Internal multiple prediction and generator spectra

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Overview

Goal of internal multiple prediction:

- Correctly predict the amplitudes of all internal multiples without predicting primaries

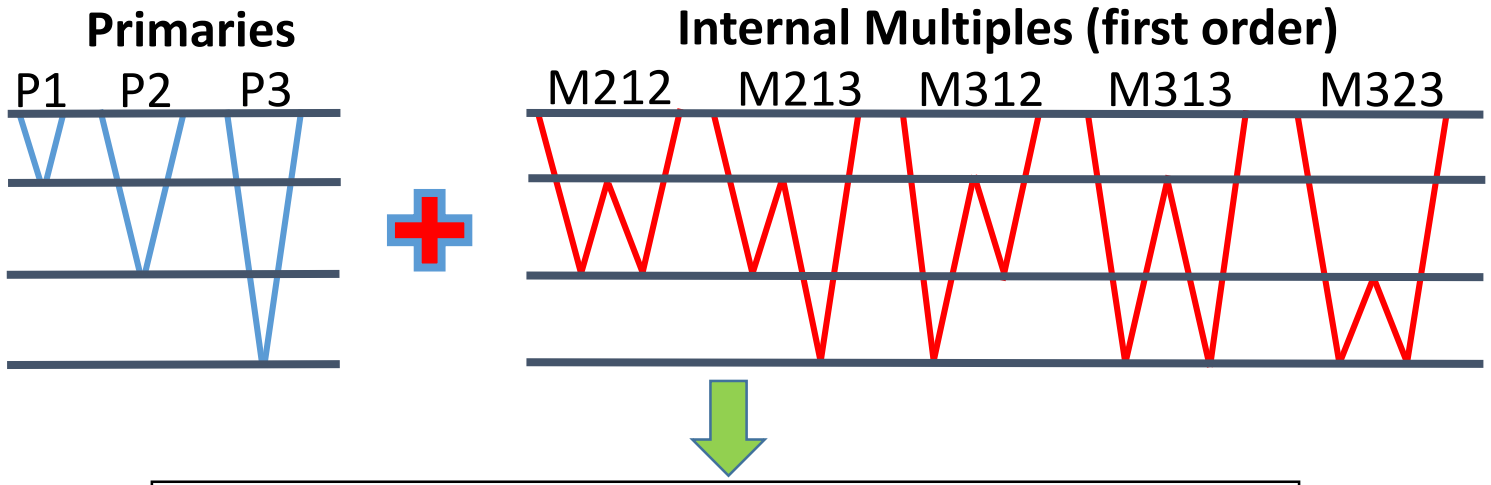
In practice:

- Optimal approximation to amplitudes and minimize artifacts of prediction
- Prediction then input into adaptive subtraction

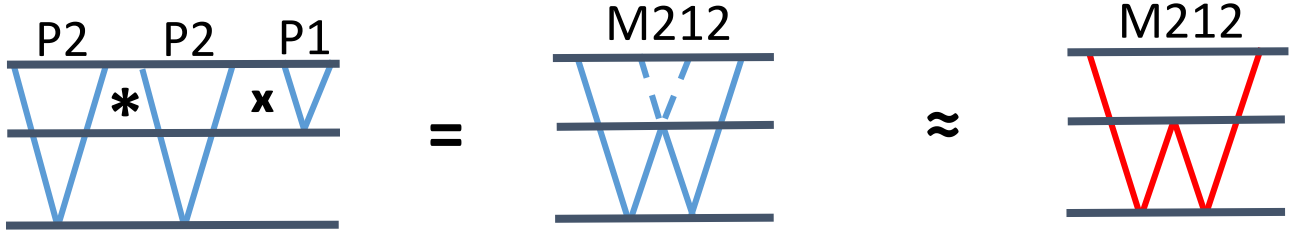
Accomplished using inverse scattering series internal multiple prediction:

- Wave equation based method
- Requires no prior subsurface information

Internal Multiple Prediction



$$b_3(\omega) = \int_{-\infty}^{\infty} dz_1 e^{-i2\frac{\omega}{c_0}z_1} b_1(z_1) \left[\int_{z_1+\varepsilon}^{\infty} dz_2 e^{i2\frac{\omega}{c_0}z_2} b_1(z_2) \right]^2$$



Amp = $T_{01}R_2T_{10}$ $T_{01}R_2T_{10}R_1$ Amp = $T_{01}R_2R_1R_2T_{10}$ Error = $T_{01}T_{10}$

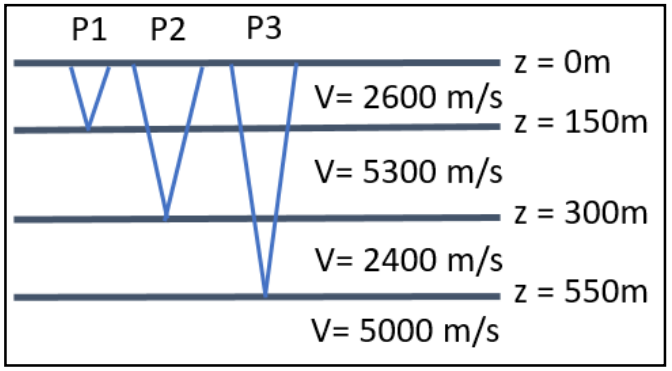
b_1 = Input Data

ε = Search limiting parameter

Inverse Scattering Series

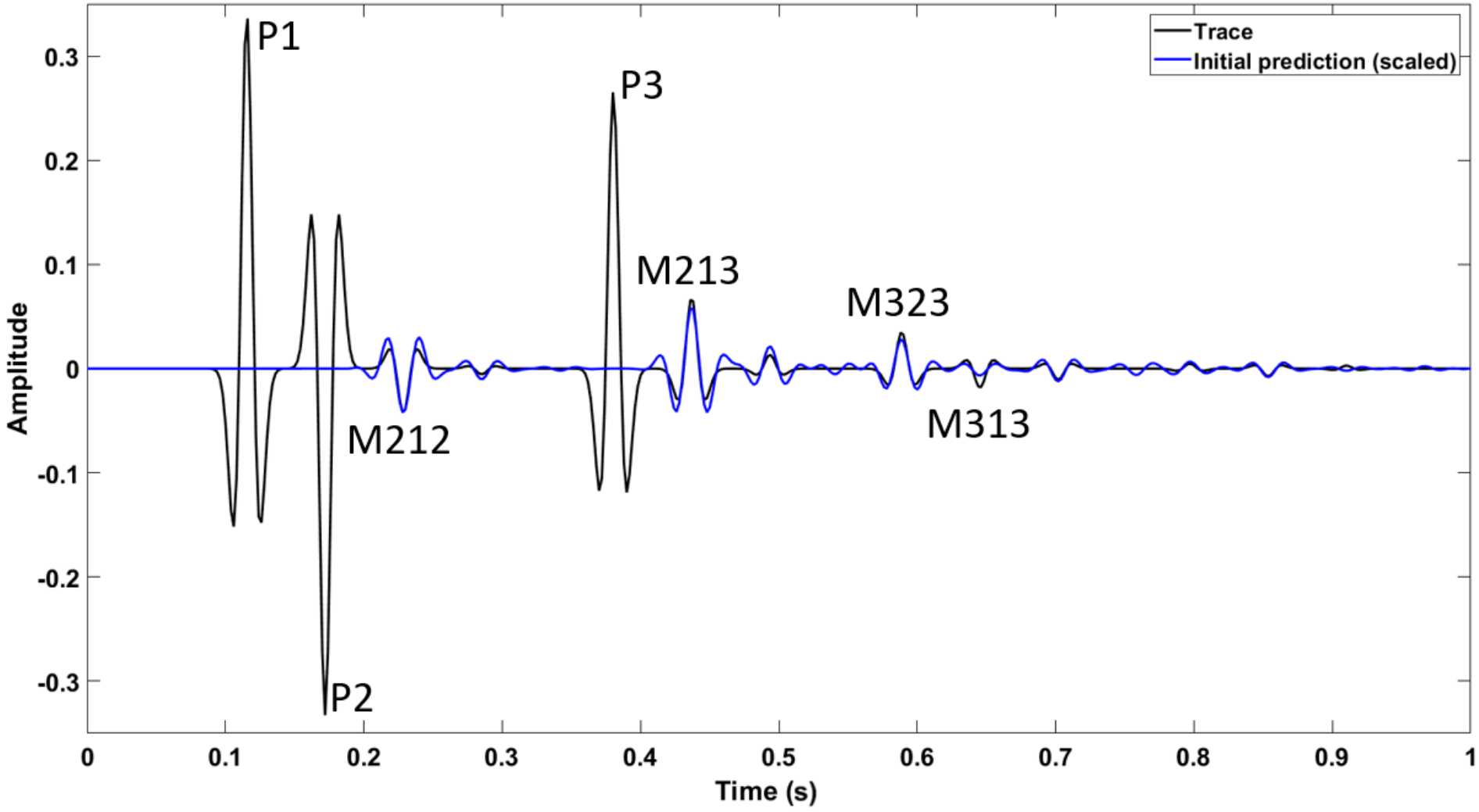
- Only input data and epsilon required
- Predict internal multiples from sub events in the data
- Error is a function of downward generating horizon

