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Correction of clock errors in seismic data using noise cross-correlations

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Correct and verifiable timing of seismic records is crucial for most seismological applications. For seismic land stations, frequent synchronization of the internal station clock with a GPS signal should ensure accurate timing, but loss of GPS synchronization is a common occurrence, especially for remote, temporary stations. In such cases, retrieval of clock timing has been a long-standing problem. The same timing problem applies to Ocean Bottom Seismometers (OBS), where no GPS signal can be received during deployment and only two GPS synchronizations can be attempted upon deployment and recovery. If successful, a skew correction is usually applied, where the final timing deviation is interpolated linearly across the entire operation period. If GPS synchronization upon recovery fails, then even this simple and unverified, first-order correction is not possible.

In recent years, the usage of cross-correlation functions (CCFs) of ambient seismic noise has been demonstrated as a clock-correction method for certain network geometries. We demonstrate the great potential of this technique for island stations and OBS that were installed in the course of the Réunion Hotspot and Upper Mantle - Réunions Unterer Mantel (RHUM-RUM) project in the western Indian Ocean. Four stations on the island La Réunion were affected by clock errors of up to several minutes due to a missing GPS signal. CCFs are calculated for each day and compared with a reference cross-correlation function (RCF), which is usually the average of all CCFs. The clock error of each day is then determined from the measured shift between the daily CCFs and the RCF. To improve the accuracy of the method, CCFs are computed for several land stations and all three seismic components. Averaging over these station pairs and their 9 component pairs reduces the standard deviation of the clock errors by a factor of 4 (from 80 ms to 20 ms). This procedure permits a continuous monitoring of clock errors where small clock drifts (1 ms/day) as well as large clock jumps (6 min) are identified. The same method is applied to records of five OBS stations deployed within a radius of 150 km around La Réunion. The assumption of a linear clock drift is verified by correlating OBS for which GPS-based skew corrections were available with land stations. For two OBS stations without skew estimates, we find clock drifts of 0.9 ms/day and 0.4 ms/day. This study salvages expensive seismic records from remote regions that would be otherwise lost for seismicity or tomography studies.