Seismic attenuation variations from train signals: two case studies

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Introduction

Subsurface physical properties, such as fluid saturation and pore pressure, can be related to temporal changes in the propagation of seismic waves. We can extract the seismic attenuation variations from traffic [1.] or train signals by quantifying the relationship between these variations and the train frequency content. The measured attenuation is compared with environmental observations such as rainfall, temperature, etc. This single-station method allows us to continuously monitor the subsurface, providing new ways to obtain observables that can help better constrain the poroelastic processes related to groundwater dynamics.

Theory

Base on the wave equation propagation: $E_i = \frac{E_o}{r^2} \times \exp(\frac{-2\pi f(x/v)}{Q})$ [2.]

1. We seek to parameterize the attenuation (1/Q), base on its frequency dependence:

$$A(f) = \log(E(f))$$

$$\frac{\partial A(f)}{\partial f} = -\frac{-2\pi x}{Qv} = -\frac{-2\pi x}{v} \times \alpha$$

2. Then we evaluate the variation with respect to a time reference

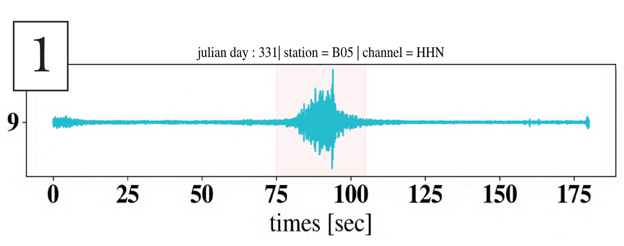
$$\frac{\partial A(f)}{\partial f} - \left[\frac{\partial A(f)}{\partial f}\right]_0 \approx -\frac{-2\pi x}{v_0} \times \Delta\alpha$$

$$where: \Delta\alpha = \frac{1}{Q} - \frac{1}{Q_0};\ v_0 \approx cte$$

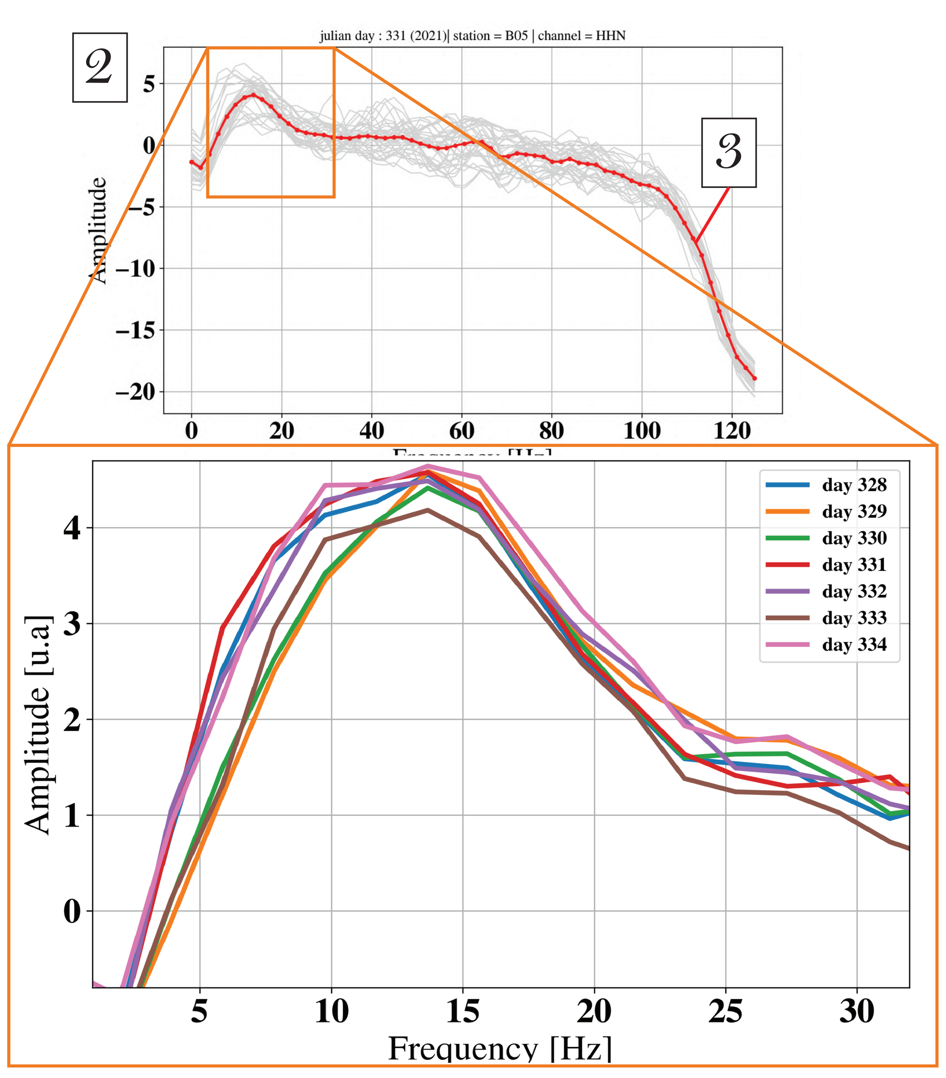
Thus, we retrive the attenuation variation in time base on changes of the frequency content

