Using impedance inversion to investigate the low frequencies present in the Hussar data

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Outline

- Introduction to Reflectivity and Impedance
- BLIMP Method
- Well Tying
- Impedance Inversions
- Low-Frequency Investigation
- Conclusions

INTRODUCTION TO IMPEDANCE AND REFLECTIVITY

Relationship between I & r

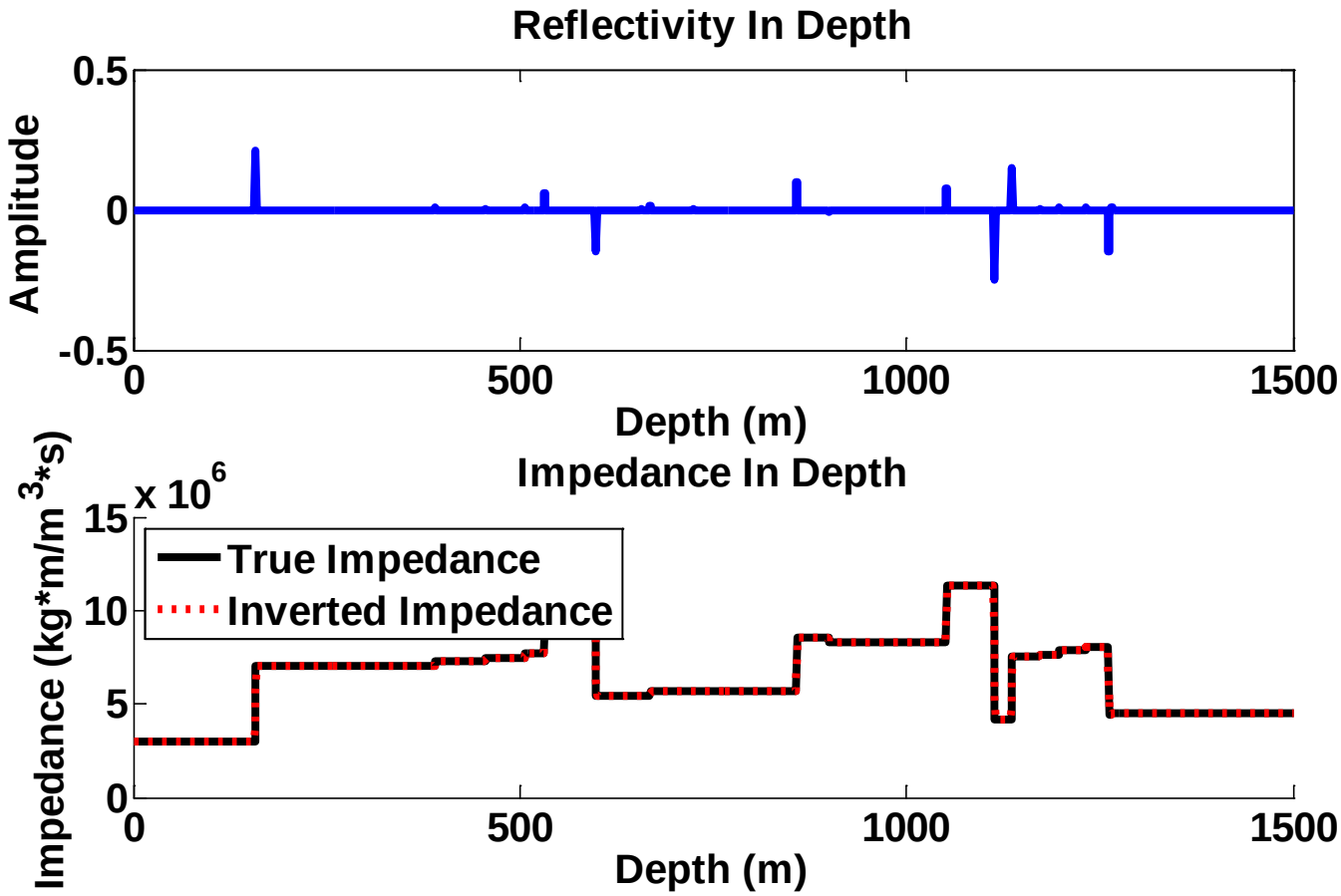
$$r_1 = \frac{I_2 - I_1}{I_2 + I_1}, \quad where$$

$$I_1 = \rho_1 v_1, \quad and, \quad I_2 = \rho_2 v_2$$

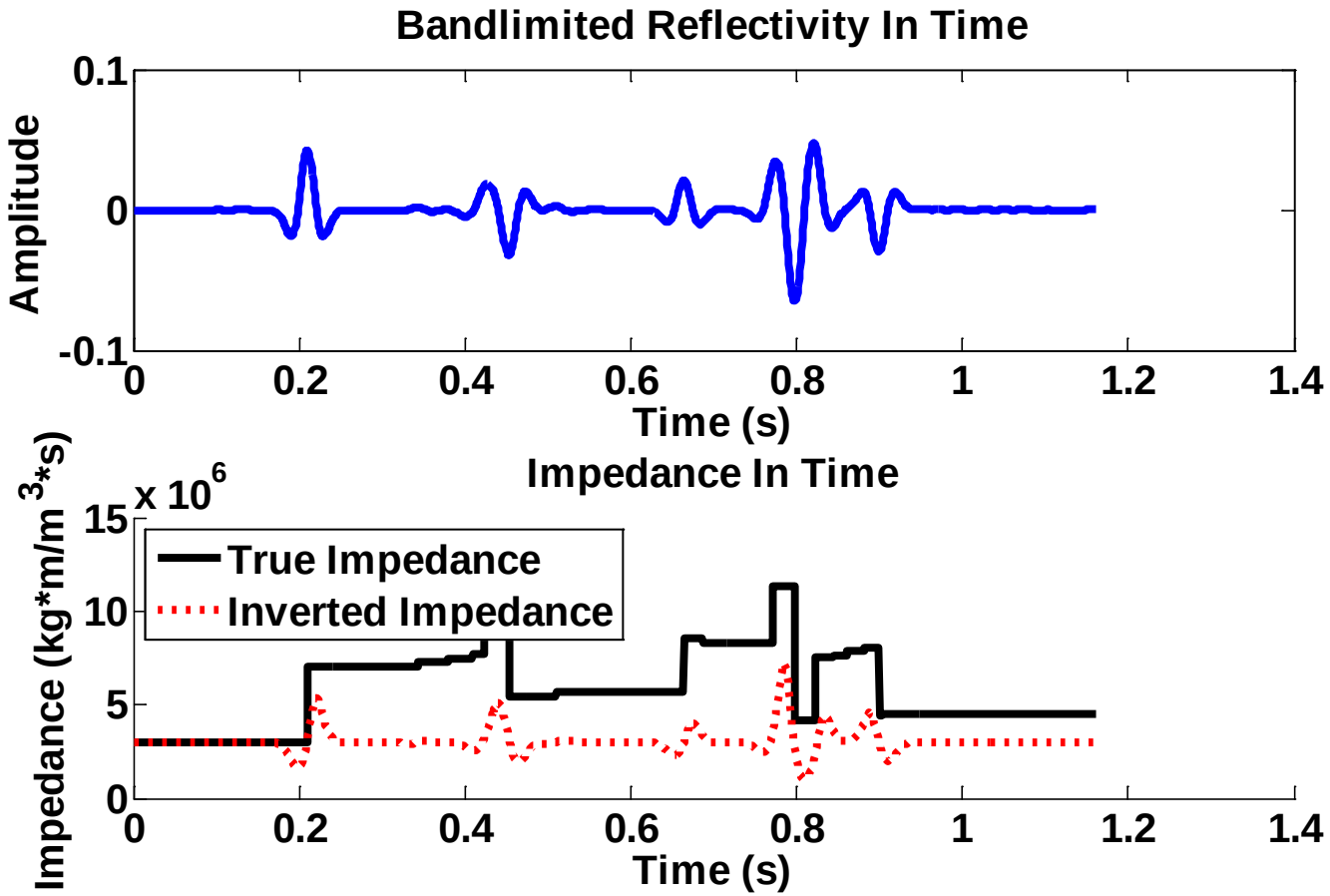
Recursion Formula

$$I_j = I_0 e^{2 \sum_{k=0}^{j} r_k}$$

Depth Inversion



Bandlimited Time Inversion



Properties of Reflectivity and Impedance

Reflectivity

- Estimated from seismic or well log data
- Limited low frequencies mathematically
- Missing low frequencies are not as critical for the character of the curve.

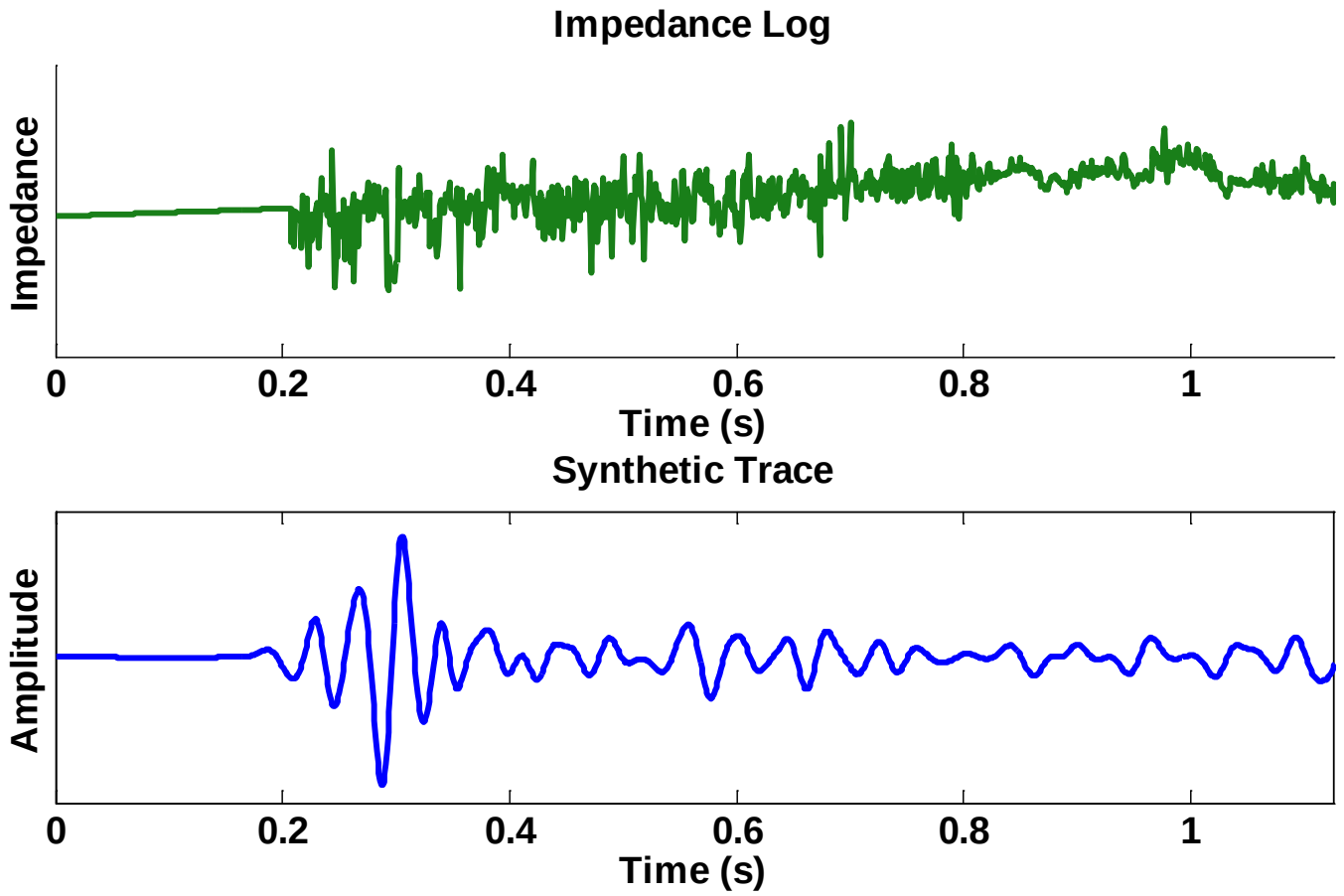
Impedance

- Intrinsic property of the rock layers
- Contains more resolution and detail than seismic
- Missing low frequencies cause significant errors

