ESSSP 2024
地球科學暑期學生專題研究計畫

Characterizing Seismic Background Noises at Taoyuan Guanyin Intertidal Zone Using Ocean Bottom Nodes
解析桃園觀音潮間帶節點式海底震儀

Cheng-You Hsieh* and Pei-Ying Patty Lin
謝承佑 林佩瑩
*rick20030928@gmail.com

Introduction & Objectives

The United Nations strongly supports the goal of net-zero emissions by 2050, and Taiwan is fully committed to reaching this important target.

⟶ Carbon Capture and Storage (CCS) is one of the key strategies to help achieve the net-zero emissions goal.

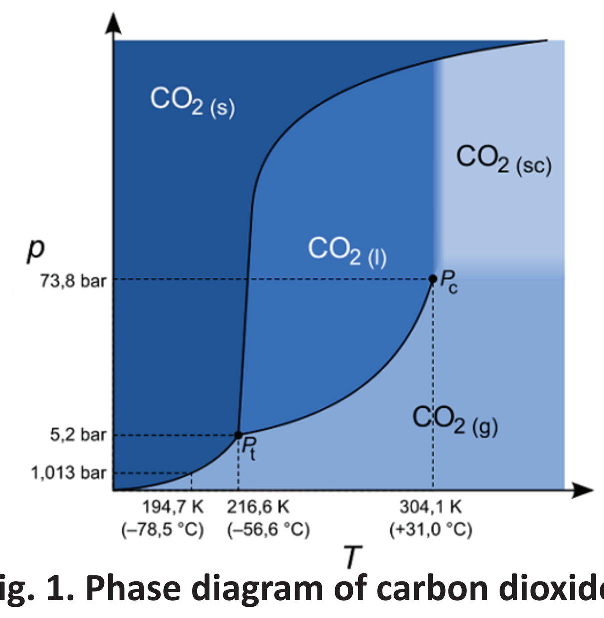


Fig. 1. Phase diagram of carbon dioxide (Nowak & Winter, 2017).

- The target depth for carbon storage is typically **greater than 800 meters**, a depth considered relatively safe, where carbon dioxide reaches a supercritical state (Fig. 1).
- The investigation, evaluation, injection, and monitoring of the offshore carbon sequestration sites require the sub-surface information that can be imaged using seismic waves.

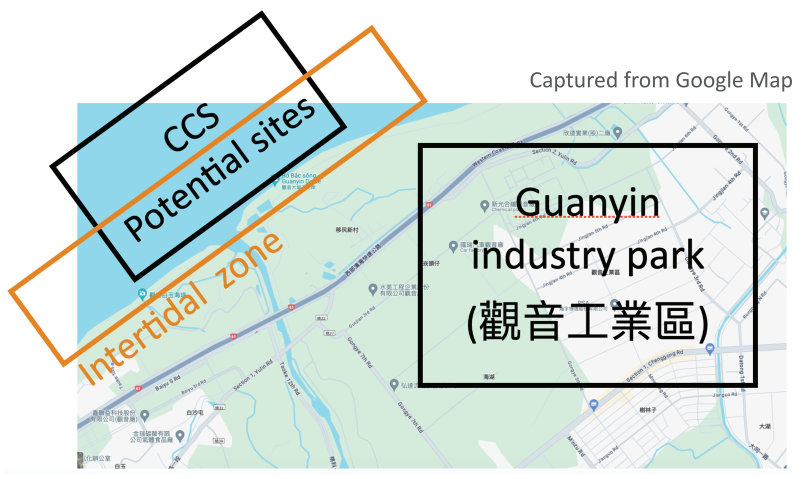


Fig. 2. Taoyuan Guanyin intetidal zone (modified from Google Map, 2004). The Guanyin intertidal zone is a potential candidate for CCS due to its proximity to the Guanyin industrial park.

- However, the intertidal zone (Fig. 2), a transitional area deep beneath and across the coastline, is **a largely unexplored region** due to technological limitations and challenges.