Standard Internal Multiple Prediction



Model displayed above with 3 primaries

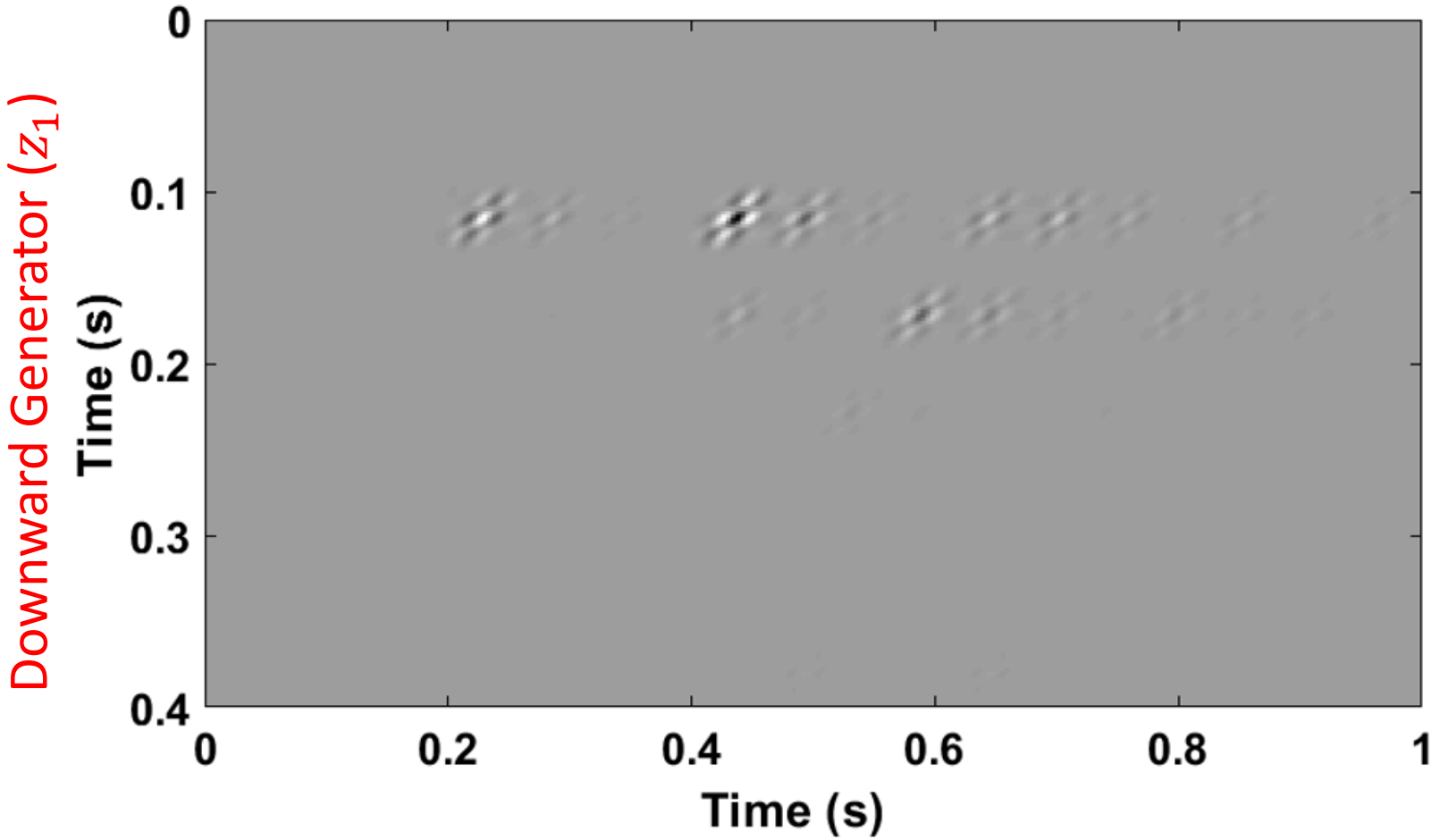
Internal multiples have been predicted but with amplitude mismatches



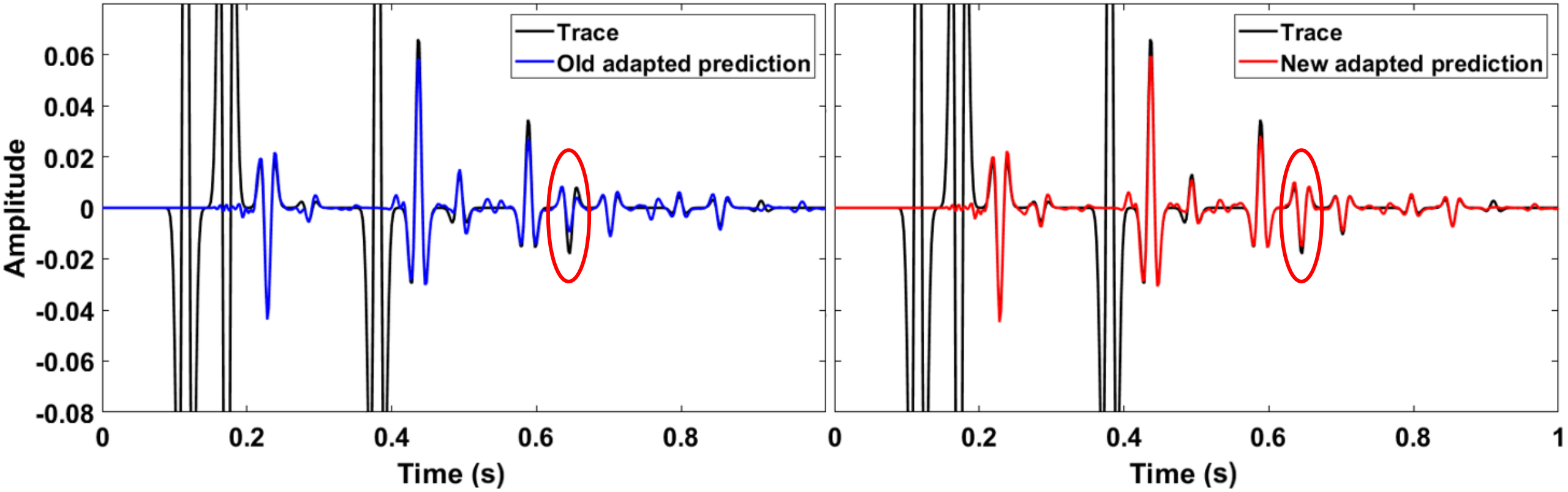
2D Downward Generator Space

$$b_3(\omega) = \int_{-\infty}^{\infty} dz_1 e^{-i2\frac{\omega}{c_0}z_1} b_1(z_1) \left[\int_{z_1+\varepsilon}^{\infty} dz_2 e^{i2\frac{\omega}{c_0}z_2} b_1(z_2) \right]^2$$

- Downward generator space
  - X-axis – standard prediction time
  - Y-axis – function of downward generator time
- Each event is an individual internal multiple
- Standard prediction can be created by summing over Y-axis
- Use 2D adaptive subtraction in this space