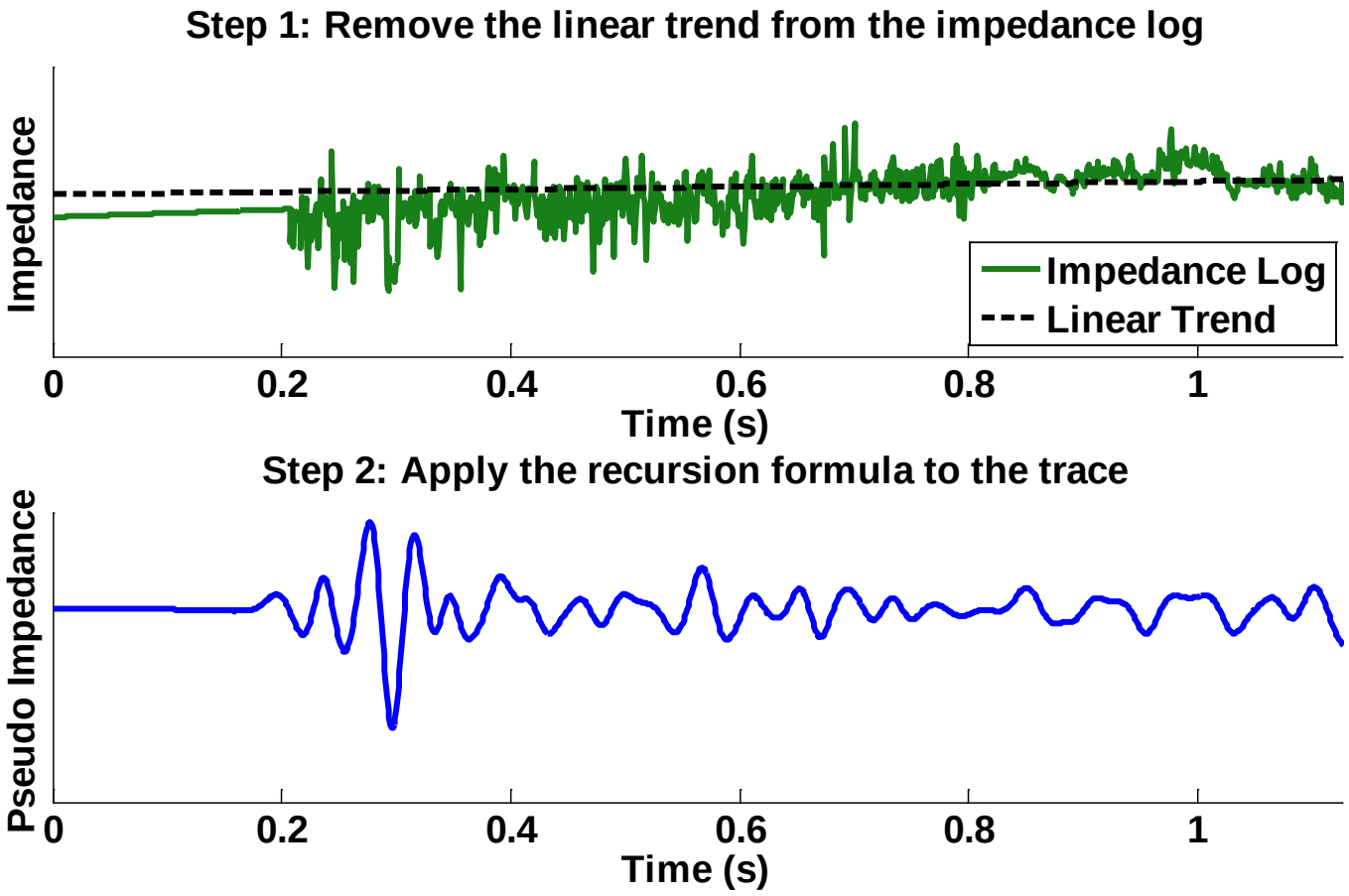
BLIMP METHOD

(Ferguson and Margrave, 1996) and (Lindseth,1979)

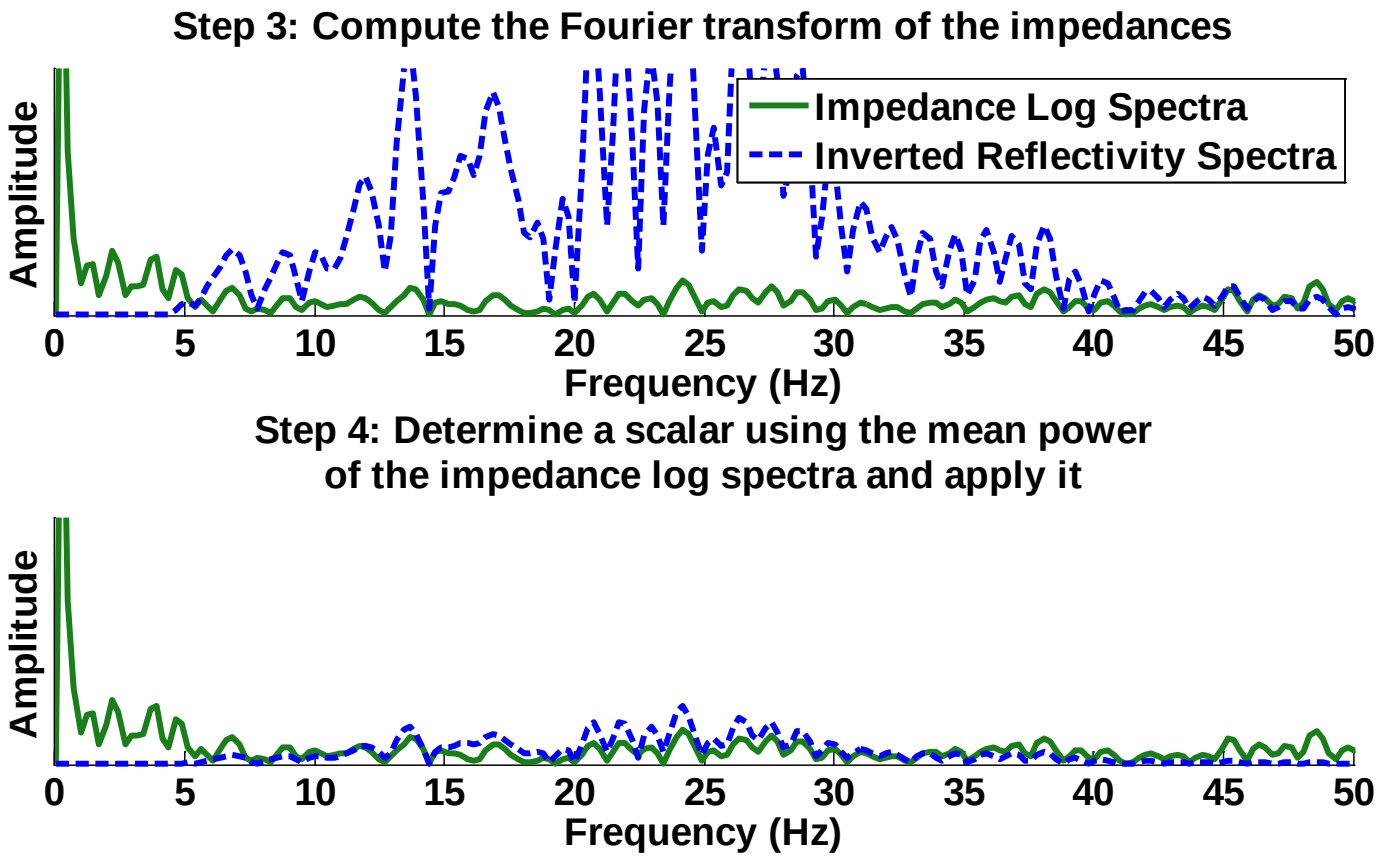
Borrow low-frequencies using BLIMP



BLIMP Steps 1 & 2

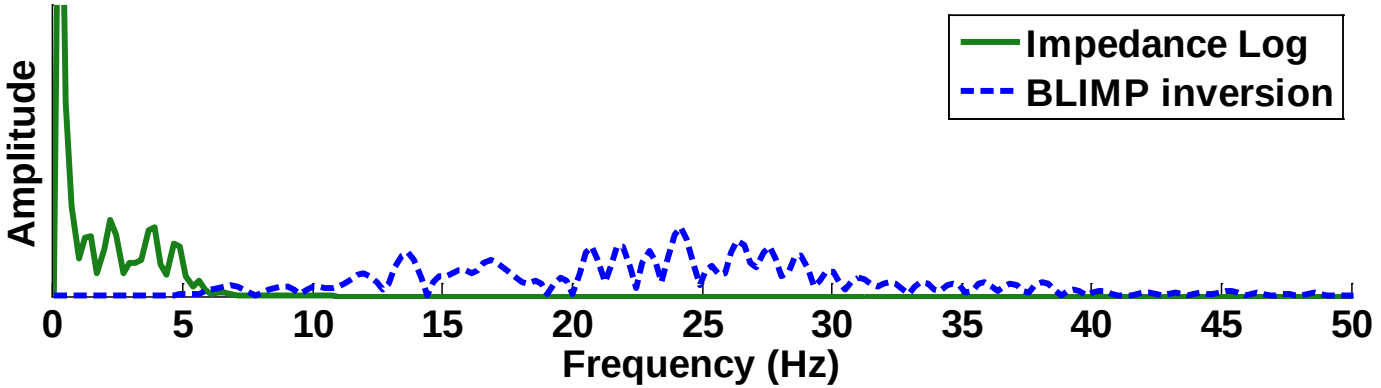


BLIMP Steps 3 & 4

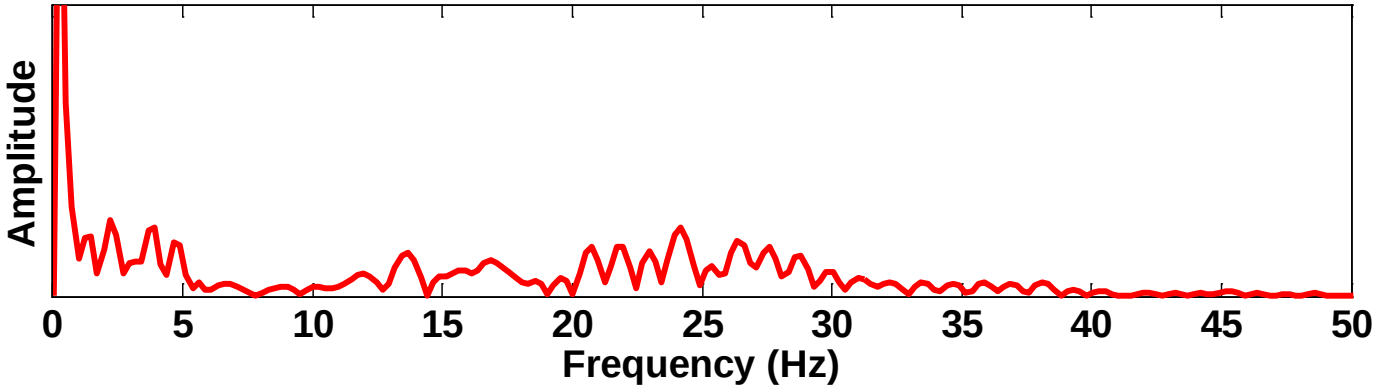


BLIMP Steps 5 & 6

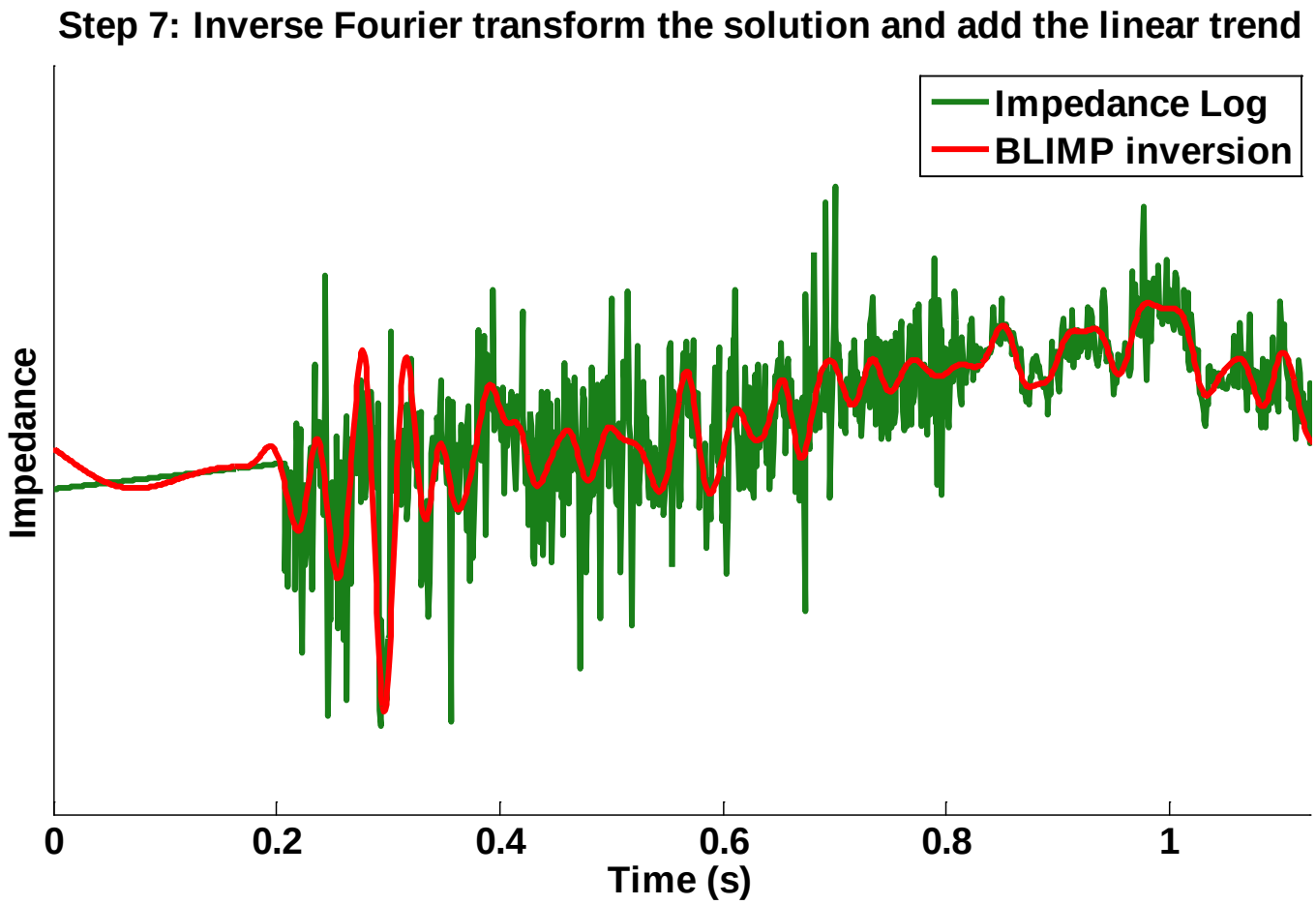
Step 5: Apply filters to the impedance log and inverted reflectivity spectra



Step 6: Combine the filtered impedance log and inverted reflectivity spectra



BLIMP Step 7


Step 7: Inverse Fourier transform the solution and add the linear trend
Impedance Log
BLIMP inversion
Impedance
0
0.2
0.4
0.6
0.8
1
Time (s)

Comparison of Inversion Methods

	Low Frequency	Seismic Frequency Band	High Frequency
Band Limited Inversion	Logs	Seismic	None
Sparse Spike Inversion	L1 Minimization	Seismic	L1 Minimization
Model Based Inversion	Logs	Seismic	Model Estimation

