Les Journées Scientifiques

PROSE+ Project: Seafloor Seismic Measurements Applied to Offshore Wind Geotechnics in Nearshore Areas

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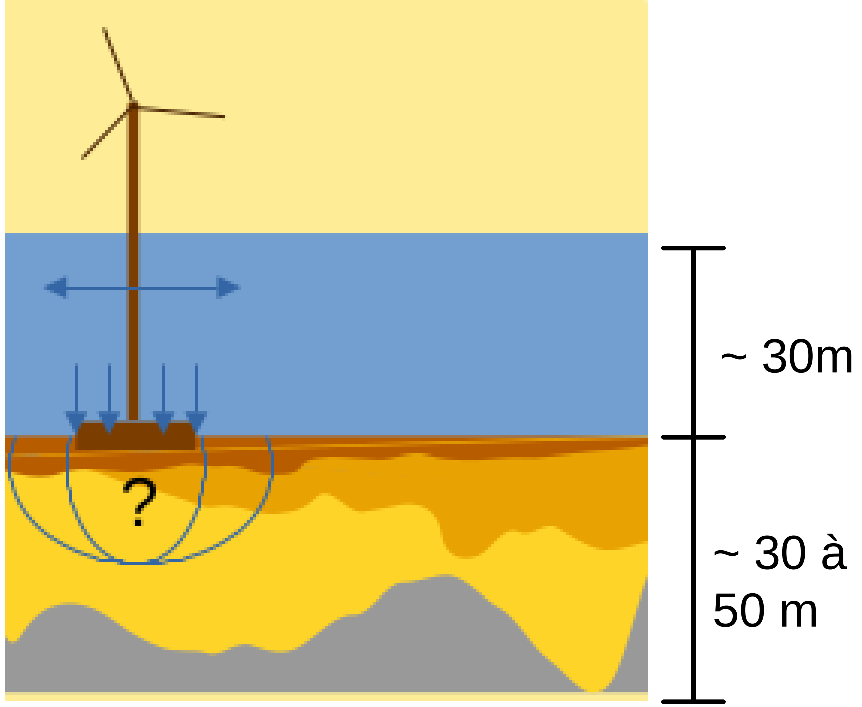
INTRODUCTION AND OUTLINES



Context : Optimize foundations and anchoring systems for subsurface conditions in shallow offshore areas.

Challenge: Borehole geotechnical surveys are expensive and limited to specific areas.

