Evaluating and correcting short-term clock drift in data from temporary seismic deployments

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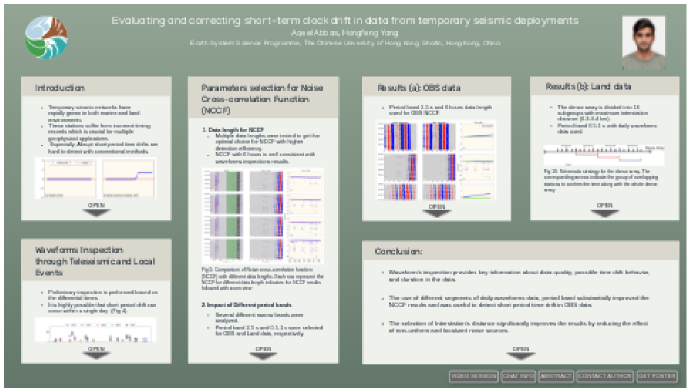
Abstract

Temporary seismic network deployments are quite common both in land and offshore. The acquired data have significantly helped improve our understanding of earthquake processes and internal structure of the Earth. However, some temporary stations, especially these all-in-one units without external GPS timing system, suffer from incorrect timing record and thus pose a challenge to fully utilize the valuable data. To inspect and fix such time problems, ambient noise cross-correlation function (NCCF) is widely adopted by using daily waveforms. However, it is difficult to identify short-term time drift after stacking the NCCF output for several days to months. To detect such clock errors, travel times of local and distant earthquakes are utilized along with NCCF. We apply such a strategy on an Ocean Bottom Seismograph (OBS) dataset from southern Mariana subduction zone and a dataset from a temporary dense network from Weiyuan shale gas field, Sichuan, China. By inspecting travel times from local and distant events, we identify a very short-term clock drift (˜25 sec) on the OBS data that was not detectable using NCCF only. To overcome the problem, short segments (3, 6, 12 hours) of daily wavefrom data is inspected as clock errors become stable within the selected segments. In addition, the data quality is carefully inspected with impact of different interstation distance and period band on NCCF. In particular, we find that the 6-hour segment with a period band of 2-5 sec is able to detect and correct short term changes, including linear drift. For the dense array data, we observe that NCCF symmetry is well-preserved for short interstation distance (within 1 km) but becomes distorted for larger interstation distances. Therefore, we split our dense array (79 stations) into 16 groups with a maximum interstation distance of 500 meters and 1-2 sec period band was selected after testing. Short data segments improve the time-drift detection efficiency in NCCF results, which is consistent for both local and distant events. In a nutshell, the carefull selection of data length and NCCF parameters can be helpful to identify and correct the time drift errors of temporary seismic stations.

Evaluating and correcting short-term clock drift in data from temporary seismic deployments



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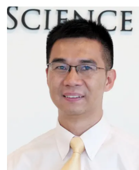

PRESENTED AT:

INTRODUCTION

- Temporary seismic networks have rapidly grown in both marine and land environments.
- These stations suffer from incorrect timing records which is crucial for multiple geophysical applications.
- Especially, Abrupt short period time drifts are hard to detect with conventional methods.