BLIMP Inversion Problems

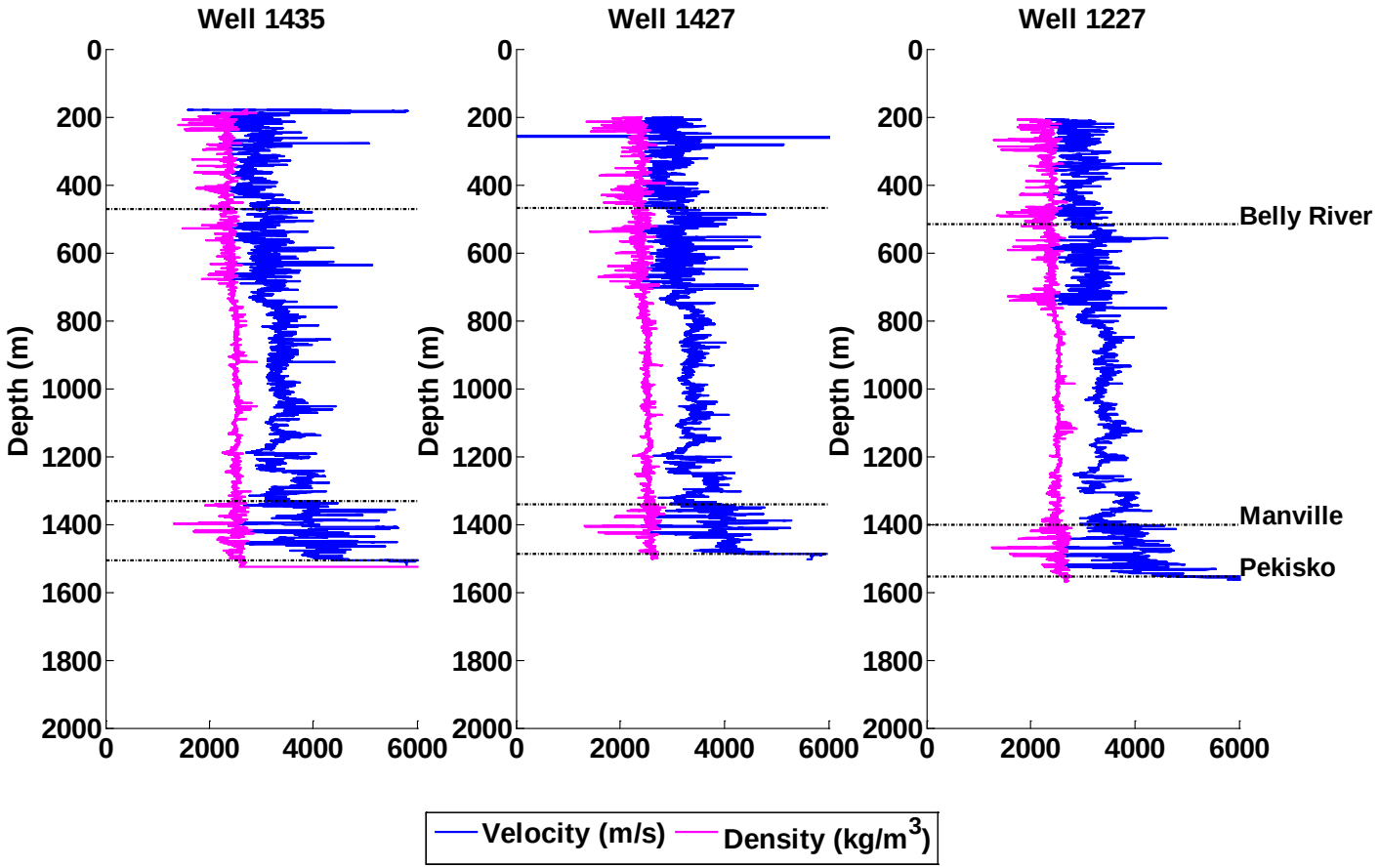
- Sensitive to low-frequency cut-off
- Best applied to one trace or a model without structure
- Relies heavily on log information

WELL TYING

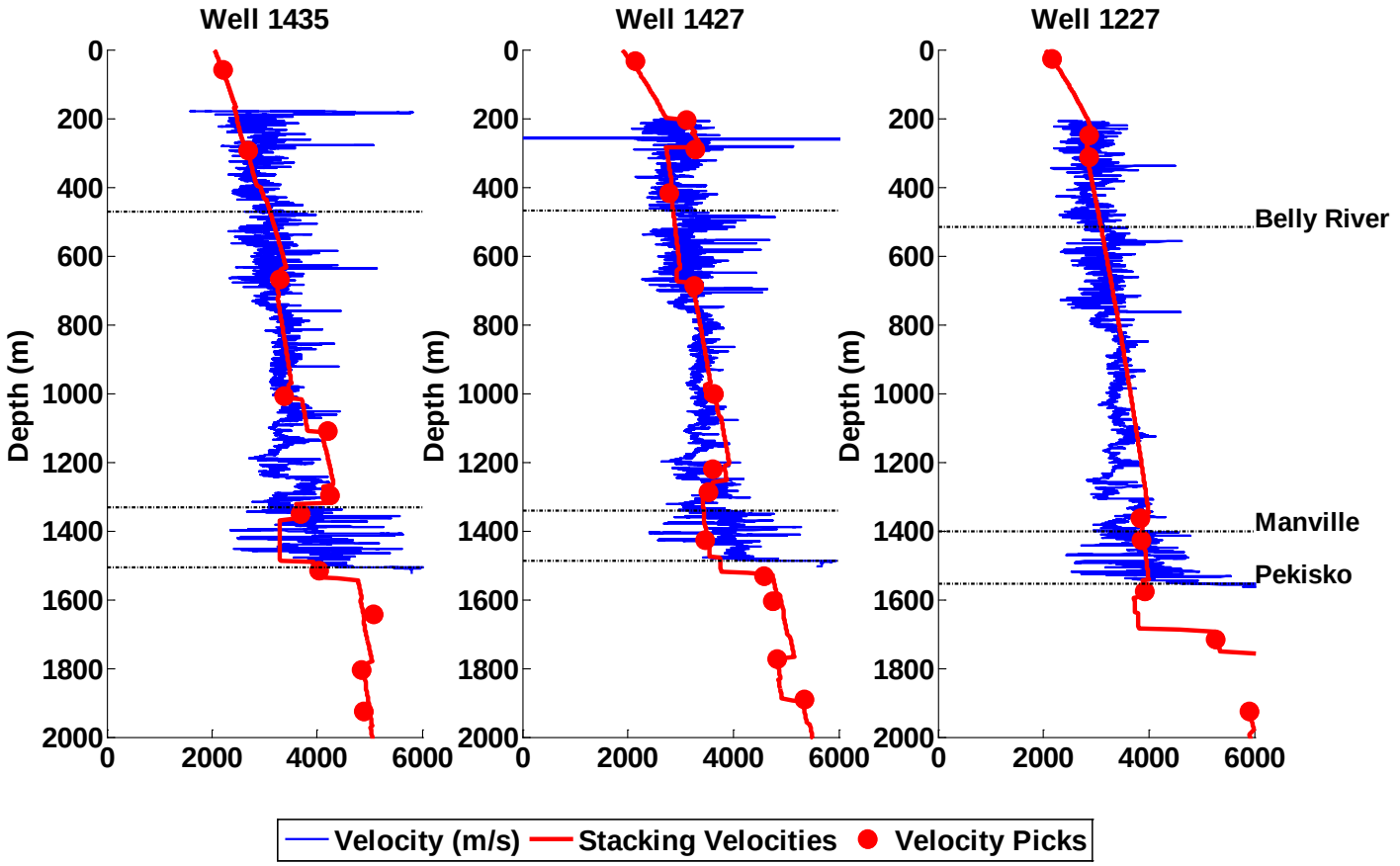
Well Tying Procedure

- Applied Overburden and Underburden to Well logs
- Time-Variant Balanced Seismic
- Estimated Wavelet
- Modified sonic logs by matching events with seismic
- Final Well Tie