1 Characteristics of seismic signals recorded in the intertidal zone

By deploying active seismic sources, we aim to quantify the propagation distances of various seismic signals and determine the conditions under which the energy can exceed background noise levels and be detected by instruments in the intertidal zone.

2 Response characteristics of various seismic instruments

The objective is to convert data from various instruments and formats into a unified format while ensuring the consistency of physical quantities such as amplitude and phase.

3 Horizontal orientation determinations

Due to the difficulty of verifying instrument orientation in marine environment, so we employed a seismological method to determine horizontal alignment.

3 Types of Seismic Instruments Used In This Work

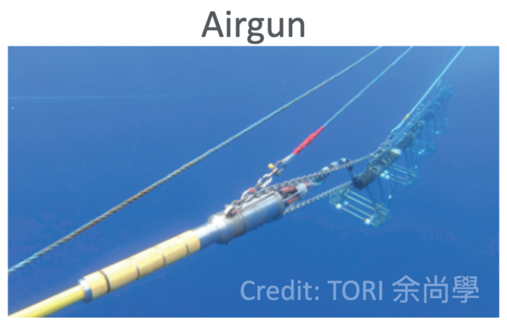
	Smartsolo	GPR	OBN-TW
Suitable deployment environment	Land	Land/Sea	Land/Sea
Sampling rate (Hz)	500	500	400
Sensor types and channels	Velocity sensors: 1 vertical : Z 2 horizontals: N & E	Acceleration sensors: 1 vertical : V 2 horizontals: C & I Pressure sensor	Velocity sensors: 1 vertical : Z 2 horizontals: 1 & 2

- Smartsolo and GPR are commercial instruments, while OBN-TW is the custom-built instrument developed by Dr. Chun-Hung Lin's group in NSYNU.
- Only GPR has a pressure component, allowing us to learn about phenomenon in the water.

GPR signals from active seismic sources

We employed two types of active seismic sources: an airgun array deployed in the ocean and the seismic vibrator vehicle used on land.