Methodology

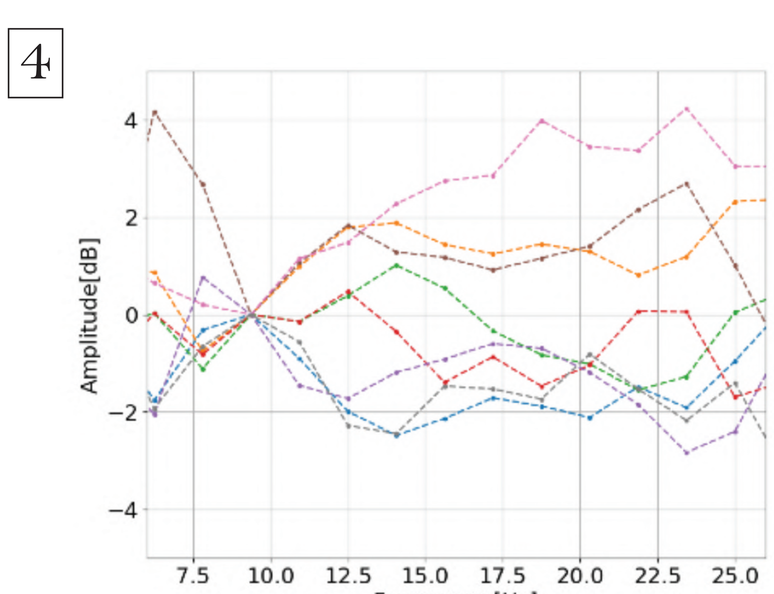
1. Extract train signals.



2. For each train signal, compute PSD.
3. Compute PSD reference as the mean PSD of all trains



4. For each train signal, correct the PSD from the reference PSD selected frequency range.
5. For each train, extract the attenuation variation by doing a linear regression

