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On the growth-speed of the ambient noise cross-correlation function and its application

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Retrieving the Empirical Green's function (EGF) between two receivers by cross-correlating continuous records is now a well-recognized technique and the derived EGFs have been applied to various fields of seismology. In the common operation of noise cross-correlation, it is known that the signal-to-noise ratio (SNR) of cross-correlation functions (CCF) is generally increasing with the total correlation time. However, little attention has been given to a more quantitative description on how the noise-derived CCFs are developing with time. In this study, we analyze the CCF growth-speed quantitatively, and discuss its potential applications.

In theory, the noise-derived CCF is approximately composed of two parts, the time-independent term, which is related to the Green's function, and the time-dependent term, which is the product of unrelated noise sources, and its contribution in the CCF is decreasing with the total correlation time. Defining the final CCF, the one derived from all the available data, as the reference CCF, we may quantify the strength of unrelated noise sources using the rms of the waveform residual between a target CCF and the reference CCF. Since the rms is dropping with the growing correlation time of the target CCF, we may relate the rms to the CCF growth-speed when it is scaled by a properly defined time-dependent term.

We evaluate the growth-speed for realistic CCF data set derived from the vertical component continuous seismic data recorded at 63 short period stations and 89 broadband stations in Taiwan. To remove the effects of temporal variations of the noises strength, the growing target CCFs are taken from a randomly daily CCF stack.

In Taiwan, we have noted that the noise excitations in the frequency band of short period secondary microseism (3-7 seconds) is highly correlated with the the water depth of the surrounding ocean, and its signature is clearly shown in the resulting CCFs. Interestingly, such correlations do not exist in the CCF growth-speed, which remains nearly constant through the evaluation of any station pairs, implying that the spatial distribution of the unrelated noises is relatively homogenous, unlike the apparent bathymetry-dependent "signal" sources.

Assuming the CCF with infinite correlation time is "noise-free", we may evaluate the "noises" strength in the CCFs at any given correlation time with the growth-speed. Instead of using an empirically defined SNR, the estimated "noise" strength provides a quantitative measure for the EGF quality. Such analysis could be used in any given time window in the CCF trace as well. For instance, we may evaluate how the CCF coda quality varies with trace length, and such measure allows us to make a meaningful choice for the window length of quality coda.