A comparative study of data from different DAS interrogators

Jorge E. Monsegny, Don C. Lawton and Daniel Trad*
University of Calgary and CMC

Summary

Distributed acoustic sensing is a technology with a high potential for seismic monitoring. Apart from the optical fibre, that is the sensing element that replaces the traditional geophone, the other part of this system is the interrogator that transforms the back-scattered light from the fibre into a digital seismic signal. The fibre is usually installed permanently but the interrogator is interchangeable, not only by newer and more sophisticated models, but by different vendors' models. We compare distributed acoustic sensing data obtained at the same locations, with the same sources and optical fibre, and almost at the same frame time, but generated by interrogators from three different vendors, at the Containment and Monitoring Institute Field Research Station in Alberta, Canada. We compare these datasets with one other, and against vertically oriented geophone data. We found that after some data conditioning, all vendors agree in wave character at the early times, however, at later times there are delays in the events arrivals that depend on the trace depth.

Introduction

The Containment and Monitoring Field Research Station, CaMI-FRS, is a research facility located near Brooks in Alberta, Canada (Lawton et al., 2015). It has a surface area close to 1 square km. CO 2 is being injected annually over a 5 year operation plan. Several monitoring technologies have been deployed there and are actively being tested (Lawton et al., 2017).

Among these technologies, there is a 5km loop of optical fibre that is buried at 1m depth along a 1km trench and down two 340m depth boreholes several times. This optical fibre is used as the sensing element of a Distributed Acoustic Sensing (DAS) system. The other part of the DAS system is the interrogator, that is interchangeable and is in charge of sending light pulses through the fibre and transform any back-scattered light to a digital seismic signal (Hartog, 2018).

It is reported that interrogators have an internal interferometer with different path lengths in order to produce the interference pattern from the light backscattered from two fibre sections separated by a gauge length (Hartog, 2018). But apart from this, it is not publicly known what else is inside commercial interrogators or how they calculate the strain based in the interference pattern.

In this abstract we compare VSP data recorded by three different interrogators at CaMI-FRS. In order to make the comparisons significant, we used VSP gathers acquired with the same fibre. at the same place, with the same source and in most cases, in the same frame of time. We also compare the corresponding geophone data.

Results

The DAS data to compare comes from two vertical seismic profile (VSP) gathers at CaMI-FRS. We use DAS data from three different vendors and that means, different DAS interrogators, but the same DAS fibre infrastructure. Our aim is to compare DAS data from these three vendors acquired at the same location, in the same time frame and with the same source. We accomplished all of this with one exception.

Table 1 shows the two sets of gathers used in the comparison. The first set is composed of one geophone and two DAS vendors data. DAS vendors are going to be called Vendor 1 and Vendor 2 hereafter. These three gathers are from the same location, namely, shot point 130 from line 23, and were acquired in October of 2017. The source was the same, an Envirovibe with a linear sweep of 16 seconds from 10 to 150Hz. The geophones were oriented vertically.

Vendor	Line	Acquisition time	Shot Point
Geophone	23	October 2017	130
Vendor 1	23	October 2017	130
Vendor 2	23	October 2017	130
Geophone	21	October 2017	131
Vendor 1	21	October 2017	131
Vendor 3	21	February 2018	131

Table 1: List of vertical seismic profile (VSP) shot gathers used in the comparison. They are divided in two sets according to their similarity. Note that Vendor 1 in both sets refers to the same DAS provider. The sources were, in all cases, an IVI EnviroVibe with a linear sweep of 20s between 10 and 150Hz.

The second set is also composed of three gathers, with one geophone and two DAS vendors data. The differences with respect to the first set are that the location is shot point 131 from line 21, the DAS vendors is different, Vendor 3 from now on, and the VSP gather from this vendor was acquired in February of 2018. The source was the same used for the first set and the geophone were also oriented vertically. Note that the Vendor 1 in both sets refers to the same DAS provider. The distance between shotpoints 130 and 131 is less that 10m.