Internal Multiple Prediction

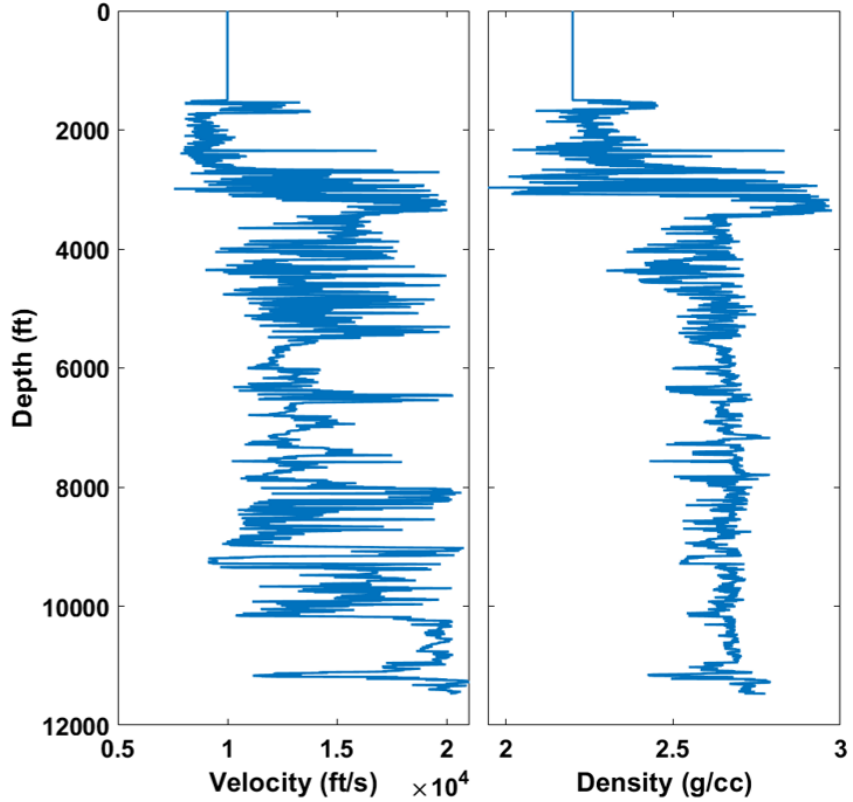


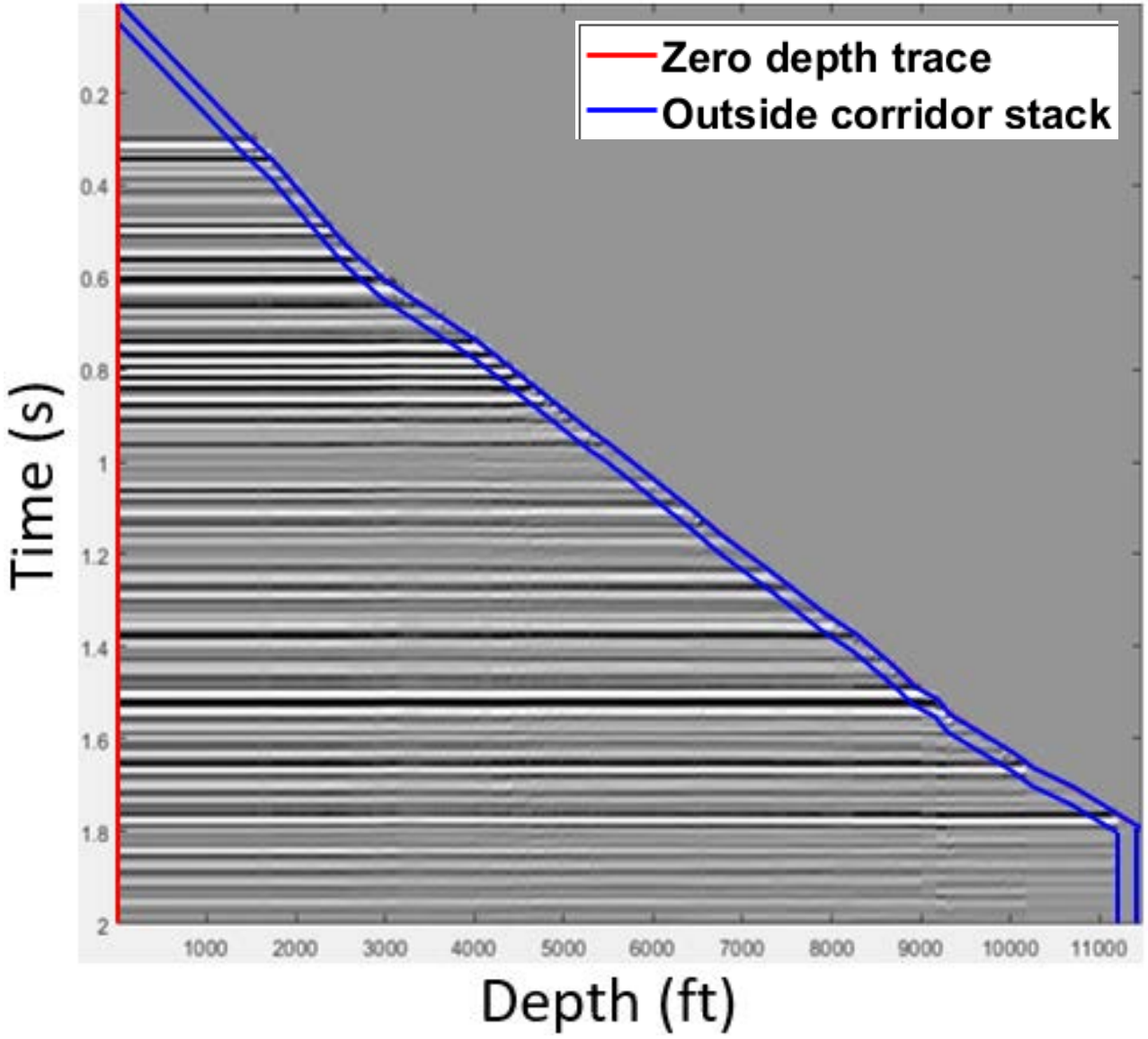
This 2D adaptive subtraction has improved the prediction

Synthetic VSP

Used well log to create synthetic VSP

- Outside corridor stack (primaries only)
- Zero depth trace (primaries and internal multiples)



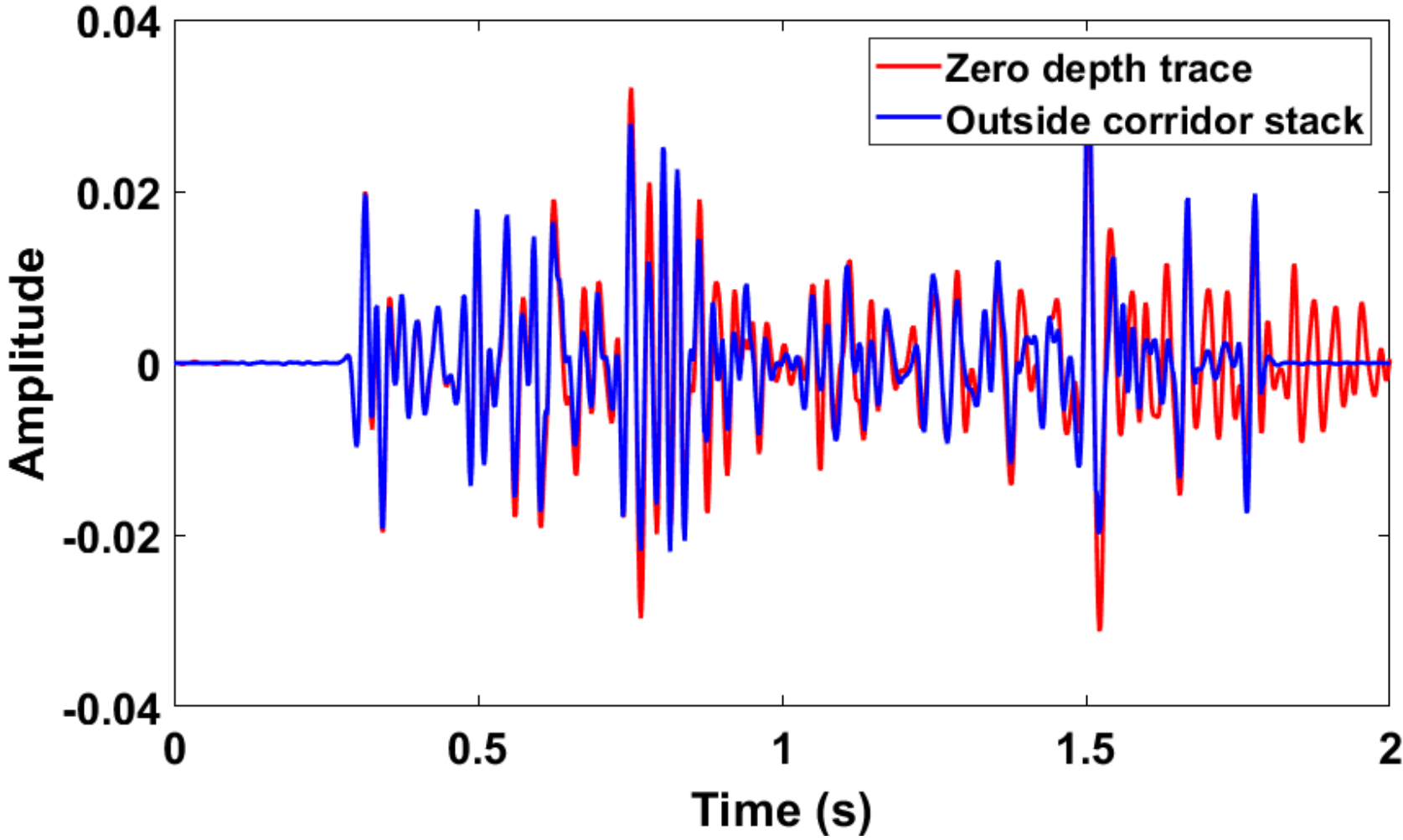


Synthetic VSP Traces

Comparing the outside corridor stack (primaries only) and zero depth trace (primaries and internal multiples)