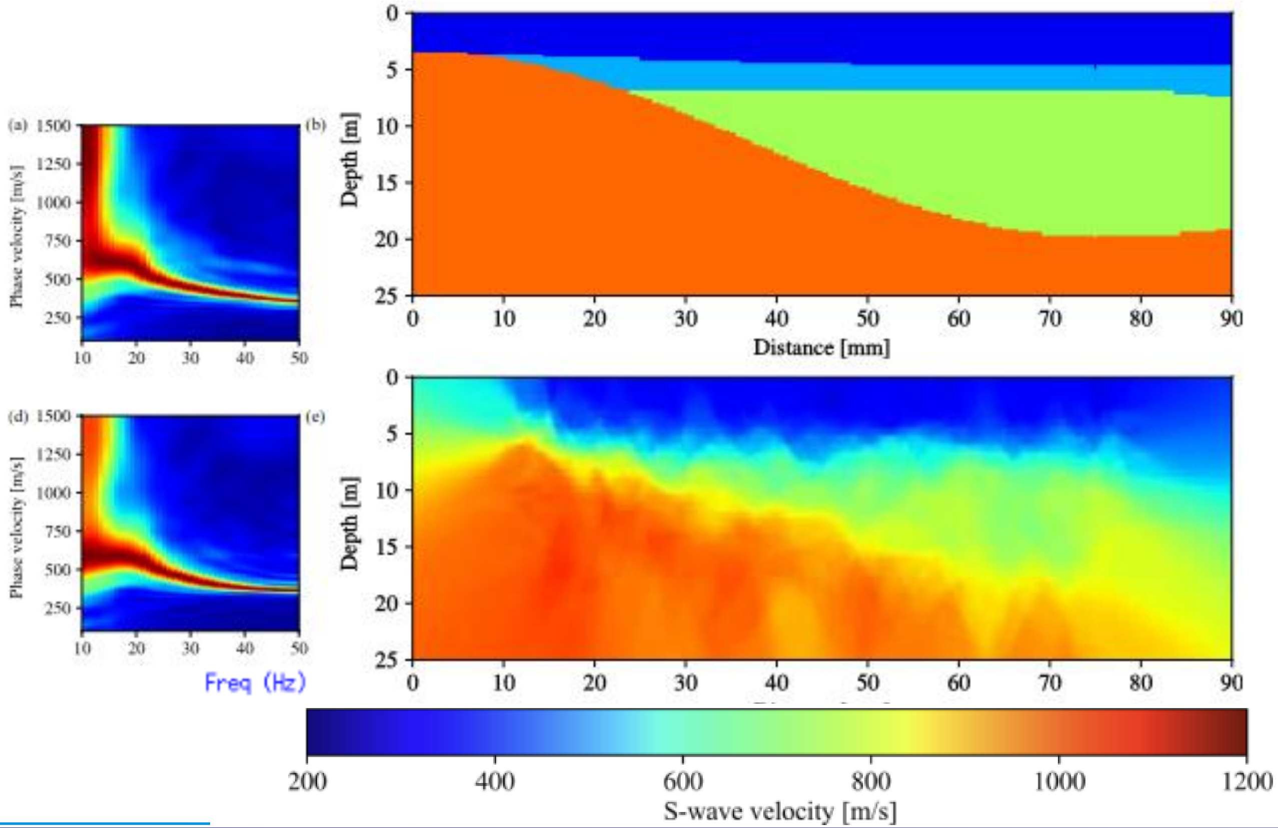
2D Geophysical investigation

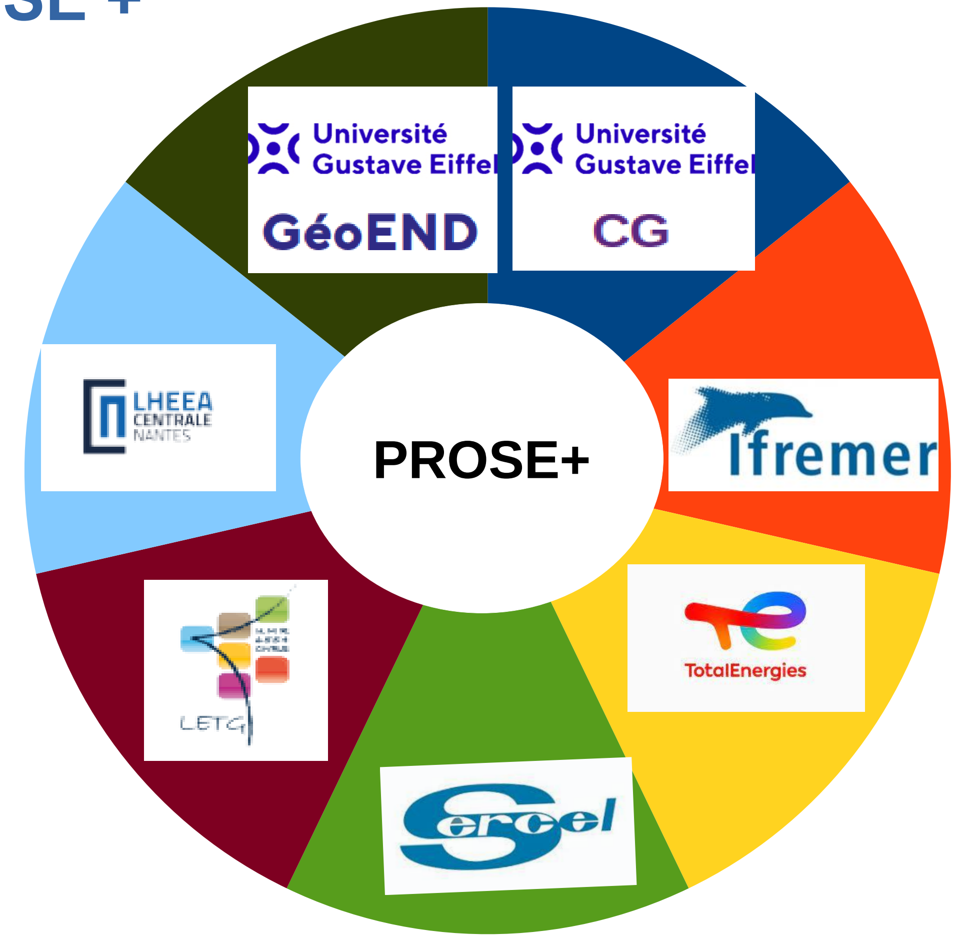
PROSE+ : Develop 2D Shear wave velocity (Vs) for nearshore subsurface imaging

INTRODUCTION AND OUTLINES

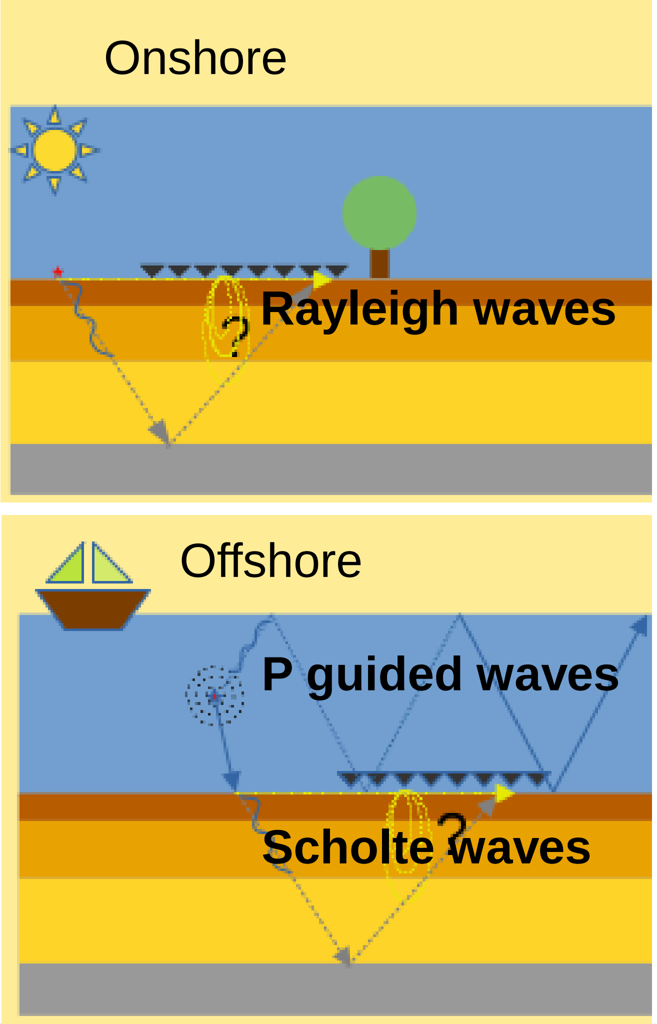
PROSE → PROSE +

PROSE result / onshore 2D PSO INVERSION





INTRODUCTION AND OUTLINES



Offshore vs Onshore

- Water column effects and sediment interface influence energy penetration.
- More complex coupling; underwater sources (e.g., airguns) interact with water and seafloor
- Ryleigh waves vs shcolte and guided P waves.
- Scholte waves: Surface waves confined at the water–sediment interface, highly sensitive to Vs.
- Guided P-waves: Result from constructive interference, sensitive to both compressional (Vp) and shear (Vs) velocities.

OBJECTIVE

PROSE : Develop 2D Shear wave velocity (Vs) for onshore imaging using PSO method

PROSE + : Develop 2D Shear wave velocity (Vs) for nearshore subsurface imaging

Understand how the seismic source position affects seabed sensor recordings

1. Numerical modeling :

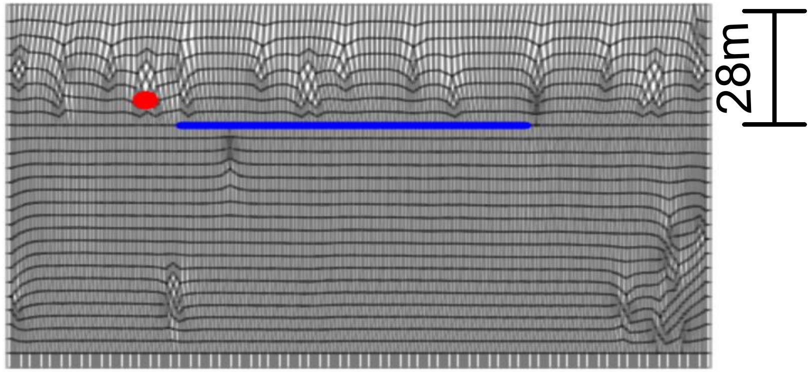
- ✓ Airgun source depth.