The spatial DAS sampling, separation between adjacent traces, is 0.25m for Vendor 1, 0.6667m for Vendor 2 and 1.0254m for Vendor 3. All DAS datasets go from the surface to an approximate depth of 345m. On the other hand, geophones are located from 191m to 306m every 5m. Four of the 24 geophone channels were muted because they were very noisy.

Figure 1 shows the Vendor 3 data at shot point 131. Our first concern is the checkerboard low frequency noise that contaminates this and the other DAS datasets.

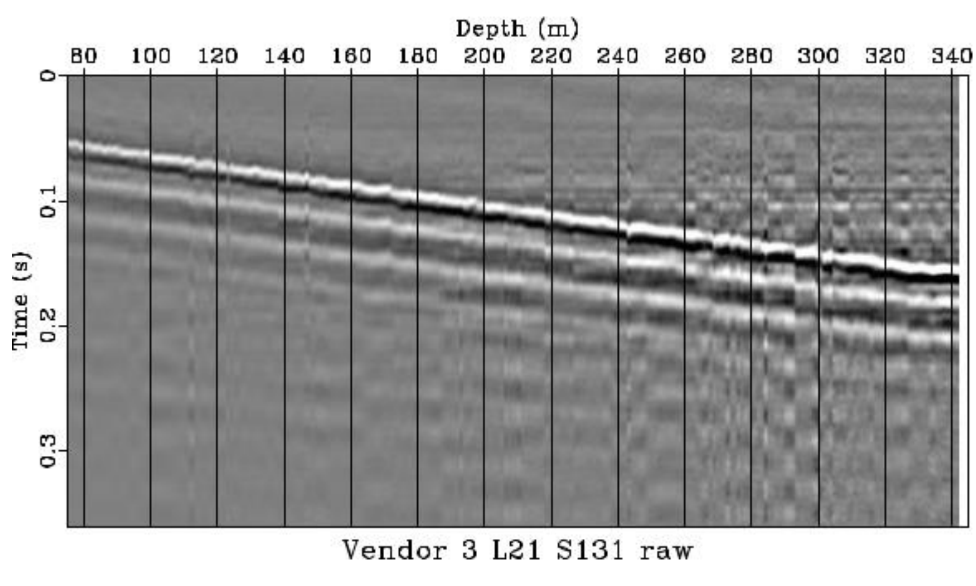

Figure 1: DAS dataset from Vendor 3 at shotpoint 131. It shows the low frequency checkerboard noise that also appears in the other datasets.

Several low cut filters were tried to suppress the checkerboardnoise. A 50Hz low cut, shown in Figure 2, was the most successful. Even though it is a filter value too high for these datasets, we are going to restrict the comparisons to frequencies above this value. We also applied this filter to the geophone gather and as a result the character of the downgoing and upgoing events look more similar to the corresponding events in the DAS gathers.

