RTM of a distributed acoustic sensing VSP at the CaMI Field Research Station, Newell County, Alberta, Canada

Jorge E. Monsegny*, Daniel Trad and Don C. Lawton
jorge.monsegnyparra@ucalgary.ca

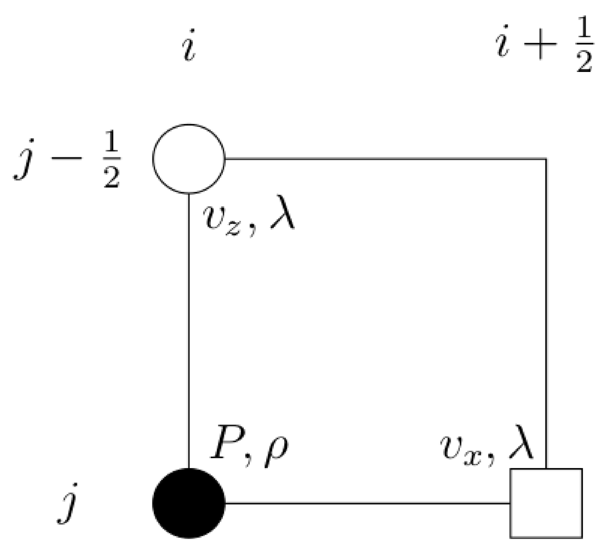
ABSTRACT

We applied a reverse time migration (RTM) algorithm to distributed acoustic sensing (DAS) data from a walkaway vertical seismic profiling (VSP) acquisition at the CaMI Field Research Station at Newell County, Alberta, Canada. The RTM algorithm used a system of coupled first degree differential equations for pressure, vertical and horizontal particle velocities. As DAS data measurements are usually strain rate, we transformed them to vertical particle velocity before the RTM algorithm back propagated them. We tested the techniques of Daley et al. (2016) and Bóna et al. (2017) to do this transformation. We also tested the RTM with the original DAS data. Apart from a polarity reversal, there were no important differences between the different RTM tests. In addition, we migrated geophone data from the same VSP acquisition for comparison and found a similar imaging quality.

Acoustic finite differences for modelling and RTM

This is a staggered system in pressure P , vertical v_z and horizontal particle velocity v_x with density ρ and first Lamé parameter λ:

$$\frac{\partial P}{\partial t} = \lambda\left(\frac{\partial v_x}{\partial x}+\frac{\partial v_z}{\partial z}\right)+s$$
$$\frac{\partial v_x}{\partial t} = \frac{1}{\rho}\frac{\partial P}{\partial x}$$
$$\frac{\partial v_z}{\partial t} = \frac{1}{\rho}\frac{\partial P}{\partial z}$$



Pressure P and density ρ are at integer coordinates (i, j), vertical particle velocity v_z is at coordinates (i, j−1/2), horizontal particle velocity v_x is at (i+1/2, j) and Lamé parameter λ is defined at both (i, j−1/2) and (i+1/2, j).

Normalized RTM imaging condition

$$I(x,z)=\frac{\int_0^T v_z(x,z)\hat{v}_z(x,z)dt}{\int_0^T v_z(x,z)^2dt},$$

where the hat symbol "^" indicates back propagation, the denominator term is used to correct the source illumination and T is the maximum time recorded.

