Extracting Noise-Correlation Functions from Analogue Seismograms

Thomas Lee[1], *Miaki Ishii[1], Paul Okubo

1. Department of Earth & Planetary Sciences, Harvard University

Ambient noise correlation functions have been shown to be a powerful tool for investigating subsurface processes through subtle changes in seismic wave speeds with time. In order to capture slowly-varying effects, it is critical to extend the observation duration as long as possible. While waiting to accumulate more digital recordings over years to come, it is possible to begin to utilize seismograms recorded during the pre-digital era. Analogue seismographs have been recording ground motion for more than 100 years, and in many cases, daily continuous seismogram records exist over multiple decades. Even though an unknown fraction has been discarded, many of the seismogram collections are still intact and available. Correlation of the background noise recorded by these analogue seismograms expands the time window over which the subsurface evolution can be examined.

There are, however, difficulties associated with analogue recordings, with one of the obvious challenges being extracting digital time series from analogue seismogram images. If digital time series are available, then the biggest issue facing the calculation of the ambient noise correlation function is the relative time uncertainty. The analogue data are recorded during a time predating GPS clocks and, often, the time has been kept by separate mechanical clocks at each station. These clocks are calibrated to some central time at regular or irregular intervals. The implication is that, at any given time, seismogram timing at two stations may not be synched. Additional uncertainties in relative time between two stations can be introduced when recording media are changed, typically from one day to the next, making stacking of noise correlation functions over multiple days impractical.

We overcome these difficulties by estimating relative time corrections between two stations using the symmetry property of noise correlation functions. We demonstrate this by analyzing digitized time series from multiple analogue seismograms recorded at two stations in Hawai`i in 1988. Time corrections on the order of seconds are obtained, which are compatible with those estimated using teleseismic arrivals and modern recordings of corresponding arrivals. The magnitudes and signs of the time corrections change considerably between sets of recordings from consecutive days, suggesting that change of media may be a significant source of uncertainty. The relative time corrections enable stacking of noise correlation functions over multiple days to enhance coherent signals, and the resulting function is comparable to noise correlation functions calculated using data from 2018 recorded at the contemporary equivalent stations.

Keywords: analogue seismograms, noise correlation function, relative time correction