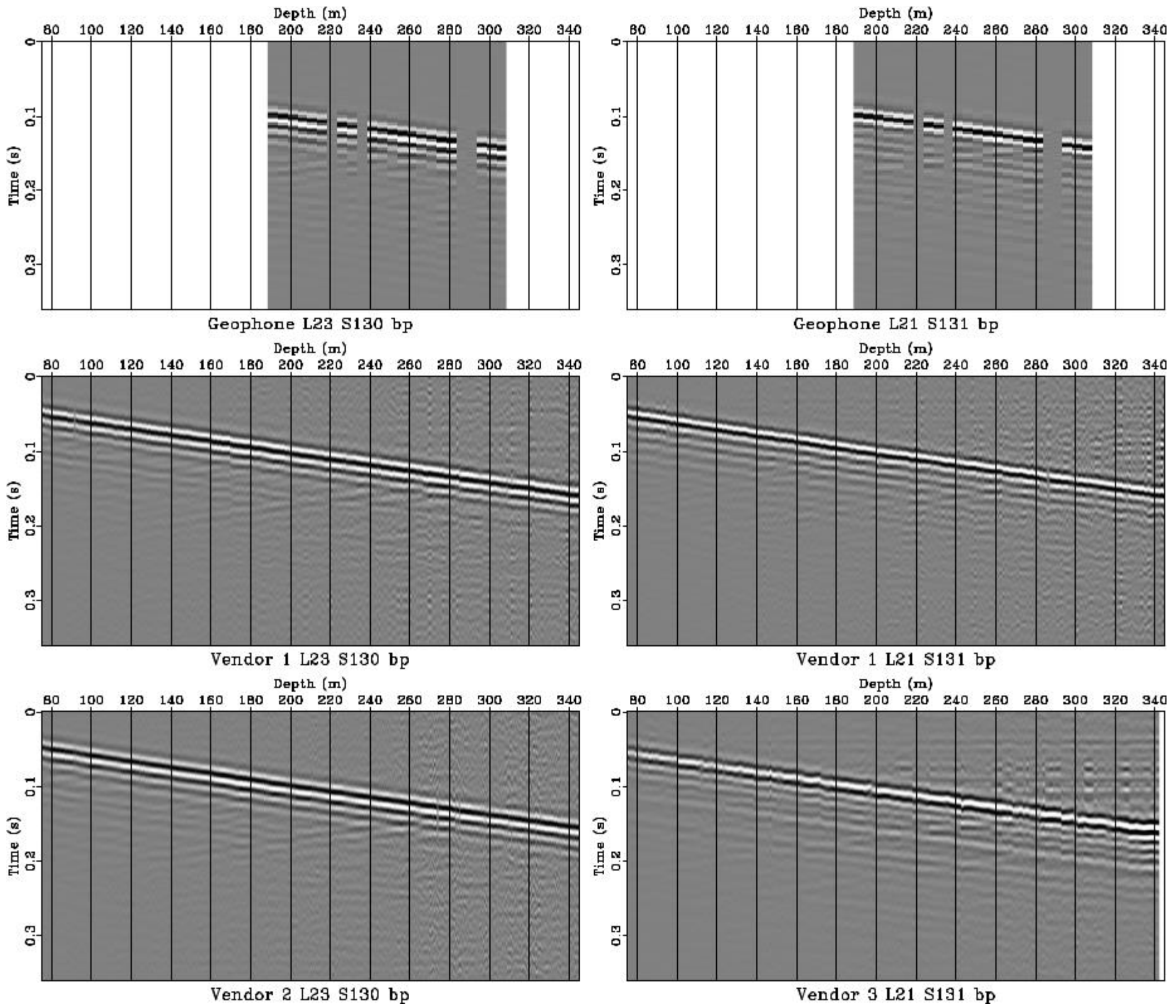

Figure 2: Shot gathers from shot point 130, on the left, and from shot point 131, on the right, with a 50Hz low cut filter applied. The checkerboard low frequency noise was suppressed. Also, the character of the first arrivals in the geophone data became more similar to the corresponding event in the DAS datasets.

Now we are going to overlay geophone and DAS traces to observe their differences in detail. We choose the traces at 191m depth, where the shallowest geophone is located. The DAS depths were calibrated by calculating the maximum local cross-correlation with the pilot geophone trace.

Figure 3 shows the overlaid normalized traces of the two sets of gathers. In the case of the first set, there is a small phase difference between Vendor 1 and Vendor 2 traces at the first arrivals.

Then, the phase difference starts to increase with time. At the end, both traces are totally out of phase. With respect to the relative amplitudes they mostly agree in the first half, but towards the end, the amplitudes of the Vendor 2 trace are noticeable higher than the Vendor 1 trace.

