Preliminary FWI results from Snowflake II

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ABSTRACT

In 2022 a vertical seismic profile survey was shot at the Carbon Management Canada Newell County Facility as a follow-up to a 2018 survey, after years of CO_2 injection at the site. We perform preliminary processing and inversion of the new data, using the inversion approaches and parameters used on the 2018 data set. Probable errors in the inversion output motivate a strong possibility that several of the inversion parameters may need to be modified to achieve a comparable result with the 2022 data set.

INTRODUCTION

In 2018, a vertical seismic profile (VSP) survey was carried out at the Containment and Monitoring Institute (CaMI) Field Research station as a baseline survey for later time-lapse monitoring of CO_2 injection at the site. This dataset included both downhole accelerometers, straight fibre distributed acoustic sensing (DAS) measurements, and helical fibre DAS measurements. In 2021, full-waveform inversion of these datasets was performed (Eaid et al., 2021a,b; Keating et al., 2021a). In August 2022, a monitor survey was acquired, with approximately the same survey geometry, and the same sensor types deployed.

This report is a summary of some early work towards preparing the monitor data-set for inversion. In the following sections, we summarize the acquisition geometry, processing of the accelerometer data, and preliminary results of inversion of the accelerometer data.

PROCESSING

While both accelerometer and DAS data were acquired in this survey, our focus here is on the substantially smaller accelerometer dataset. Processing and inversion of the full dataset is ongoing. A schematic of the source and receiver locations that were active for this survey is shown in Figure 1. The accelerometers were placed at 1m depth increments, with an increase to 2m at about 140 m depth.

In our preliminary processing, we are attempting to work with a minimal workflow. Broadly speaking, we consider only two main steps here: first we rotate the horizontal components to an in-line and cross-line coordinate system, then we eliminate noisy or inconsistent traces. We eliminate traces only after the coordinate rotation because the bad traces are easier to identify after the rotation, while the rotation itself incurs negligible cost.

Our coordinate rotation is based on the assumption that the in-line horizontal direction will be the horizontal component containing the maximal energy at early times. This is based on our assumption that the cross-line component will be completely insensitive to P-waves, while the in-line component will be maximally sensitive. We choose the rotation angle through a grid-search method, where a set of possible angles are tested, and the maximal energy rotation is chosen. An example shot gather is shown in Figure 2 for a measured horizontal component (left) and for the calculated in-line horizontal component (right) af-

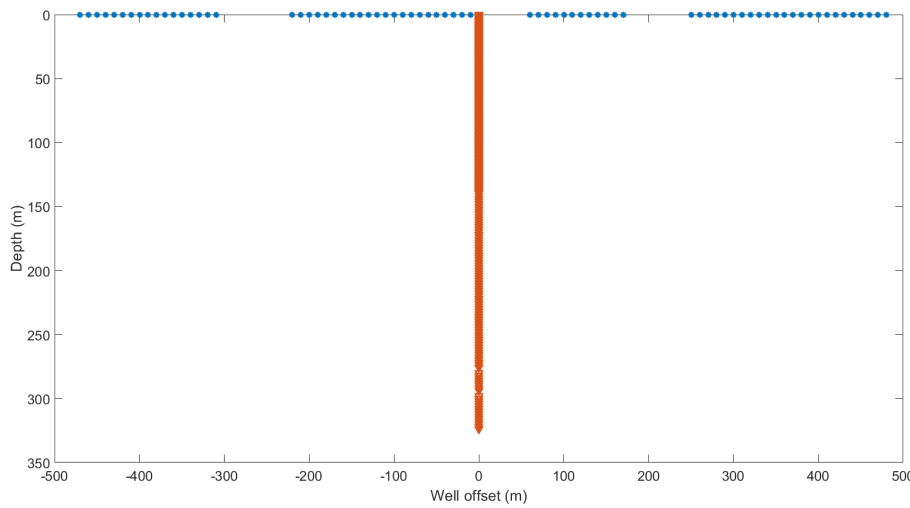

FIG. 1. Locations of sources (blue) and receivers (orange) in the survey.

ter muting the bad traces. We observe significant continuity after rotation, suggesting that the result is plausible.