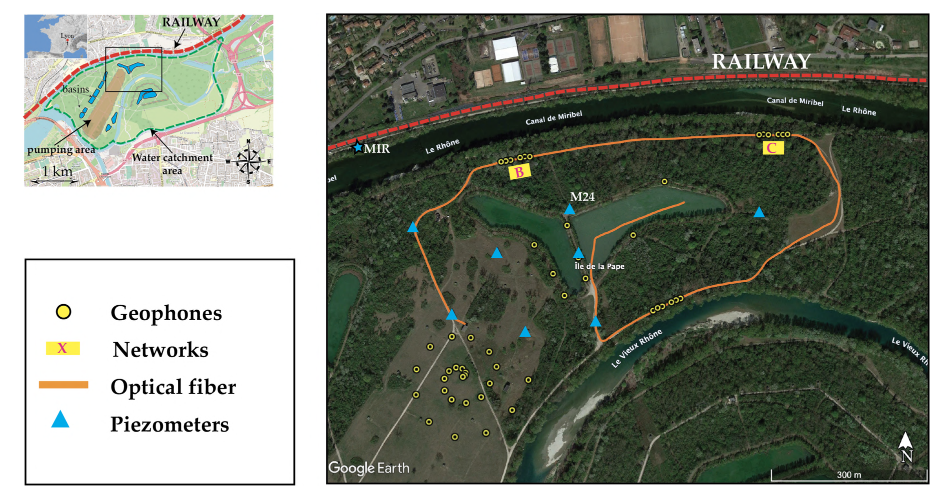


References

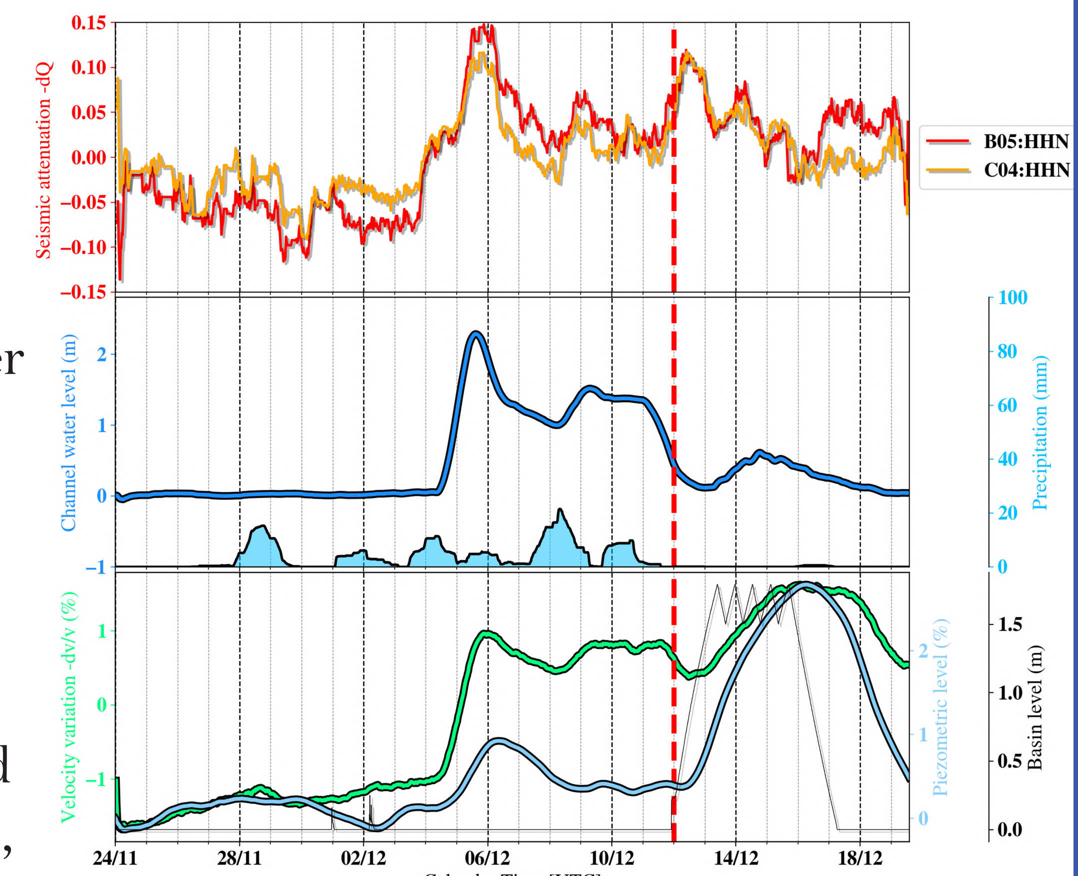
1. T. Clements and M.A. Denolle, 2023
2. Aki and Richards, 2002
3. Y. Zhao et al., 2023
4. Y. Sheng, et al., 2022

Case 1: Lyon water catchment

Context:
- The site covers more than 87% of Lyon's water needs
- Hydraulic dome created artificially and well instrumented
- Temporal and spatial monitoring needed



Processing parameters:
- 26 days of continuous data
- Frequency band: 14 - 24Hz
- On average 35 trains per day
- Temporal resolution 30 min
- 24 hours moving window

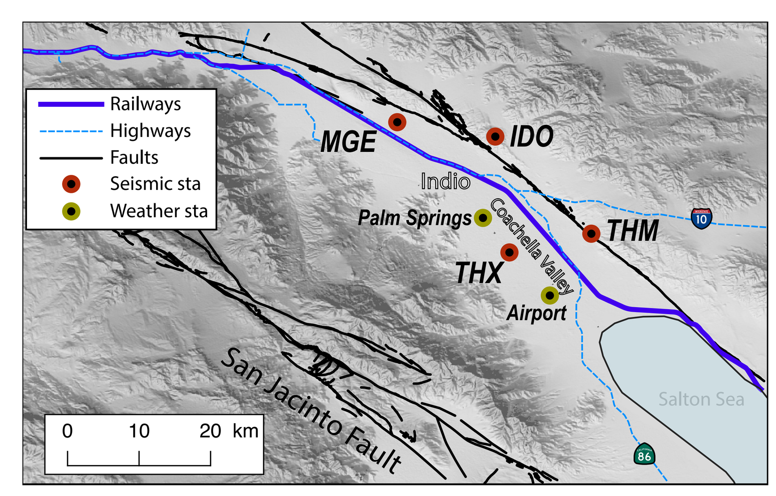


Preliminary Results:
- Variation realeted to the water channel before 12/12
- After 12/12 other parameter controls the attenuation (Basin level?)
- Apparent correlation with dv/v, channel water lever, and piezometric level up to 12/12, then (?)