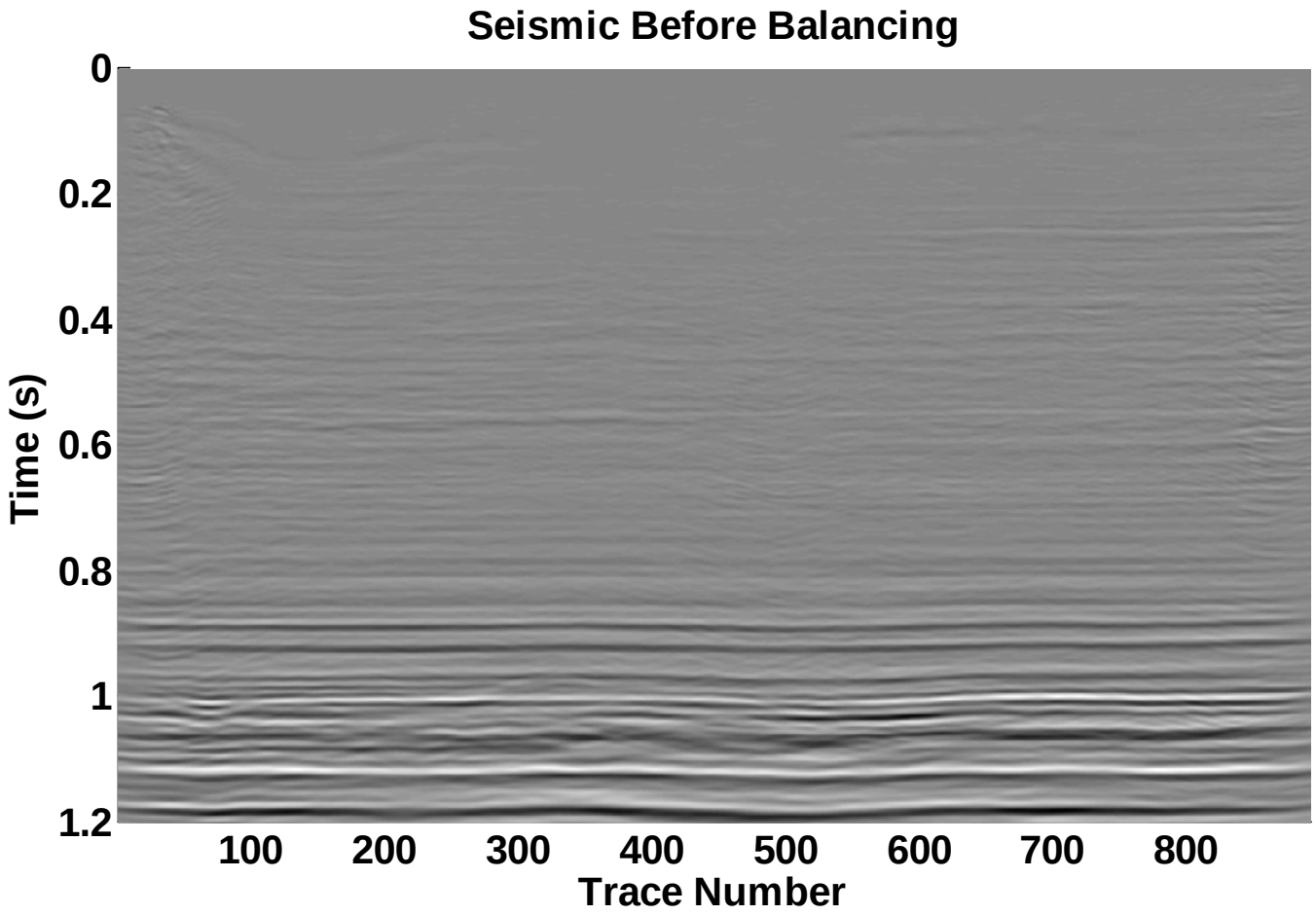
Well Logs in Depth



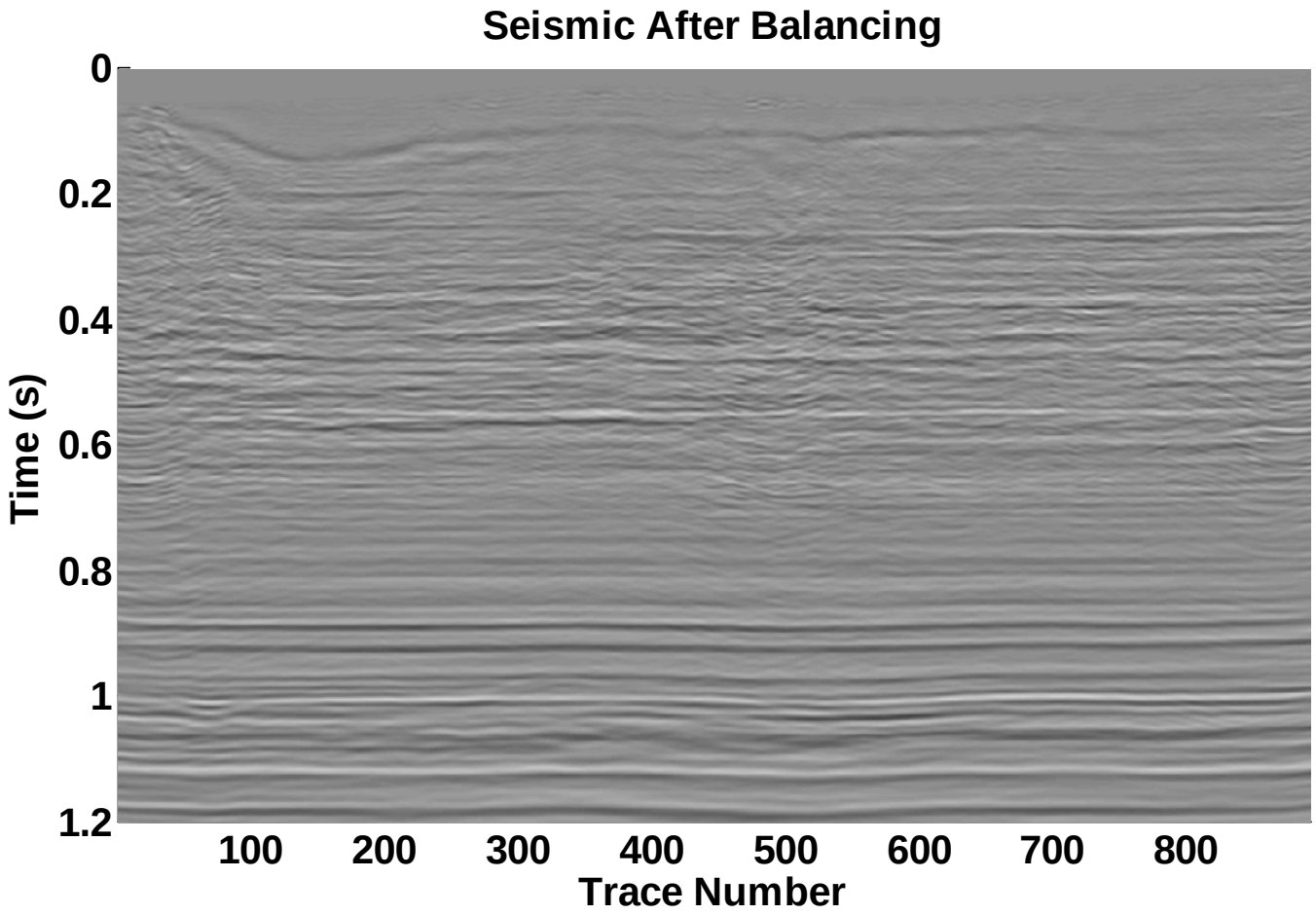
Burdened Well Logs



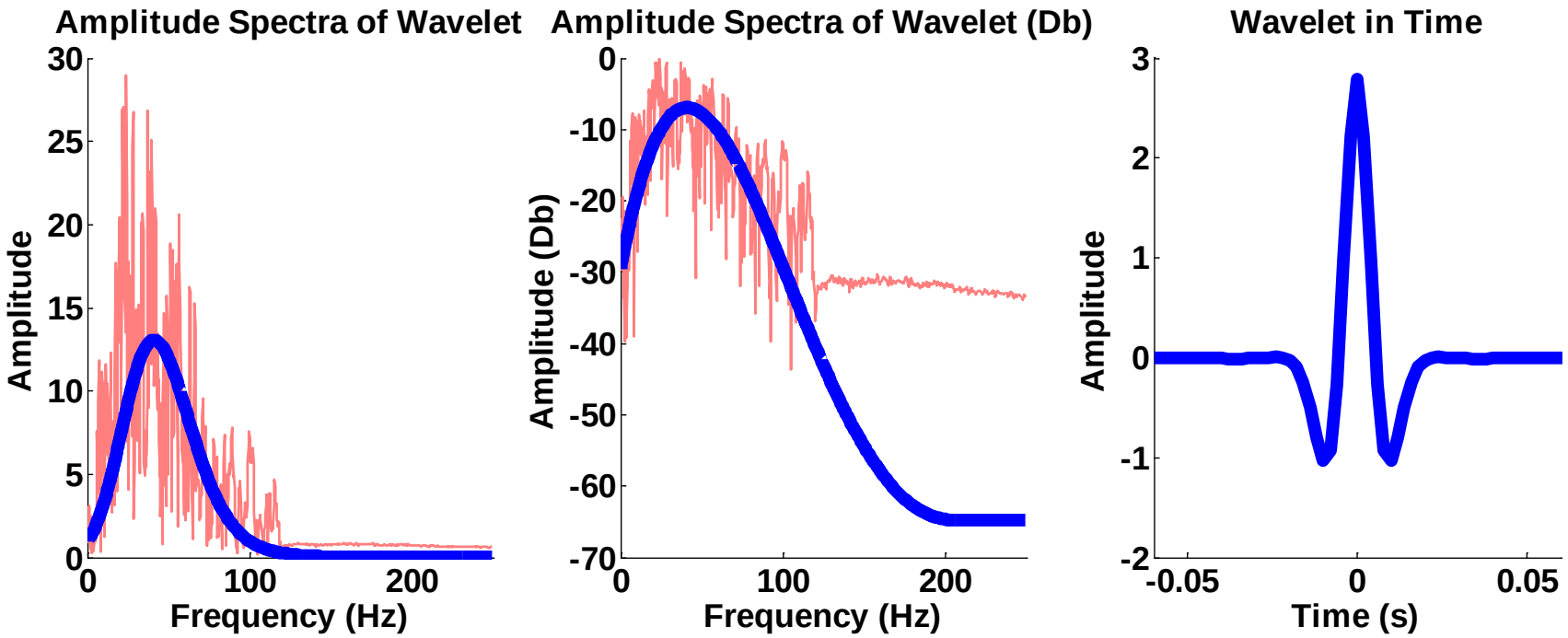
Starting Migrated Stacked Seismic Section



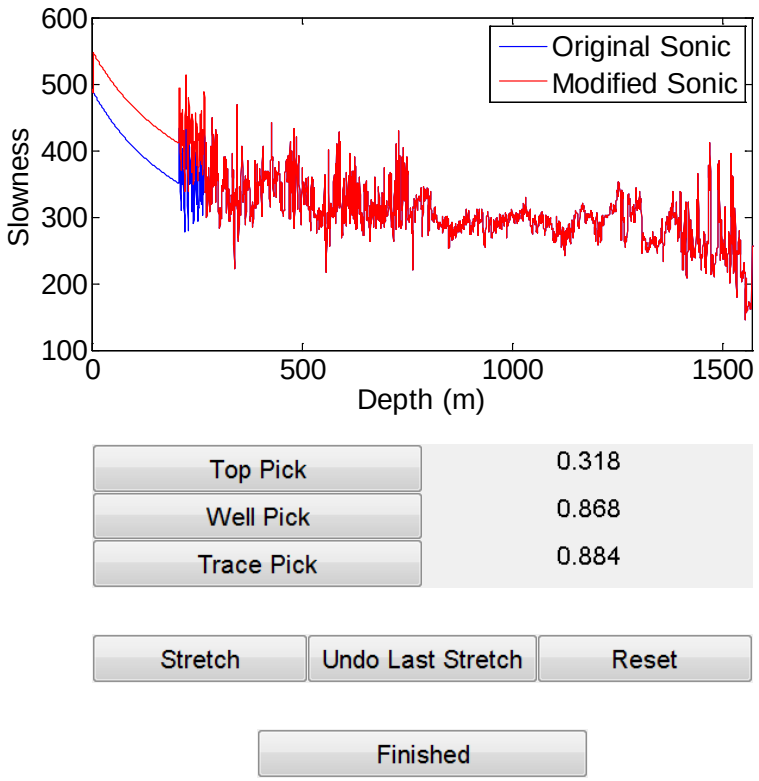
Seismic Balanced by Matching Well Amplitudes

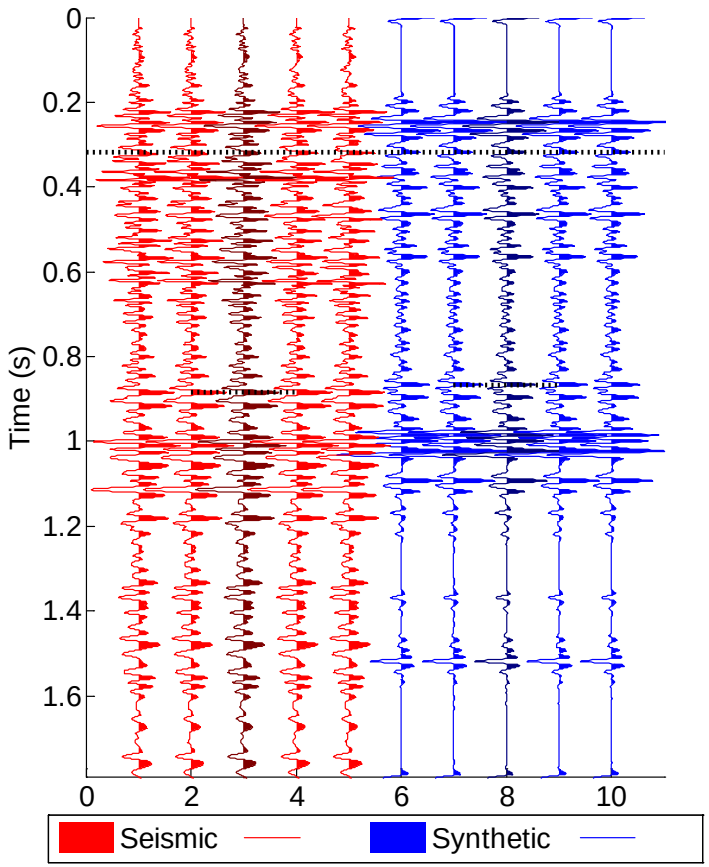


Wavelet

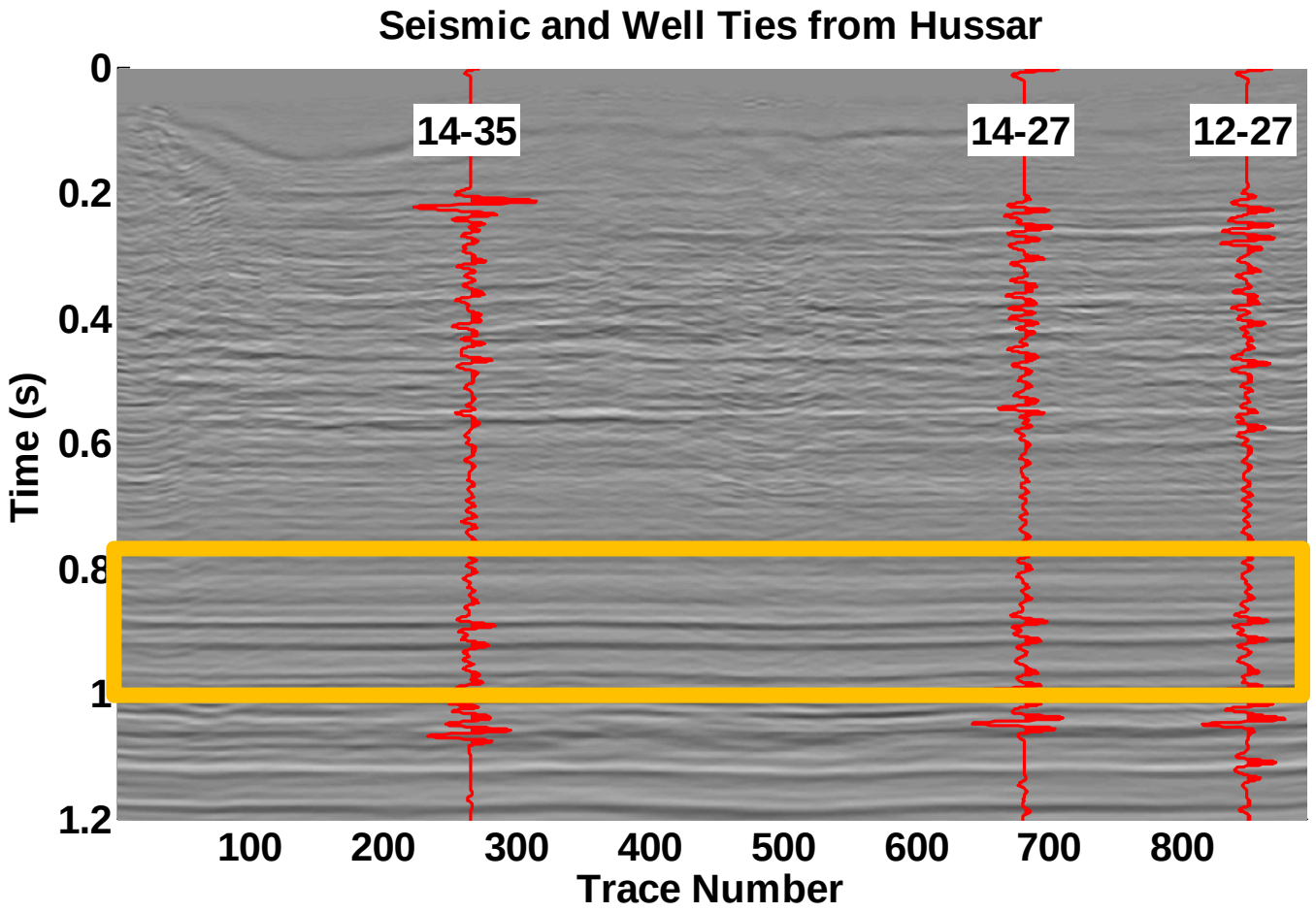

Amplitude Spectra of Wavelet
Amplitude
Frequency (Hz)
Amplitude Spectra of Wavelet (Db)
Amplitude (Db)
Frequency (Hz)
Wavelet in Time
Amplitude
Time (s)