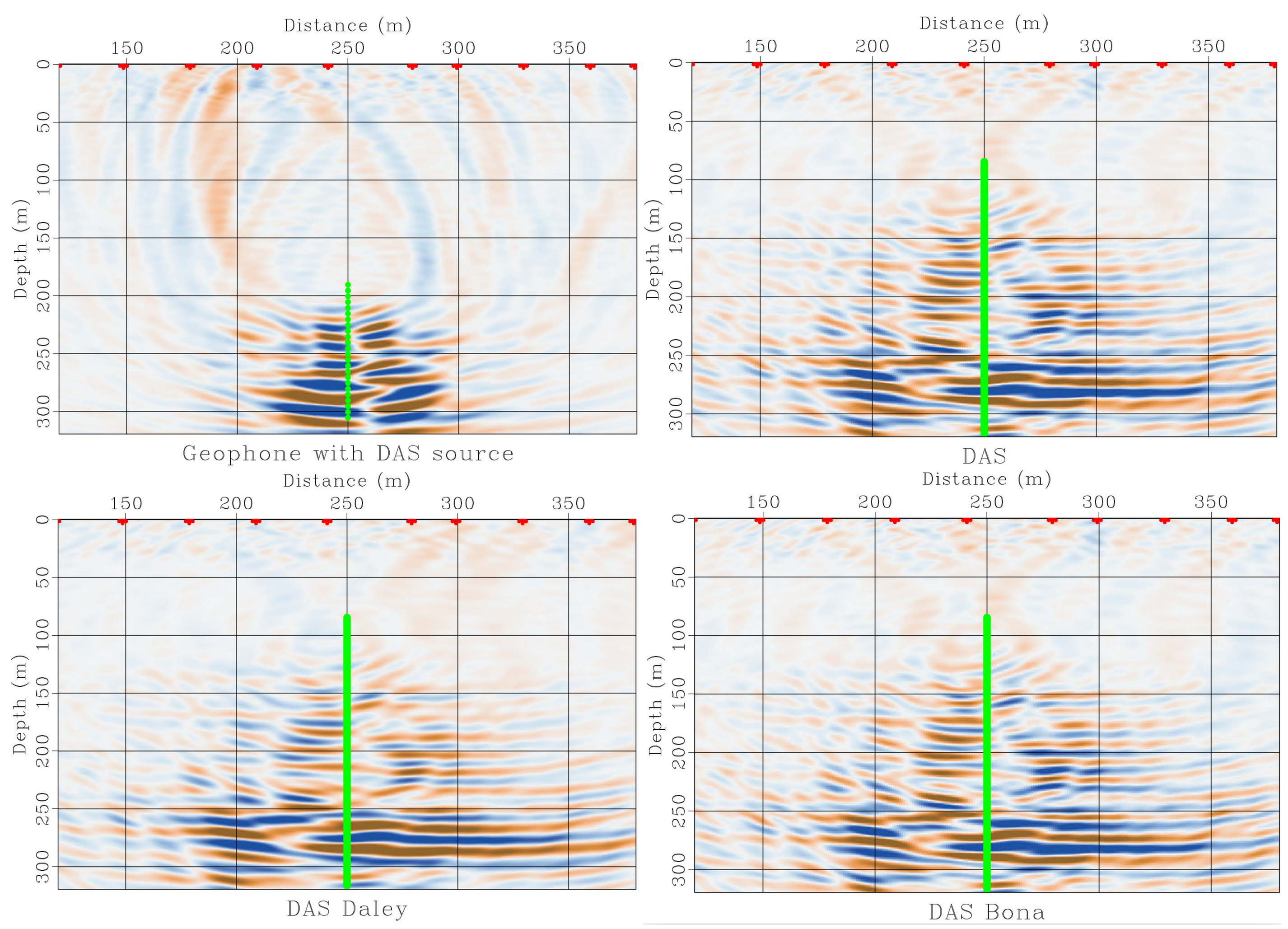
Strain rate to particle velocity transformation

A vertical DAS measures vertical strain rate $f = \partial\epsilon_z/\partial t$ where ϵ_z is the strain along the z axis.

