# Time domain internal multiple prediction on Vertical Seismic Profiles

Matthew Eaid*, and Kris Innanen
mveaid@ucalgary.ca

## ABSTRACT

Inverse scattering series internal multiple prediction (Weglein et al., 1997) has proven to be a powerful method of internal multiple prediction. A time domain algorithm was derived by Innanen (2015). We review this algorithm and then employ it on synthetic and land zero offset VSP data. A method of improving the prediction is introduced and then tested on both the synthetic and land data sets.

## TIME DOMAIN INTERNAL MULTIPLE PREDICTION

Starting with the frequency domain formula proposed by Weglein et al. (1997).

$$IM_\omega = \int_{-\infty}^{\infty} dz\, b_1(z) e^{ik_z z} \int_{-\infty}^{z-\epsilon} dz' b_1(z') e^{-ik_z z'} \int_{z'+\epsilon}^{\infty} dz'' b_1(z'') e^{ik_z z''} \quad (1)$$

Replacing $b_1(z)$ with d(t), and $k_z z$ with $\omega t$:

$$IM_\omega = \int_{-\infty}^{\infty} dt\, d(t) e^{i\omega t} \int_{-\infty}^{t-\epsilon} dt' d(t') e^{-i\omega t'} \int_{t'+\epsilon}^{\infty} dt'' d(t'') e^{i\omega t''} \quad (2)$$

Recognizing the products, as a partial convolution and correlation we arrive at, the formula proposed by Innanen (2015).

$$IM_t = \int_{-\infty}^{\infty} dt'\, s(t'-t) \times \int_{\alpha(t,t')}^{\beta(t)} dt'' s(t'-t'') s(t'') \quad (3)$$

$$\alpha(t,t') = t' - (t-\epsilon), \beta(t) = t - \epsilon \quad (4)$$

## SYNTHETIC EXAMPLE

Inverse scattering series internal multiple prediction automatically searches through datasets and combines subevents that obey a lower-higher-lower relationship. For this reason it is important to prepare datasets by removing direct arrivals, surface multiples, and ghosts. The upgoing wavefield of VSP data is a good candidate for internal multiple prediction as it already has the direct arrival, ghosts and surface multiples removed. Figure 1 shows the synthetic data and the resulting internal multiple prediction. While the prediction is accurate it is obvious that multiples are not predicted to their full lateral extent. Focusing on the multiple around 0.33 seconds, once the first primary truncates the multiple that is generated by the first interface is no longer predicted in depth. This is because the algorithm now lacks one of the primaries need to predict the internal multiple.

