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Multi-component fibre sensor and geophone data comparison to synthetic data

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Summary

A seismic survey was acquired in March 2025 at Carbon Management Canada's Newell County Field Research Station (Figure 1) and can be compared to previous surveys acquired in 2024 (Hall et al., 2025). Vibe Points (VP; red dots) were acquired using the University of Calgary's IVI EnviroVibe, using a 16 second long 10-150 Hz linear sweep with 0.2 s start and end tapers. Lines 7, 13, 15, and 41 were shot with 4 sweeps per VP, and lines 200 and 420 were shot with 20 sweeps per VP. A total of 310 VP were acquired over the course of the survey. Permanently installed optical fibre at the site includes straight and helically wound single-mode fibre cables that traverse the observation wells (OBS1 and OBS2) and Line 13. Two types of experimental multi-component optical fibre sensors have also been installed at the site. The Pretzel consists of two 10x10 m squares of fibre, with one square rotated 45-degrees relative to the other at 2 m depth. The Croissant sensors consist of 1x1 m plastic frames buried vertically just below topsoil at three locations, wrapped with fibre in the vertical and two orthogonal horizontal directions. Three-component geophones (Inova SM7, 10 Hz) were planted on the surface at the corners of the Pretzel and Croissant sensors (Figures 3 and 4). Additionally, synthetic 3C geophone data was created for source line 41 and virtual geophones along line 13, as well as synthetic DAS data for Croissants 1-3 and source line 41 using ElasWave3D. We present a comparison of field DAS, field geophone, synthetic DAS, and synthetic geophone results.

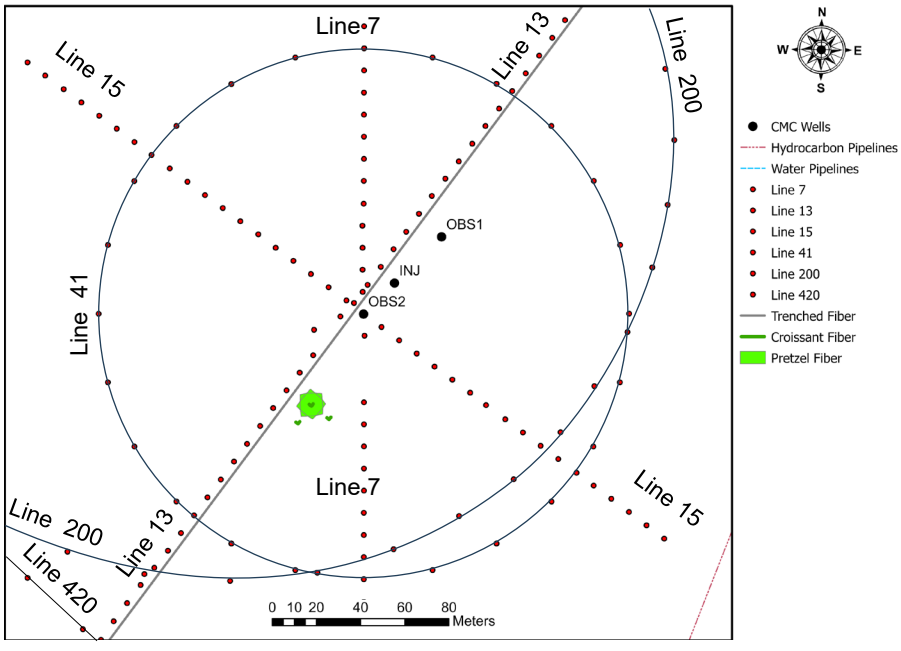


Figure 1: Map showing Vibe Point locations acquired in March 2025 relative to the observation and injection wells (black dots), trenched fibre (Line 13), and the experimental Pretzel and Croissant multicomponent fibre sensors.

Method

ElasWave3D is a GPU-accelerated finite-difference solver used to simulate elastic wave propagation in environments with complex, irregular terrain (Sánchez-Galvis et al, 2025). The DAS-recorded strain rate is computed by projecting the full strain-rate tensor onto the fibre's local tangent direction (Eaid et al, 2020). ElasWave3D was used to create two synthetic datasets that approximate the field geometry for source line 41 for two cases; (1) Approximately 350 m of receiver line 13 at 45 deg azimuth (actual azimuth is 37 deg) recorded on virtual 3C geophones spaced 1 m apart, and (2) all three Croissants using a velocity model provided by CMC and the fibre path parameterization described by Acosta et al. (2025). High frequencies were deliberately excluded from the wavelet used in ElasWave3D.

Results

We show a qualitative comparison of synthetic data for Croissant 1 created with ElasWave3D (Figure 2) to DAS data for Croissant 1 (Figure 3). and to surface geophone data at the Croissant 1 location after converting the horizontal geophone components to strain-rate (Figure 4). Data are presented with no filters, but with AGC for display. The results are generally comparable, although air blast is not present in the synthetic data. Ground roll is more prominent in the synthetic data than in the field data.

