic data are the ratios between vertical seismic data to pressure data and also between horizontal seismic data to pressure data for frequencies between 0.005 Hz and 0.05 Hz. The method is an iterative nonlinear inversion from a starting model using depth sensitivity kernels that are computed at each iteration step. The framework of inversion is similar to surface-wave phase velocity inversion. The product is a layered elasticity structure beneath a co-located station.

Keywords: Land-Atmosphere Interaction, Shallow elasticity structure, Inversion of pressure and seismic data