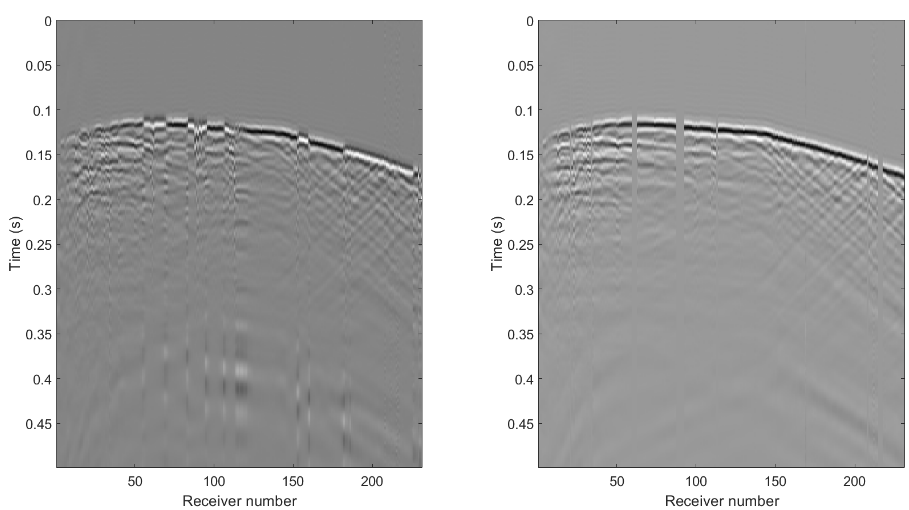

FIG. 2. Horizontal component before (left) and after (right) rotation and muting of bad traces for 220 m offset shot.

A number of traces are significantly discontinuous from their neighbours in both vertical and horizontal components. These traces were qualitatively assessed, and replaced with a linear interpolation of their neighbours. About 15 of the 231 accelerometers deployed in this survey were replaced in this way during processing.

PRELIMINARY INVERSION RESULTS AND ANALYSIS

The inversion of the 2018 survey is described in detail in Eaid et al. (2021a) and we adopt the same formulation here. In short, we use a frequency-domain inversion code, considering frequencies from 10 to 25 Hz, and formulate the inversion in terms of a single, elastic parameter that describes the main elastic trends observed in the well log for the site. We use an effective wavefield inversion strategy, wherein characterization of the near-surface is replaced with inversion for the wavefield for each source at a chosen depth. These strategies are described in detail in Eaid et al. (2021a) and Keating et al. (2021b).

An inversion result using the same parameters for regularization, frequency bands, number of iterations, etc. is shown in Figure 3. A clear issue with this result is the prominence of the well, where significantly large deviations from the main trends are evident. This suggests that the region near the well is being treated differently than the rest of the model by the inversion. The real part of the frequency-domain measured and modeled data for an example shot at 220 m offset is shown in Figure 4. There is a good level of agreement between the measured and modeled data in this case, suggesting that lack of data fit is not responsible for the model errors we observe.

