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Time-lapse DAS-VSP data acquisition from a permanent seismic source at Aquistore CO_2 storage site in 2020

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Summary

Herein we investigate the effectiveness of reservoir monitoring using a permanent seismic source (accurately-controlled, routinely-operated signal system; ACROSS) and permanent receivers (fiber optic distributed acoustic sensing; DAS) at the Aquistore CO_2 storage site. Baseline and monitoring surveys using ACROSS and DAS were conducted in Dec. 2016, Mar. 2018, Apr. 2019 and Jan. 2020. In this presentation, we discuss the results of the processed Jan. 2020 data, including ACROSS signal processing, data matching, vertical seismic profile (VSP) data processing and 4D noise suppression. A repeatability index was calculated to evaluate the 4D responses relative to the Dec. 2016 data. Data acquisition and processing were successful, resulting in the confirmation of high repeatability of the vertical seismic profile - common depth point (VSP-CDP) sections, and potentially an indication of a 4D seismic response.

Introduction

Since 2012 JOGMEC has been developing ACROSS for oil/gas reservoir monitoring. Highly accurate monitoring data can be acquired by combining ACROSS and DAS because the source and receivers are installed permanently in a fixed position. Since 2014 an ACROSS demonstration test has been ongoing at the Aquistore CO_2 storage site near Estevan, Saskatchewan. The demonstration test has shown that ACROSS produces a highly repeatable seismic waveform (Nakatsukasa et al., 2019). CO_2 injection started in 2015 and total injection volume reached ~341K tonnes by Feb. 2021 with sustained injection rates of 400 tonnes/day (Movahedzadeh et al., 2021). Figure 1 shows the locations of the observation well, the injection well, the ACROSS unit and the CDP line. Fiber optic cable was permanently installed behind the casing of the observation well which is about 150 m from the injection well. Although ACROSS was initially operated near the observation well, in 2016 it was moved to a location about 750m away from the observation well. Subsequently, we acquired ACROSS-DAS data in Dec. 2016 (injection volume: 104K tonnes; baseline survey), Mar. 2018 (injection volume: 141K tonnes; monitor survey 1), Apr. 2019 (injection volume: 200K tonnes; monitor survey 2) and Jan. 2020 (Injection volume: 272K tonnes; monitor survey 3). A wireline DAS survey was also conducted at the same time as monitor survey 3 (Jan. 2020). VSP data processing was applied to the baseline survey and monitor surveys 1 and 2, through which the systematic data processing workflow, including repeatability evaluation, was established (Ichikawa et al., 2020). Though there still remains some future data processing improvements, we apply this systematic data processing workflow to the monitor survey 3 data and continue to evaluate the 4D responses.

Data processing

Following the method of Ichikawa et al. (2020), the data processing workflow consisted of ACROSS signal processing, data matching (to correct the amplitude level and global phase based on the baseline data), VSP data processing and 4D noise suppression. After applying these processes, the repeatability indices of normalized root mean square (NRMS) and predictability (PRED) (Kragh et al., 2002) were calculated for both the reservoir gate (1.865s±0.025s: around 3300m MD) and an upper gate (1.4s±0.025s: around 2000m MD) to evaluate the 4D responses of the baseline and monitor data.

Results and conclusions

Figure 2 shows the ACROSS-DAS shot gathers of the baseline and monitor 3 survey data after application of a global matching filter. Although there are some quality differences due to acquisition parameter changes, the direct wave and some later phases were similar to each other. This means that the data acquisition using ACROSS and DAS has been operating stably in the field for over 4 years. Figure 3 shows the VSP-CDP sections for the baseline and monitor survey 3 data after 4D noise suppression. 4D noise was eliminated adequately and the repeatability index of the shallower layer gate was high (NRMS<15% and PRED>95%). This suggests that our systematic data processing workflow was also suitable for the monitor survey 3 data, and that we have established an efficient method to obtain highly repeatable seismic sections. The PRED near the base reflector of the injection layer is lower than one of shallower layers, but stable (PRED>80%). Also, the NRMS of the injection layer is stable except near the injection well. The difference section shows some changes at the reservoir and slightly stronger amplitude on the injection well side. These changes seem to indicate a possible 4D response in the injection layer. Other monitoring results (White et al., 2019) show that the injected CO_2 migrated to the north-east area selectively. Our main imaging area is slightly out of the CO_2 plume because of the ACROSS configuration and because the fiber optic cable does not extend down to the reservoir level. These changes are still imperceptible and uncertain, and thus we are trying to continue to improve the processing sequence and the detection of 4D responses. On the other hand, the wireline data which was collected deeper than the installed fiber optic cable might help to evaluate the 4D analysis.

