Seismic velocity changes in the epicentral area of the Mw 7.8 Pedernales (Ecuador) earthquake from cross-correlation of ambient seismic noise

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Introduction

- Temporal variations in the elastic behavior of the Earth’s crust can be monitored through the analysis of the Earth’s seismic response throughout time.
- Seismic noise allow us to retrieve seismic Green’s functions from the cross-correlation of records of a random seismic wave-field.
- Noise is recorded continuously and does not depend on earthquake sources.
- CC functions are analogous to records from continuously repeating doublet sources placed at each station, and can be similarly used to extract observations of variations in seismic velocities.
- On 26 April 2016, a Mw 7.8 megathrust earthquake affected the central-north Ecuadorian margin.
- Our goal is to explore the crust’s response to the mainshock by analysing CC functions of ambient seismic noise.

Data

- Raw waveforms from Permanent Ecuadorian Network [1] and from Pedernales Aftershock Deployment [2].
- Instruments correspond to a mix of broadband and intermediate-period sensors. Short-period marine and land stations were not considered.
- Data availability from Permanent Network is scarce, whilst the Temporary Deployment recorded quasi-continuously between mid-May 2016 to May 2017.

Methods

1. Pre-processing

- Daily merged traces (2 component)
- We use code package Whisper [3]
- Resample daily records to 2 Hz.
- BP-filter 1-40 s (0.025 – 1 Hz)
- Glitch correction (6/30)
- Spectral whitening
- Glitch seismicity (3/11)
- 1-bit normalization

2. Cross-correlations

- Daily cross-correlation windows of 240 s.
- Stacking of periods of 20 days with overlapping of 80%

3. Calculation of relative velocity variations

We use Moving Window Cross Spectral Analysis (MWCS) [43], in turn based on the Doublets method [5]. The goal is to determine transient changes in travel-times between a reference cross-correlation function CCref and a current cross-correlation function CCor. These changes are proportional to those in the velocity field such as that:

\[ \frac{\Delta t}{\Delta v} = \frac{v}{v + c} \]

Errors are estimated following [6].


4. Inversion of relative velocity variations

We performed a Bayesian least-squares matrix inversion following [7], avoiding the use of an arbitrary reference function and thus improving the robustness of our results.

Results and Discussion

- Steep decrease of velocities from the beginning of the studied period (mid-March 2016) to mid-May
- Steady increase of velocities (recovery) from mid-May 2016 until December 2016
- Increase flattens out from December 2016 onwards
- Geographical distribution from single-station inversions shows larger amplitudes of velocity decrease in front of the rupture area and towards the south along the coastline
- Velocity changes interpreted as the crust’s response to the dynamic/static stress changes induced by the Pedernales earthquake
- Velocity variations could be due to the mainshock fracture damage and presence of pressurised pore fluids and/or the action of the ensuing afterslip.

Examples of single-station inversions

Acknowledgments

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References

1. Agurto et al. [2019]. Inversioning shows lateral ambient velocity changes following the 2016 Ecuadorian earthquake.
6. Clowes, R. et al. (2013). Inversion of relative velocity changes observed near the 2010 face.