Modify Sonic Logs

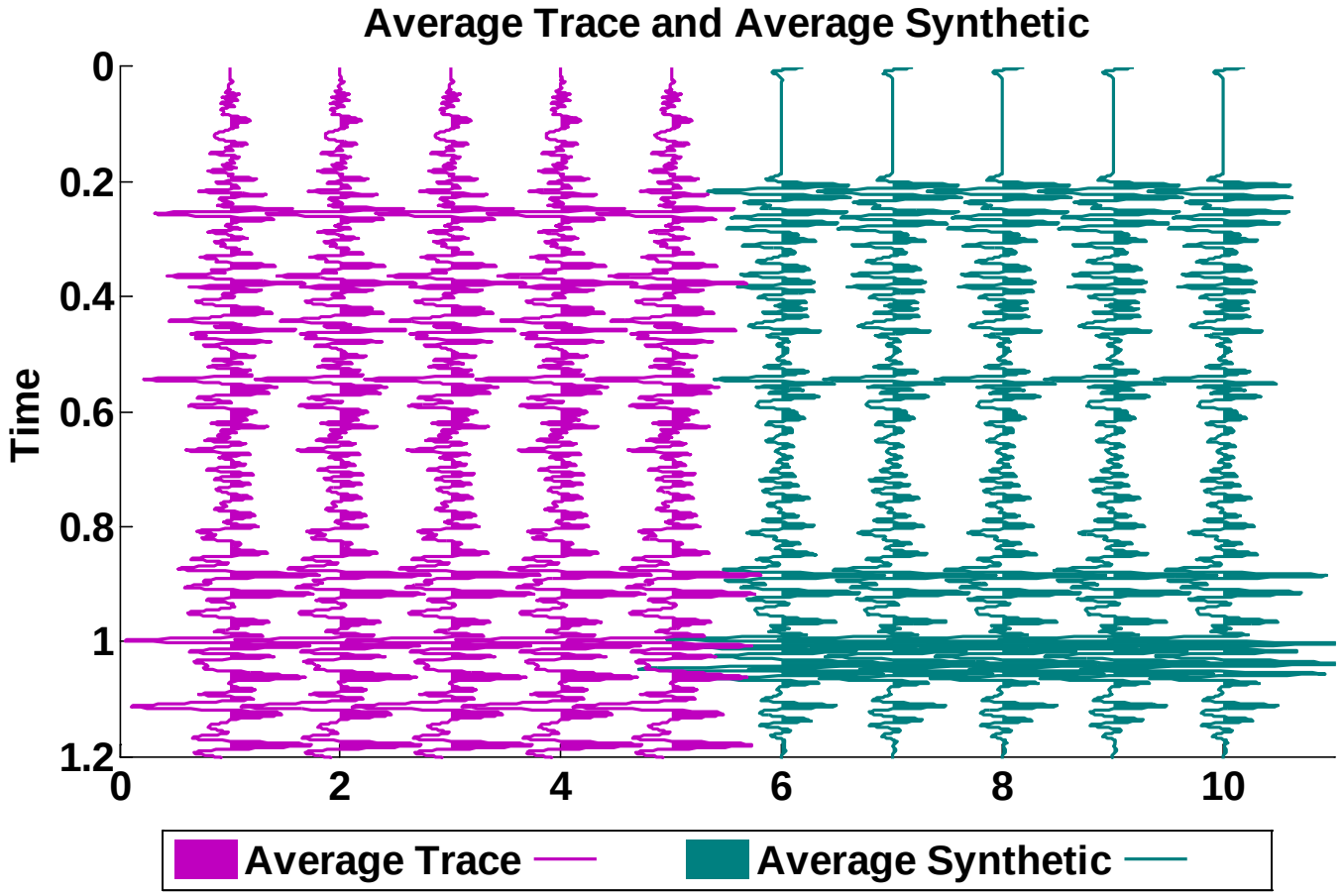




Seismic & Well Ties

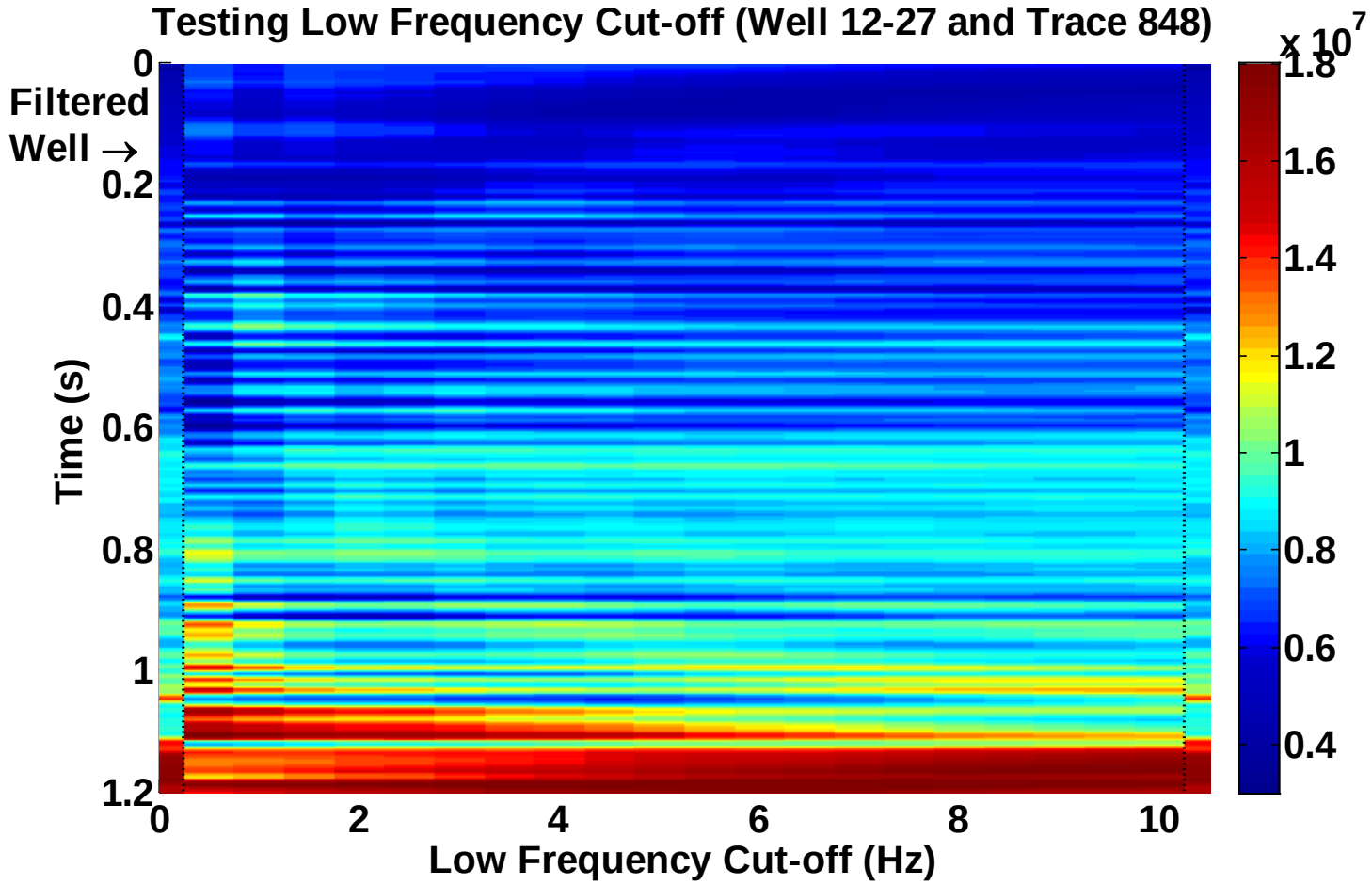


Average Trace and Synthetic

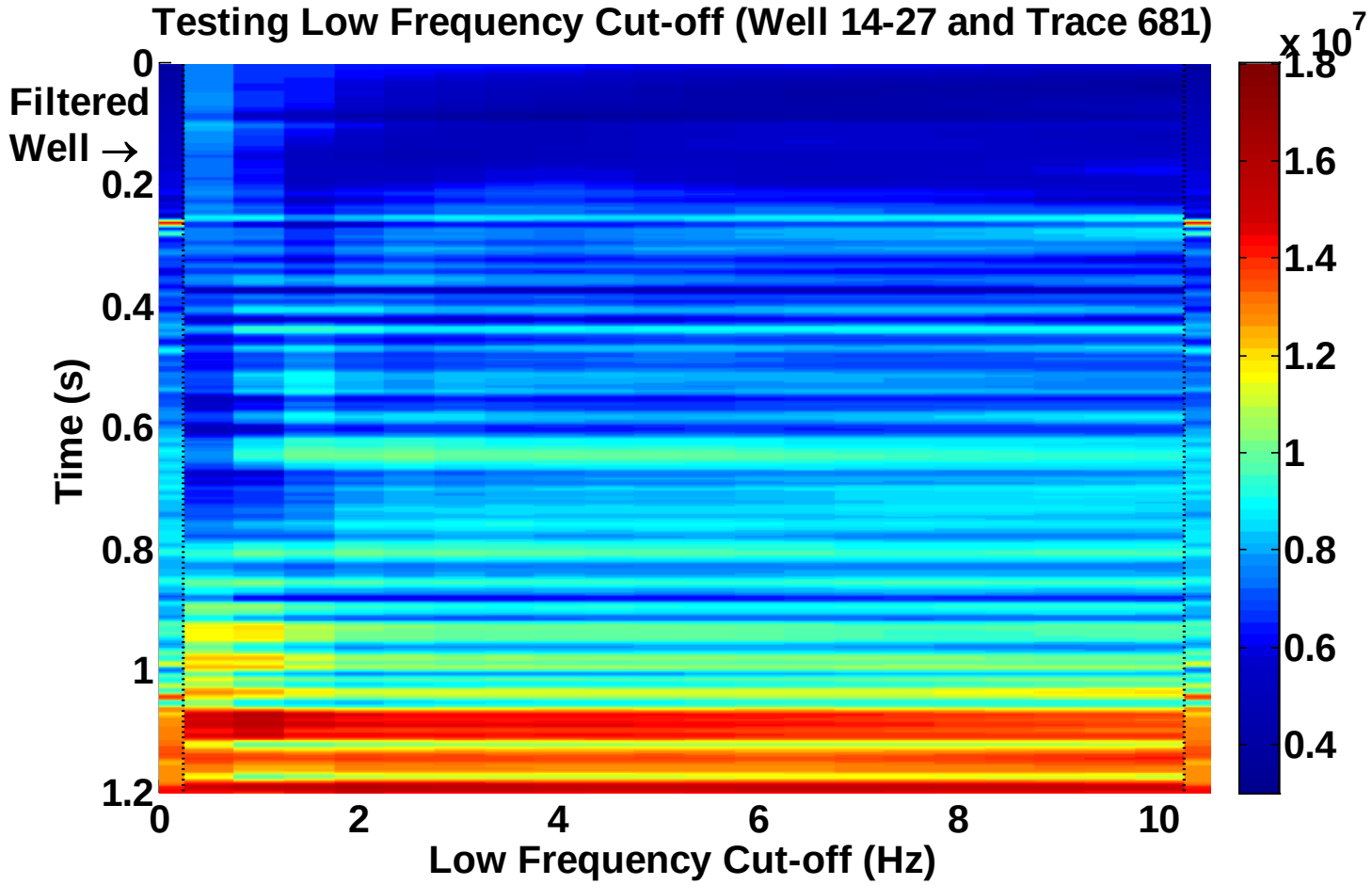


IMPEDANCE INVERSIONS

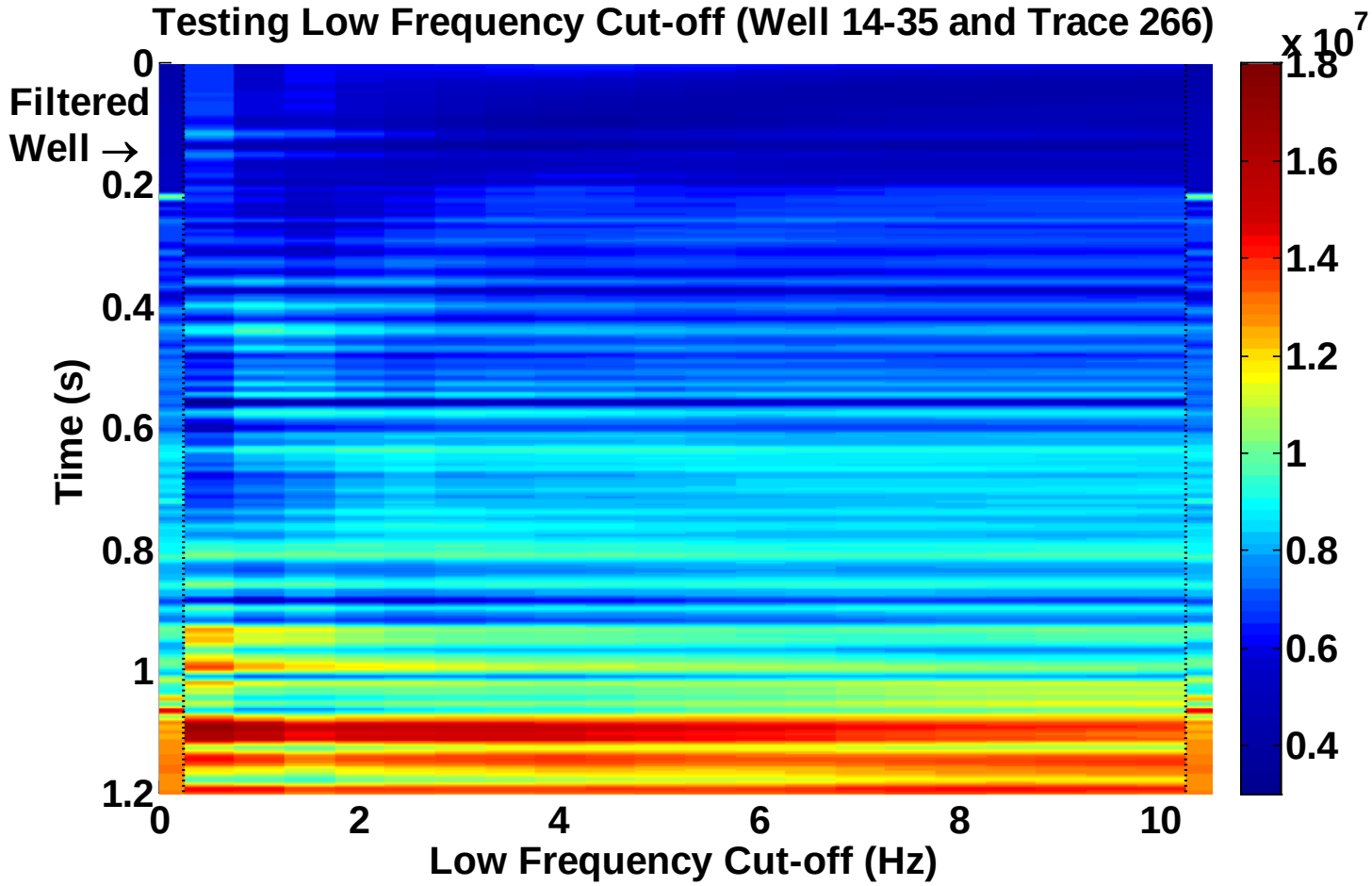
Testing Low-Frequency Cut-offs