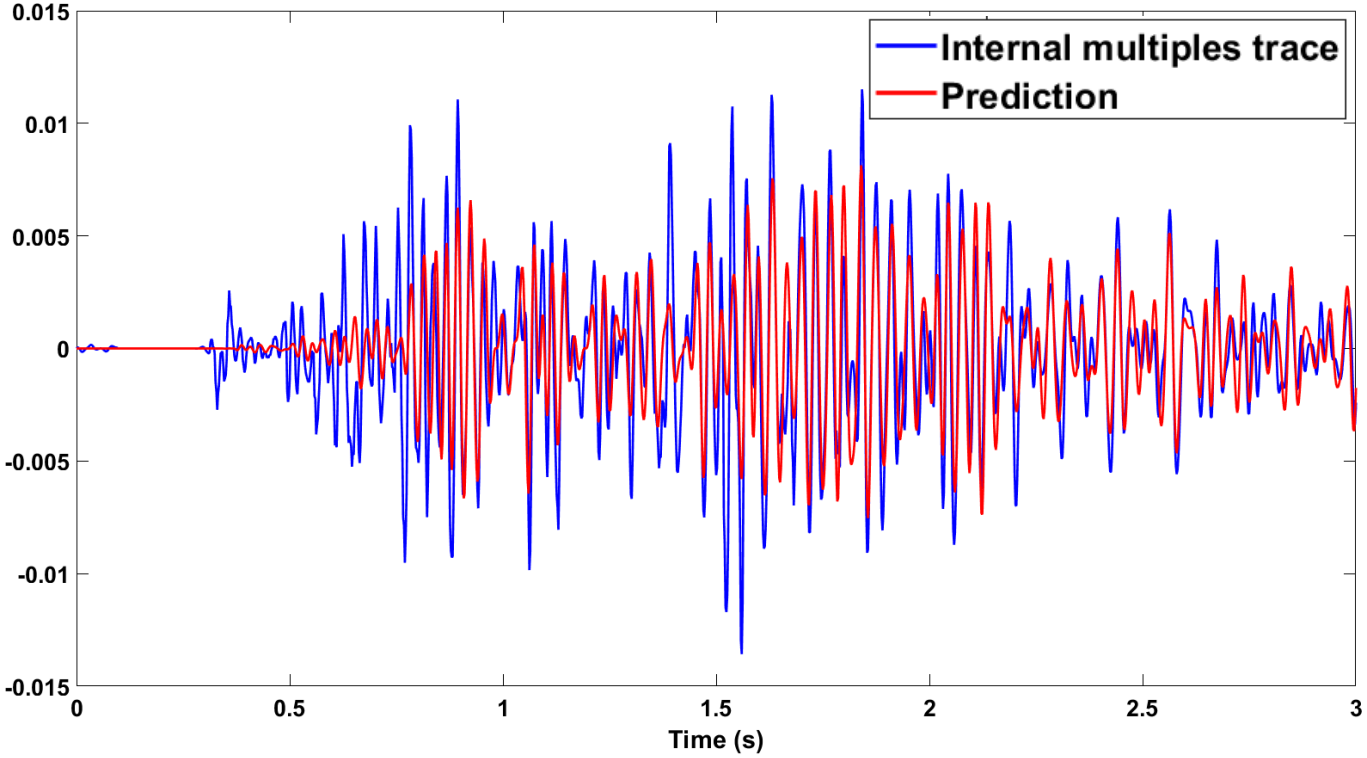
Difference between the two is the internal multiples trace