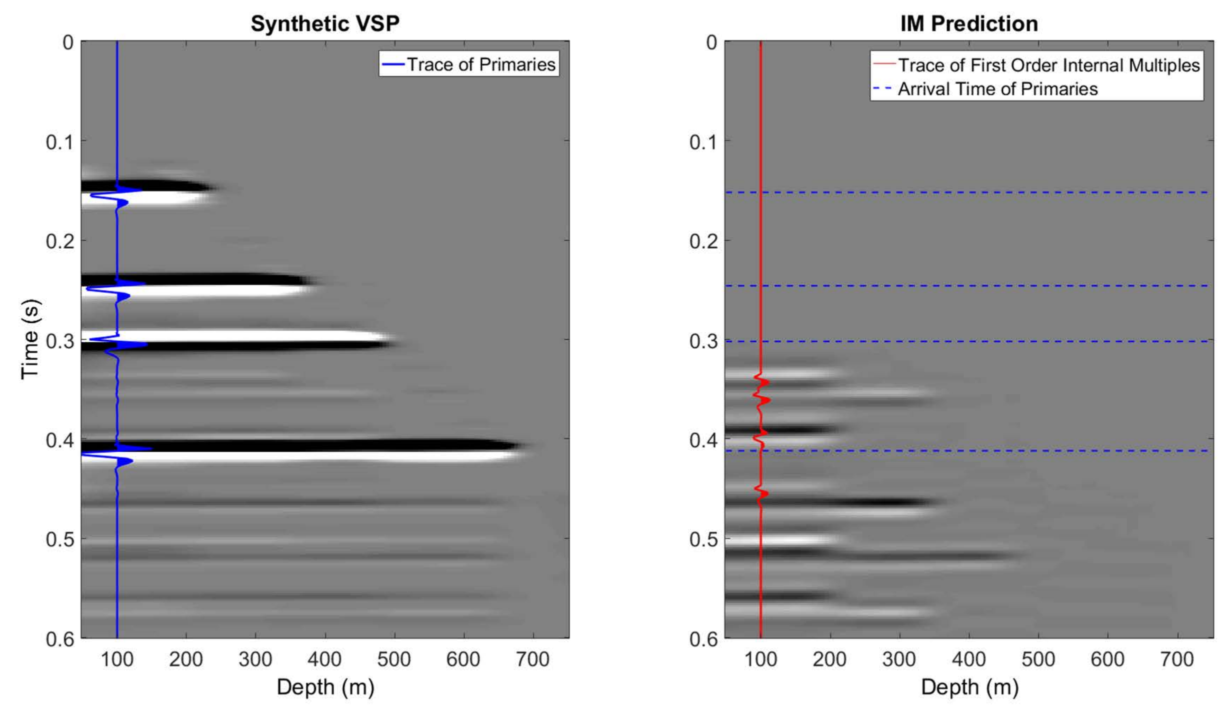


FIG. 1. Synthetic VSP data (left), resulting internal multiple prediction (right). Blue trace, and red trace represent primaries and IM respectively.

We propose extending these events laterally by calculating the mean at a given time, and then inputting this value at every depth value for this time, after the event truncates.

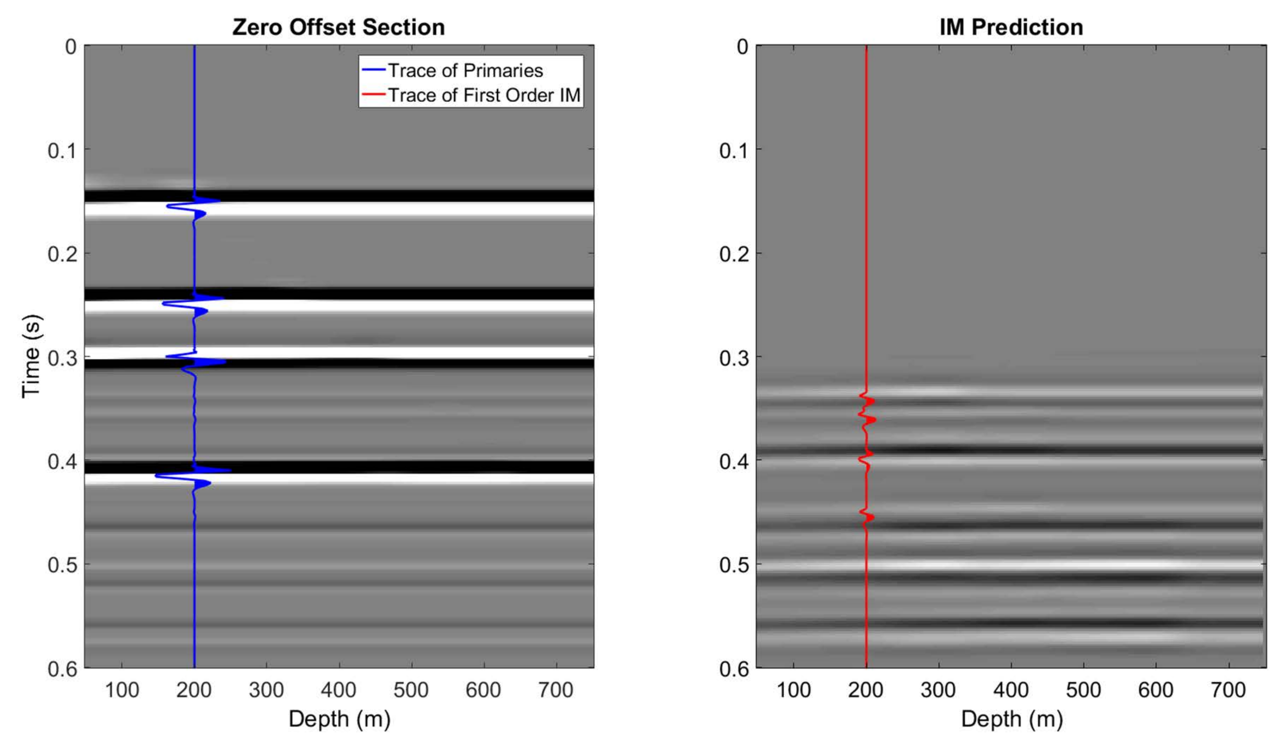


FIG. 2. Synthetic zero offset section (left), resulting internal multiple prediction (right). Blue trace, and red trace represent primaries and IM respectively.