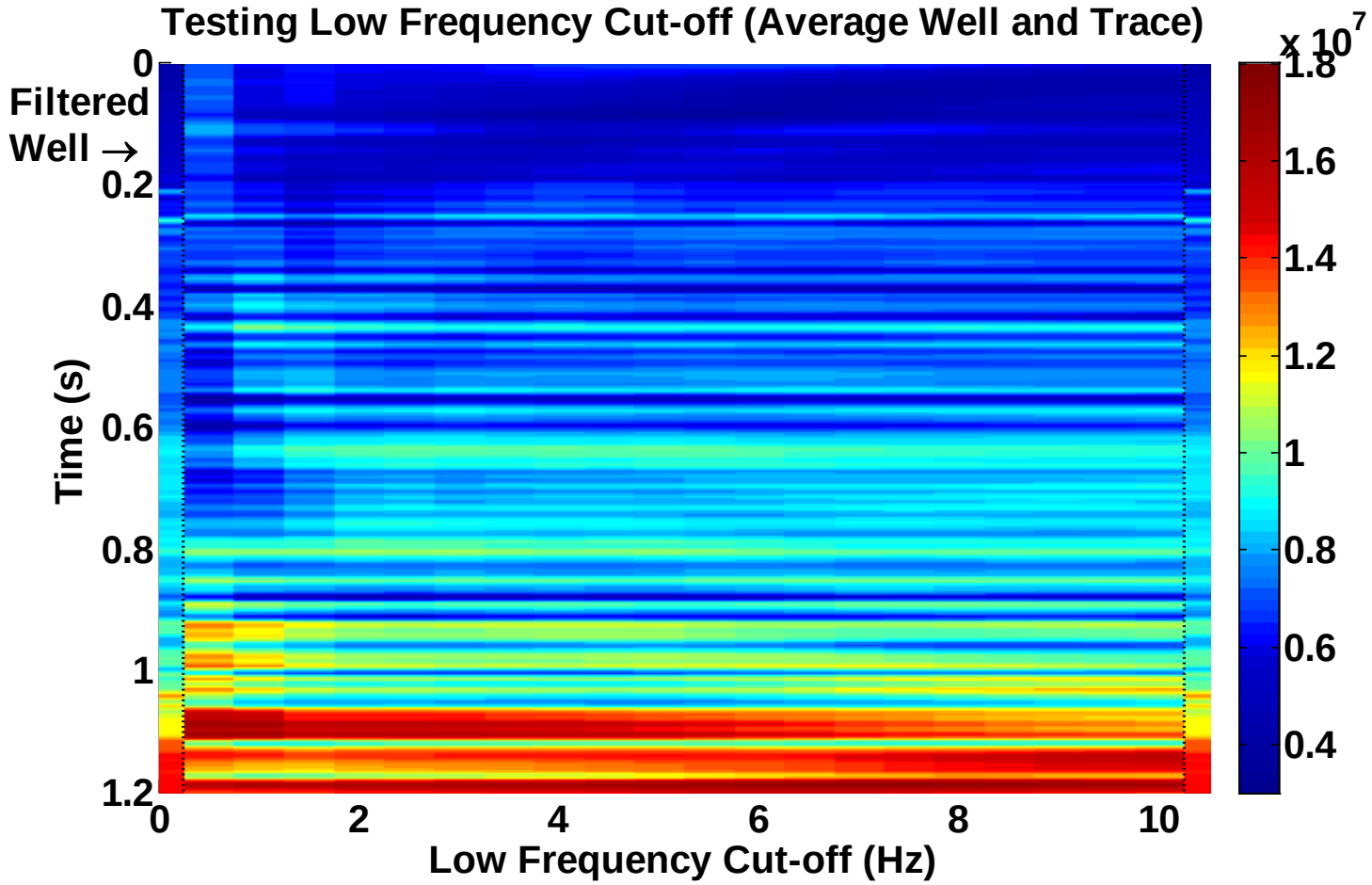
Testing Low-Frequency Cut-offs



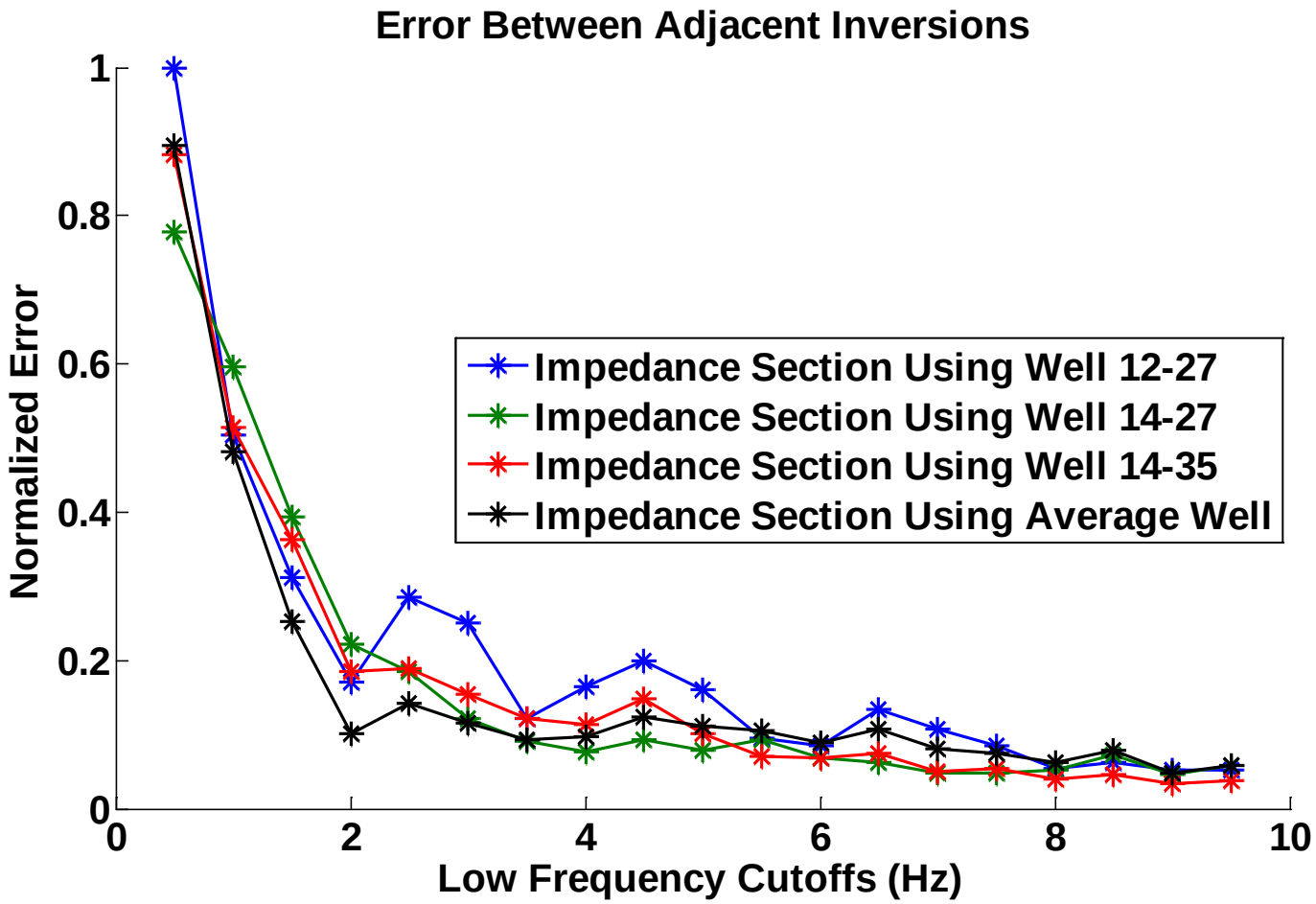
Testing Low-Frequency Cut-offs



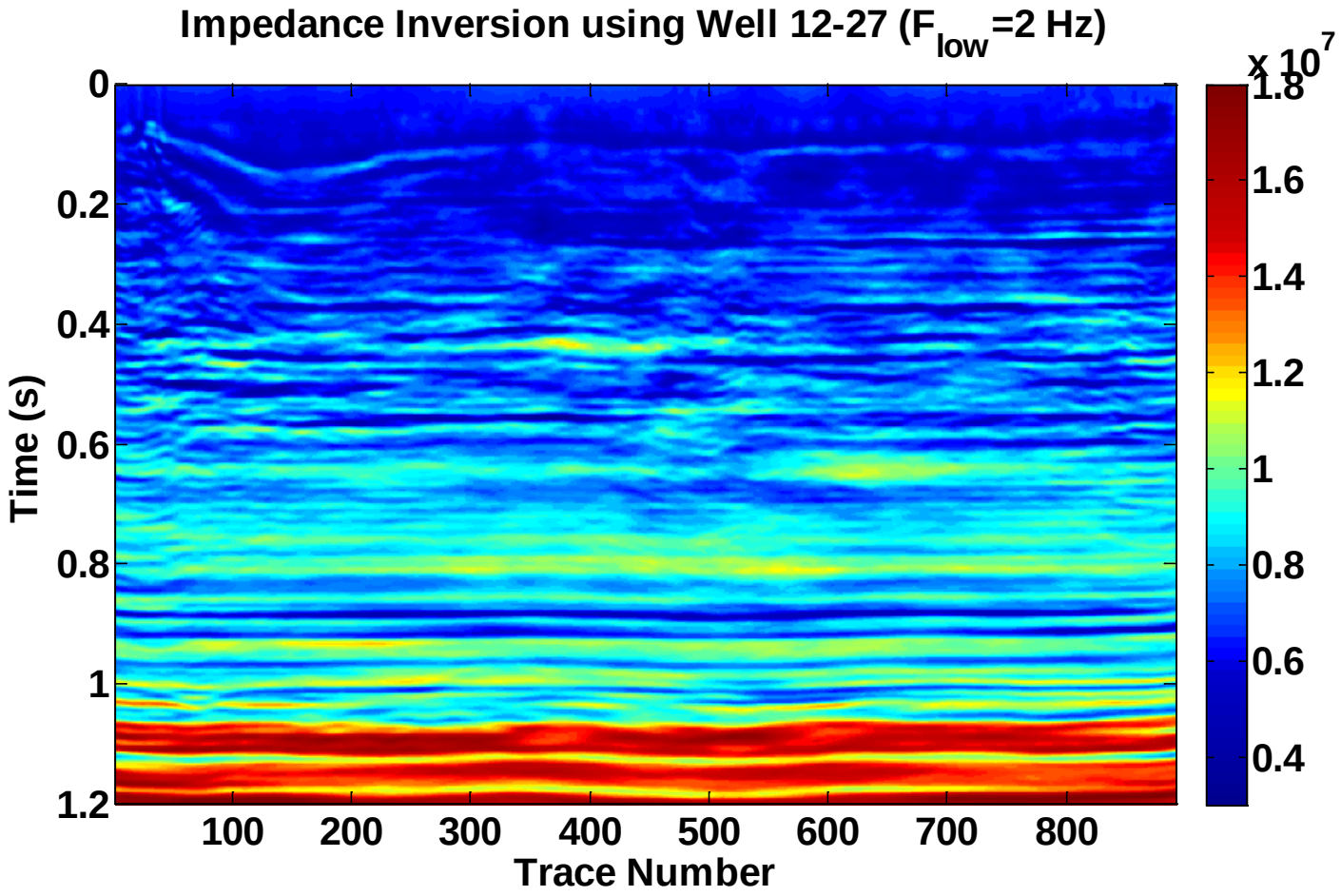
Testing Low-Frequency Cut-offs



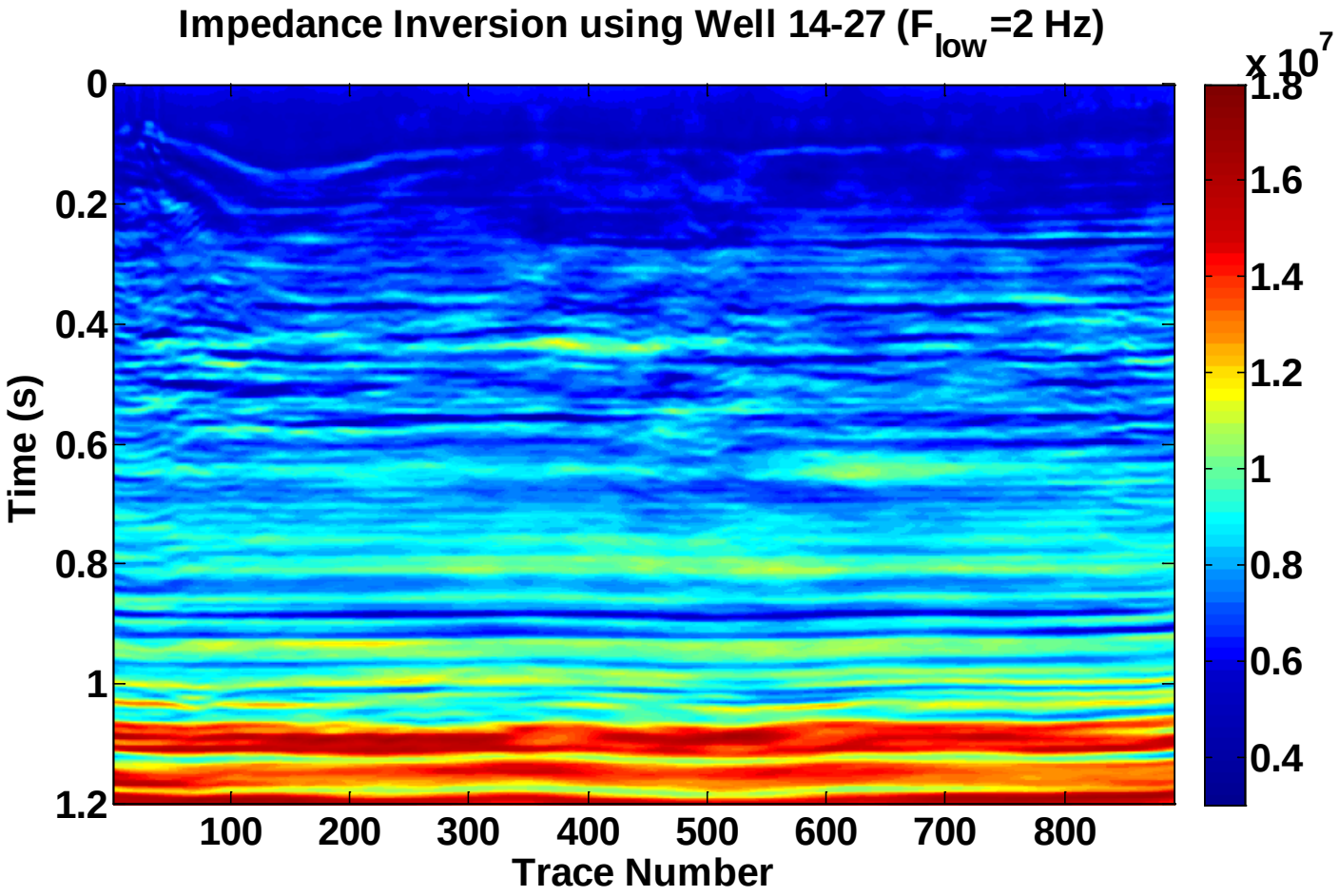