Airgun



Vibrator vehicle

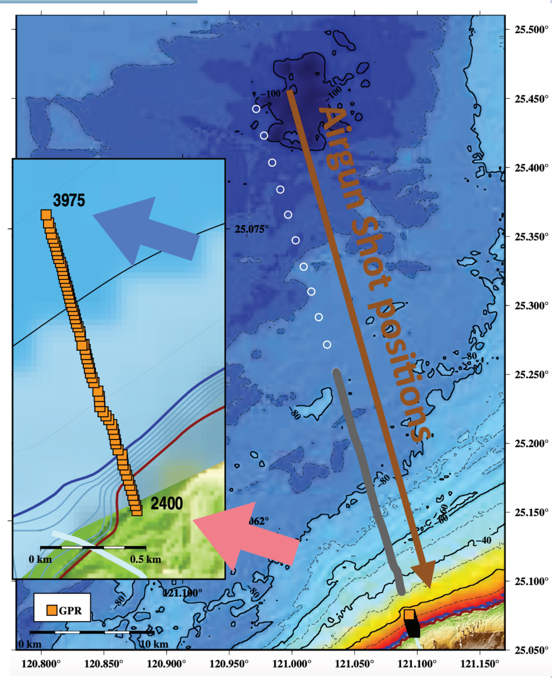


Fig. 3. The map of the airgun-firing and GPR-site locations

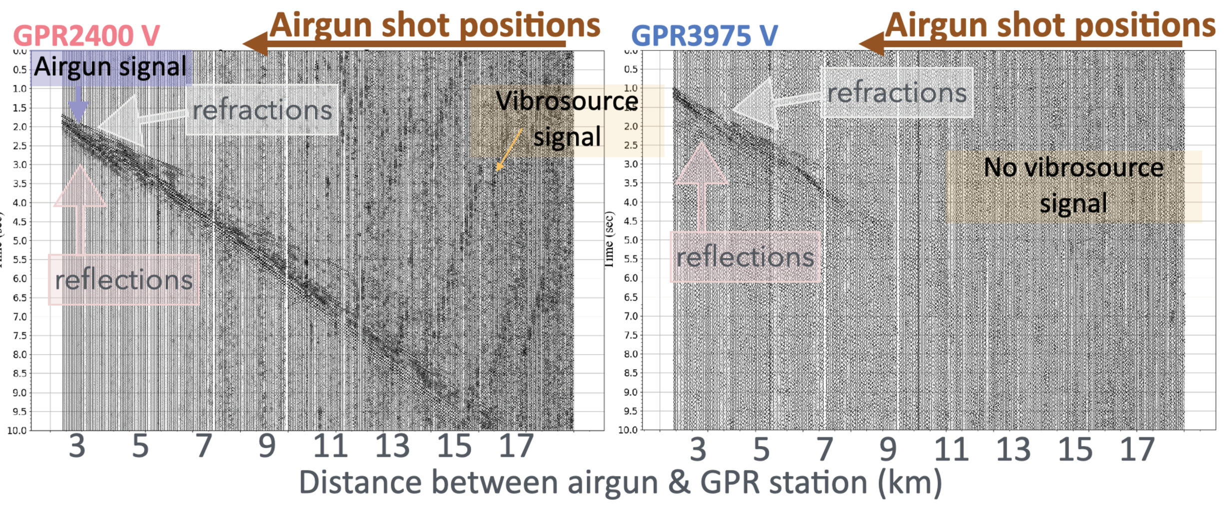


Fig. 4. The time series for GPR2400 and GPR3975 in vertical (V). The y-axis shows the 10 sec after the airgun firing and the x-axis shows the distance between the GPR and the airgun.

- Airgun source can propagate through the whole intertidal zone (Fig. 4.).

With the increased energy output of the airgun source (1240 cubic-in), both refraction and reflection seismic signals were clearly detectable at all deployed GPR stations

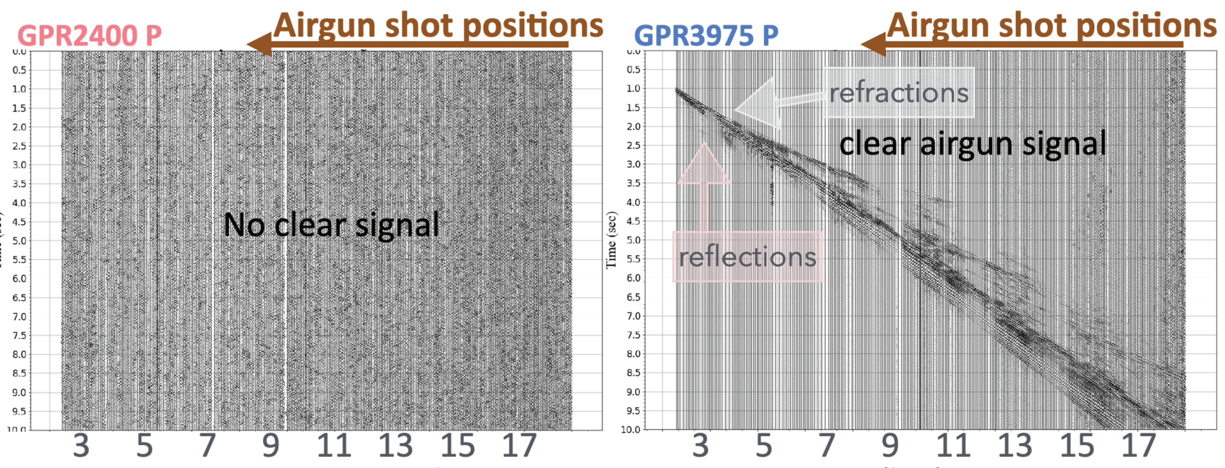


Fig. 5. The time series for GPR2400 and GPR3975 in pressure (P).

- Vibroseis signals were detected at most coastal GPR stations (Fig. 4.).
- The pressure component of the GPR instrument successfully captured the seismic signals generated by the airgun (Fig. 5.).