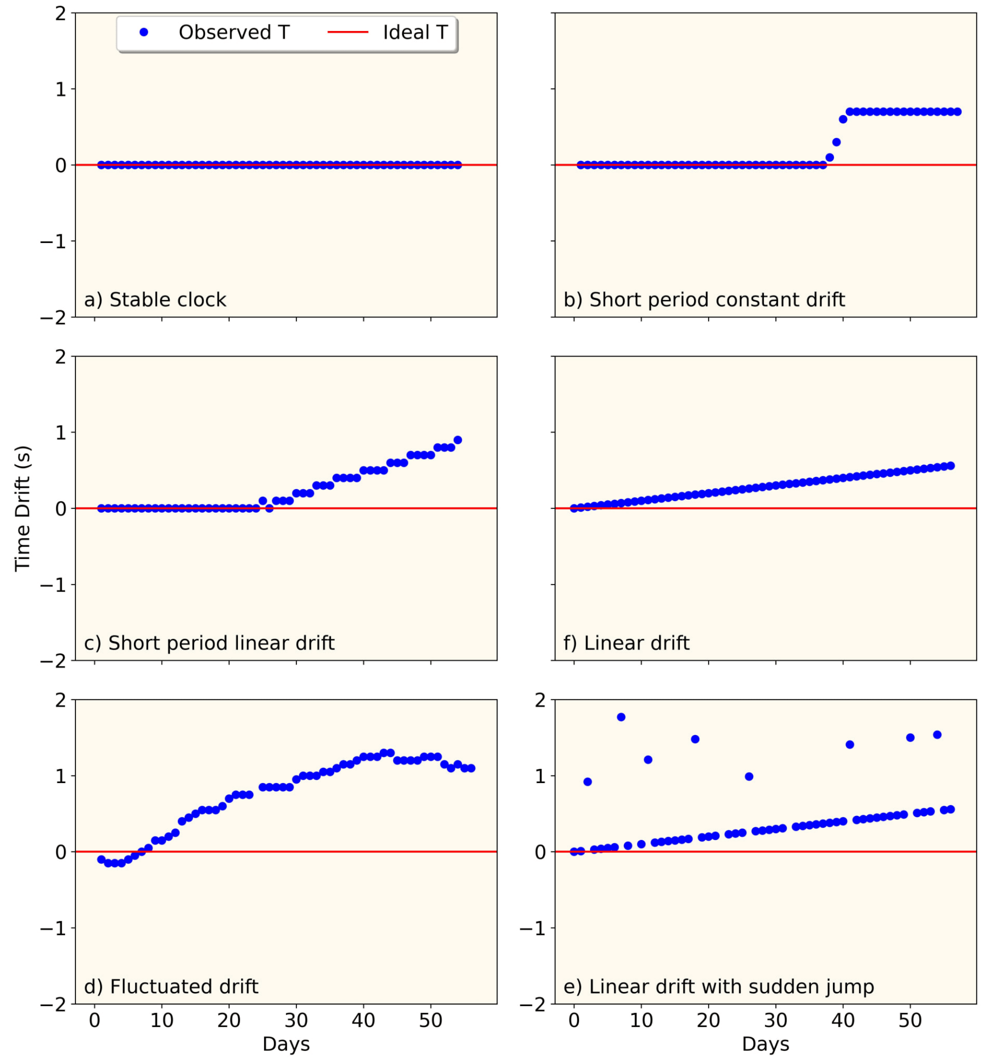

Fig.1: All the potential timing problems, detected in both Ocean Bottom Seismometer (OBS) and Land stations.

Study Area:

We analyze the data collected during an OBS deployment in the southern Mariana subduction zone and a temporary dense network in the Weiyuan shale gas field in the Sichuan Basin, China.