Well log synthetic has significant internal multiples

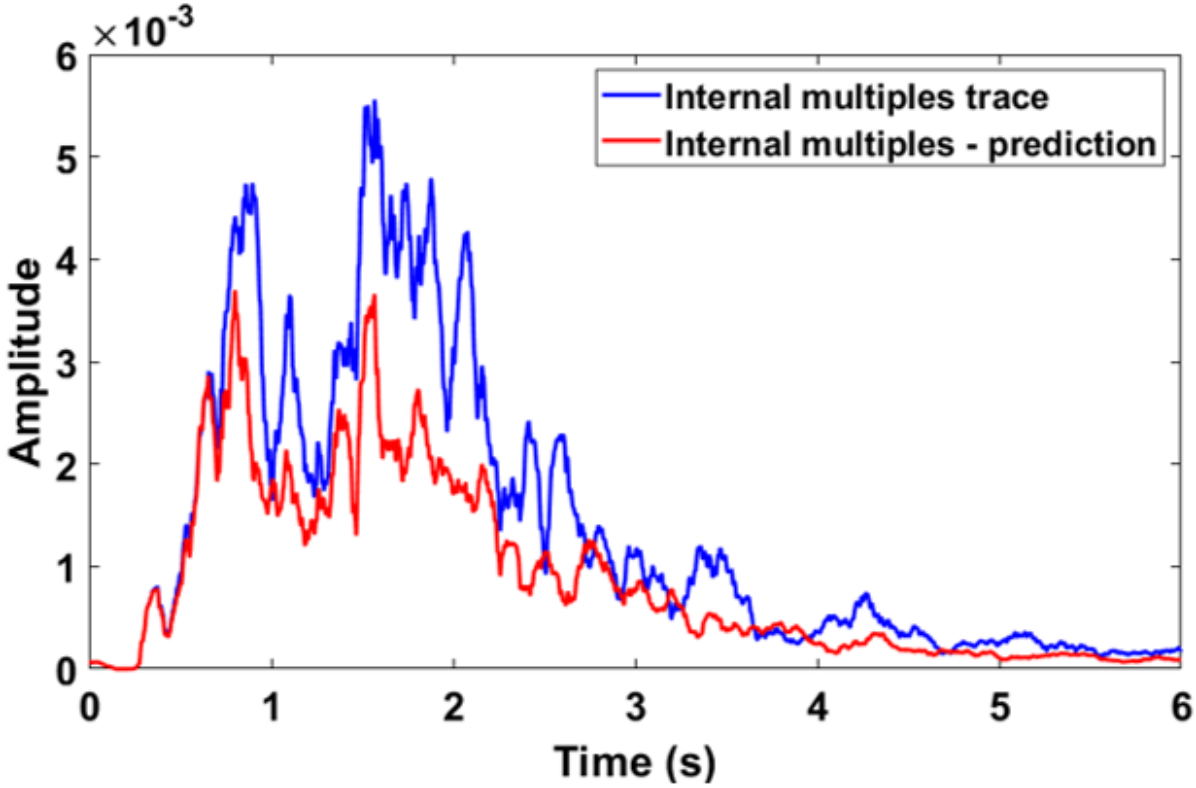


Internal Multiple Prediction

Internal multiples trace and prediction



Absolute value with rolling average

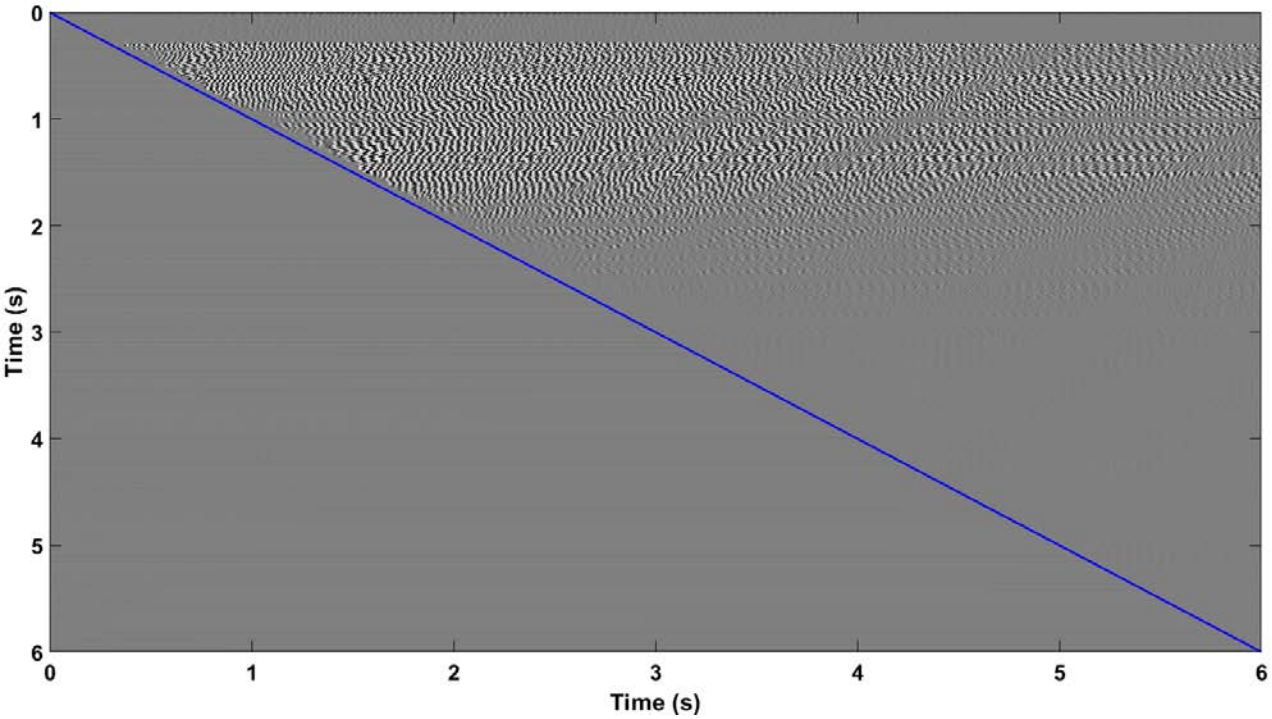


The standard method gave good prediction of internal multiples

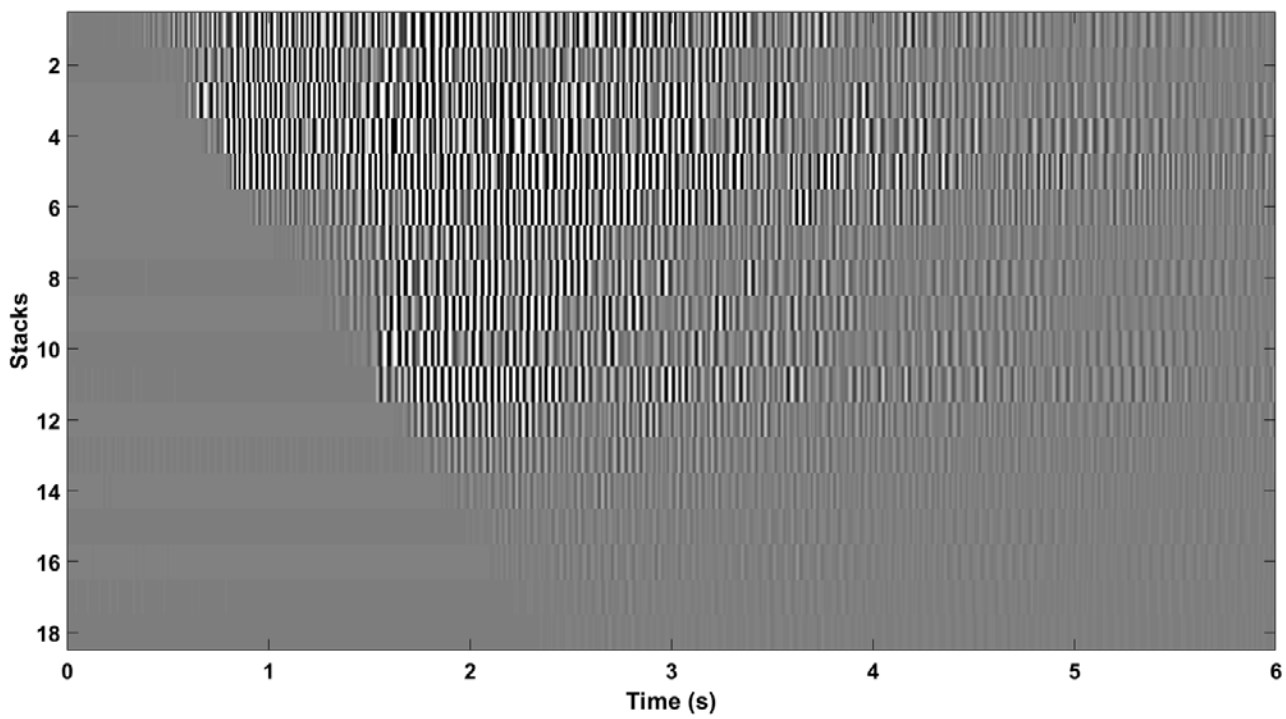
From subtracting the two can see the decrease in internal multiples

