Submission code: 608M94D8BL

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Identifying seismic waveforms generated by tidal forces in the Pará River estuary

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Abstract

In passive seismic surveys, a large volume of data is recorded from different types of sources such as wind, rain, human activities, etc. Identifying and selecting events is complex and time-consuming. This paper presents preliminary results on the detection of seismic waves generated by tidal forces in the Pará River estuary. Here we show that a single station event detection by waveform cross-correlation recognition can be used to produce more waveforms, expanding a catalog for detection of new events.

Introduction

The last decades have witnessed a remarkable growth in the application of passive seismic to address a series of problems ranging from large-scale tectonic studies to environmental monitoring. (EATON, 2018). From the onset one main issue is identifying the seismic signals of interest for the objective, as it is usual to accumulate a great volume of data.

We work here with data from a passive seismic acquisition made in Tatuoca Island (TTB) situated on the Para River, $\approx 11\text{km}$ NW of the city of Belém. The Pará River is an estuary subject to high-amplitude tidal variations, modulated seasonally by climate, which generate intense turbulent flow during the high-gradient tide phases.

Three qualitatively distinct and interconnected zones develop in the interfacial layer with the rough substrate of the river flow: a thin layer, dominated by viscosity, in direct contact with the substrate, followed by a transition layer and ending with an external layer, dominated by turbulence, in contact with the atmosphere through a free, deformable surface.

There is a very drastic change in velocity in the viscous layer, with thickness varying from a fraction of one mm to several mm, the mixing of the turbulent flow at its top by diffusion, while at the interface with the substrate both the velocity and the shear stress become zero; $\mathbf{u}\,(z = 0) = 0$ and $\tau = 0$. In this layer occurs the transformation of the turbulent flow energy to seismic energy through the frictional forces on the roughness of the substrate, which propagate through the rocks. The seismic source mechanism is represented by the chain of events tide $\rightarrow$ energy transfer from the turbulent flow to substratum $\rightarrow$ seismic wave propagation. The morphology of the river bed conditions the propagation of the tidal wave and the dynamics of the riverine floods and, by consequence the location of the seismic sources in the river.

In this work we show an effective way to detect events recorded in TTB using the similarity of waveforms of known event(s), or template(s), for single-station triggers. An arbitrary number of template waveforms can be provided for any station. The main computational rests on the need to evaluate cross-correlations.

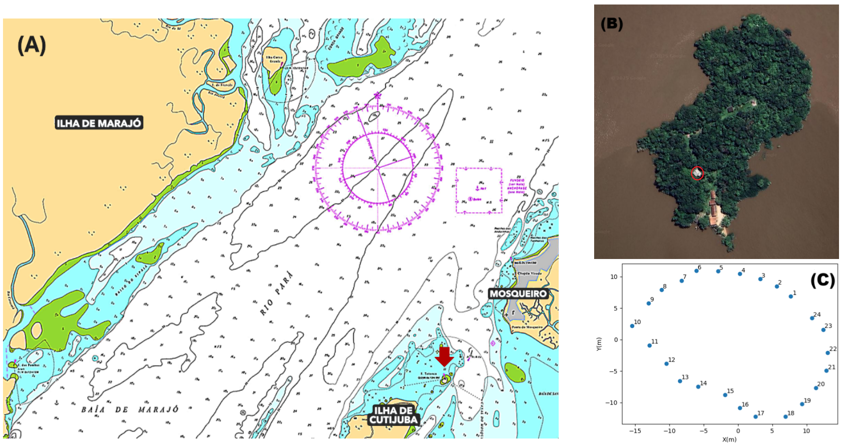

Figure 1: **(A)** Location of TTB on a bathymetry map of the Pará River. **(B)** The gather location of the gather is marked with a red circle. **(C)** The seismic gather with 24 geophones.

The Dataset

The data was obtained during a passive seismic acquisition in TTB, a region subject to intense variations and large tidal amplitude, which can reach $4\mathrm{m}$. We used a Geode seismograph with 24 vertical $10\mathrm{Hz}$ geophones distributed on a more or less circular gather with a diameter of $20\mathrm{m}$, located in the southern portion of the Island, refer to Figure 1. We can assume the gather is surrounded by a diffuse $360°$ distribution of sources on the riverbed. Traces were obtained continuously with a sampling rate of $f_s = 250\mathrm{Hz}$, in time windows of $60\mathrm{s}$. The flow of the Pará River produces seismic events, with measurable energy in the frequency range $[10, 125]\,\mathrm{Hz}$.

Figure 2 shows a seismogram of the 24 geophones, with a strong conspicuous event at $20\mathrm{s}$, as well as a zoom of it showing the arrivals of the waveforms. Other events can be seen in the same seismogram at later times. Judging by the timing of the phase arrivals on the zoomed panel of Figure 2 the source is at NE of the gather. We have used Figure 3 shows a cut of geophone 2 displaying the waveform of the prominent event zoomed in Figure 2. Here we show the triggering results obtained using this template waveform.