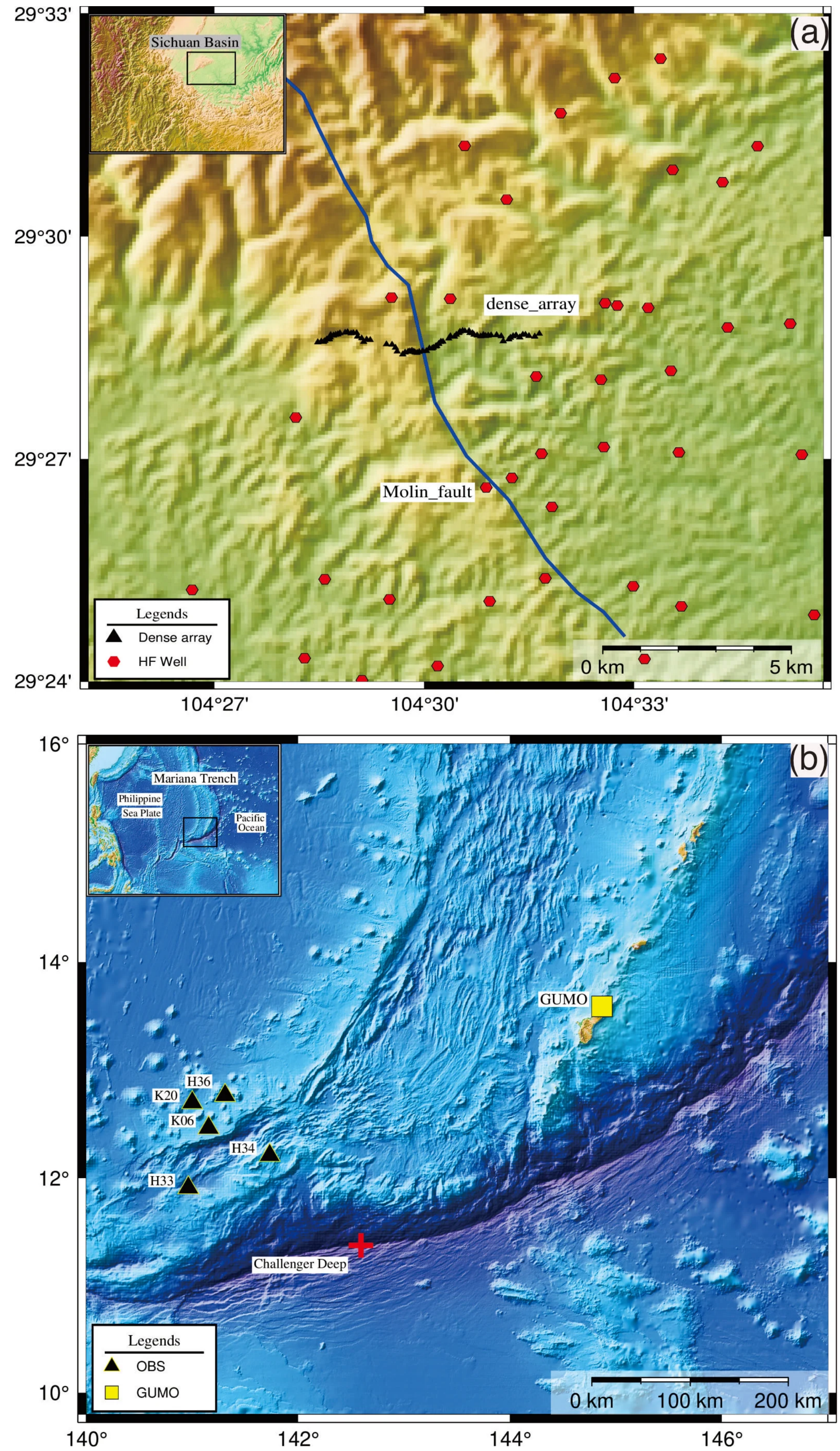

Figure 02: Deployment location of stations in two experiments: (a) dense array along the Molin Fault in Sichuan basin. Blue line, and red pentagon represent Molin Fault and hydraulic fracking wells, respectively. (b) Locations of OBS and GUMO (nearest permanent station) along the Southern Mariana subduction zone.

WAVEFORMS INSPECTION THROUGH TELESEISMIC AND LOCAL EVENTS

- Preliminary inspection is performed based on the differential times.
- It is highly possible that short period drift can occur within a single day (Fig 4).