Synthetic VSP Downward Generator Space

Downward generator space



Downward generator space stacked

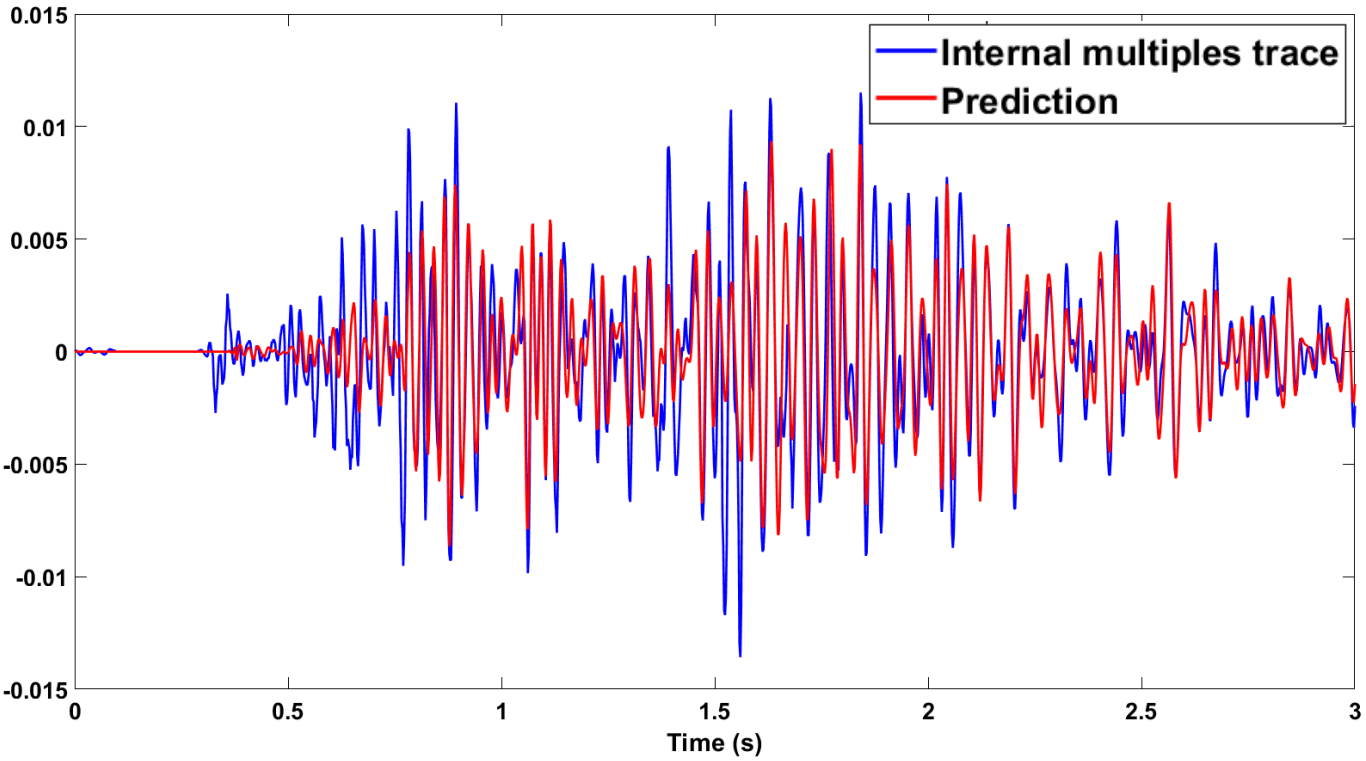


The space for the well log synthetic is significantly more complex

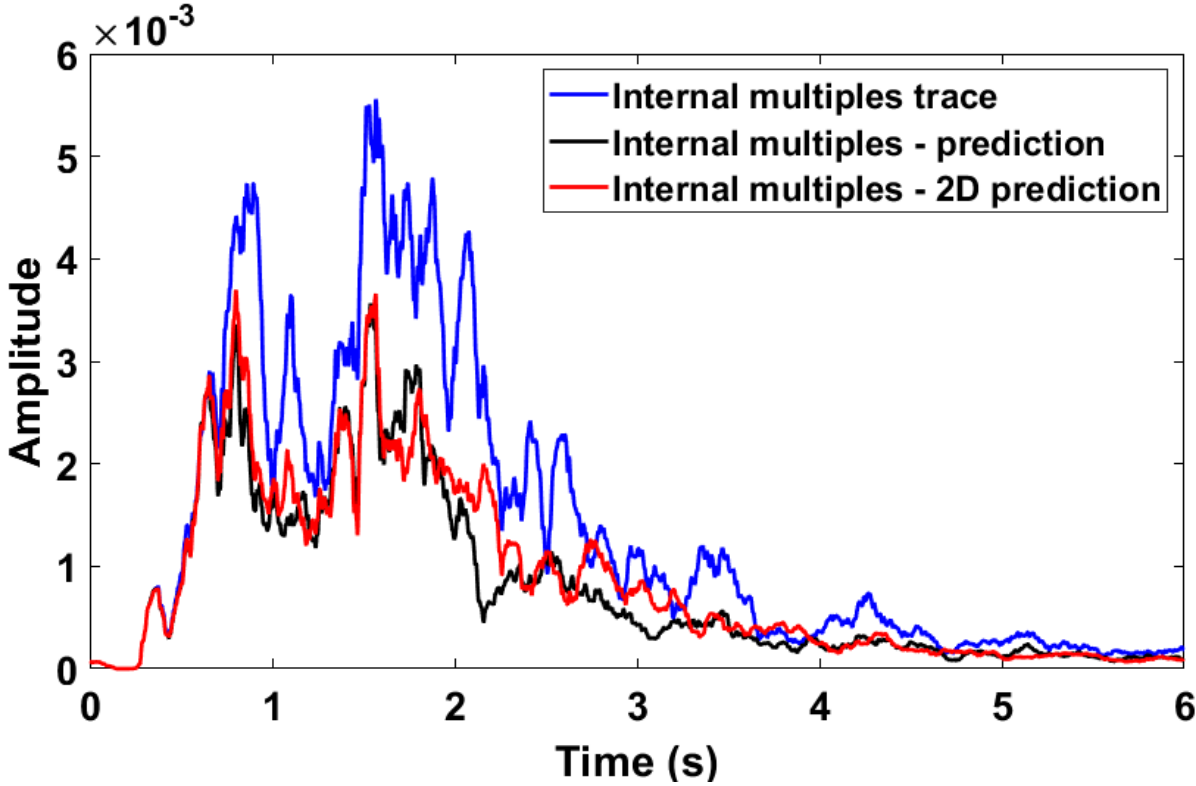
The traces are partially stacked in the vertical direction to reduce overfitting and computational time