Testing Low-Frequency Cut-offs



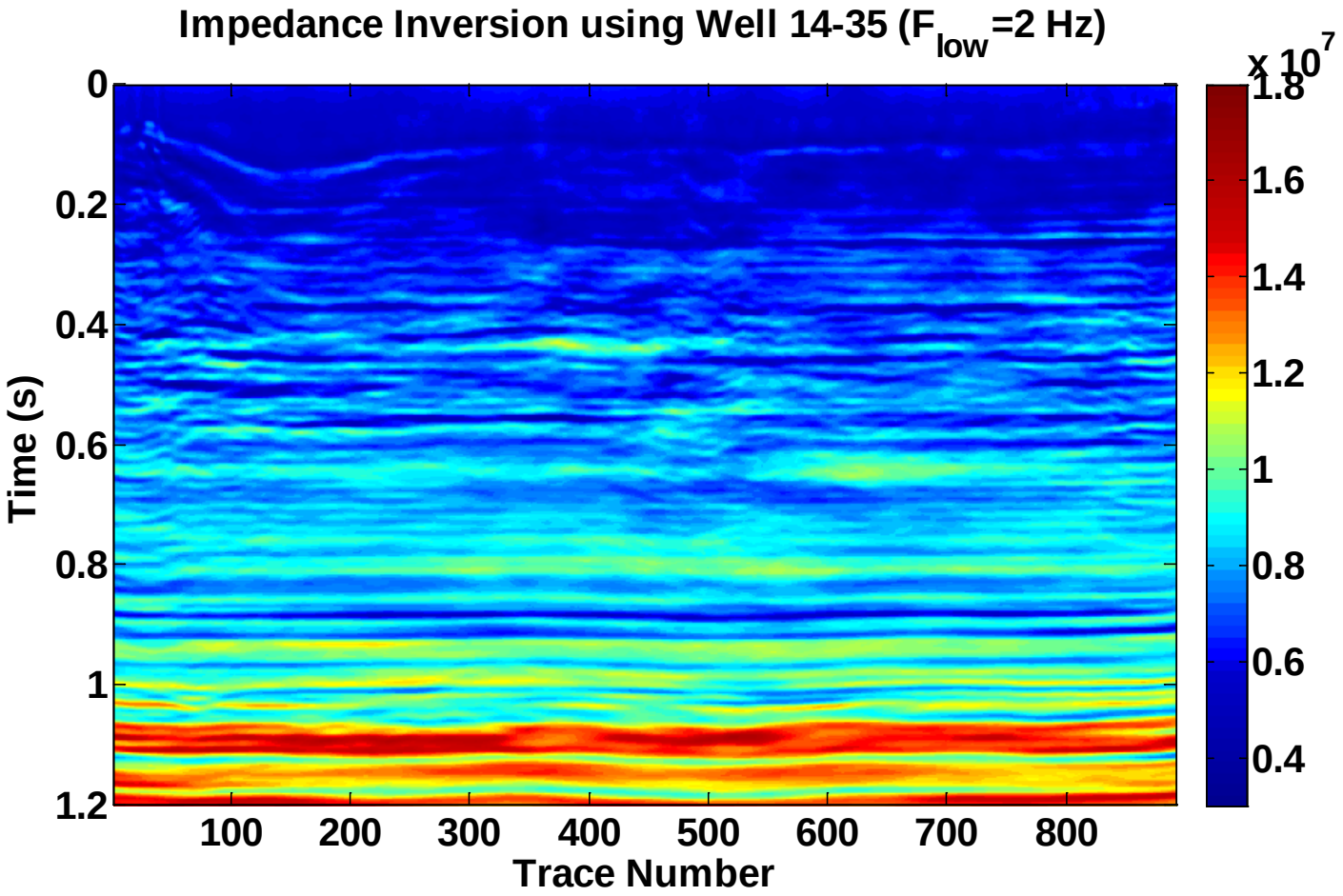
Low Frequency Source: Well 12-27



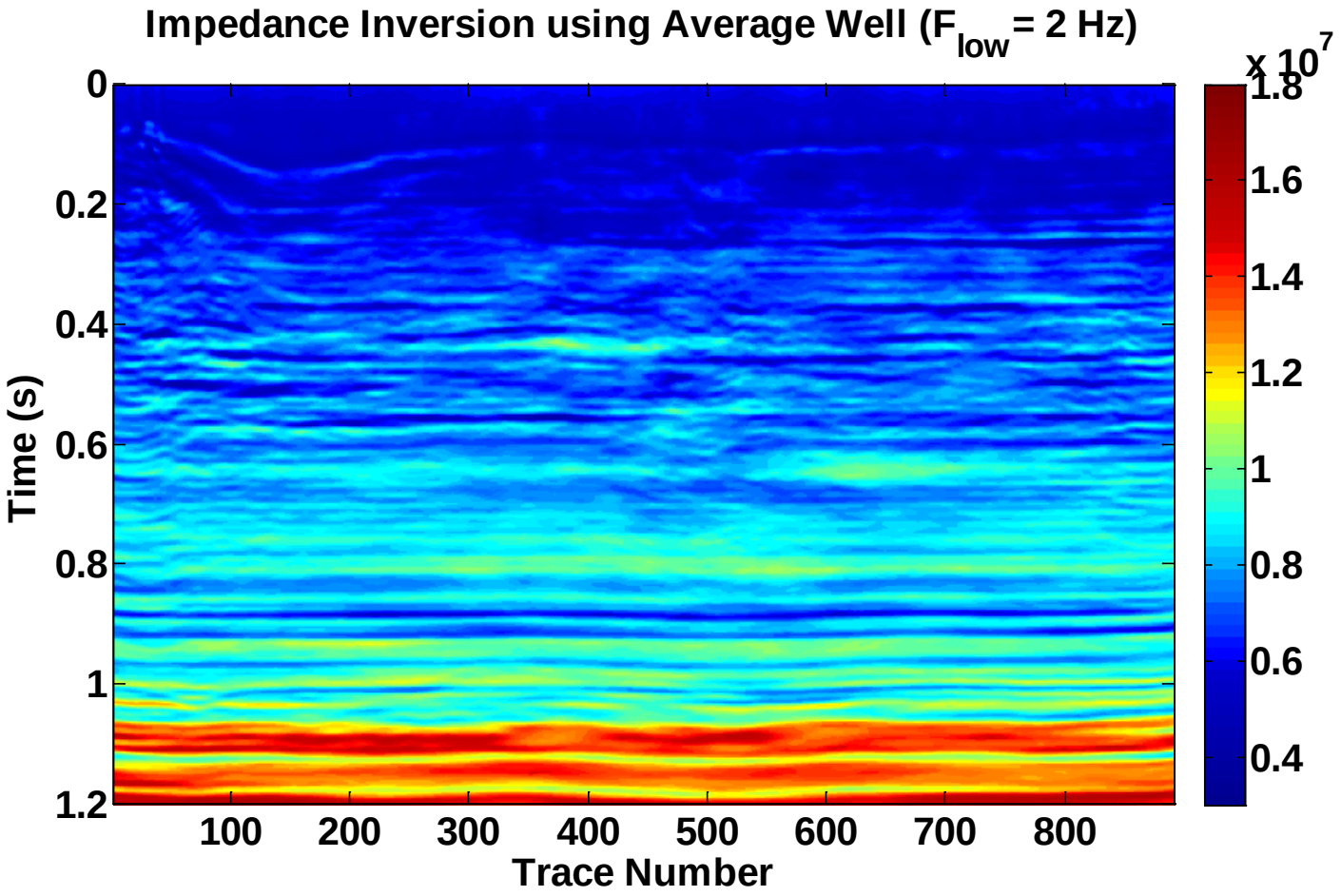
Low Frequency Source: Well 14-27



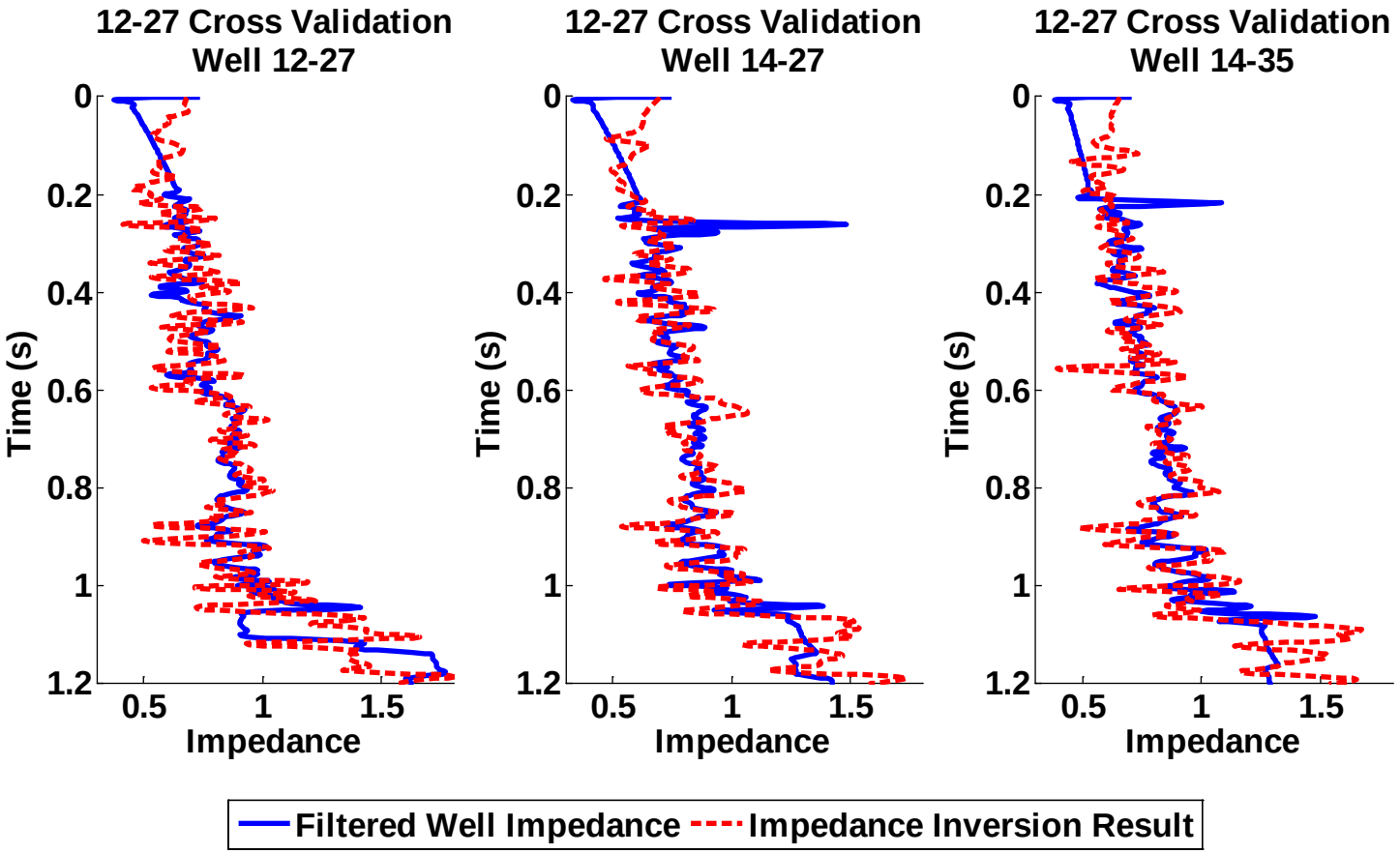
Low Frequency Source: Well 14-35



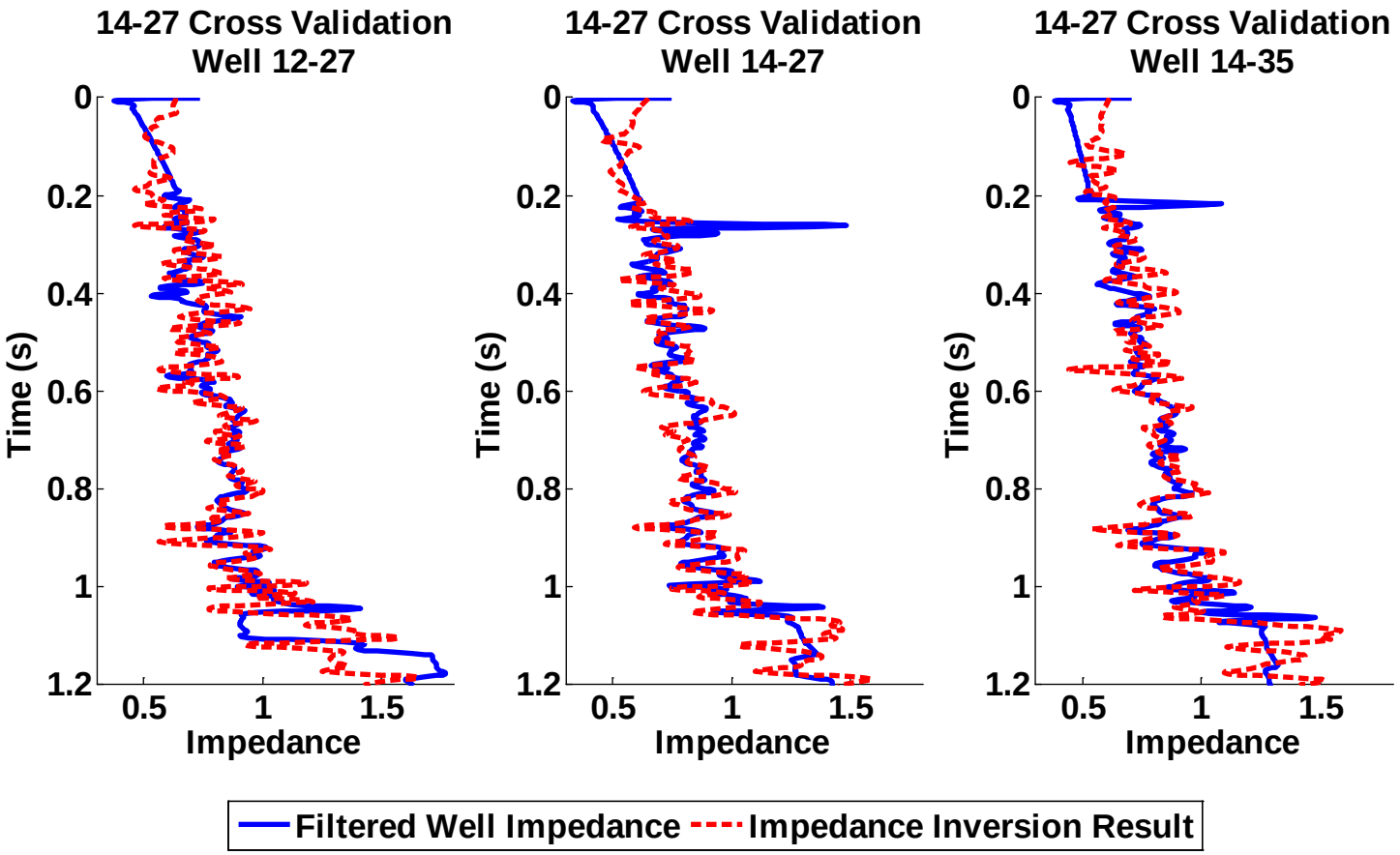
