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DOI
10.5194/egusphere-egu21-13999

Publication date
2021

Document Version
Final published version

Citation (APA)
Naranjo Hernandez, D. F., Parisi, L., Jousset, P., Weemstra, C., & Jónsson, S. (2021). *Determining OBS clock drift using ambient seismic noise*. Abstract from EGU General Assembly 2021. https://doi.org/10.5194/egusphere-egu21-13999

EGU21-13999, updated on 16 Apr 2021
https://doi.org/10.5194/egusphere-egu21-13999
EGU General Assembly 2021

Determining OBS clock drift using ambient seismic noise

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Accurate timing of seismic records is essential for almost all applications in seismology. Wrong timing of the waveforms may result in incorrect Earth models and/or inaccurate earthquake locations. As such, it may render interpretations of underground processes incorrect. Ocean bottom seismometers (OBSs) experience clock drifts due to their inability to synchronize with a GNSS signal (with the correct reference time), since electromagnetic signals are unable to propagate efficiently in water. As OBSs generally operate in relatively stable ambient temperature, the timing deviation is usually assumed to be linear. Therefore, the time corrections can be estimated through GPS synchronization before deployment and after recovery of the instrument. However, if the instrument has run out of power prior to recovery (i.e., due to the battery being dead at the time of recovery), the timing error at the end of the deployment cannot be determined. In addition, the drift may not be linear, e.g., due to rapid temperature drop while the OBS sinks to the seabed. Here we present an algorithm that recovers the linear clock drift, as well as a potential timing error at the onset.

The algorithm presented in this study exploits seismic interferometry (SI). Specifically, time-lapse (averaged) cross-correlations of ambient seismic noise are computed. As such, virtual-source responses, which are generally dominated by the recorded surface waves, are retrieved. These interferometric responses generate two virtual sources: a causal wave (arriving at a positive time) and an acausal wave (arriving at a negative time). Under favorable conditions, both interferometric responses approach the surface-wave part of the medium's Green's function. Therefore, it is possible to calculate the clock drift for each station by exploiting the time-symmetry between the causal and acausal waves. For this purpose, the clock drift is calculated by measuring the differential arrival times of the causal and acausal waves for a large number of receiver-receiver pairs and computing the drift by carrying-out a least-squares inversion. The methodology described is applied to time-lapse cross-correlations of ambient seismic noise recorded on and around the Reykjanes peninsula, SW Iceland. The stations used for the analysis were deployed in the context of IMAGE (Integrated Methods for Advanced Geothermal Exploration) and consisted of 30 on-land stations and 24 ocean bottom seismometers (OBSs). The seismic activity was recorded from spring 2014 until August 2015 on an area of around 100 km in diameter (from the tip of the Reykjanes peninsula).