Discussion and Future Work

Synthetic DAS and geophone data has been generated using ElaseWave3D for comparison to field data. Converting synthetic geophone data to strain-rate and comparing synthetic Croissant data shows similarities, but not as close of a match as we might expect. Similarly, comparing field geophone data converted to strain-rate to field Croissant data shows similarities, but the results are not identical. Possible causes may include, (1) coupling issues, (2) differences in receiver depth, (3) Sampling 1 m coils of fibre with a 7 m gauge length, (4) bandwidth differences between the field and synthetic data. Data processing is on-going.

Acknowledgements

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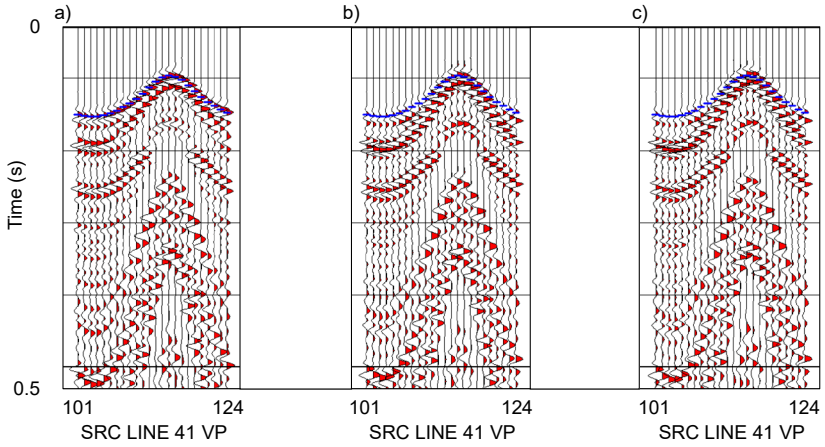


Figure 2: Synthetic receiver gathers; (a) Vertical, (b) Inline-13, and (c) Crossline-13 components.

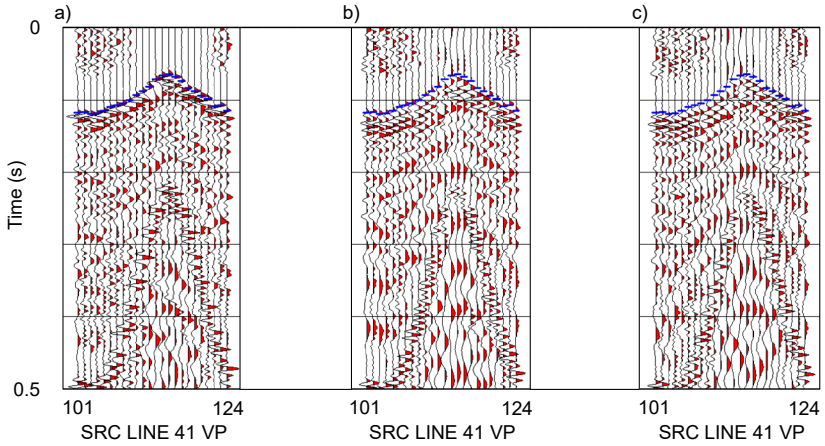


Figure 3: DAS receiver gathers; (a) Vertical, (b) Inline-13, and (c) Crossline-13.

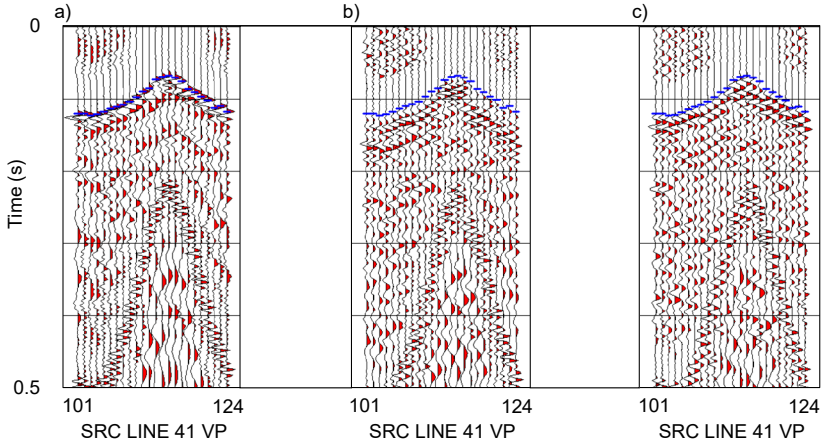


Figure 4: Geophone receiver gathers; (a) Vertical, (b) Inline-13 converted to strain-rate, and (c) Crossline-13 converted to strain-rate components.