2. On Field :

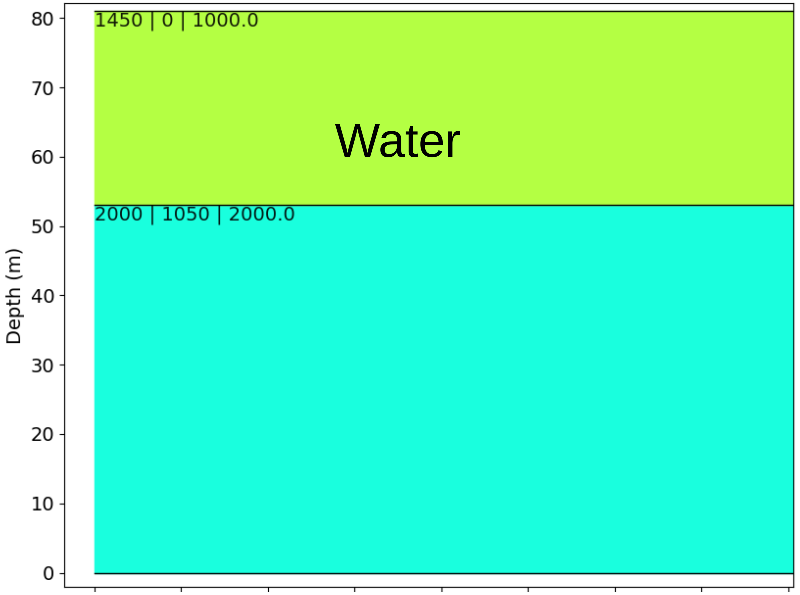
- ✓ Seabed instrumentation.
- ✓ Airgun source depth.

Numerical modeling approach

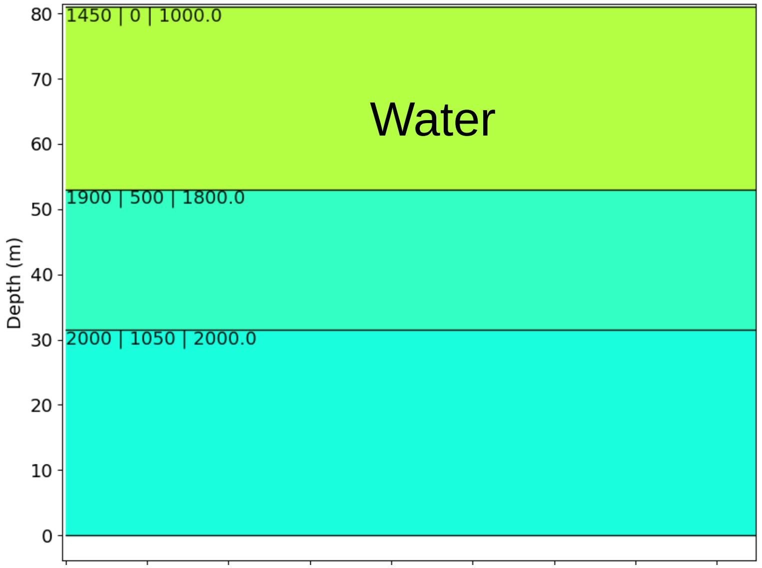
- Tool: SPEC2DY (Spectral Element Method) [Capdeville Y.].
- Source: Ricker wavelet (100 Hz).
- Source depth: 5 m, 13 m, 22 m.
- Receivers: 200 seabed receivers, 1 m spacing.