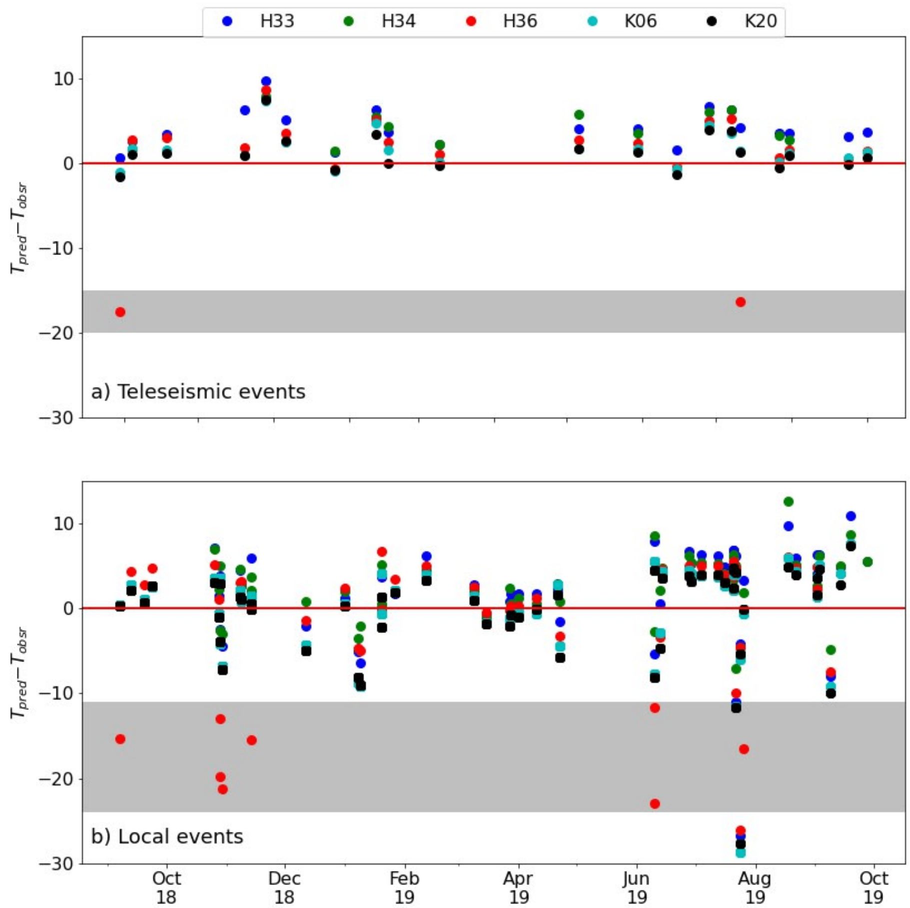

Fig 3: Differential time between observed and predicted arrival time (a) Teleseismic events (b) Local events. shadow color indicates the short-time drift.

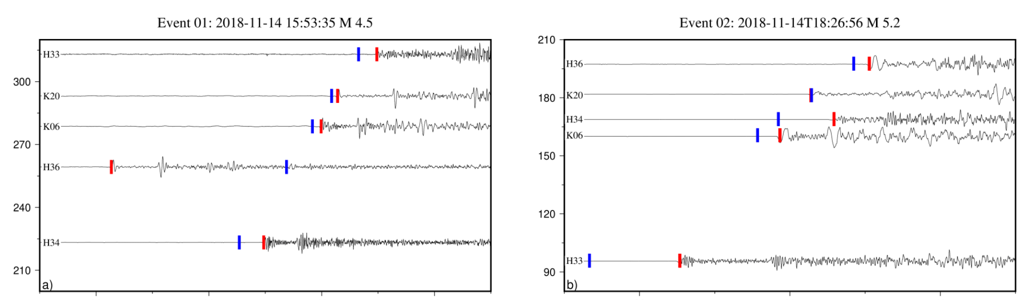

Fig 4: waveforms profiles of two local events, station H36 shows (a) a clear time shift at 15:53 (b) which becomes normally at 18:26 for the next recorded event.

PARAMETERS SELECTION FOR NOISE CROSS-CORRELATION FUNCTION (NCCF)

1. **Data length for NCCF**

- Multiple data lengths were tested to get the optimal choice for NCCF with higher detection efficiency.
- NCCF with 6 hours is well consistent with waveforms inspections results.