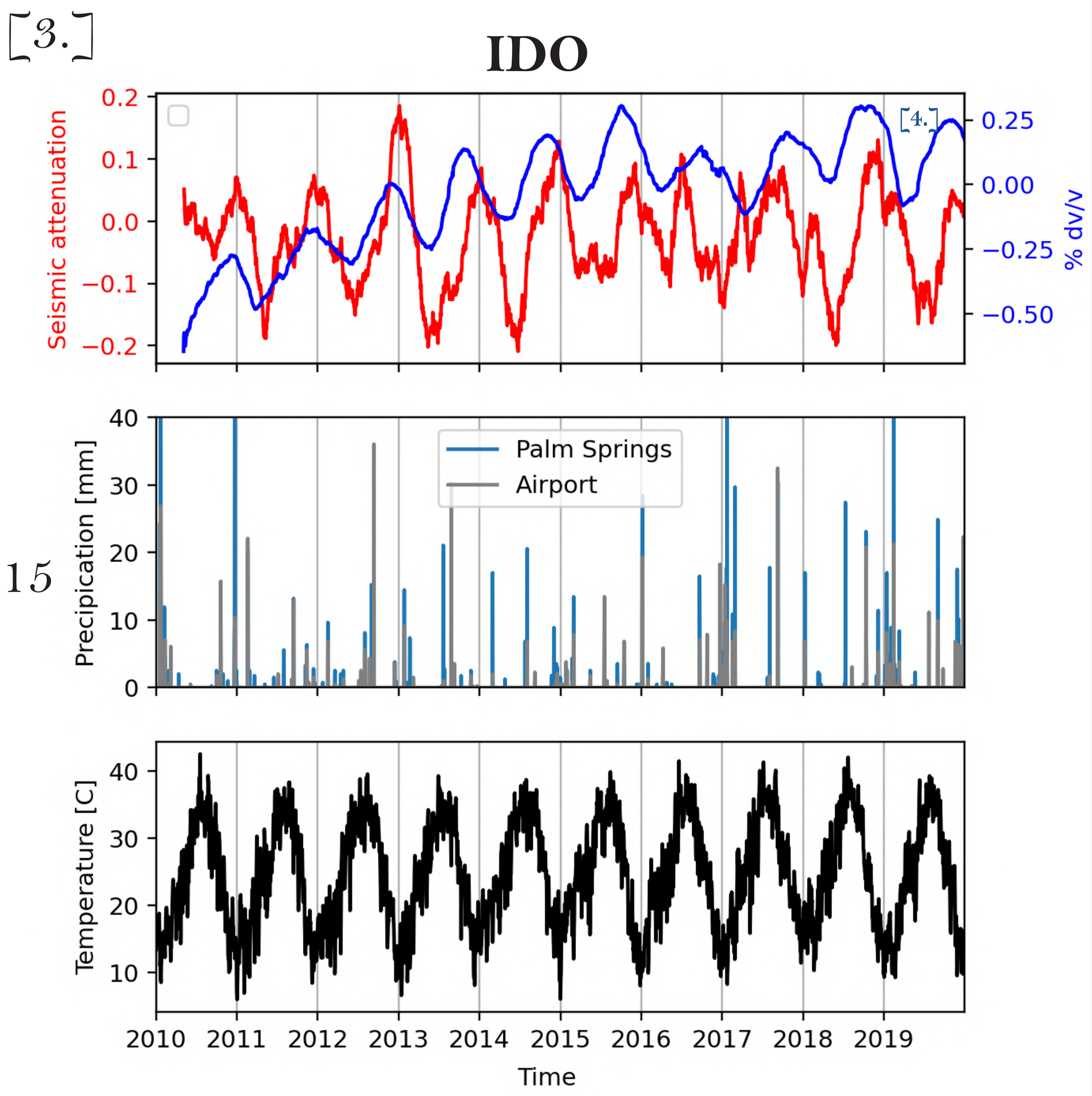
Going Forward
1. Compare with future meassurements (4D tomography)
2. Poroelastic modeling

Case 2: Coachella valley

Context:
- Desertic environment
- Mayor Drough 2012 -2017
- Important groundwater pumping



Processing parameters:
- 10 years of continuous data
- Frequency band: 4 - 6Hz
- On average 3 trains per day [3.]
- Temporal resolution 1 day
- 90 days moving window



Preliminary Results:
- Annual cycles
- Apparent correlation with dv/v (?)
- Amplitude increase 2012-2015
- Amplitude decrease 2016-2018
- Non-apparent long-term trend
- Annual cycle is less visible between 2016-2018 -->drought end (?)

Going Forward
1. Applying the method to the other stations in the valley
2. Poroelastic modeling