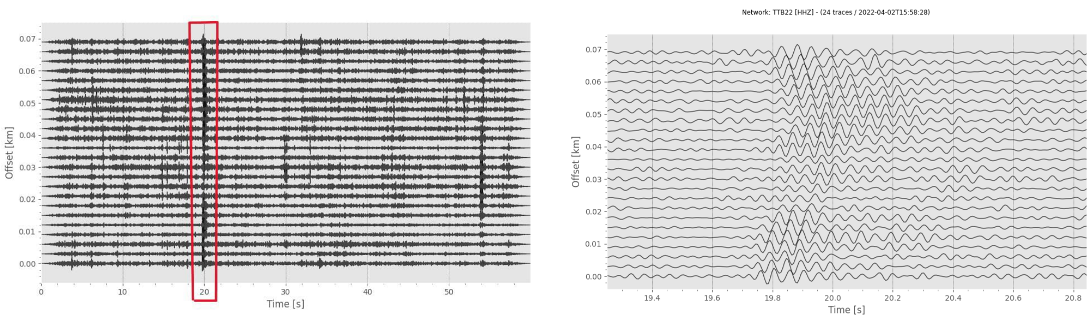

Figure 2: Left panel: a seismogram showing several events. Right panel: zoom of the event highlighted with a red rectangle.

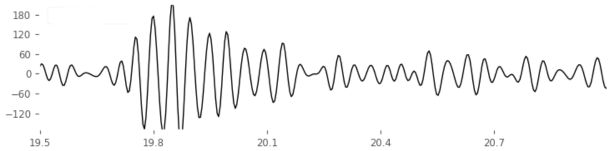

Figure 3: Waveform of the prominent event zoomed in Figure 2 in geophone 2.

Results

A cross-correlation detector takes one or more template events or a synthetic template and computes the cross-correlation with sliding windows on the data set. Here we use a cut of the waveform shown in Figure 3 as our template to detect other waveforms build a catalog of events. This system of event detection using correlation of waveforms(Lewis, 1994) is widely used in the identification of earthquakes (Arrowsmith et al., 2016).

Figure 4 shows the result of the cross-correlation triggering mechanism in two other geophones. The trigger is capable of identifying other events in the traces. Figure 5 shows the events the trigger was able to detect on the sismogram of Figure 2. With those events it is possible to construct a catalog of events shown in Figure 6. This expanded catalog can then be used to trigger more events.

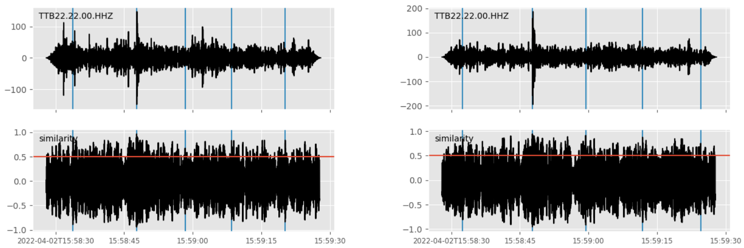

Figure 4: Events triggered in two distinct geophones.

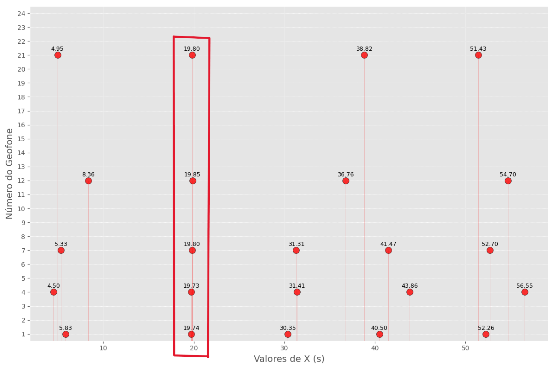

Figure 5: Events detected on the sismogram of Figure 2 with the waveform shown in Figure 3.

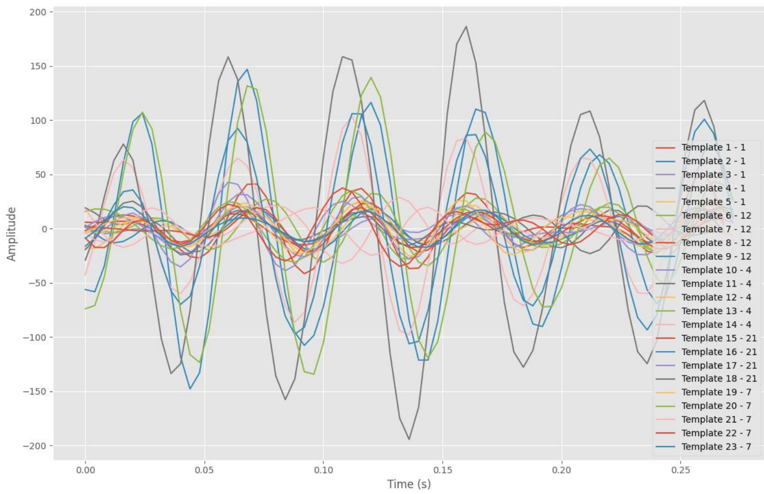

Figure 6: Catalog of waveforms, created with the events detected in the sismogram.

Conclusions

The reliable automatic detection of seismic events still poses great challenges if only few sensors record an event and/or the signal-to-noise ratio is very low. The single station event detection by a comparison of waveform cross-correlation recognition can be used to produce more waveforms in a straightforward way. The technique used here proved effective in detecting new wave patterns, increasing the number of waveforms in a given catalog, even in the presence of important amplitude and phase variations.

References

Arrowsmith, S. J., C. J. Young, S. N. Ballard, M. E. Slinkard, and K. L. Pankow, 2016, Pickless event detection and location: The waveform correlation event-detection system (wceds) revisited: Bulletin of the Seismological Society of America.

EATON, D. W., 2018, Passive seismic monitoring of induced seismicity fundamental principles and application to energy technologies: University of Calgary.

Lewis, J., 1994, Fast template matching: Vis. Interface.