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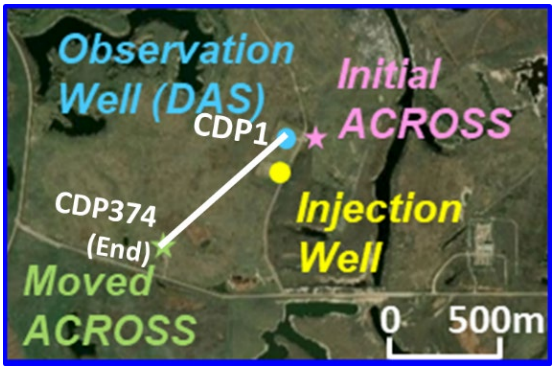

Fig. 1 Locations of the observation well, injection well and ACROSS unit at the Aquistore CO_2 storage site

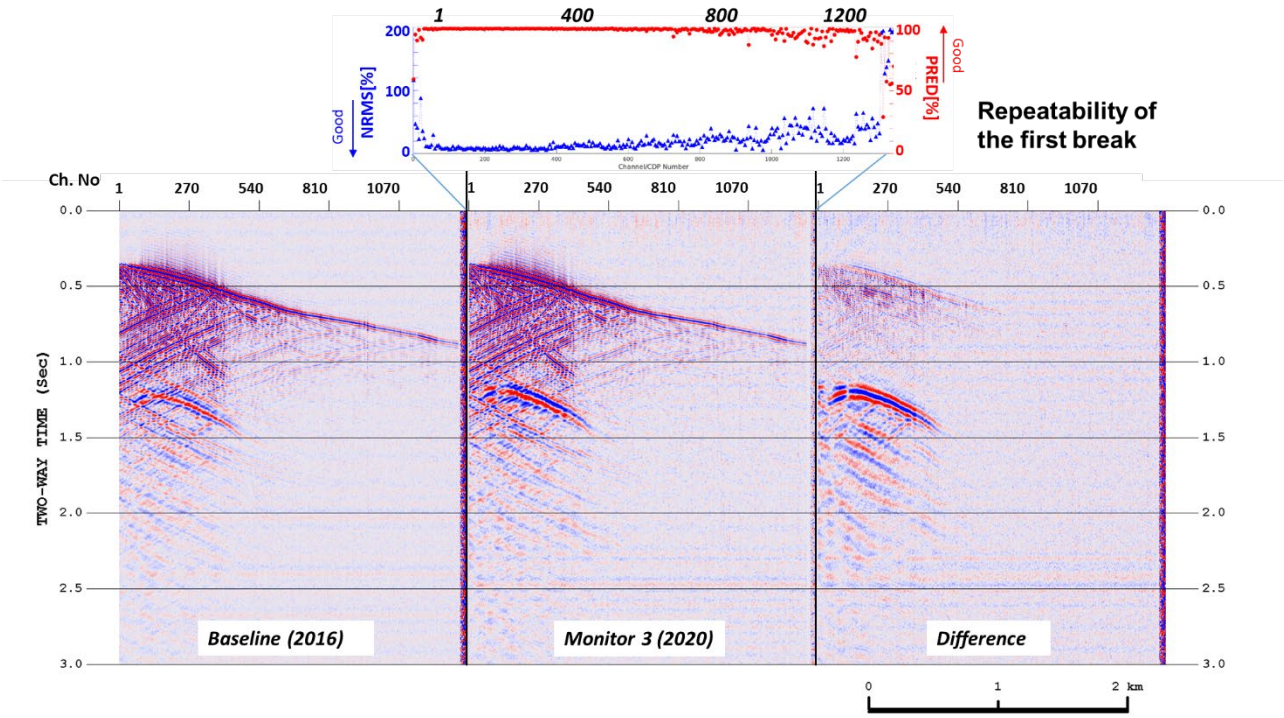

Fig. 2 ACROSS-DAS shot gathers of the baseline, monitor survey 3 data after application of the global matching filter, and difference section. Top: repeatability indices (normalized root mean square and predictability).

