Introduction

Recently, earth scientists from different fields, such as seismology, climate studies and regular weather monitoring, have become increasingly interested in low-frequency wind-induced ground motion. Due to developments of high-quality seismic network with co-located seismometers and barometers, we can learn the characteristics of the background seismic noise in a more systematic manner.

In a previous study, Tanimoto et al. (2016) used TA stations in North Carolina and observed that above certain threshold values, ground motion amplitudes increase as pressure increases at low frequency bands (0.01-0.05 Hz), thereby indicating local atmospheric pressure change is the main source of energy for ground motion.

Results

1. Shallow Structure

\[ \frac{S_g}{S_p} = \frac{c^2}{4\mu} \left( \frac{\lambda + 2\mu}{\lambda + \mu} \right)^2 \]  \hspace{1cm} (1)

\[ \frac{S_p}{S_v} = \frac{g^2}{4\mu\omega^2} \left( \frac{\lambda + 2\mu}{\lambda + \mu} \right)^2 \]  \hspace{1cm} (2)

Equations 1 & 2. Derived from Sorrells et al. (1971,73). \( S_g \): PSD for ground motion. \( S_p \): PSD for pressure. \( c \): wind speed. \( \mu \): shear modulus. \( \lambda \): Lame parameter.

Equations 1 and 2 are derived from Sorrells et al. (1971,73), and they are two equations with only two unknowns, which are wind velocity and shear modulus. We assumed \( \frac{\lambda + 2\mu}{\lambda + \mu} \) as ~ 1 in our study. The LHS of both equations is the ratio between vertical/horizontal ground motion and pressure as shown in figure 1 yellow lines, and these ratios can be calculated from stations with clean slopes after certain threshold values selections (vary between stations). We use the average amplitudes of \( N \) and \( W \) components as the horizontal amplitude.

![Normalized Calculated Shear Modulus Overlying Vs 30](image)

Fig 1. Ground motion amplitudes increase as pressure increases after a threshold pressure value. F04D is a TA station located at Rainier, OR. Yellow lines are slope used to calculate shear modulus.

Based on equations introduced by Sorrells et al. (1971,73), we have derived a series of equations to calculate the shear modulus of the shallow earth and associated wind velocity near the surface based on the ratio between different ground motion components and pressure. We have also noticed daily variation in stacked 24-hour ground motion PSD plots for most stations. In general, all three ground motion have higher amplitude at noon and lower amplitude at midnight.

In this study, there are two major components in our results: (i) shallow structure information from ground motion-pressure ratio and (ii) daily variation in ground motion.

Methods

Seismic data from stations in North Carolina (NC) and Southern California (SC) are used in this study. All TA stations with infrasound sensor attached after mid-2011 are analyzed. 12 SC CI stations data from 2002 to 2009 are acquired from SCEC. The same type of ground motion and barometric pressure data are acquired from both IRIS and SCEC, but the infrasound microphone (pressure) data are not available at CI.

Horizontal components are constantly affected by tilting of the Earth that is caused by the propagation of plane wave pressure. The tilts can represent a major source of noise in horizontal components signals (Sorrells et al.1971). Thus, we mainly focus on vertical ground motion in this study.

Data segments affected by large earthquakes are removed according to local and global earthquake catalogs, because earthquakes can produce a sudden and drastic increase on ground motion, which is not desirable.

Discussion

Equations 1 & 2 provide new approach to obtain shallow structure information such as shear modulus and associated wind speed for locations with co-located infrasound sensor and seismometer. Based on the good fit between our results and Vs 30 Model, we are confident that equations 1 & 2 could at least provide an accurate qualitative determination of shear modulus.

Such results are easy to obtain with two requirements:

- Station with co-located infrasound sensor and seismometer (one sps is enough).
- Station with at least one year long continuous data recording.

The amplitude of ground motion is generally higher at daytime, then it introduces more uncertainty and scattered points. Due to the potentially complicated controlling factors of this daily variation pattern, we are not certain about the cause of it; however, we can still incorporate it to improve our datasets. In general, we can obtain cleaner plots and slopes by only picking data sections at nighttime.

Because TA has installed infrasound sensor since mid-2011, we will have a large data set to work with in the future. We can do more calculation once TA stations are deployed again in the West Coast. The large dataset and straightforward calculation process give more potential of this new approach. The result can help us understand more about the fundamental physics between atmosphere and solid earth, as well as the shallow earth structure.

Reference

Sorrells, G. G., John A. McDonald, and Anne Mcdonald, “Relationship between long-period ground motion and local pressure changes in the atmosphere: A preliminary investigation using a 14-station infrasonic network,” SC/CEC, no. 26 (September 1973); 1583-1601.

Sorrells, G. G., D. A. Leideck, and J. A. McDonald, “Effect of local atmospheric pressure changes on long-period ground motion,” Geophysical Journal 32, no. 3 (December 1973); 565-574.