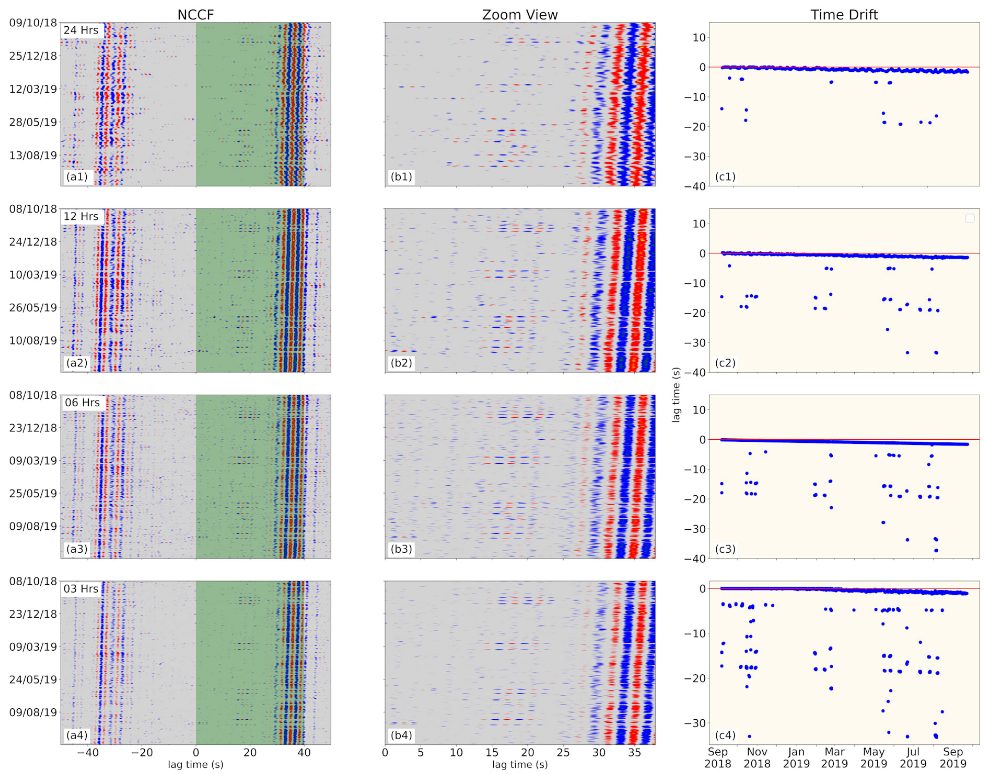

Fig 5: Comparison of Noise cross-correlation function (NCCF) with different data lengths. Each row represent the NCCF for different data length indicates the NCCF results followed with zoom view

2. Impact of Different period bands

- Several different narrow bands were analyzed.
- Period band 2-5 s and 0.5-1 s were selected for OBS and Land data, respectively.

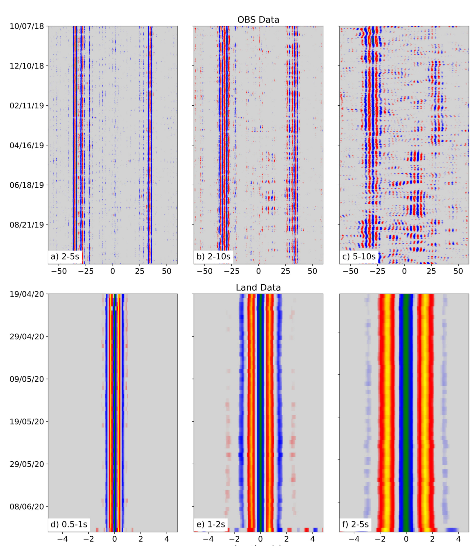

Fig 6: Impact of different period bands on the same pair of OBS and Land Stations.

3. Impact of Interstation Distance (land data)

- Impact of interstation distance on NCCF are analyzed
- Phase symmetry preserved for a short inter-station distance but consistently distorted with the increase in distance