Another benefit of VSP data is that we may ground truth our prediction, by comparing it to the corridor stacks. A future research topic will be to guide the selection of epsilon using the corridor stacks.

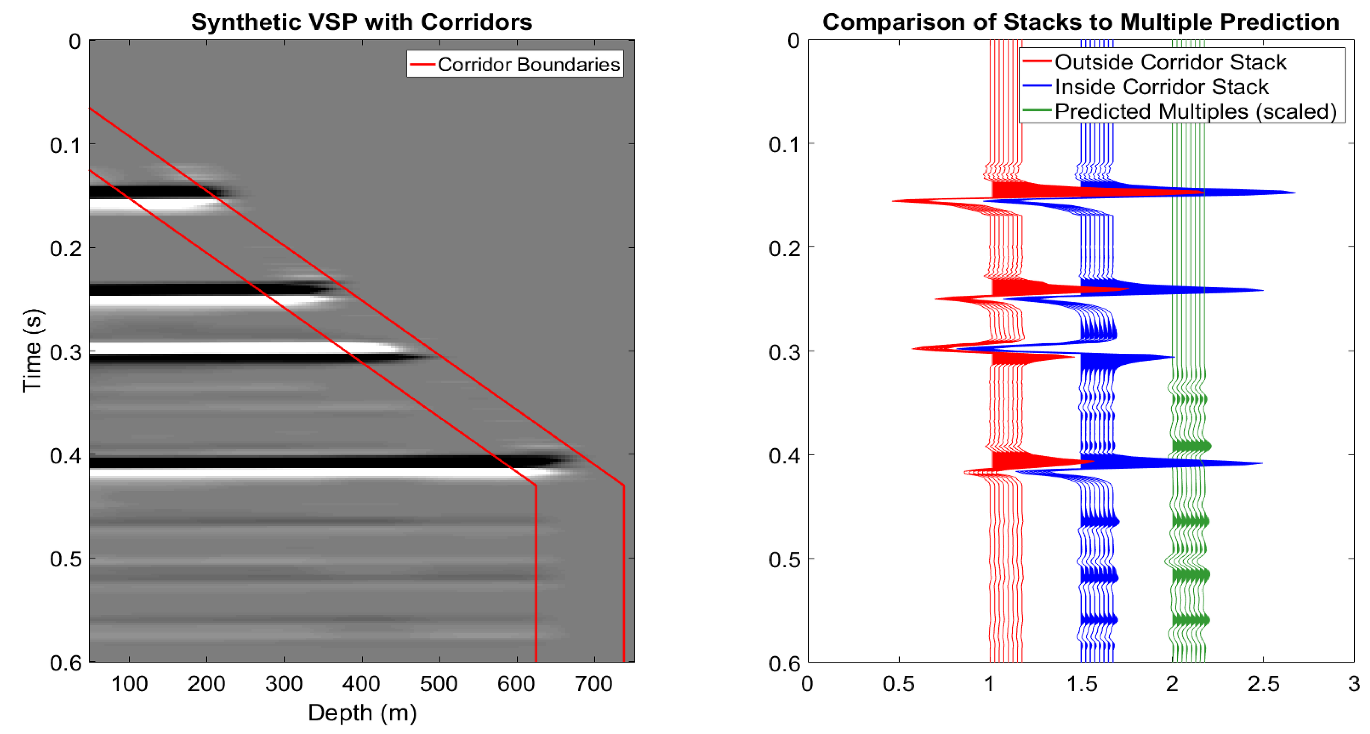


FIG. 3. Synthetic VSP with overlain outside corridor (left), comparison of corridor stacks to internal multiple prediction (right).