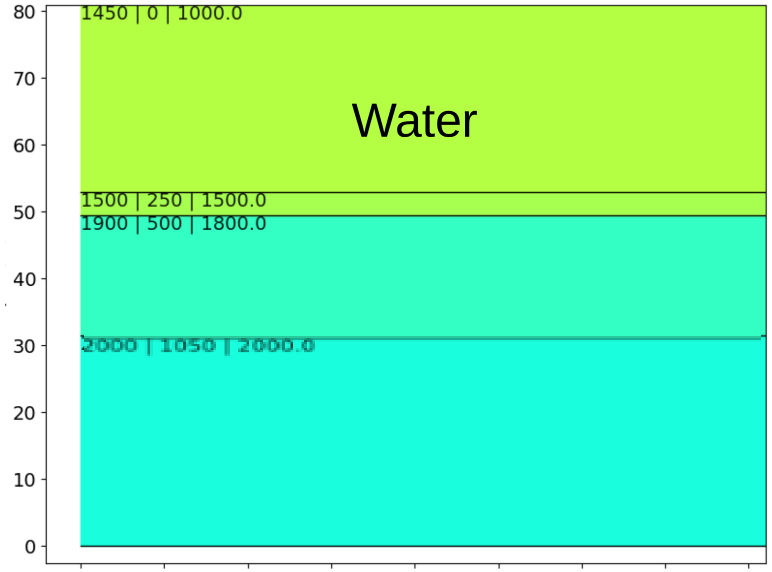
Model 1



Model 2

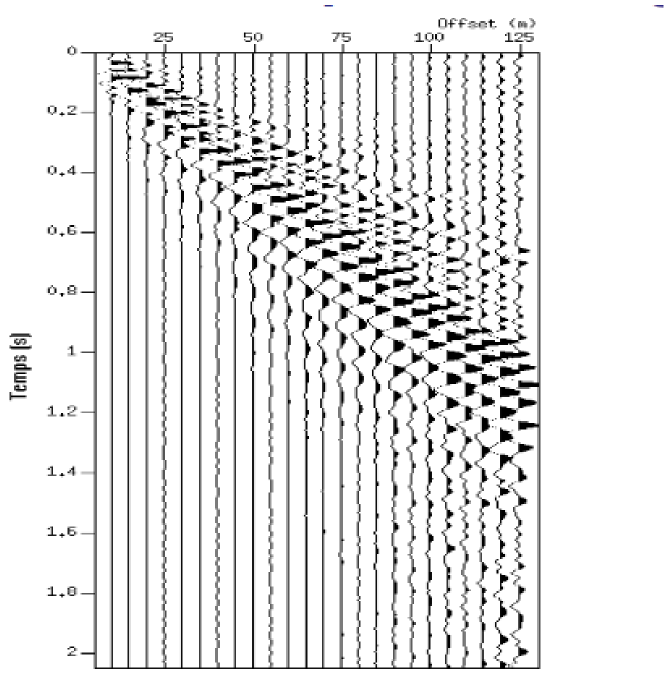


Model 3

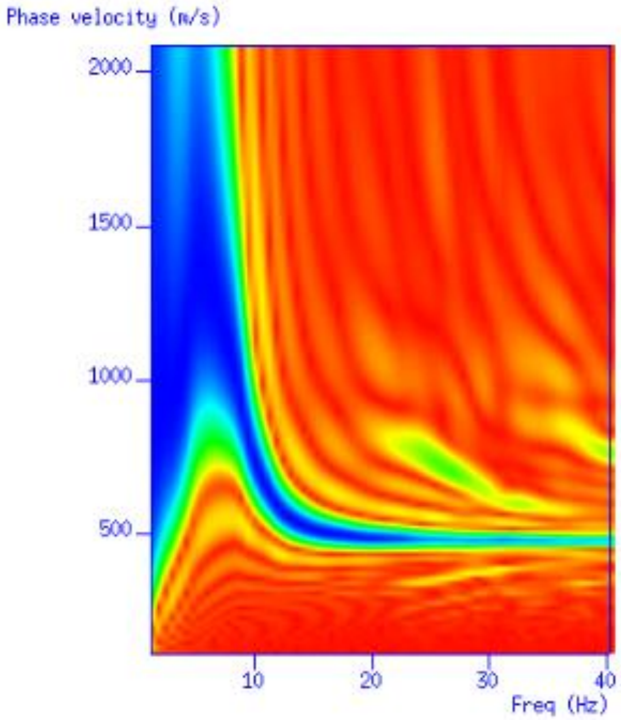


NUMERICAL MODELING APPROACH

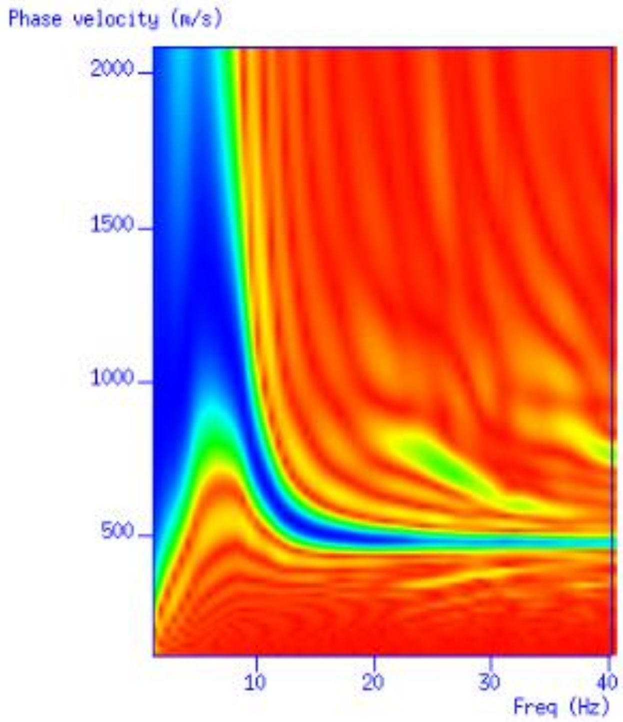
Dipersion diagram calculation



Seismic shot



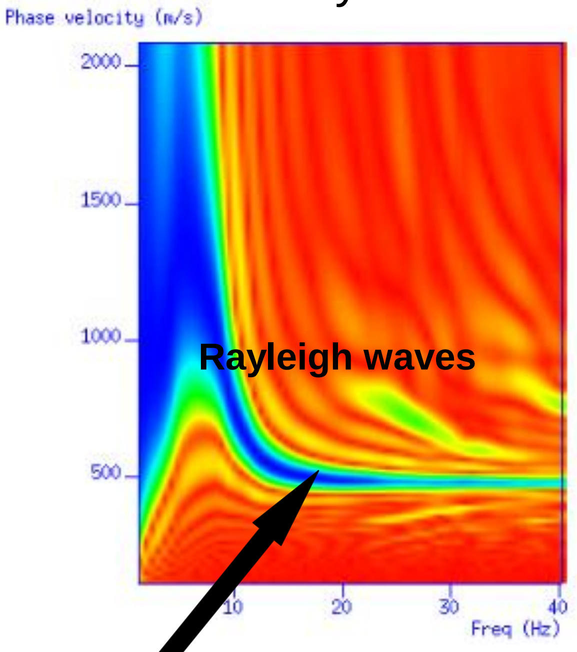
Dispersion diagram : Phase Shift Between receivers recording /(P–ω) transform