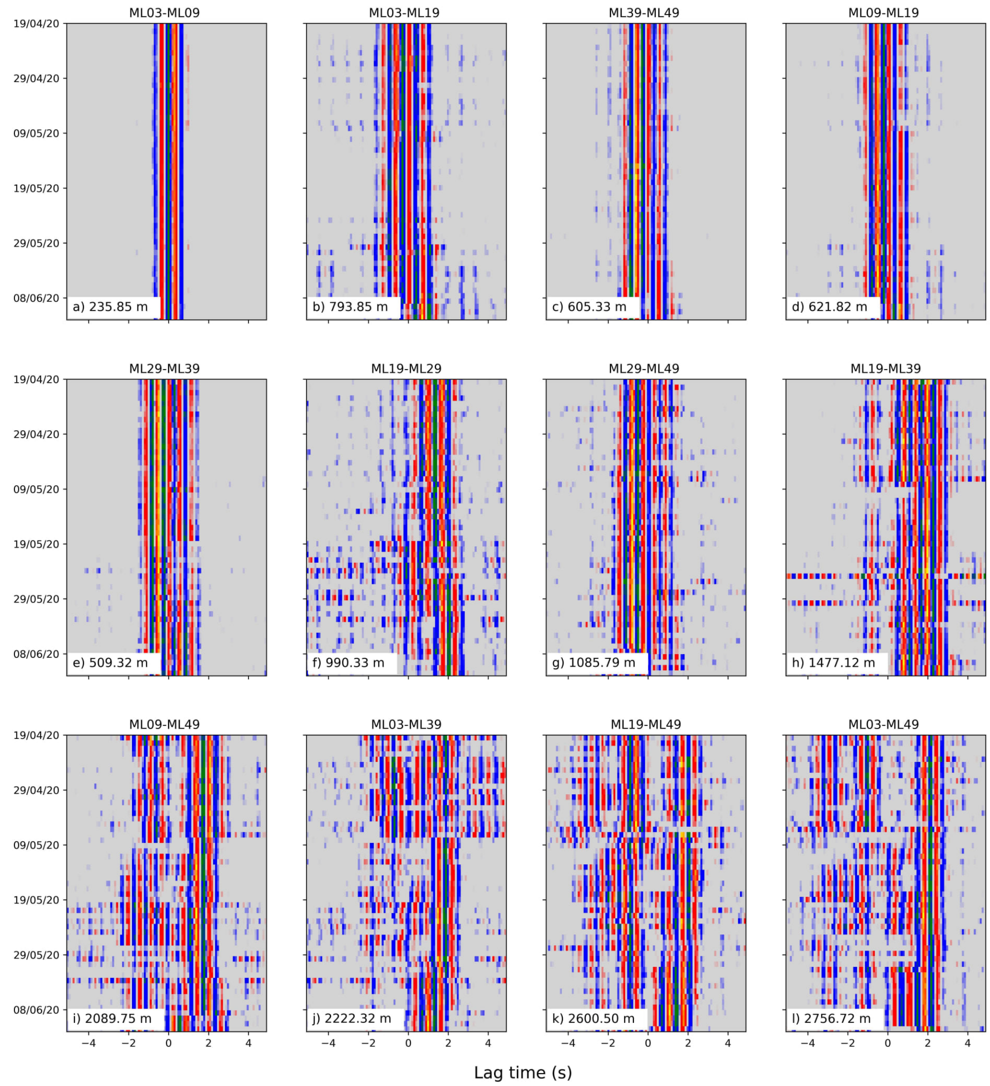

Fig 7: Impact of interstation distance on NCCF. Interstation distance gradually increases from a-l.

4. Influence of different start/end-time or missing data

- Important to differentiate the sharp changes in the NCCF results, whether these are caused by clock error or data issues.

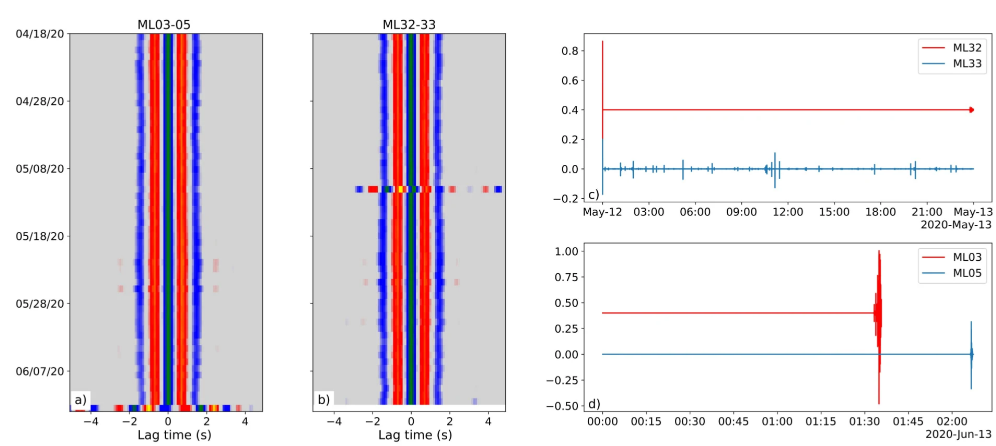

Fig 8: Impact of missing data or different data length on NCCF

RESULTS (A): OBS DATA

- Period band 2-5 s and 6 hours data length used for OBS NCCF.