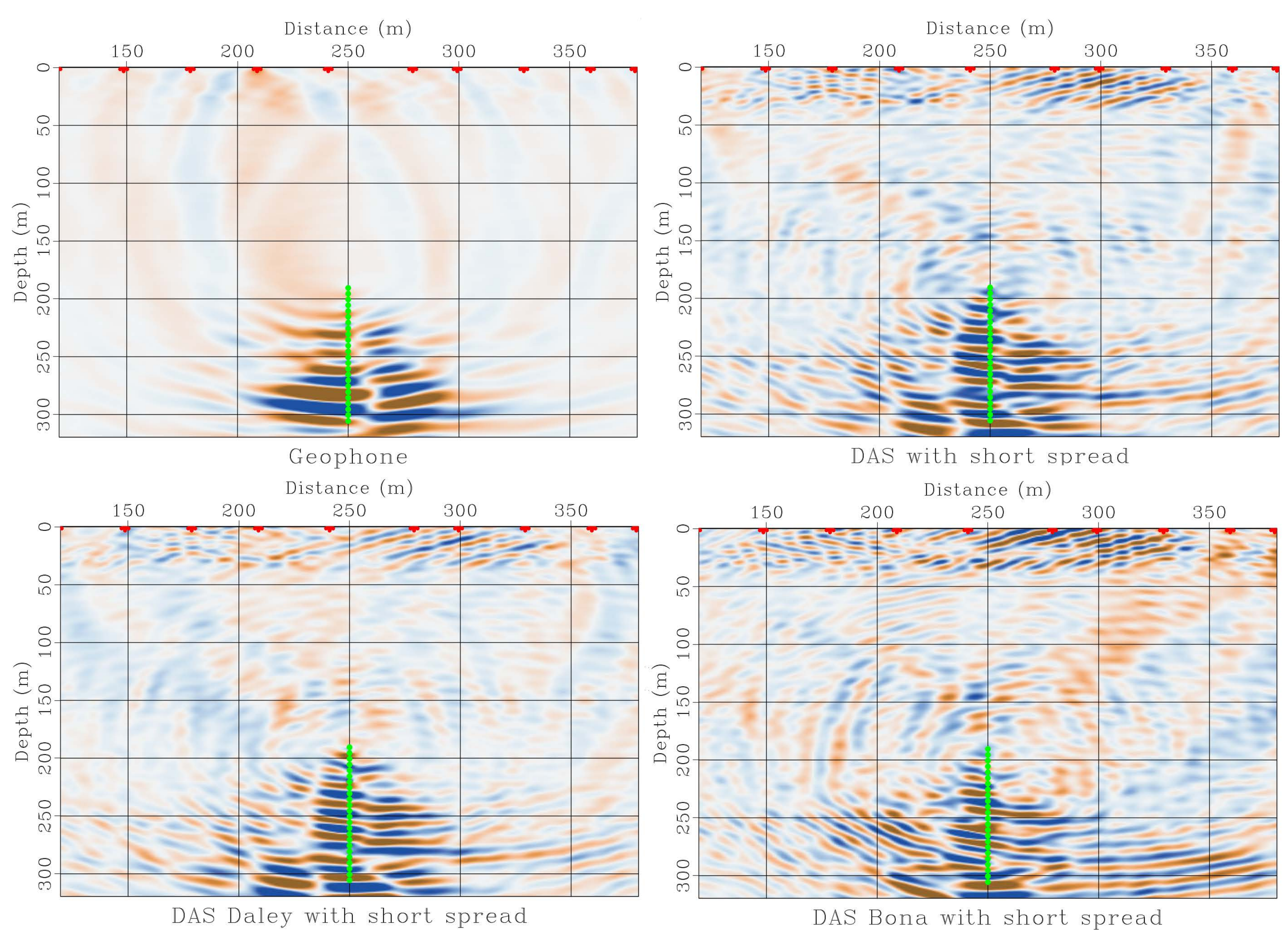
Daley: $$v_z(z) = -c(z)\int f(z)dt,$$

Bóna: $$v_z(k_z) = f(k_z)\frac{-ik_z}{(1-e^{ik_zL})(1-e^{ik_zG})+\gamma},$$

where c(z) is the apparent particle velocity along the well, L is the pulse length, G is the gauge length and γ is a small constant used to avoid division by zero.



Top row left is the RTM from 24 vertical geophones located inside the well (green dots) between 191m and 306m deep every 5m and 17 source positions placed at the surface (red crosses). Top row right is the RTM from a DAS fibre located in the well (green line) between 85m and 317m deep. It uses the same sources of the previous figure. The DAS data was not transformed before being used in the RTM, i.e. strain rate was back propagated by the migration algorithm. Bottom left uses the same DAS and sources configuration but transforms the strain rate measurements into particle velocity using the technique of Daley et al. (2016). Bottom right also transforms DAS measurements to particle-velocity but it uses the technique of Bóna et al. (2017). Laplacian filtering was not applied to any figure because it did not produce any noticeable effect.