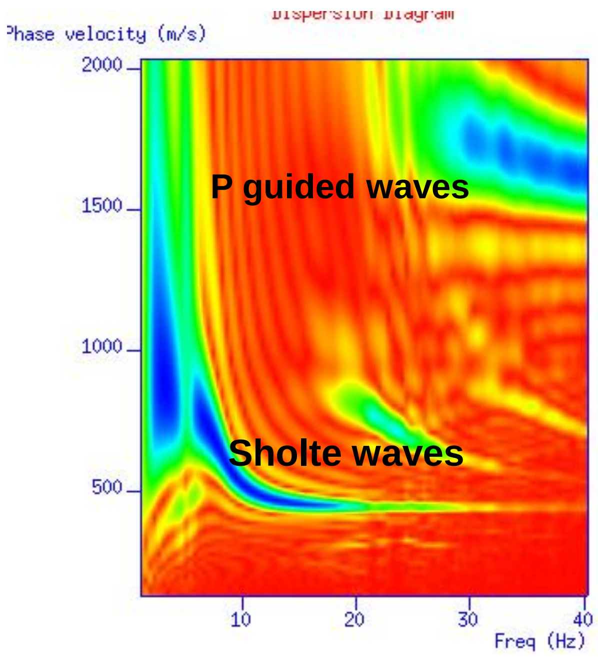
Dispersion curve plotting

NUMERICAL MODELING : RESULTS

Without water layer

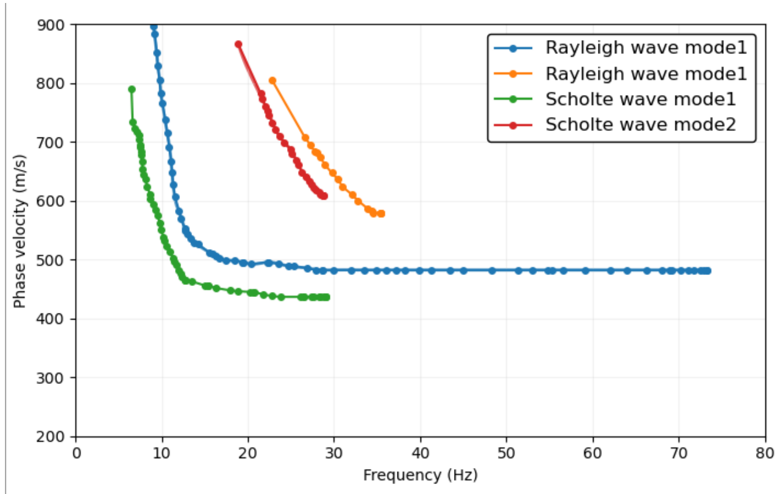


With water layer

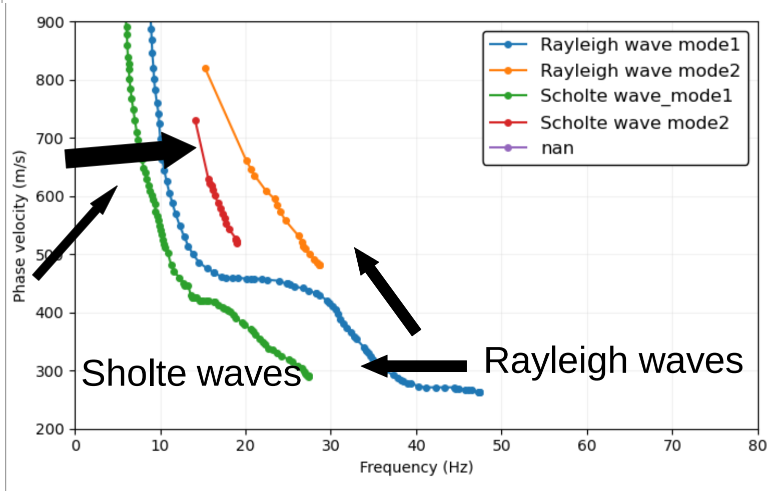


Dispersion Curve

Model 2



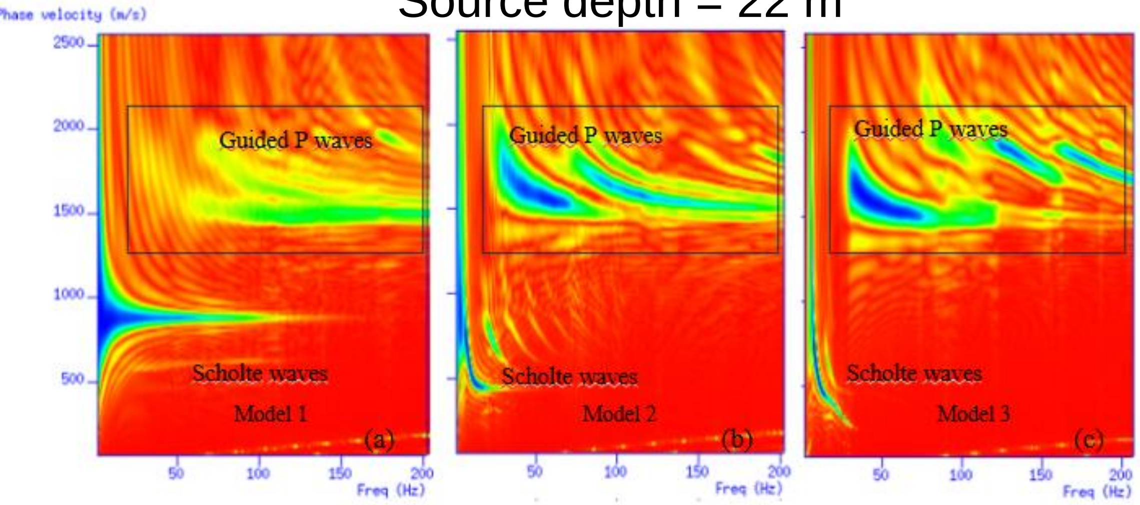
Model 2



Model 3

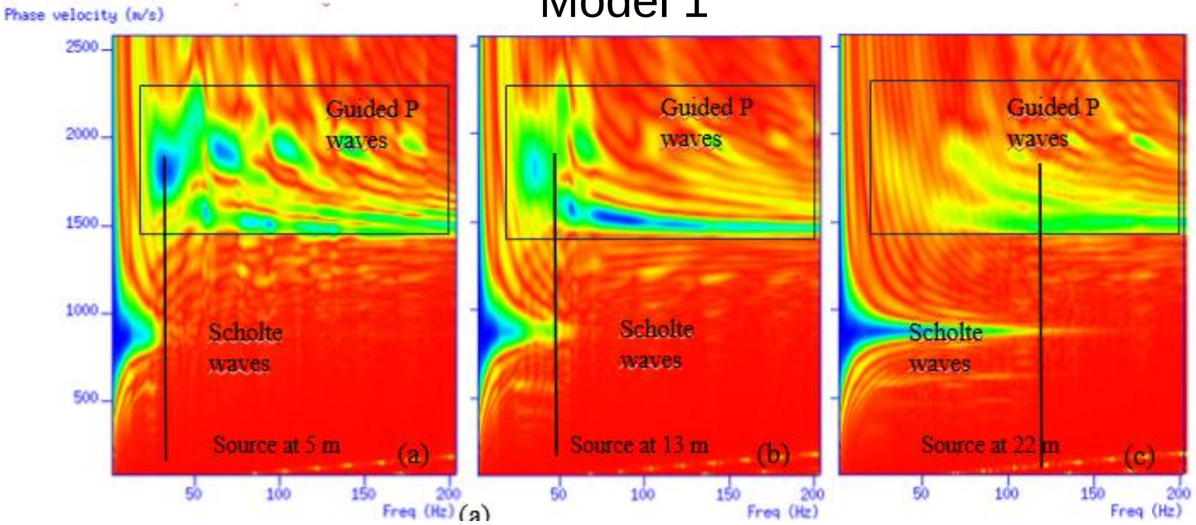
NUMERICAL MODELING : RESULTS

Source depth = 22 m



Model 1 | Model 2 | Model 3

Model 1



Source depth = 5 m | Source depth = 13 m | Source depth = 22 m

Phase velocity of guided waves becomes increasingly complex with the number of layers.