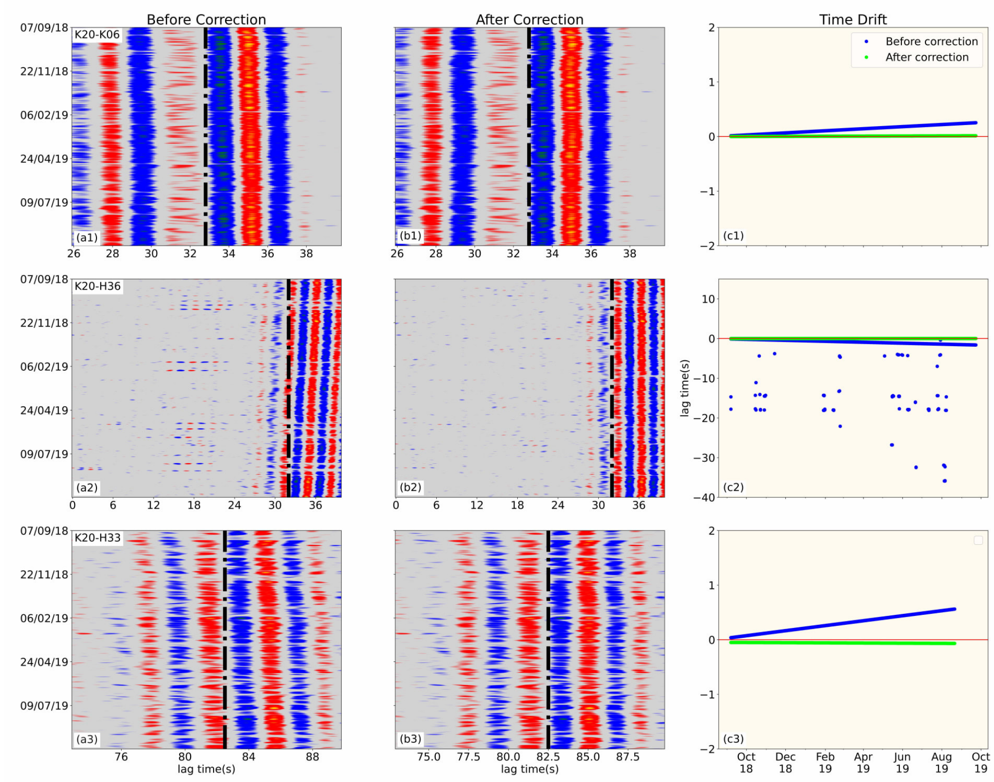

Fig 9: NCCF results in a) Before Correction b) After correction c) drift before and after correction

RESULTS (B): LAND DATA

- The dense array is divided into 16 subgroups with maximum interstation distance (0.3-0.4 km).
- Period band 0.5-1 s with daily waveforms data used.

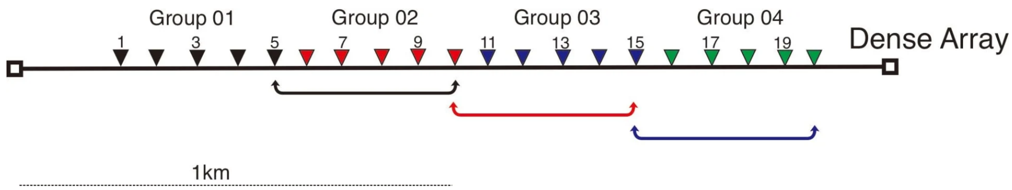

Fig 10: Schematic strategy for the dense array. The corresponding arrows indicate the group of overlapping stations to confirm the time along with the whole dense array

