Imaging shallow structures in Dublin city using seismic interferometry of seismic body waves generated by train traffic

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General Assembly 2020

#16678

Introduction

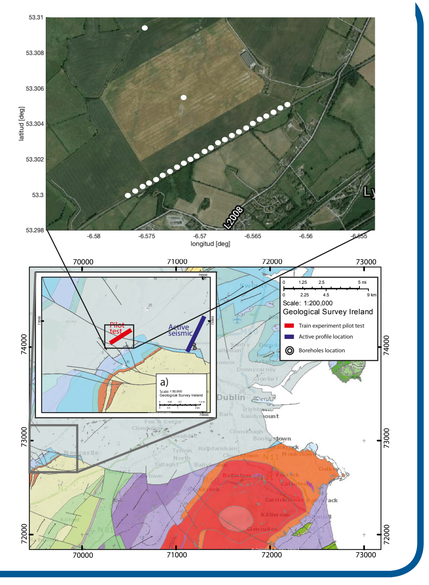
Although train-induced vibrations are mainly regarded as a source of unwanted noise for classical seismological applications, these vibrations act as powerful sources for seismic imaging using seismic interferometry. Most of the seismic interferometry studies to date have concentrated on using the ambient seismic field generated by natural processes but the appropriate use of train-induced vibrations could result in higher resolution images. Here we focus on body wave extraction from train signals.

Deployment and Data

* A pilot study array of 26 seismometers (3-component 1Hz SP sensors; shown by white circles in the figure) recorded railroad traffic data for 3 days along a railway in Dublin, Ireland

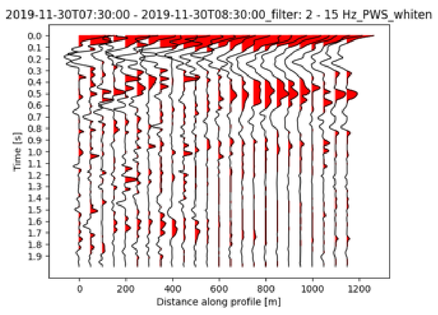
- 24 sensors with 50m spacing, parallel to the railroad and 5m away from it

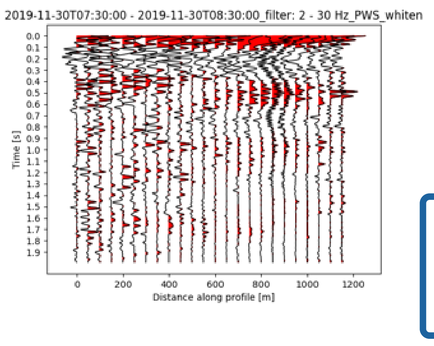
- 2 sensors perpendicular and at 350m and 900m distance to the railroad



Parameters selection

- Cross-correlation of 1hr of data with 6 trains (3 in each directions)





* Bandpass filter 2-15 Hz
* 1 bit normalization
* Phase Weighted Stacking (PWS)
* Noise whitening

Raw data

Select specific time windows (e.i. train passes)

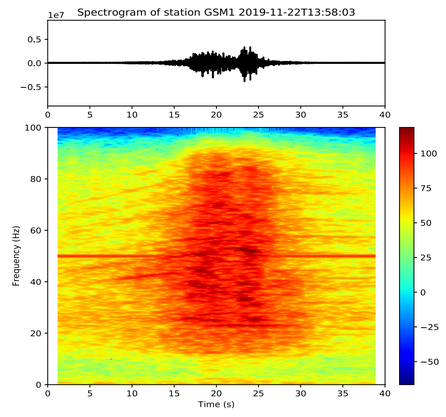
Remove instrument response, Band-pass filter, Noise whitening

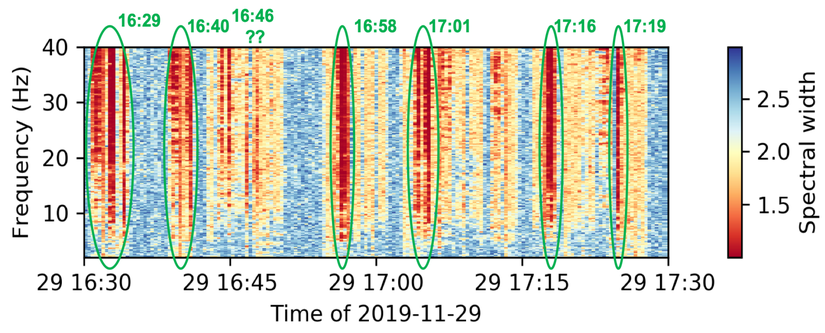
Data normalization

Train detection

Methods:

- Manual detection
- Covariance Matrix method
- Beamforming





- Cargo vs. passenger trains

- Train lengths (e.g. 3-4, 5-6, 7-9, and/or 10-11 wagons).