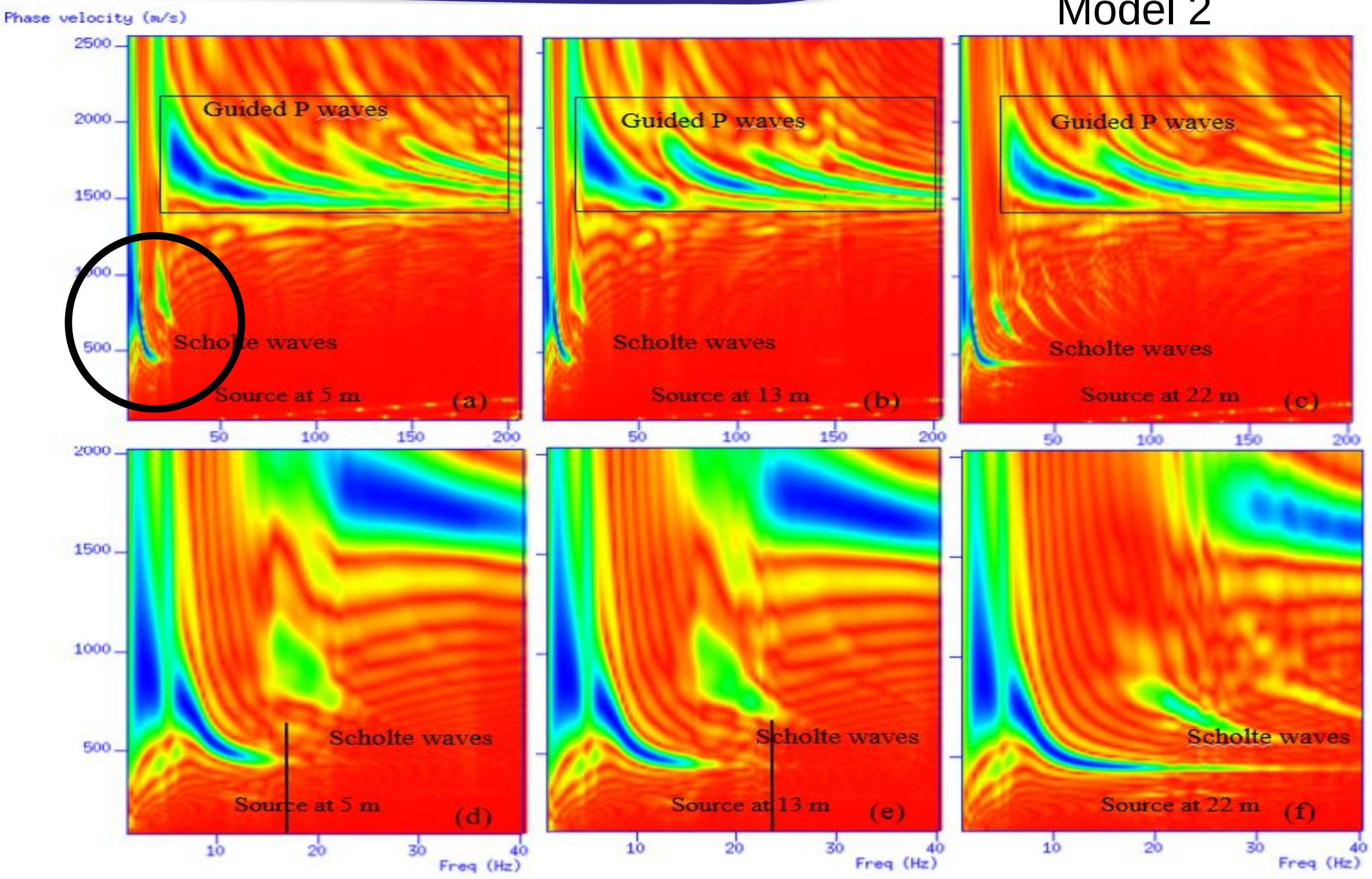
Source Depth Effect:

- Deeper source (22 m): Stronger Scholte wave excitation, broader frequency band.
- Characteristic frequency (fc): Inversely proportional to source–seabed distance, fc ≈Vwater/2d.

NUMERICAL MODELING : RESULTS

- Deeper source (22 m): Stronger Scholte wave excitation, broader frequency band.
- Deeper sources (22 m): enhance the coherence of guided P-waves.
- Characteristic frequency (fc): half that in Model 1 for all source depths.

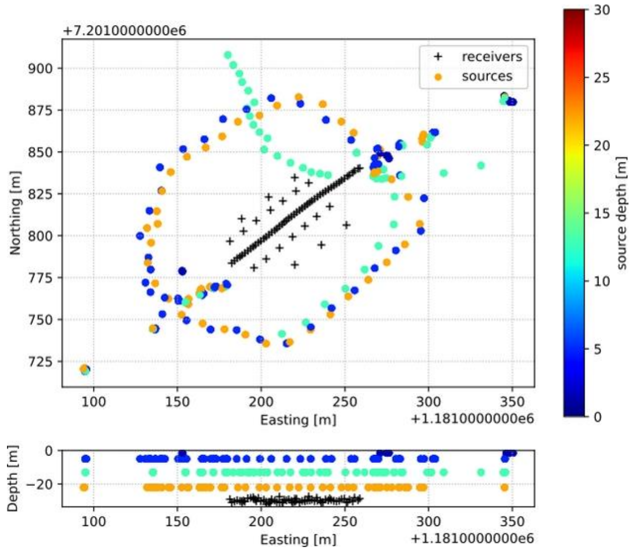
Model 2

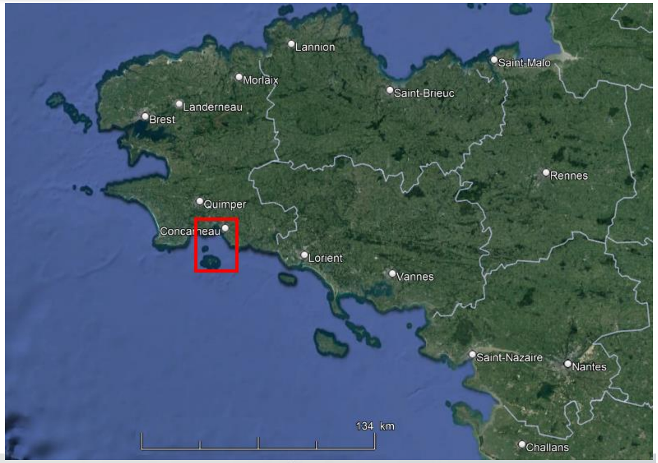


Source depth = 5 m   Source depth = 13 m   Source depth = 22 m

FIELD DATA : CONCARNEAU

- Location: Nearshore Concarneau, South Brittany, France (28 m water depth).
- Date : september/october 2023.
- Receivers: 70 4-component GPR Sercel nodes (3 accelerometers + 1 hydrophone).
- Sources: 241 airgun shots at depths of 5 m, 13 m, and 22 m.

