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Determining clock errors of ocean-bottom seismometers: an ambient-noise based method designed for large-scale ocean bottom deployments

David Naranjo[1], Laura Parisi[2], Sigurjón Jónsson[2], Philippe Jousset[3], Dieter Werthmüller[1], and Cornelis Weemstra[1,4]

[1]TU Delft, Civil Engineering & Geosciences, Applied Geophysics and Petrophysics, Delft, the Netherlands
[2]Physical Science and Engineering Division, King Abdullah University of Science and Technology, Thuwal, Saudi Arabia
[3]Helmholtz Center Potsdam, GFZ German Research Centre for Geosciences, Potsdam, Germany.
[4]Royal Netherlands Meteorological Institute, De Bilt, the Netherlands

The timing of the recordings of ocean-bottom seismometers (OBSs) is critical for accurate earthquake location and Earth model studies. GNSS signals, however, cannot reach OBSs deployed at the ocean bottom. This prevents their clocks from being synchronized with a known reference time. To overcome this, we developed OCloC, a Python package that uses time-lapse cross-correlations of ambient seismic noise to synchronize the recordings of large-scale OBS deployments. By simultaneously quantifying deviations from symmetry of a set of lapse cross-correlations, OCloC recovers the incurred clock errors by means of a least-squares inversion. In fact, because non-uniform noise illumination patterns also break the symmetry of (lapse) cross-correlations, we introduce a distance-based weighted least-squares inversion. This mitigates the adverse effect of the noise illumination on the recovered clock errors. Using noise recordings from the IMAGE project in Reykjanes, Iceland, we demonstrate that OCloC significantly reduces the time and effort needed to detect and correct timing errors in large-scale OBS deployments. In addition, our methodology allows one to evaluate potential timing errors at the time of OBS deployment. These might be caused by incorrect initial synchronization, or by rapidly changing temperature conditions while the OBS is sunk to the sea bottom. Our work advances the use of OBSs for earthquake studies and other applications.