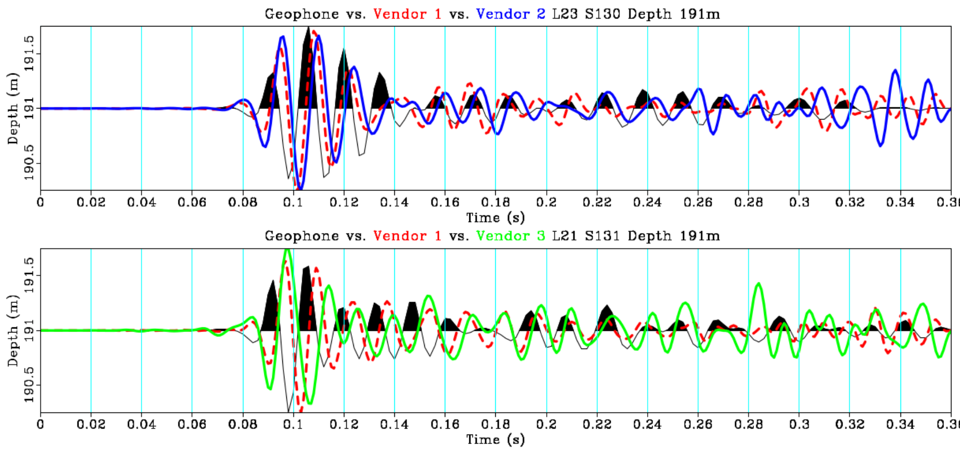

Figure 3: Traces at 191m depth from geophone and DAS data. On the top, the shot point is the 130 from line 23 and the DAS vendors are 1 and 2. On the bottom, the shot point is the 131 from line 21 and the DAS vendors are 1 and 3.

In the case of the second set, both DAS traces start at the same time but then they go out of phase and return to be in phase three times. When they are out of phase it seems to be a small lag. The relative amplitudes coincide in the first arrival events, but is different for some events towards the end of the traces.

Figures 4 and 5 show the traces from all vendors at three different depths, 191m, 226m and 261m. On Figure 4 all the traces coincide at the first arrival event, however, the trace from Vendor 2 lags behind the trace from Vendor 1 at 191m as mentioned before. This delay is smaller at 226m, while it is the opposite, i.e. the trace from Vendor 1 lags behind the trace from Vendor 2, at 261m depth. On Figure 5 the trace from Vendor 3 always lags behind the one from Vendor 1. However, at 191m and 261m both traces synchronize after a few cycles, while at 226m they do not synchronize.

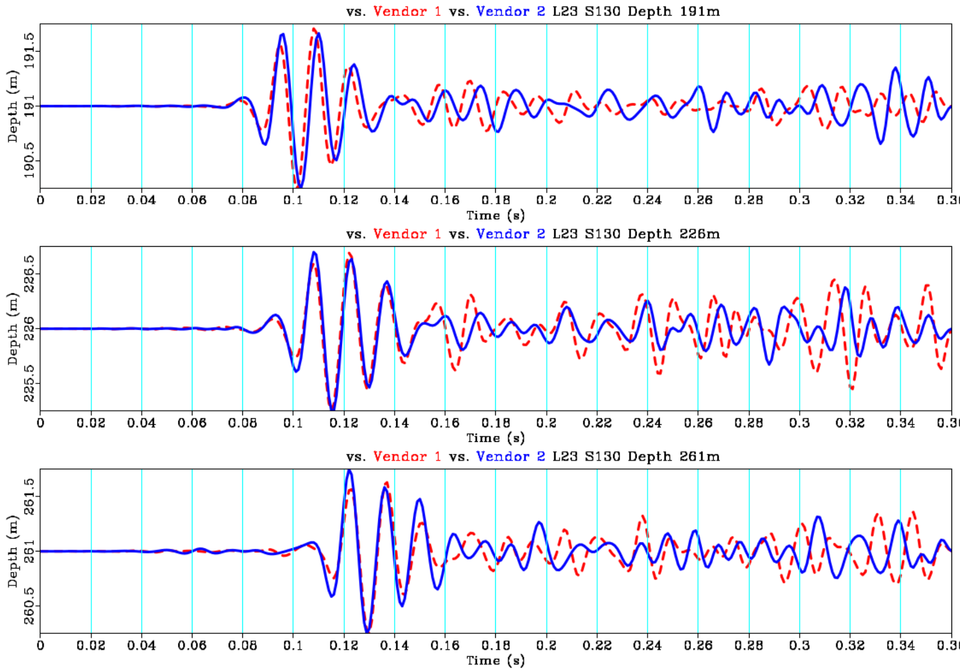

Figure 4: Traces from vendors 1 and 2 at three different depths: 191m, 226m and 261m. All of them have a good match in the first arrival event. However, on top, Vendor 2 lags behind Vendor 1 while this situation is the opposite on the bottom.