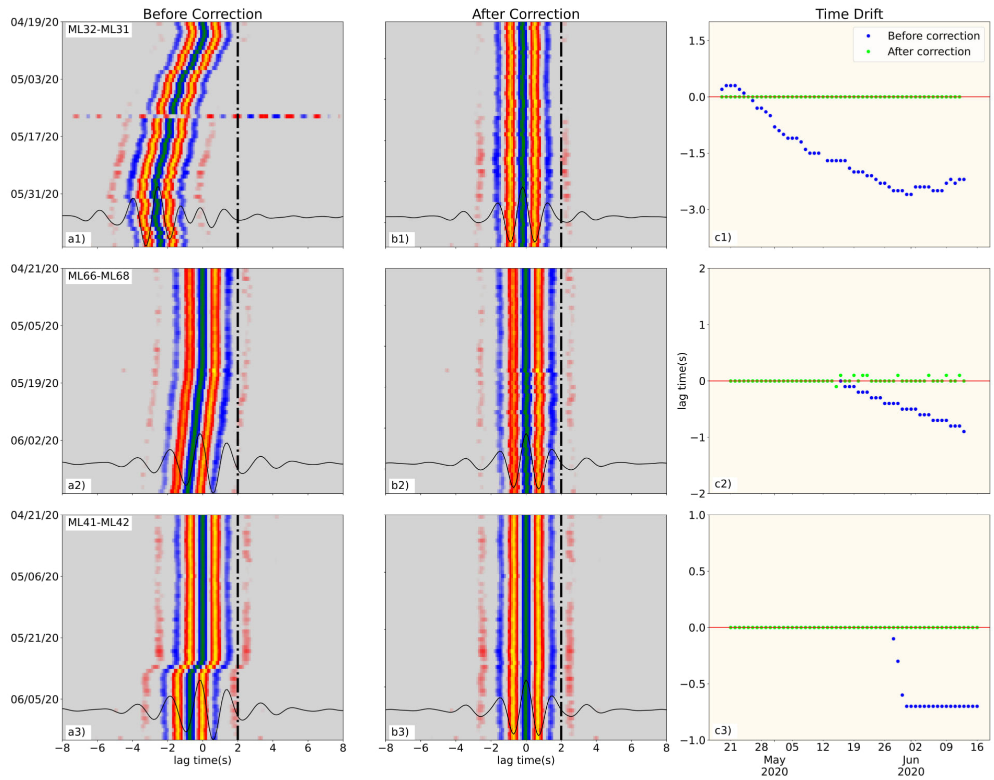

Fig 11: NCCF results a) Before Correction b) After correction and c) time drift before and after correction

CONCLUSION:

- Waveform's inspection provides key information about data quality, possible time drift behavior, and duration in the data.

- The use of different segments of daily waveforms data, period band substantially improved the NCCF results and was useful to detect short period time drift in OBS data.

- The selection of Interstation's distance significantly improves the results by reducing the effect of non-uniform and localized noise sources.

- Inclusively, the preliminary analysis of influencing factors is very imperative prior to NCCF drift correction.

ABSTRACT

Temporary seismic network deployments are quite common both in land and offshore. The acquired data have significantly helped improve our understanding of earthquake processes and internal structure of the Earth. However, some temporary stations, especially these all-in-one units without external GPS timing system, suffer from incorrect timing record and thus pose a challenge to fully utilize the valuable data. To inspect and fix such time problems, ambient noise cross-correlation function (NCCF) is widely adopted by using daily waveforms. However, it is difficult to identify short-term time drift after stacking the NCCF output for several days to months. To detect such clock errors, travel times of local and distant earthquakes are utilized along with NCCF. We apply such a strategy on an Ocean Bottom Seismograph (OBS) dataset from southern Mariana subduction zone and a dataset from a temporary dense network from Weiyuan shale gas field, Sichuan, China. By inspecting travel times from local and distant events, we identify a very short-term clock drift (~25 sec) on the OBS data that was not detectable using NCCF only. To overcome the problem, short segments (3, 6, 12 hours) of daily wavefrom data is inspected as clock errors become stable within the selected segments. In addition, the data quality is carefully inspected with impact of different interstation distance and period band on NCCF. In particular, we find that the 6-hour segment with a period band of 2-5 sec is able to detect and correct short term changes, including linear drift.

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