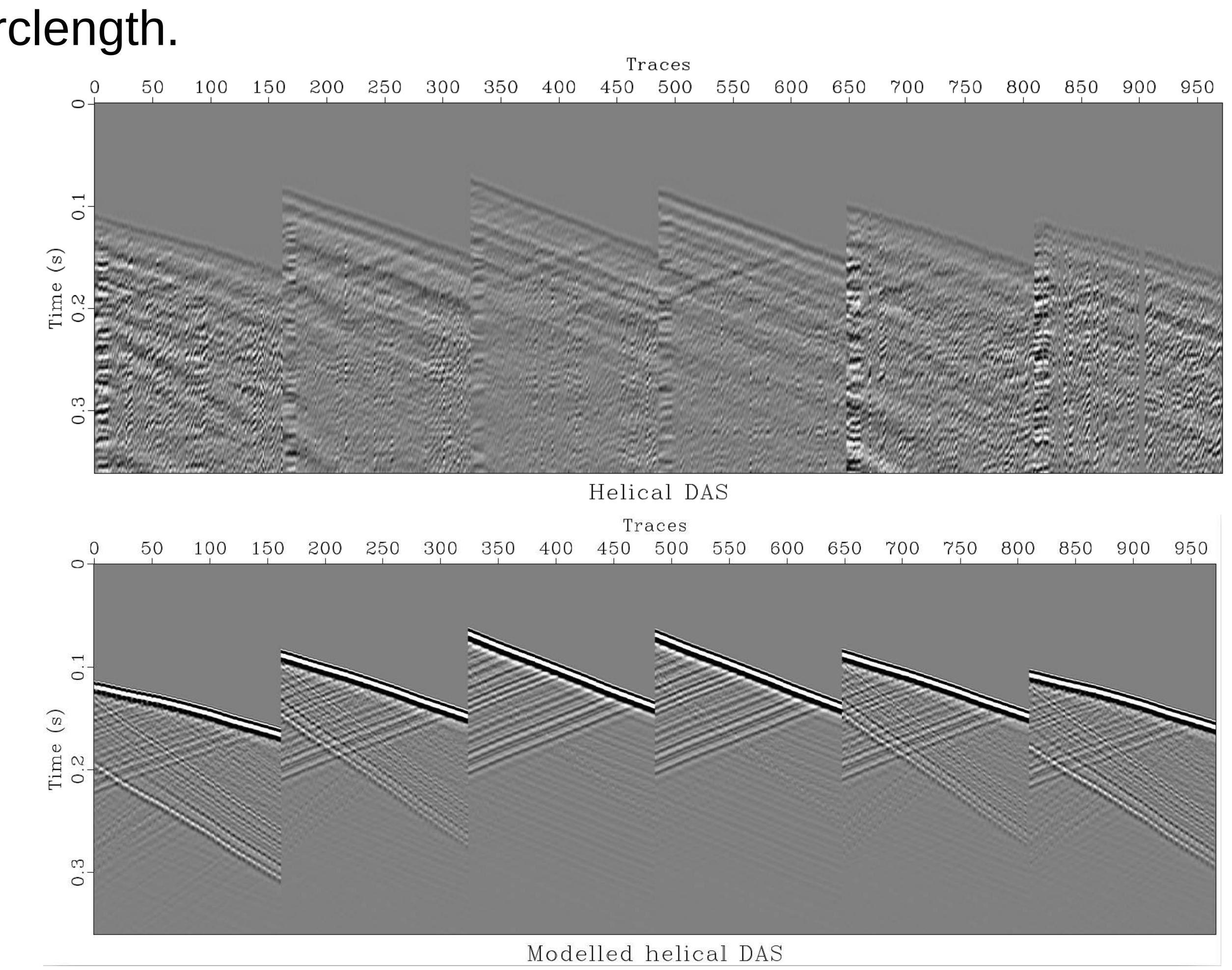


Top left is the walkaway VSP geophone RTM with a 60Hz minimum phase source wavelet. The other three RTM sections use a 100Hz source wavelet but their receiver spreads have been decimated to match the geophone receiver spread. Top right is the untransformed DAS RTM. Bottom left is the RTM of DAS data transformed using the technique of Daley et al. (2016) while bottom right uses the technique of Bóna et al. (2017).

