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Feasibility Study of 3D Distributed Acoustic Sensing (DAS) for Imaging the Steam Chamber: An Experiment of 3D DAS FWI in Sunrise Oil Sands

Hong Feng, Tony Kay, Anita Knudsen

Cenovus Energy Inc

Weizhong Wang

GeoTomo LLC

Amber Ayre

BP Canada Energy Group LLC

Summary

Distributed acoustic sensing (DAS) is a new technology that could be applied to thermal bitumen projects as a potential alternative or complementary tool for time-lapse monitoring due to low cost and operational efficiencies. DAS has been successfully used for Vertical Seismic Profiling (VSP) on offshore projects. However, the application of 3D DAS on horizontal tubing-deployed fiber-optic cables is relatively uncommon. The 3D DAS geometry is very different from conventional seismic programs in that the source points are on the surface and the receivers are underneath the steam chamber target depth. We recorded 3D DAS shot gathers simultaneously when the 4D time-lapse surface seismic was shoot. The inverted velocity from the Full Waveform Inversion (FWI), which runs on the raw shot gathers of 3D DAS provides a comparable steam chamber image with the traditional 4D inversion results. This feasibility study has demonstrated the potential application in the SAGD thermal monitoring and the limitation of the 3D DAS.

Theory / Method / Workflow

Full Waveform Inversion (FWI) initially emerged as an advanced tool for complex velocity model building (Crase et al., 1990; Kotsi and Malcolm, 2017; Warner and Guasch, 2016). The FWI-derived velocity model coupled with advanced imaging algorithms such as pre-stack depth migration (PSDM) can dramatically improve the subsurface imaging from extremely complicated structures that exhibit abrupt vertical and lateral velocity changes (Zhang and Zhang, 2011; Zhang and Huang, 2013). The oil and gas industry has seen very successful applications of FWI in different geologic settings such as the complex subsalt targets in the Gulf of Mexico.

FWI is driven by minimization of the data residual between the real raw shot gathers and the simulated shot gathers by an iterative process that results in a high-resolution velocity model (Figure 1). Two key requirements in the FWI method are efficient forward modeling and local differential computation, which are two major computational costs in the FWI process.

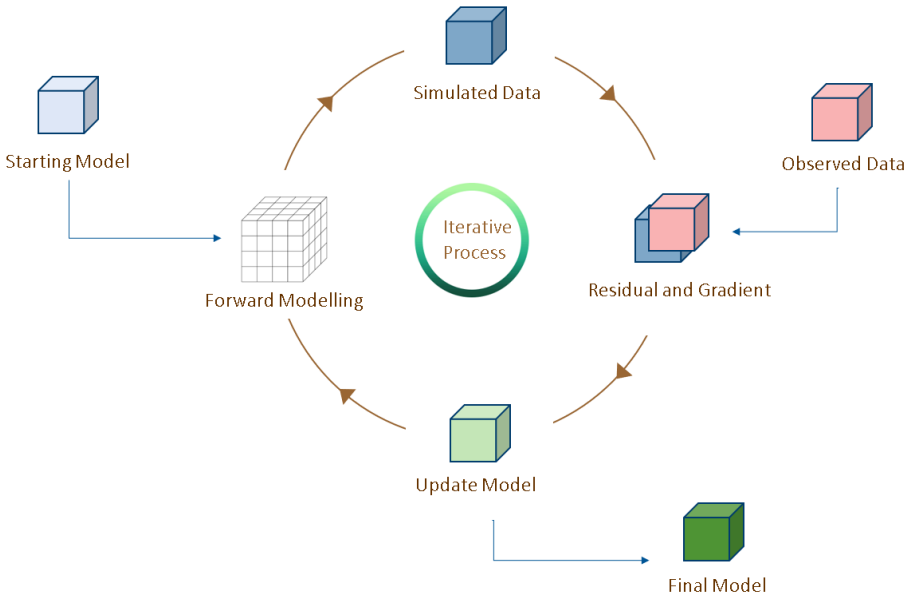

Figure 1: Workflow of full-waveform inversion (FWI)