Internal Multiple Prediction

Internal multiples trace and prediction



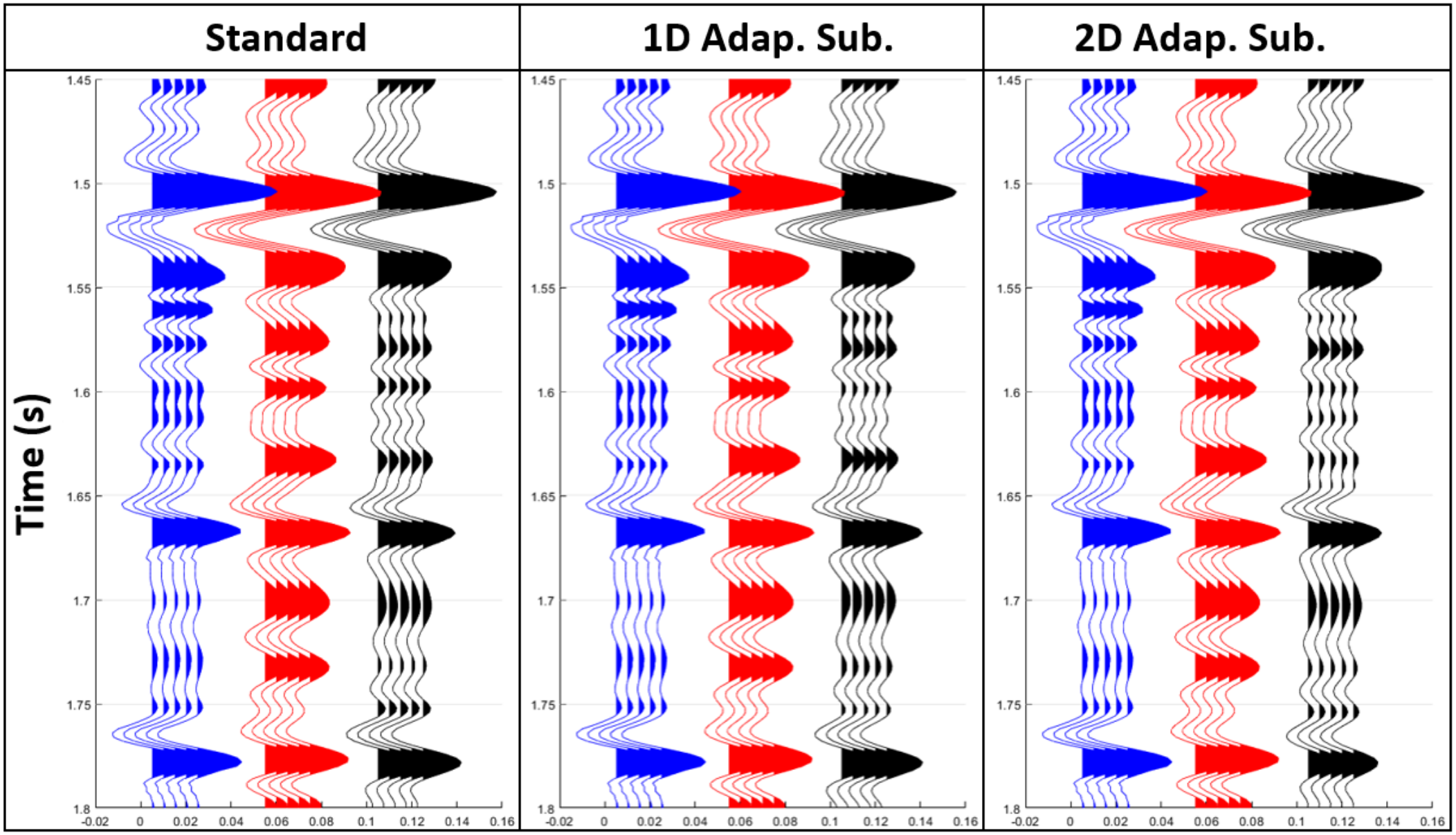
Absolute value with rolling average



2D adaptive subtraction is beneficial for the majority of the trace

Next will look in detail around 1.45-1.8 seconds

Internal Multiple Prediction Comparison

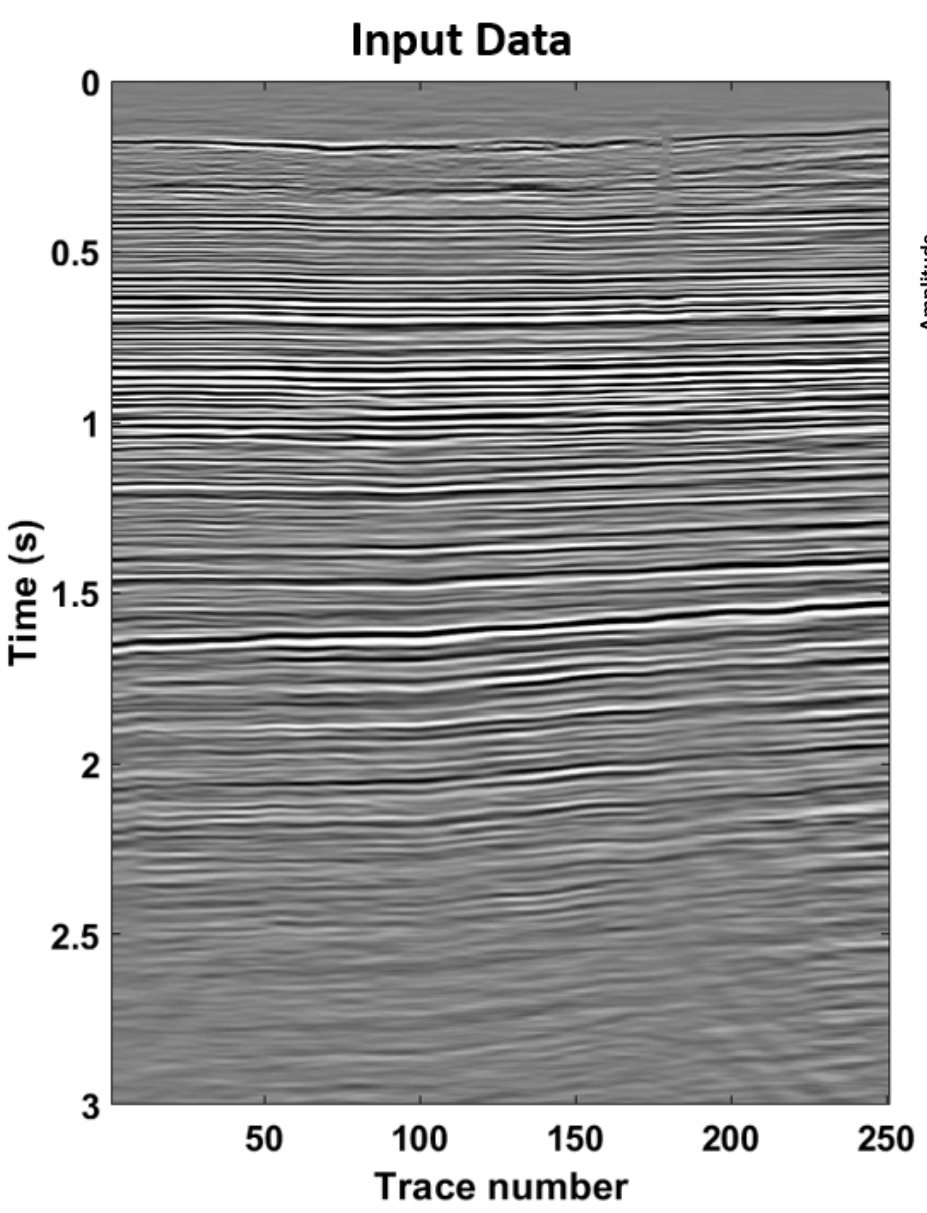


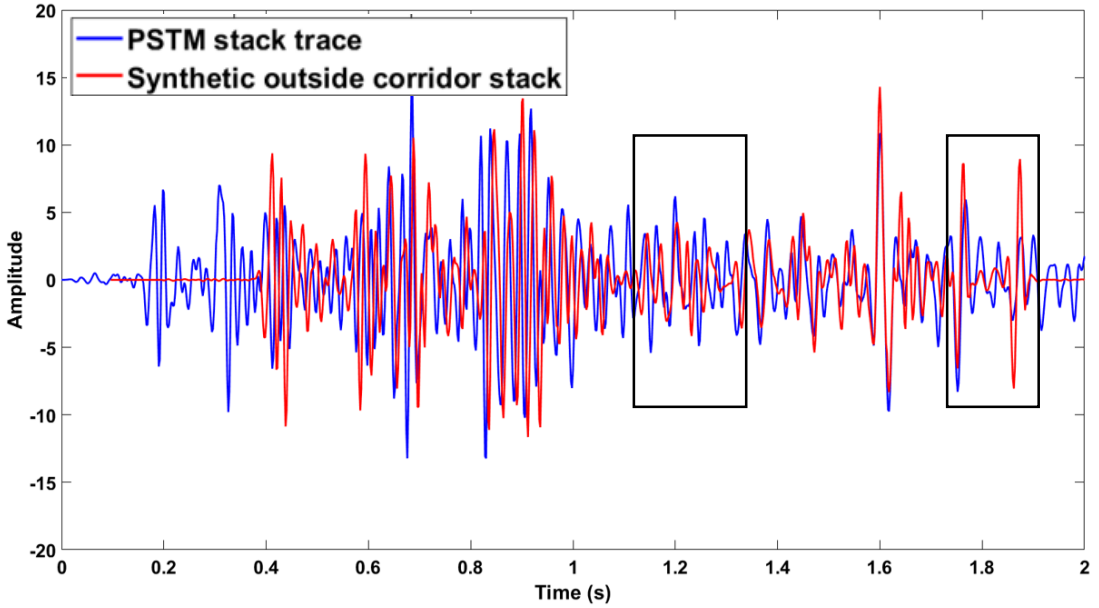
Outside corridor stack (primaries only)

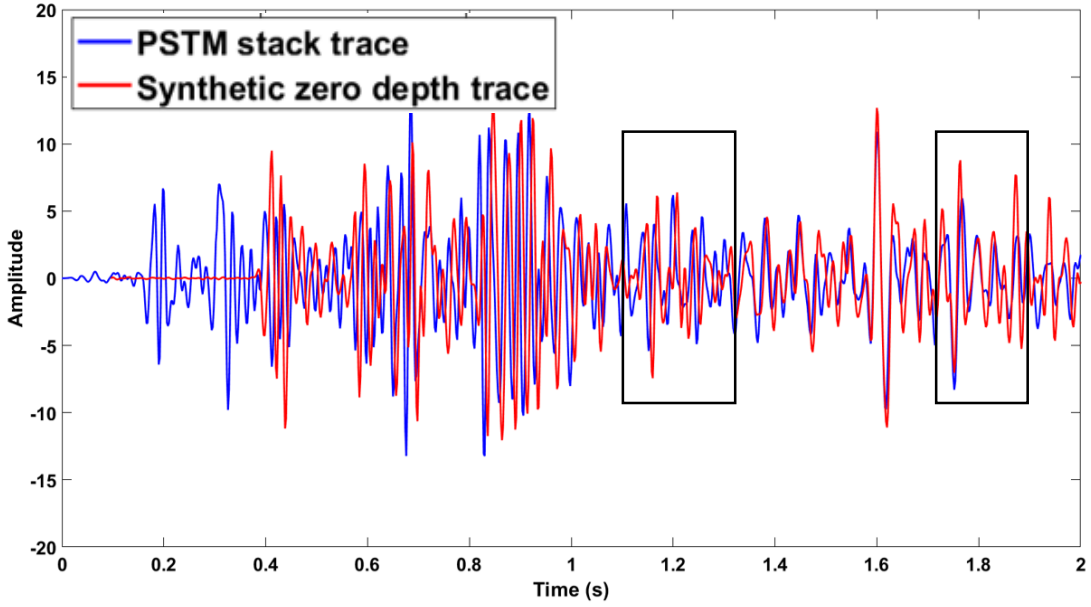
Zero depth trace (primaries and internal multiples)

Trace after multiple attenuation

PSTM Stacked Data

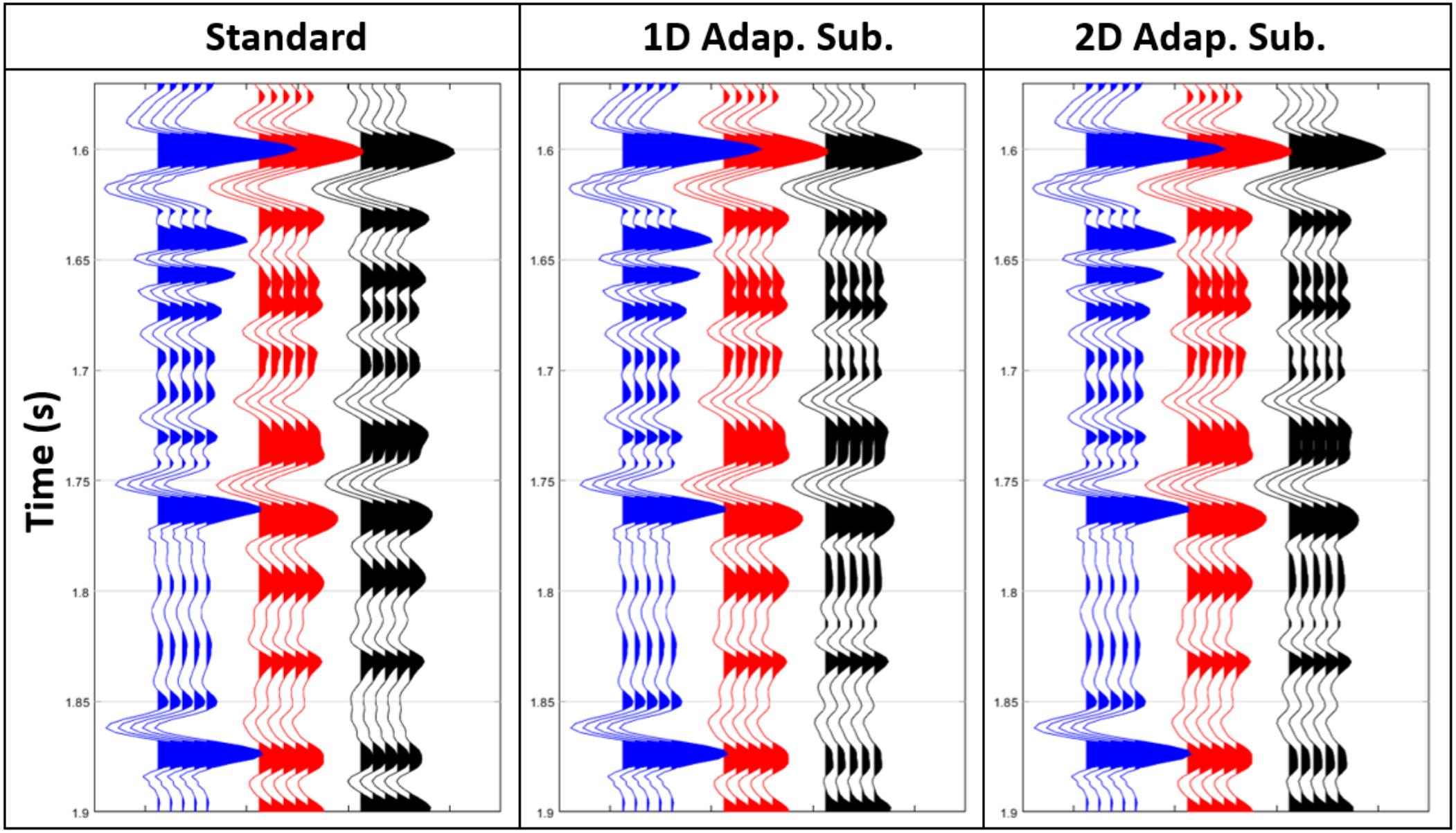






- Analysis was completed on 3D PSTM data
- Used the synthetic VSP to compare to 3D Data
- Improved tie between zero depth trace and PSTM data