ELASTIC ADVANCES

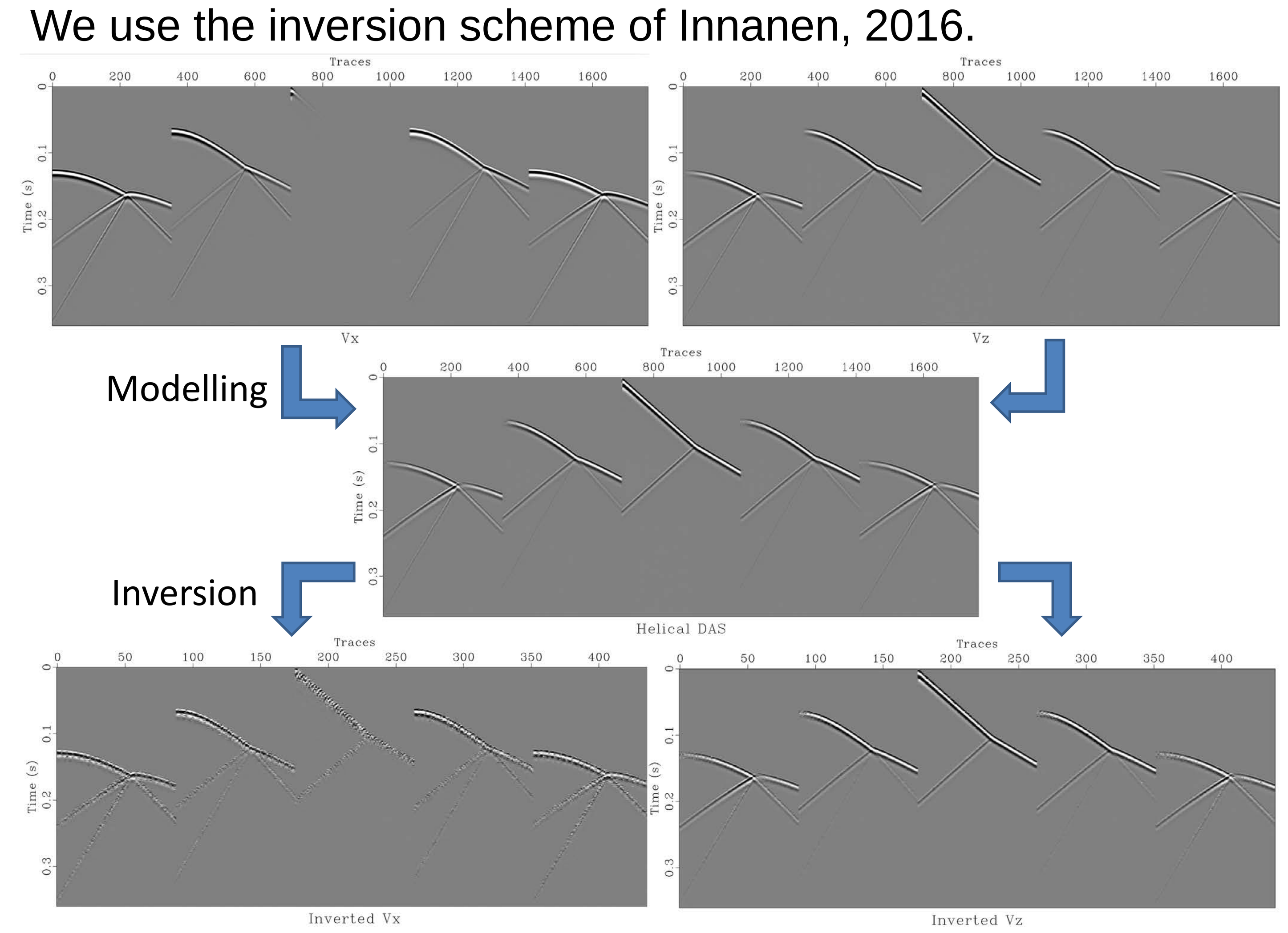
Helical DAS Modelling

We model the particle velocity Cartesian components, project them in the helix direction and derive the result along the helix arclength.



Inversion of Cartesian DAS from Helical DAS

We use the inversion scheme of Innanen, 2016.



ACKNOWLEDGEMENTS

We thank the sponsors of CREWES for continued support. This work was funded by CREWES industrial sponsors, and NSERC (Natural Science and Engineering Research Council of Canada) through the grant CRDPJ 461179-13. This work was also funded in part thanks to the Canada First Research Excellence Fund.

REFERENCES

Bóna, A., Dean, T., Correa, J., Pevzner, R., Tertyshnikov, K., and Zaanen, L., 2017, Amplitude and phase response of DAS receivers, in 79th EAGE Conference and Exhibition 2017

Daley, T., Miller, D., Dodds, K., Cook, P., and Freifeld, B., 2016, Field testing of modular borehole monitoring with simultaneous distributed acoustic sensing and geophone vertical seismic profiles at Citronelle, Alabama: Geophysical Prospecting, 64, No. 5, 1318–1334

Innanen, K. A geometrical model of DAS fibre response, CREWES, 2016