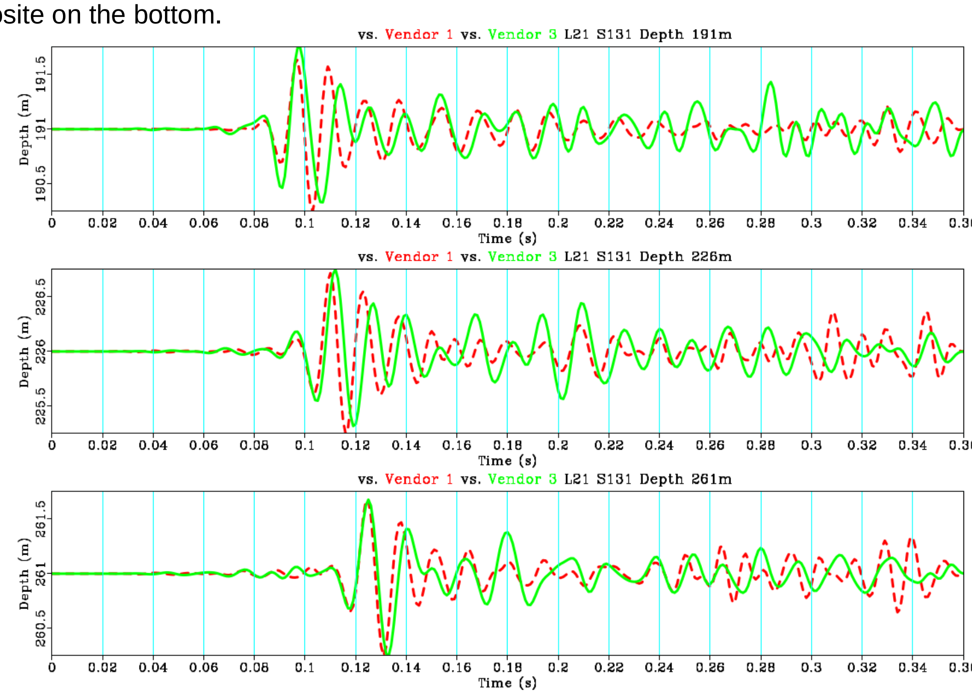

Figure 5: Traces from vendors 1 and 3 at three different depths: 191m, 226m and 261m. In all of them Vendor 3 lags behind Vendor 1, however it synchronizes with Vendor 1 trace faster at 191m and 261m than at 226m.

Discussion

The three vendors DAS data showed a checkerboard low frequency noise, maybe related to the surface operations at CaMI-FRS. The filtering applied to the DAS gathers to mitigate this noise was also applied to the geophone gathers and the result was an increase in the similarity between the two types of data.

After applying a basic data conditioning, the three vendors DAS data showed similarities in the early times, but differences in phase at later times.

The phases differences vary slowly from trace to trace. This could be a registration issue related to the separation between traces. Although all traces are synchronized at the first arrival event and even share the same wavelet shape at early times, they soon begin to lag behind each other. We used cross-correlation, as mentioned before, to find the traces that match at 191m. Then, we paired traces at other depths according to the trace separation. The differences in delays between traces with depth could be related to a wrong separation between traces. This is possible when the interrogator is using the wrong fibre parameters.

Acknowledgements

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References

Hartog, A. H., 2018, An introduction to distributed optical fibre sensors: CRC Press.

Lawton, D., M. Bertram, K. Hall, and K. Bertram, 2015, New approaches to seismic monitoring at the Brooks Field Research Station: Technical report, CREWES.

Lawton, D., M. Bertram, A. Saeedfar, M. Macquet, K. Hall, K. Bertram, K. Innanen, and H. Isaac, 2017, DAS and seismic installations at the CaMI Field Research Station, Newell County, Alberta: Technical report, CREWES.