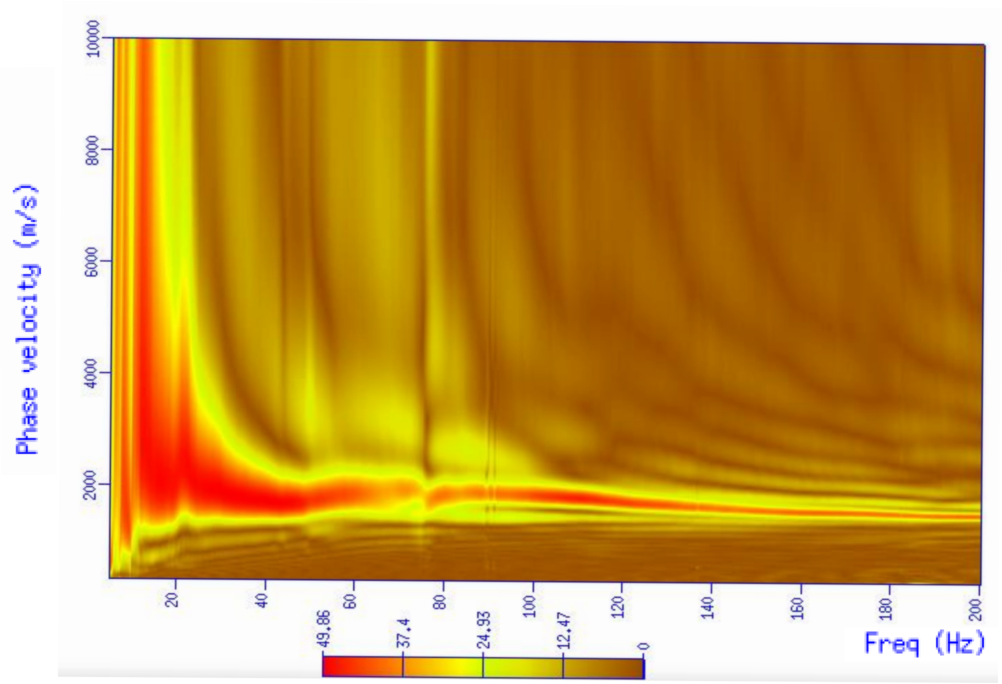




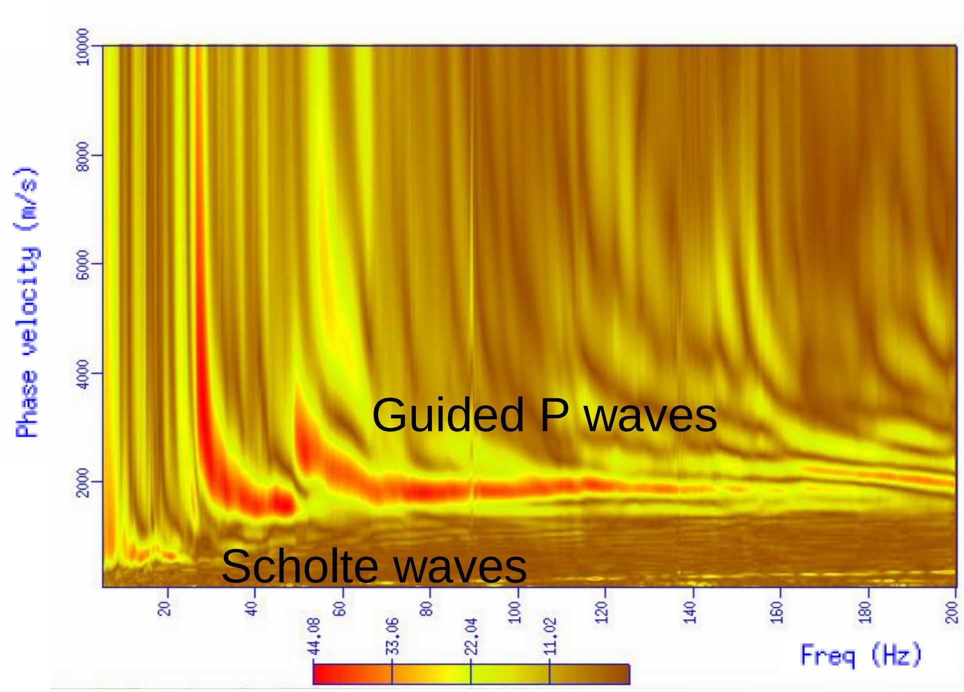
Tartoussi, N., Leparoux D., Michel L., Evain M., Lehujeur M., et al. (2025). PROSE+ project: offshore seismic …in the subsurface environment, ISFOG 2025 5TH intern. Sympos. on frontiers in offshore geotechnics.
Leparoux, D., Michel, L., Pelleau, P., ... & Lehujeur, M. (2024, May). Sea Bottom Surface Wave Seismic ...Foundations. EAGE/SUT Workshop on Integrated Site Characterization for Offshore Renewable Energy,