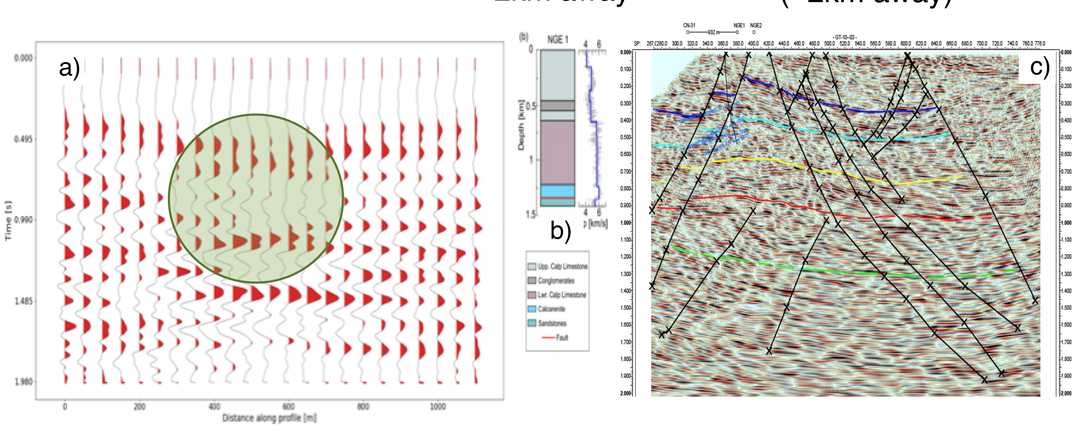
Final result

- We stacked all the 2s time windows that are related to the ~128 train passes to achieve the final reflection section.

- Our result shows 3 main interfaces that are consistent with the nearby borehole and active seismic profile especially in the shallower part.

- In the middle of the profile where the geology map projects a fault our results get disperse and difficult to follow the interface (marked by circle in bellow figure) mostly because of the station spacing of 50m.

Final result | Borehole ~ 2km away | Active profile (~2km away)



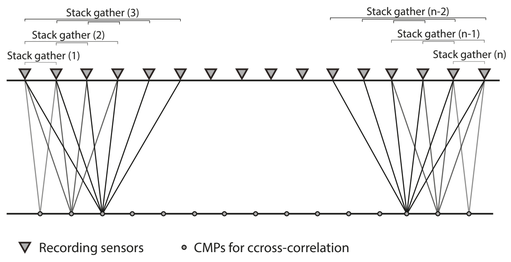
Common MidPoint (CMP) Cross-Correlation

Cross-correlation of each station pair → Clustering for common target point (midpoint) → Sort cluster based on distance of station pair → Normal Move Out (NMO) correction → Stack all the traces in the cluster → Sort the output trace of each cluster based on the location

Stacking resulted CMP-CC sections over time

Final reflection section
(Similar to active seismic images for interpretation)

Schematic view of Common-Midpoint Cross-Correlation (CMP-CC)

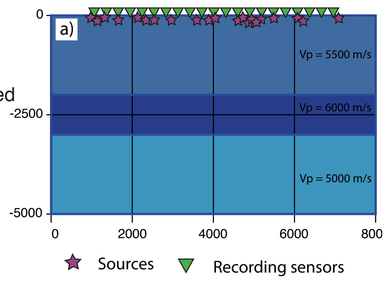


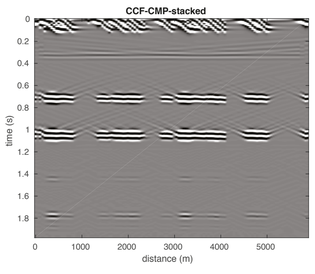
Simple synthetic simulation:

Testing the CMP-CC method

- Simple layered model
- Random noise inside the array
- SPECFEM code

* Reflectors that lie directly below the passing trains are well resolved in these simulation tests. This help inform decisions on data extraction and processing of the real field data.





Outlook

- Use more comprehensive approach to train signal simulation (Lavoué et al, in review; EGU2020-16828)

- More comprehensive investigation of nature of body waves (e.g. P v S) in the whole catalogue

- Undertake full scale field deployment

Acknowledgment

We thanks P. Smith, M. Tsekhmistrenko, M. Möllhoff, S. Subašić, C. Moriarty, M. Smyth, H. Mohamed and C. Horan for their invaluable work, technical support and helping us with the deployment.

Funding

PACIFIC - Passive seismic techniques for environmentally friendly and cost-effective mineral exploration - has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 776622.