Data Assimilation in Co-sites Experiments

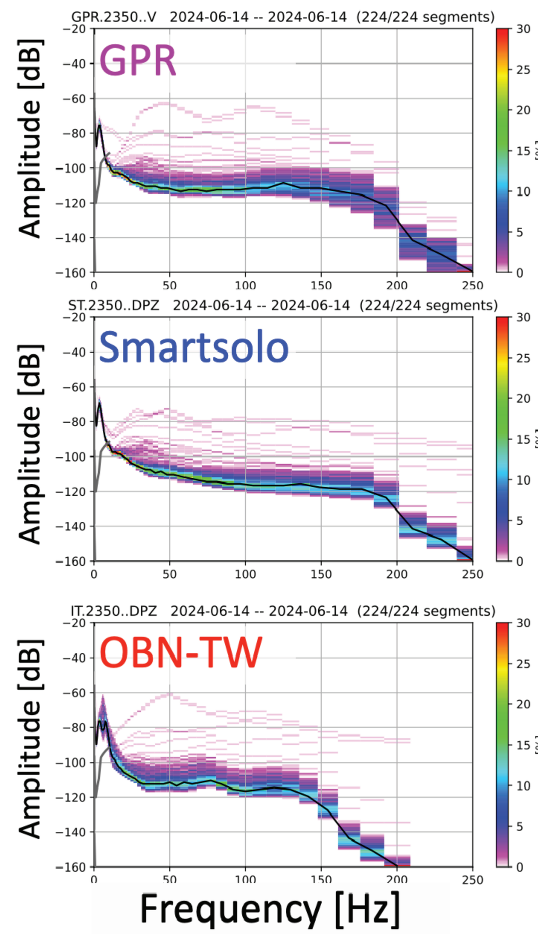


Fig. 6. Probabilistic Power Spectral Density of 3 instruments. The black line in the figure means the mode in each frequency.

Each instrument exhibits distinct characteristics, and by comparing their signal power variations across frequencies, we can highlight both the similarities and differences in their spectral responses.

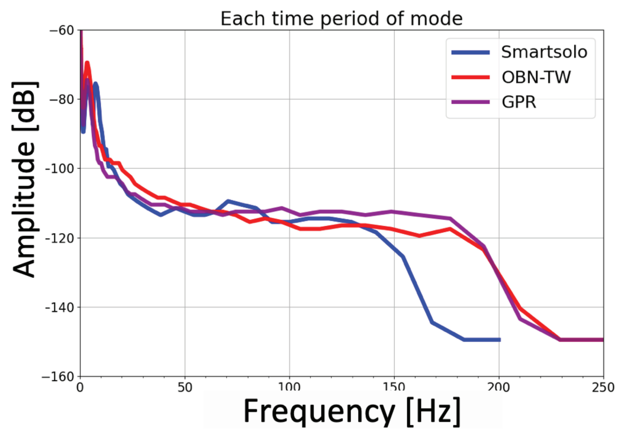


Fig. 7. PSD with highest probability comparing 3 instruments.