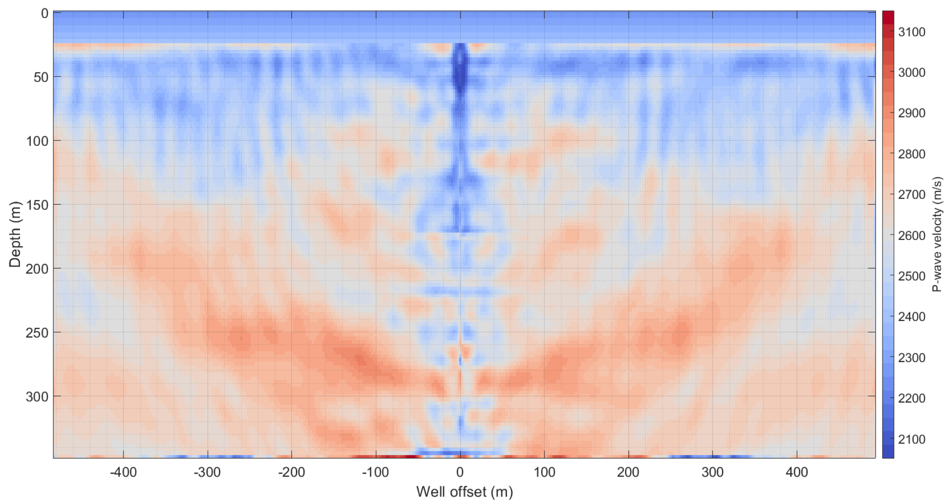

FIG. 3. Inversion result for P-wave velocity.

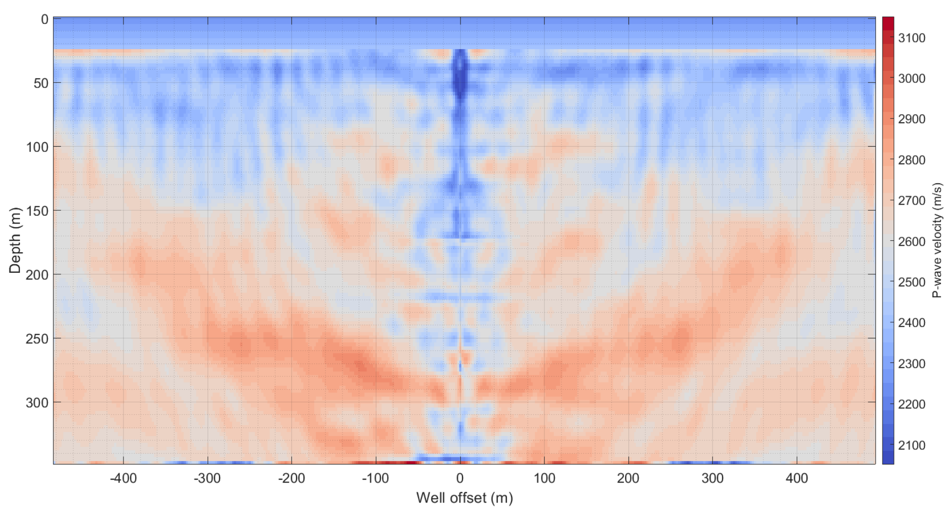

FIG. 4. Real part of frequency domain measured (top) and modeled (bottom) data. Receivers are vertical for top half and horizontal for bottom half of each panel, with depths otherwise increasing from top to bottom. Frequency indices are not directly proportional to frequency, but do progress from low on the left to high on the right.

A strong candidate for the cause of the model errors we see here is our choice of regularization terms. Differences in the measurements and the processing steps applied may have changed key scales between the 2018 survey data set and the data used here, which may have changed the appropriate weighting of the regularization terms we use here. These terms are designed to 1) promote flat layering, and to 2) ensure effective wavefield energy is plausibly distributed from the corresponding source. Both of these terms should significantly discourage the types of artifacts seen in this result, so a change in their weighting may help to improve the inversion result.

CONCLUSIONS

We have performed light processing and preliminary inversion of the 2022 VSP monitor survey. The preliminary inversion results do not seem plausible, so a refinement of the methodologies employed seems necessary. As inversion of the baseline 2018 dataset did not encounter these problems, a reweighting of the regularization terms or alternated processing methodology is likely needed to improve these results.

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REFERENCES

Eaid, M., Keating, S., and Innanen, K. A., 2021a, Full waveform inversion of das field data from the 2018 cami vsp survey: CREWES Annual Report, **33**.

Eaid, M., Keating, S., and Innanen, K. A., 2021b, Processing of the 2018 cami vsp survey for full waveform inversion: CREWES Annual Report, **33**.

Keating, S., Eaid, M., and Innanen, K. A., 2021a, Effective sources: removing the near surface from the vsp fwi problem: CREWES Annual Report, **33**.

Keating, S., Eaid, M., and Innanen, K. A., 2021b, Full waveform inversion of vsp accelerometer data from the cami field site: CREWES Annual Report, **33**.