## LAND DATA

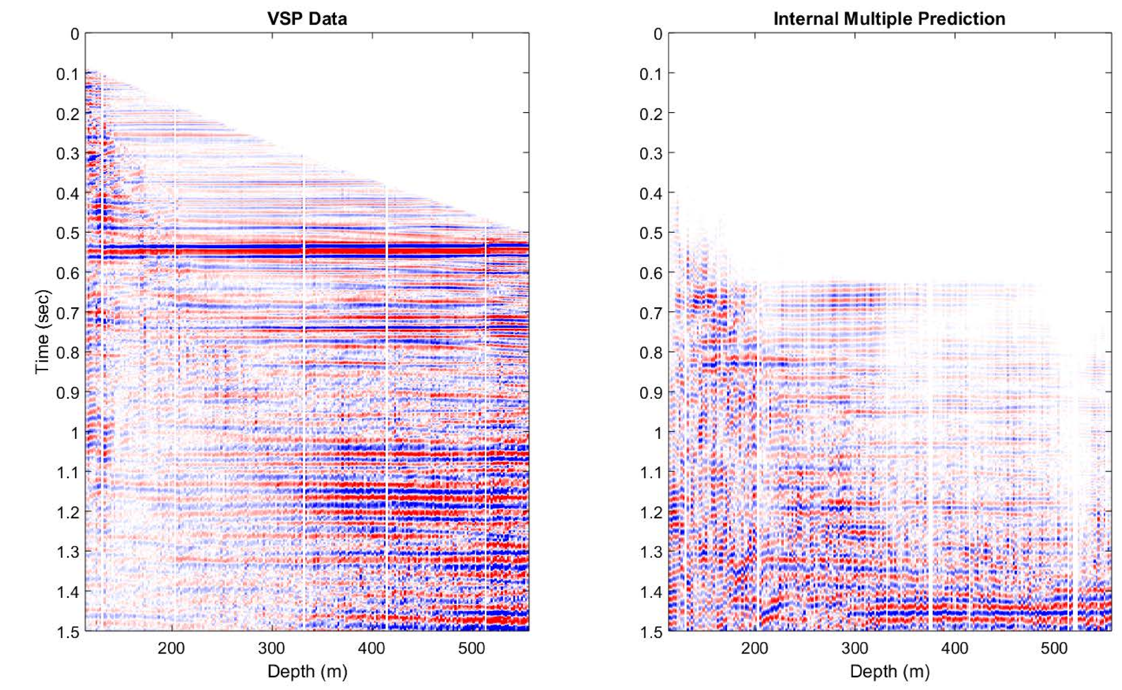


FIG. 4. VSP data (left) and time domain prediction (right)