Results

An initial approach was considered that would require tomographic reconstruction of the direct arrivals at the DAS receivers. 2D DAS FWI has demonstrated FWI can produce a reliable and high-resolution velocity model using 2D DAS synthetic data generated from the finite difference method. However, the inadequate illumination from the shadow zone in the 3D DAS due to the extremely sparse fiber-optic receiver lines (6 receiver lines with 100m spacing) imposes challenges on 3D DAS FWI. The inverted velocity along the horizontals shows a higher resolution image comparing with the cross direction which has an inadequate illumination. The preliminary analysis of the inverted 3D DAS FWI velocity shows high-resolution velocity results where the illumination is highest. On the other hand, the 3D DAS FWI velocity at the edge of the survey shows some artifacts and worse results due to the inadequate illumination. The inverted velocity from the 3D DAS is shown in Figure 2 and Figure 3.

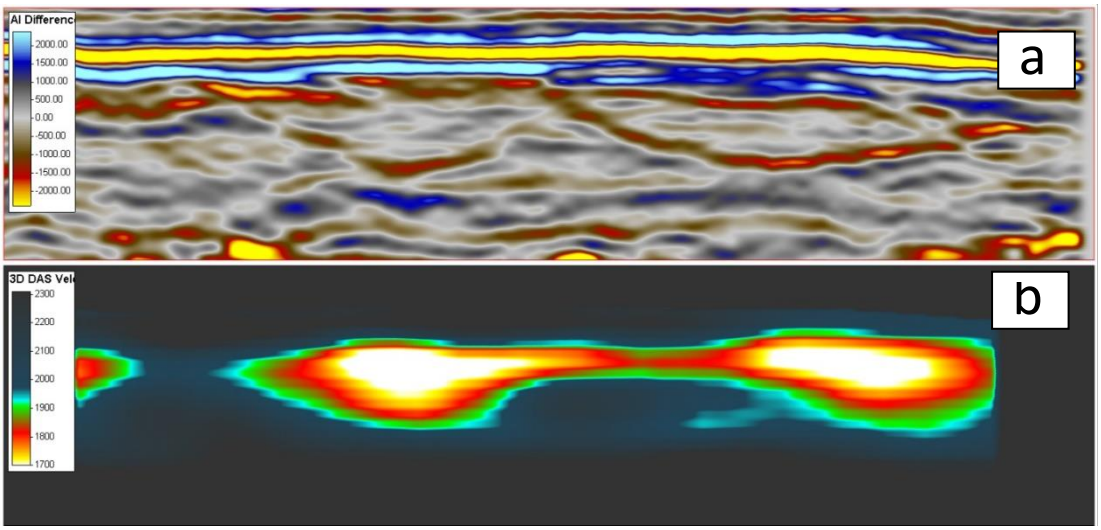

Figure 2. PSDM section image(a) and the section image of the FWI velocity from 3D DAS along the horizontal (b).