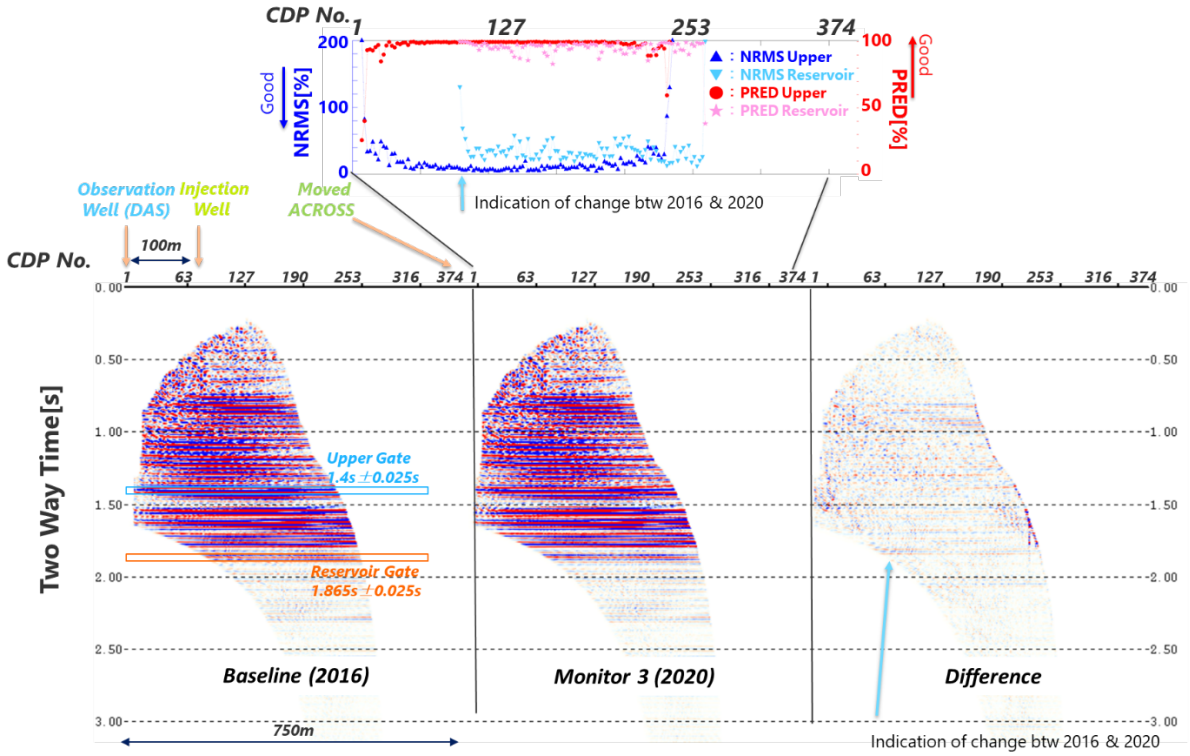

Fig. 3 VSP-CDP section of the baseline, monitor survey 3 data after the 4D noise suppression, and difference section. Top: repeatability indices (normalized root mean square and predictability). The upper gate and reservoir gate of the repeatability indices calculation are set at depths of approximately 2000m and 3300m MD, respectively.