FIELD DATA : CONCARNEAU

Dispersion diagrams from Seabed recordings



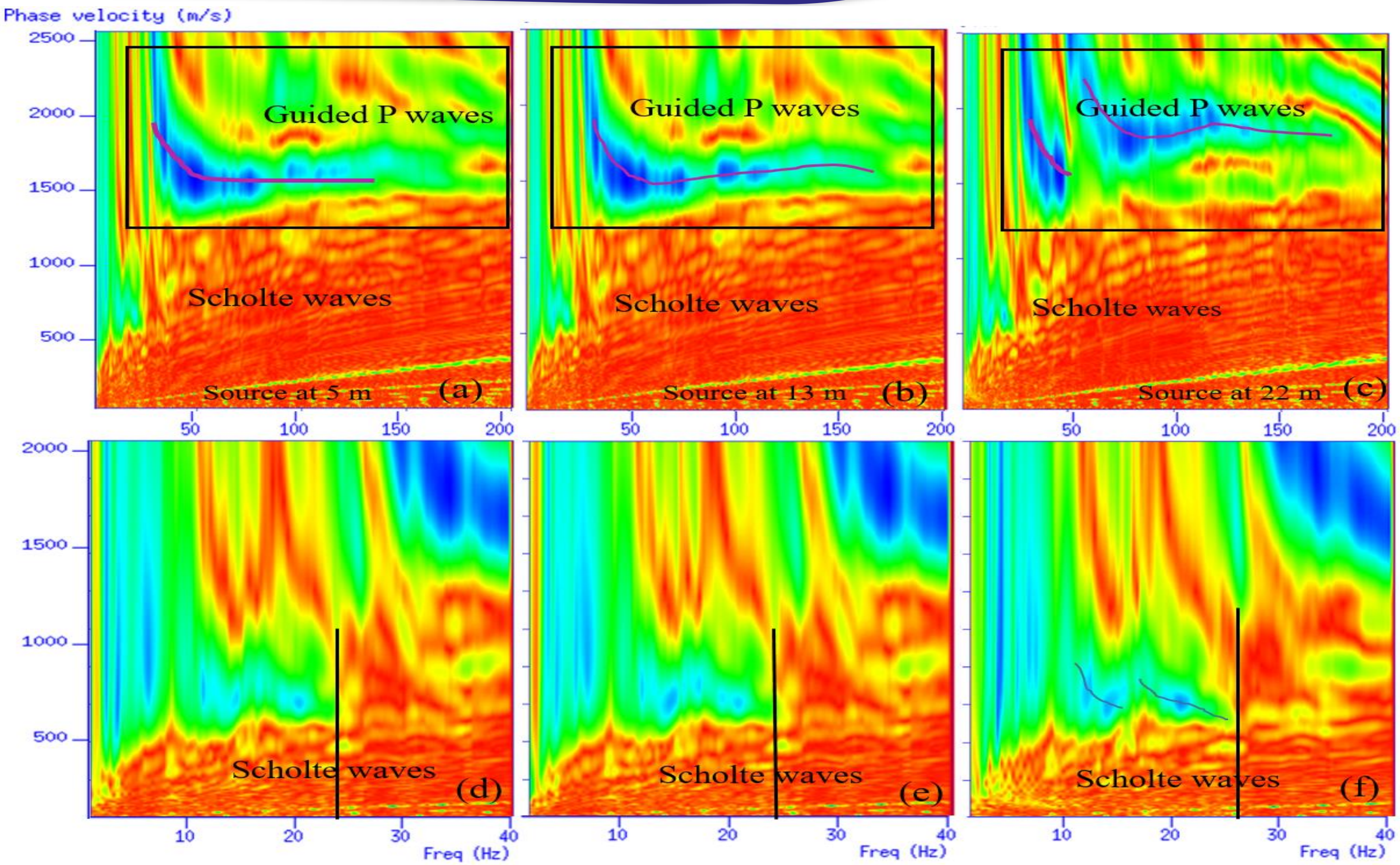
Hydrophone



Vertical components of the accelerometer

FIELD DATA : CONCARNEAU

- Deeper source enhances Scholte wave amplitude and resolution.
- fc shift smaller (5 Hz) due to attenuation in real geology.
- Shallower source depths lead to stronger, continuous guided P-waves with broader frequency content.



Source depth = 5 m

Source depth = 13 m

Source depth = 22 m

CONCLUSIONS

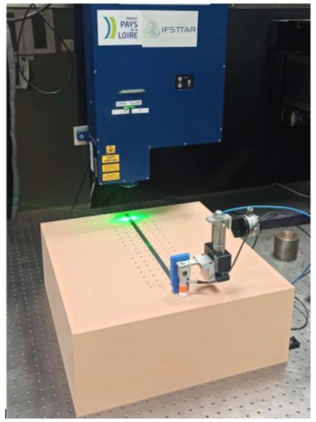
- Numerical simulations (SPEC2DY) align with field observations,confirming optimal source placement near seabed.
- Impact of a deeper airgun source (closer to the seabed):
  - Enhances the resolution, amplitude, and frequency bandwidth of Scholte waves.
  - Improves the continuity of guided P-wave modes.
- Characteristic frequency (fc) increases with source depth.

Implications: Improved acquisition strategies for marine seismic surveys.

PERSPECTIVES

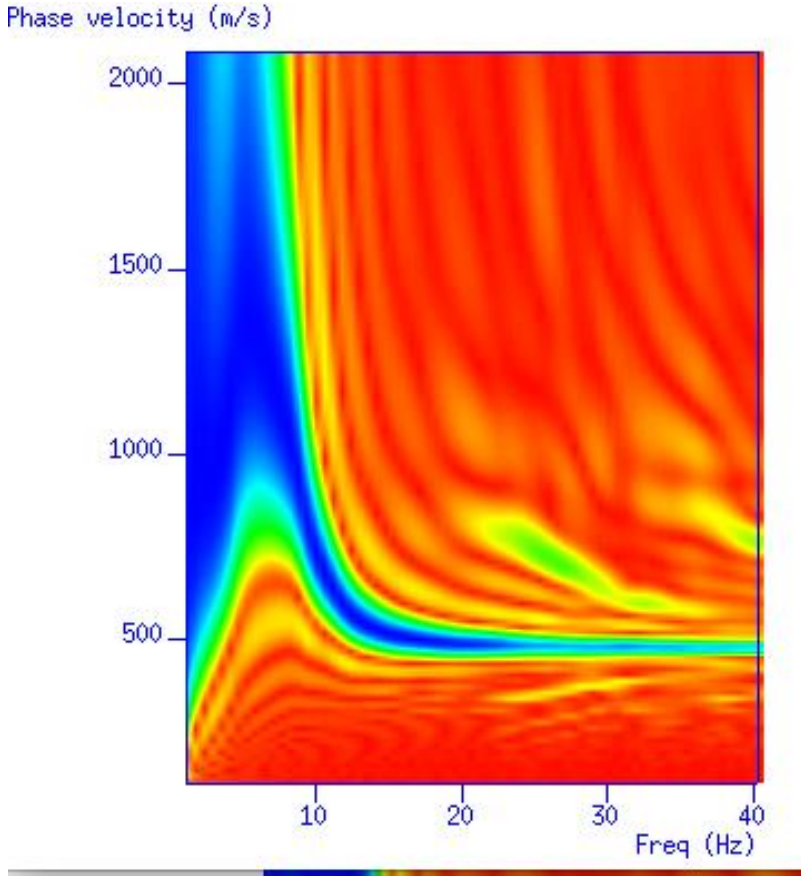
- 2D Inversion of seabed data using PSO method to recover the Vs velocity profile.

- Test the source depth effects on a reduced scale tests in a water tank.



- Combination of seismic and geoelectric data for improved seabed characterization.

THANK YOU !



Construction du diagramme de dispersion par le déphasage entre capteurs

Décomposition de chaque signal (à chaque récepteur x_n) par Transformée de Fourier :

$S(f,x_n)=$

$s(t,xn) \rightarrow |S(f,x)|\, e^{i\Phi}$: pour chaque x_n -> (|S(f)| ;)

Pour une fréquence f donnée :

$$\Phi=(\omega/v)\,x=(2\pi f)\,x/v$$

Au récepteur x1 : $\Phi 1=(\omega/v)\,x1=(2\pi f)\,x1/(v(f))$

Au récepteur x2 : $\Phi 2=(\omega/v)\,x2=(2\pi f)\,x2/(v(f))$

Au récepteur xn : $\Phi n=(\omega/v)\,xn=(2\pi f)\,xn/(v(f))$

$$\boxed{\Phi 2-\Phi 1=\Delta\Phi n=(\omega/v)(x2-x1)=(2\pi f)\,\Delta x/(v(f))}$$