Internal Multiple Prediction on PSTM

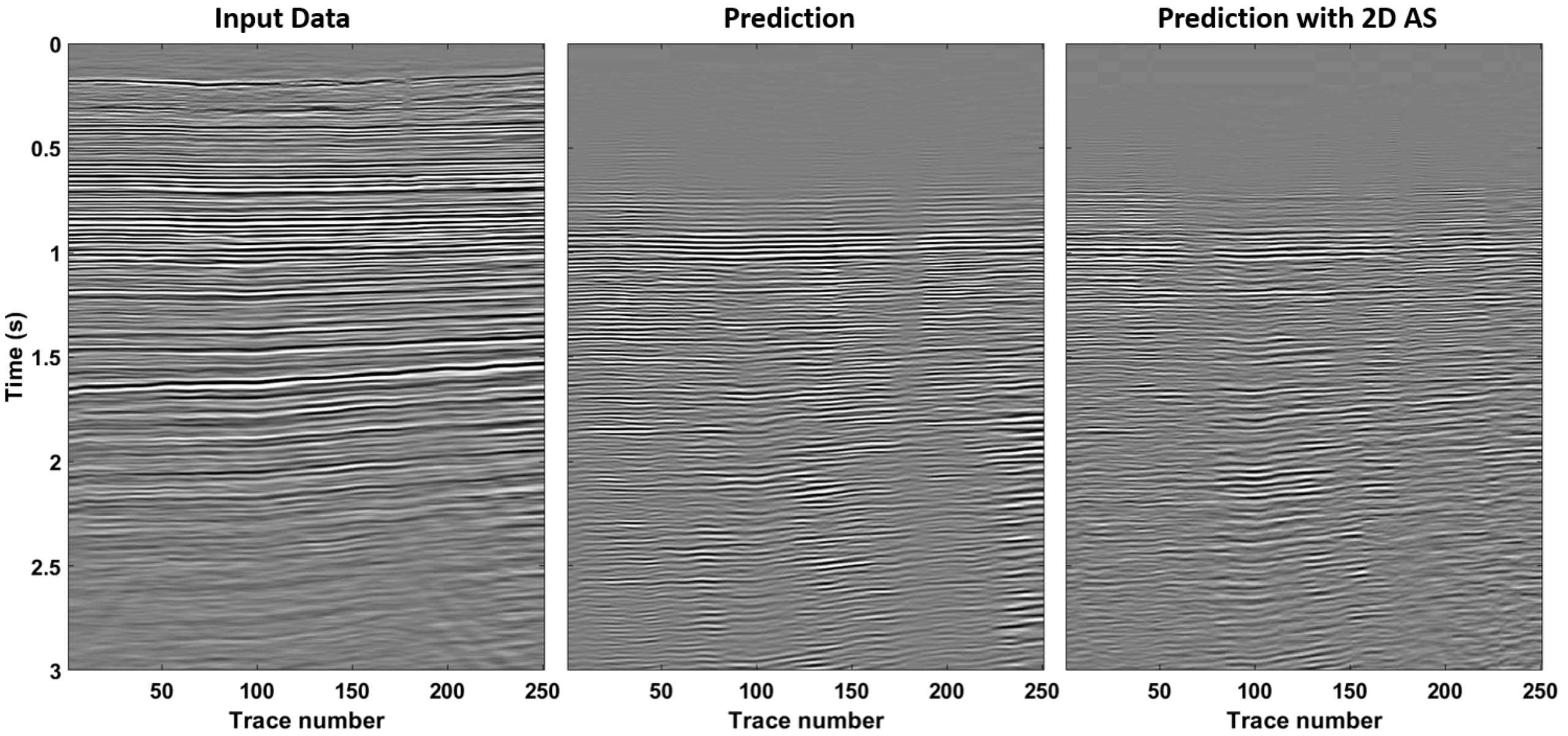


Outside corridor stack (primaries only)

PSTM stacked trace (primaries and internal multiples)

Trace after multiple attenuation

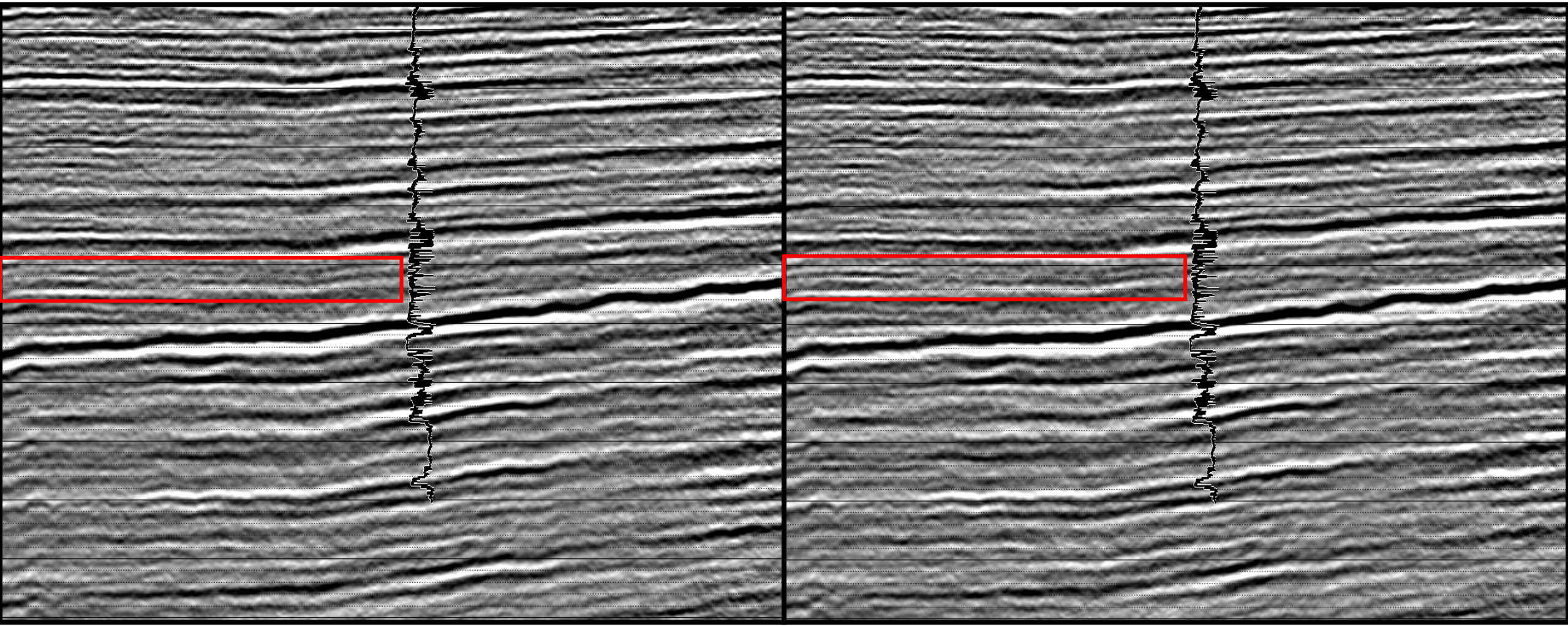
Internal Multiple Prediction on PSTM



Internal Multiple Attenuation

PSTM Input Data

With Internal Multiple Attenuation



Conclusions and future work

Conclusions:

- Downward generator space improved internal multiple prediction with 2D adaptive subtraction
- Method displayed success on complex well log synthetic
- Results on real data are encouraging but require further refinement

Future Work:

- Goal of project is to implement the method on land seismic data
  - How to implement nonstationary epsilon, downward generator space, higher order terms…
  - Is there pre-processing that could assist the algorithm
  - What stage of seismic processing workflow to apply multiple attenuation?
    - Amplitude recovery/gain, statics, deconvolution, …

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Questions?