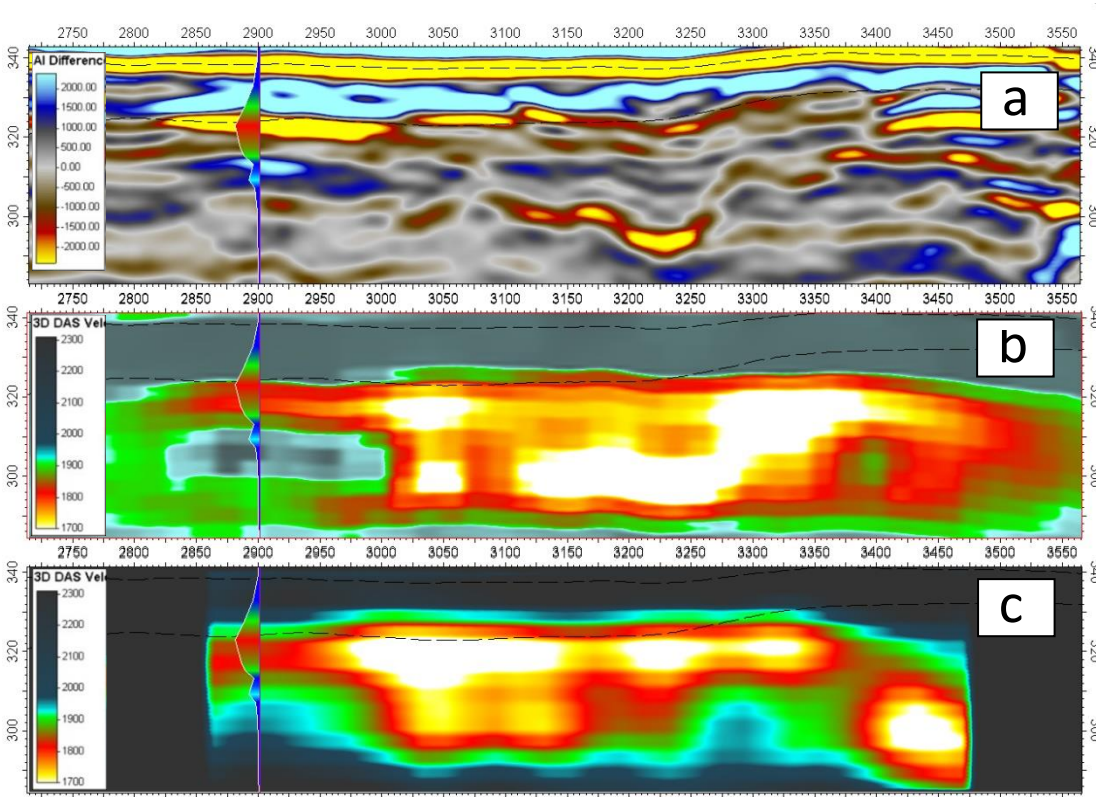

Figure 3. PSDM section image (a), Velocity difference section from 4D surface seismic FWI (b), and the section image of the FWI velocity from 3D DAS along the horizontal (c).

Conclusions

We adapted the FWI methodology for an innovative application on the 3D DAS shot gathers. Compared with the traditional 4D time-lapse surface seismic, the new 3D DAS technology demonstrated some advantages and limitations. It can deliver the velocity volume directly from the raw shot gathers with minor pre-processing of the 3D DAS, which results in a reduced turnaround time to implement production decisions. To mitigate the illumination effect in the 3D DAS technology, the trench fiber on the surface might be used to make up the illumination problem in the 3D DAS, but it will increase the operation cost.

Acknowledgments

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References

Crase, E., Pica, A., Noble, M., McDonald, J., and Tarantola, A., 1990, Robust elastic nonlinear waveform inversion: application to real data: Geophysics, 55, no. 5, pp. 527-538.

Kotsi, M., and Malcolm, A., 2017, A statistical comparison of three 4D Full-Waveform Inversion schemes: SEG International Exposition and 87th Annual Meeting,1434-1438.

Warner, M., and Guasch, L., 2014, Adaptive waveform inversion: Theory: 84th SEG Technical Program Expanded Abstracts. Society of Exploration Geophysicists, Expanded Abstracts, 1089-1093.

Mateeva, A., J. Lopez, H. Potters, J. Mestayer, B. Cox, D. Kiyashchenko, P. Wills, S. Grandi, K. Hornman, B. Kuvshinov, W. Berlang, Z. Yang, and R. Detomo, 2014, Distributed acoustic sensing for reservoir monitoring with vertical seismic profiling: Geophysical Prospecting, 62, 679–692, doi: 10.1111/1365-2478.12116.

Wu, H., Wong, W., Yang, Z., Wills, P. B., Lopez, J., Li Y., Blonk, B., Hewett, B., Mateeva, A., Dual-well 3D vertical seismic profile enabled by distributed acoustic sensing in the deepwater Gulf of Mexico, Interpretation, Vol. 3, No. 3 (August 2015); Society of Exploration Geophysics

Zhang, W., and Zhang, J., 2011, Full waveform tomography with consideration for large topography variations, SEG Expanded Abstracts 30, 2539-2542.