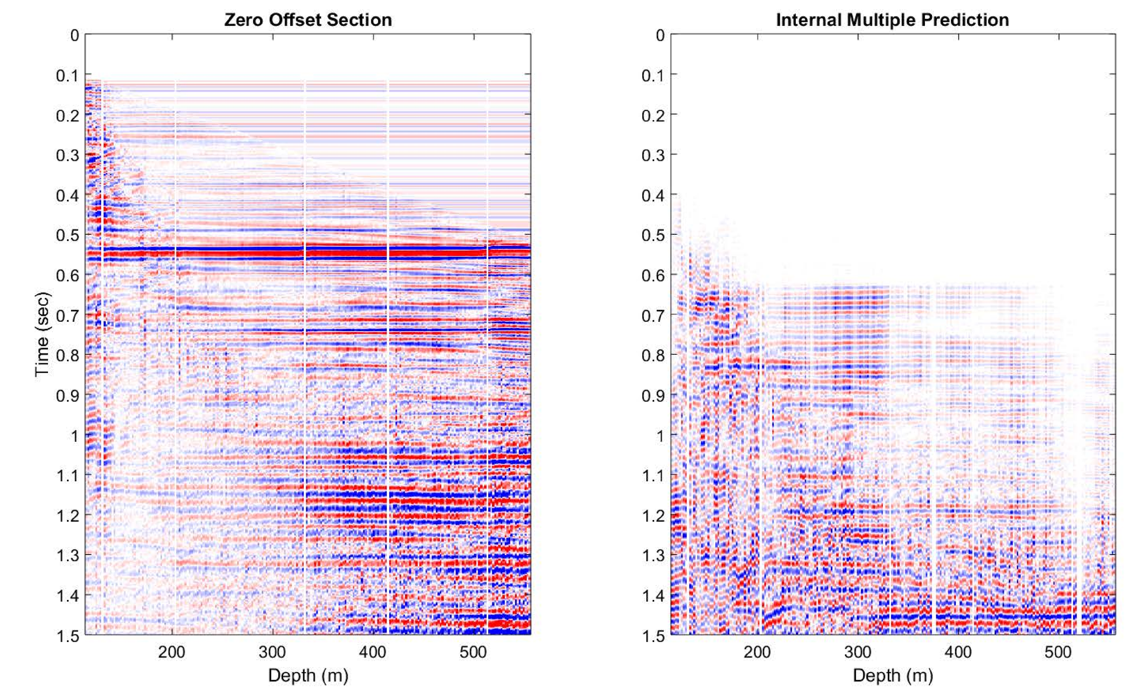


FIG. 5. Zero offset section (left) and time domain prediction (right)

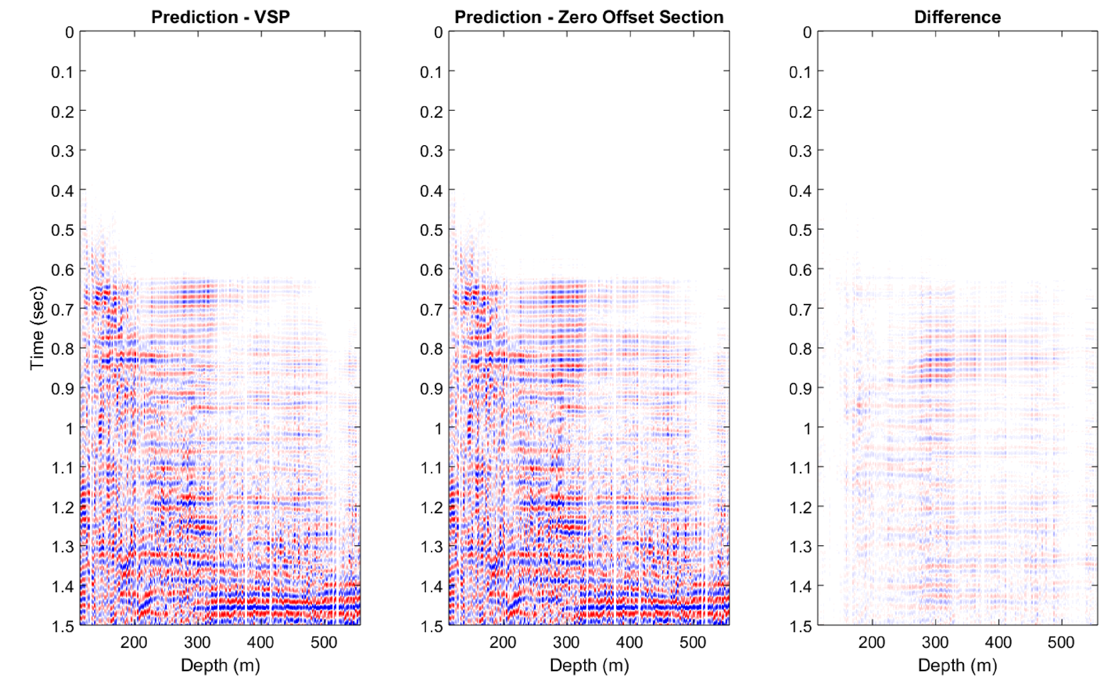


FIG. 6. VSP prediction (left), ZOS prediction (middle), difference (right).

## CONCLUSION

We employ time domain internal multiple prediction on VSP field data. Bona fide multiples were predicted by the algorithm, however once one of the contributing interfaces truncated the prediction broke down. We proposed a method of extending interfaces past their truncation point which resulted in a more robust prediction.

## ACKNOWLEDGEMENTS

The authors thank CREWES and its sponsor companies for funding this work as well as NSERC through the grant CRDPJ 461179-13. We are grateful for the donation of the dataset used.