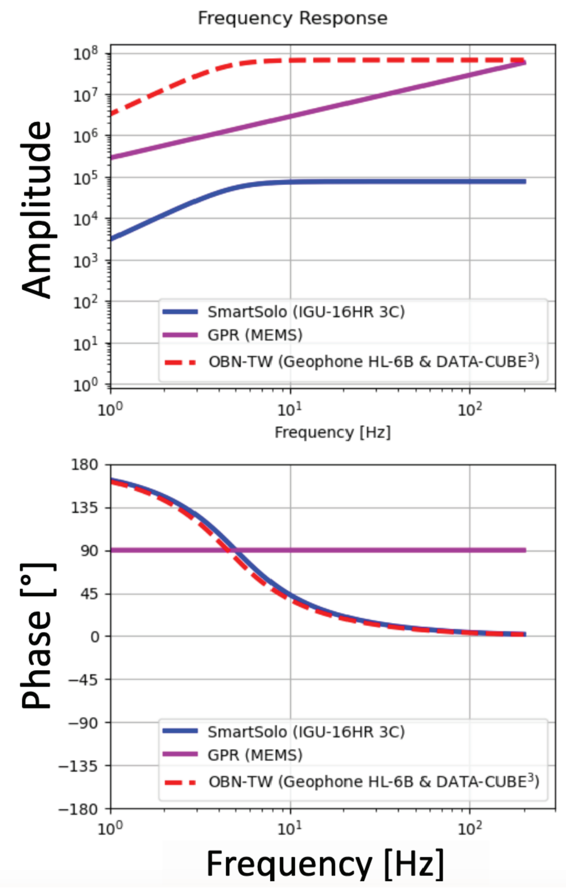


Fig. 8. Instrument response curves

- We successfully determined and validated the instrument responses, confirming consistent amplitude and phase measurements (Fig. 8). This consistency enables direct and reliable comparisons between the instruments.

Horizontal Orientation Determinations

We employ a rotation matrix to rotate the two horizontal components (Fig. 9) and determine the angles that yield maximum coherence between the rotated horizontal and vertical components (Fig. 10) within the 125-175 Hz frequency band. Take GRP3400 as an example, we found the orientation of the instrument in 'I' to be roughly 13° (193°).

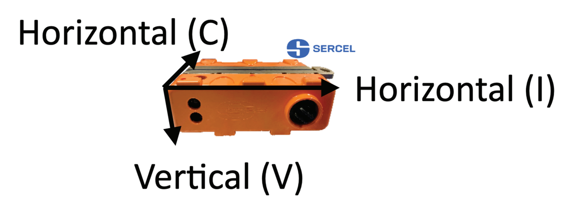


Fig. 9. Definition of each seismic component in GPR

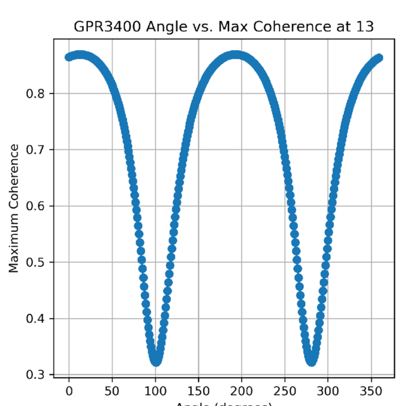


Fig. 10. Maximum coherence found by rotating the horizontal components

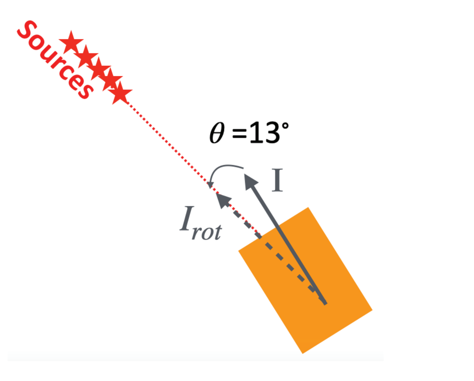


Fig. 11. Alignment of the horizontal component I with the airgun signal after 13° rotation.

Key Points & Future Perspectives

- By calibrating three different instrument types in the frequency domain, we **have verified their responses for accurate amplitude and phase measurement**. This will ensure the reliability and consistency of subsequent seismic analyses.
- During two field expeditions, we **determined the seismic source power required** to penetrate and overcome high background noise levels in the Taoyuan Guanyin intertidal zone. Refraction and reflection seismic signals were clearly detectable at all deployed GPR stations.
- By analyzing the correlation between the vertical component and the rotated horizontal components, we were able to **accurately determine the orientation** of the underwater instrument.
- We plan to **utilize ambient noise analysis** to detect and identify signals caused by tidal and current movements in the future.

References & Acknowledgements

Google Maps. (2024). Retrieved August, 2024, from https://maps.google.com

Nowak, S., & Winter, M. (2017). The Role of Sub- and Supercritical CO₂ as "Processing Solvent" for the Recycling and Sample Preparation of Lithium Ion Battery Electrolytes. Molecules, 22(3), 403. https://doi.org/10.3390/molecules22030403

python GMT ObsPy
NSTC 國家科學及技術委員會 National Science and Technology Council