# Imaging in shallow water with strong multiples.

*Mathias Louboutin*,[1], Fabio Luporini[1], Edward Caunt[1], Gerard Gorman[1], Christos Mavropoulos[3], Henry Debens[2], Robert Eliott-Lockhart[2]*
*[1] DevitoCodes Ltd, [2] Woodside Energy Ltd, [3] S-Cube*

## ABSTRACT

Shallow water imaging is a challenging problem when using streamer data with a hard water bottom due to strong surface related multiples interleaved with early first arrival. In this work, we show that impedance imaging leads to high accuracy imaging and reduces artifacts from the shallow water in the subsurface. Additionally, we show that traditional imaging provides insight on the quality of the subsurface model not available from the velocity gradient. We illustrate our method on the Galactic 2D marine seismic field survey.

## METHODS

We briefly introduce the two methods we will be considering in this study. We are interested in comparing the image obtained by computing the vertical derivative of the FWI velocity:

$$\mathscr{I}_v = \frac{d\mathbf{V}_p(x,y,z)}{dz}$$

and the image obtained by impedance imaging, that computes a standard reverse time migration using the inverse scattering imaging condition (Witte et al., 2017):

$$\mathscr{I}_i = \mathbf{J}^\top d_{\text{obs}}$$

where $d_{\text{obs}}$ is the observed data and $\mathbf{J}$ is the Jacobian of the forward modeling operator with the inverse scattering imaging condition:

$$\mathbf{J}^\top d_{\text{obs}} = \sum_t \nabla\mathbf{u}[t].\nabla\mathbf{v}[t] + \frac{1}{c^2}\frac{d^2\mathbf{u}[t]}{dt^2}\mathbf{v}[t]$$

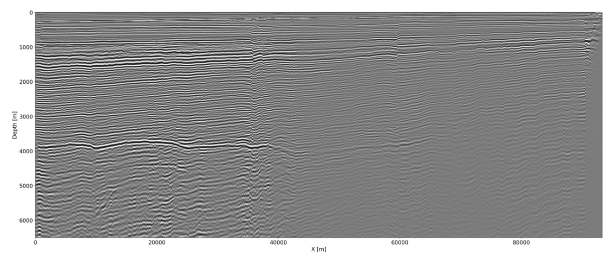
where $\mathbf{v}[t]$ is the adjoint wavefield. We show that these two methods lead to images with significant differences in term of frequency content and focusing and we argue that the combination of those two methods is more informative than FWI imaging. All results were obtained using Devito (Luporini et al., 2020; Louboutin et al., 2019) and JUDI (Witte et al., 2019).

## DATASET

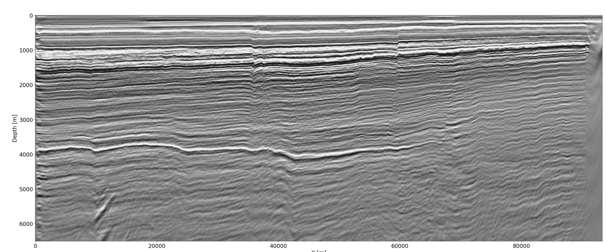
The dataset we consider for this study is the Galactic 2D marine seismic survey. The survey was acquired in 2022 over the Bonaparte Basin (offshore Northern Territory, Australia) and consists of 32 lines in water depth that range from 80m to 350m. We focus here on Line 18 of the survey that shows most complexities for inversion and imaging.

## RESULTS

We show the impedance image Figure 1 (a) and the vertical derivative of the background velocity on Figure 1 (b). We can make two main observations. First, the shallow part of the model displays sharper reflectors with RTM while the velocity image shows a shallow region with smooth variation and lower frequency content. This observation can be extended to the deeper left part of the model. Second, we observe that despite a good estimate of the velocity from an inversion standpoint, the right part of the model stays fairly unfocused after impedance imaging. The velocity image in that the area of the model is less focused as well. This can be explained by inaccurate physics (isotropic acoustic) and we intend to include elastic and anisotropic effects in the future to improve the imaging of the right part of the model.




(a)




(b)

Figure 1: Impedance imaging in the FWI final model (a) and the derivative of the velocity (b).

Through this case study, we showed that while FWI imaging provides accurate subsurface image from the differentiation of the velocity, imaging methods such as RTM with an impedance imaging condition can provide high precision subsurface images and highlights inaccuracies in the velocity model difficult to obtain from the velocity gradient. More advanced methods such as LSRTM should enhance the difference between this two methods and provide a better understanding of the subsurface.

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