Low Frequency Source: Average Well



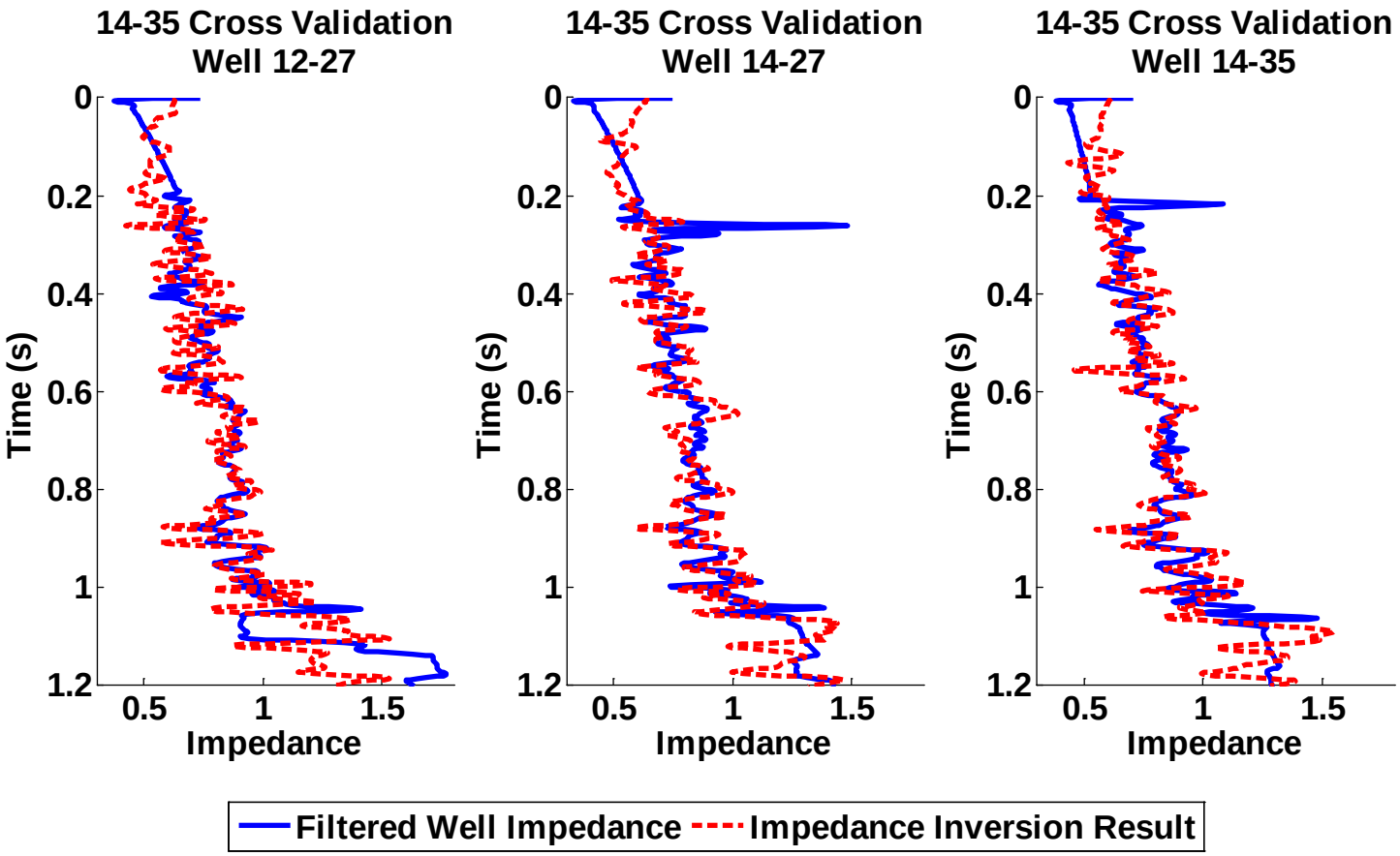
Low Frequency Source: Well 12-27



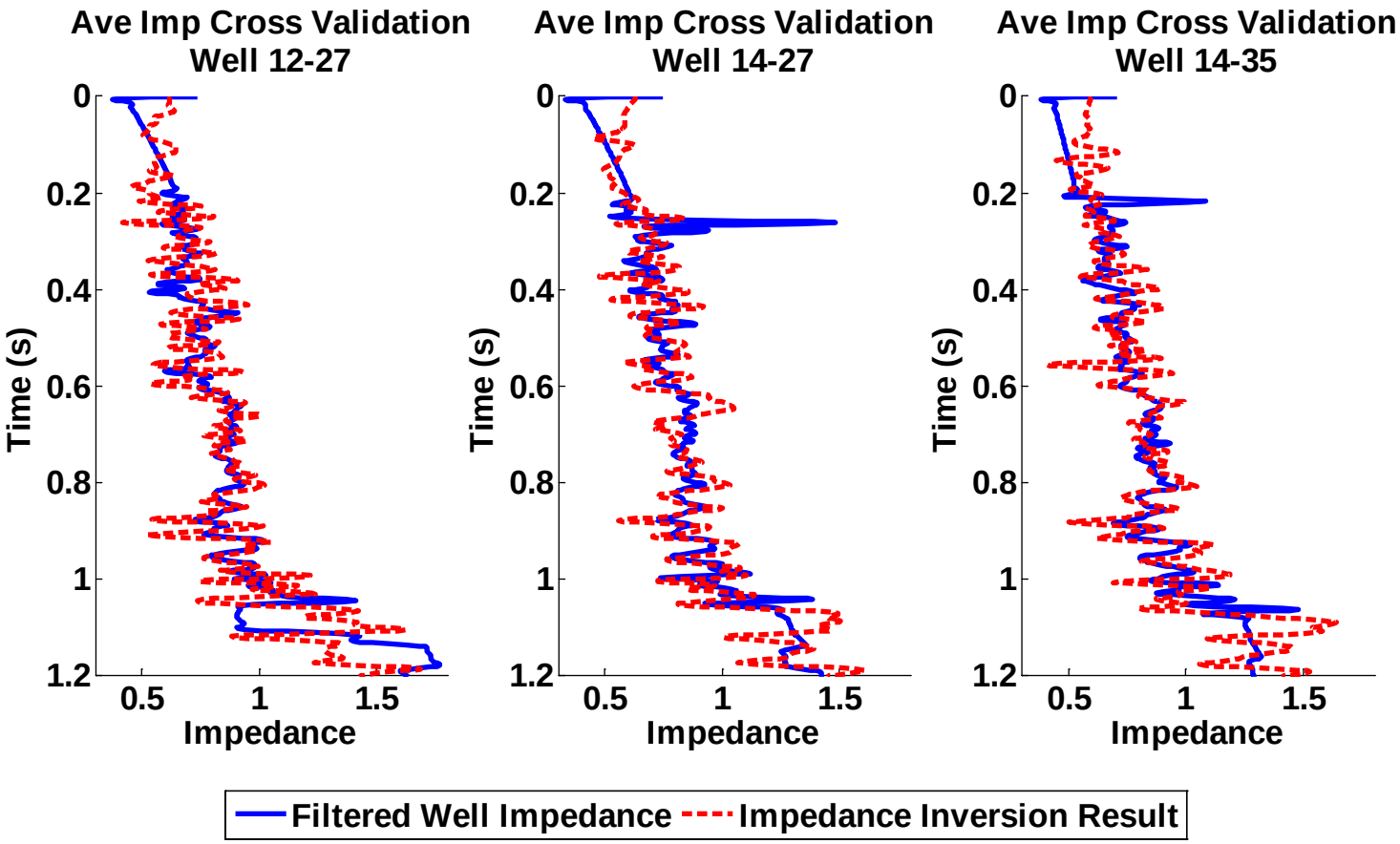
Low Frequency Source: Well 14-27

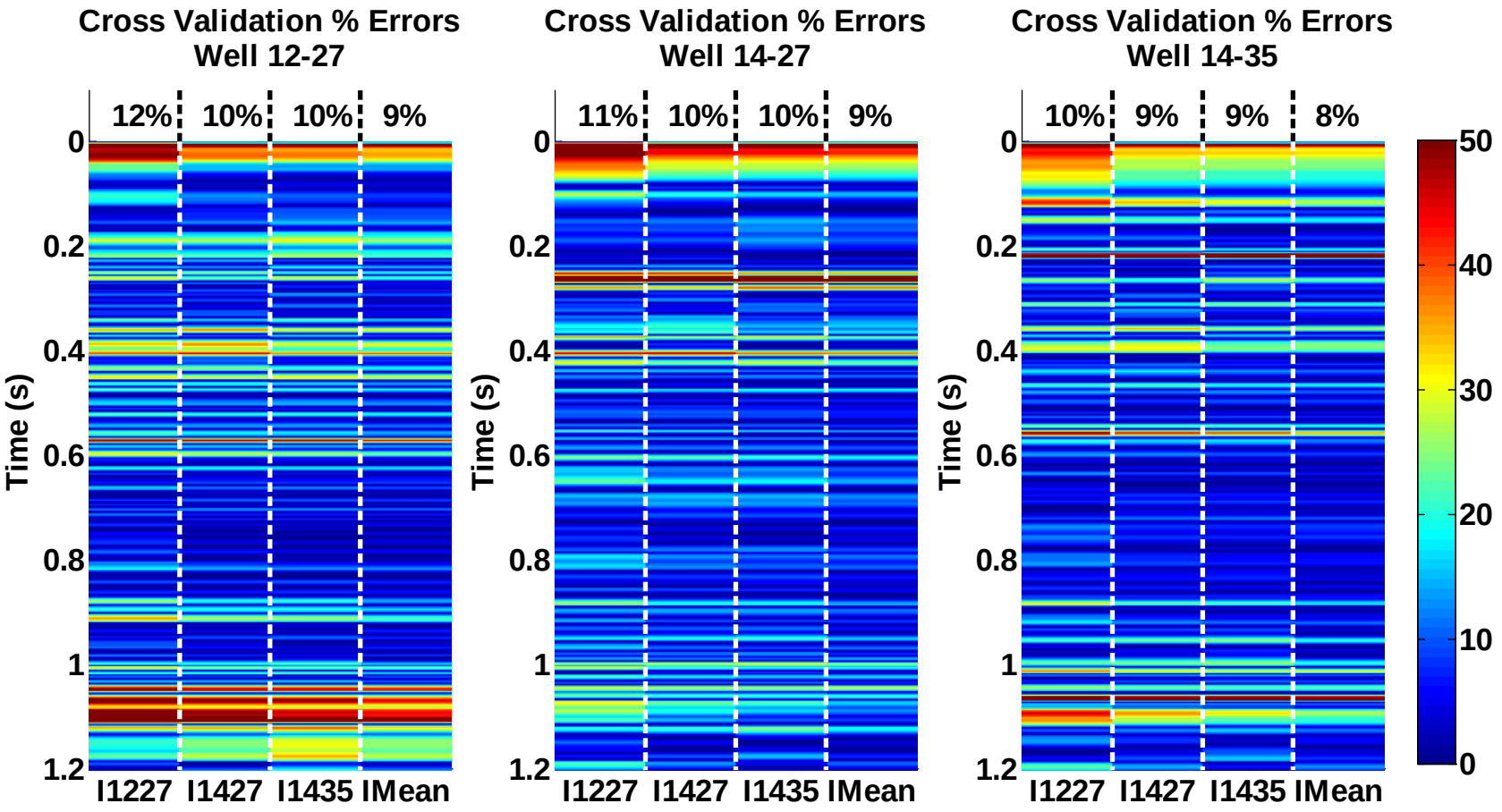


Low Frequency Source: Well 14-35



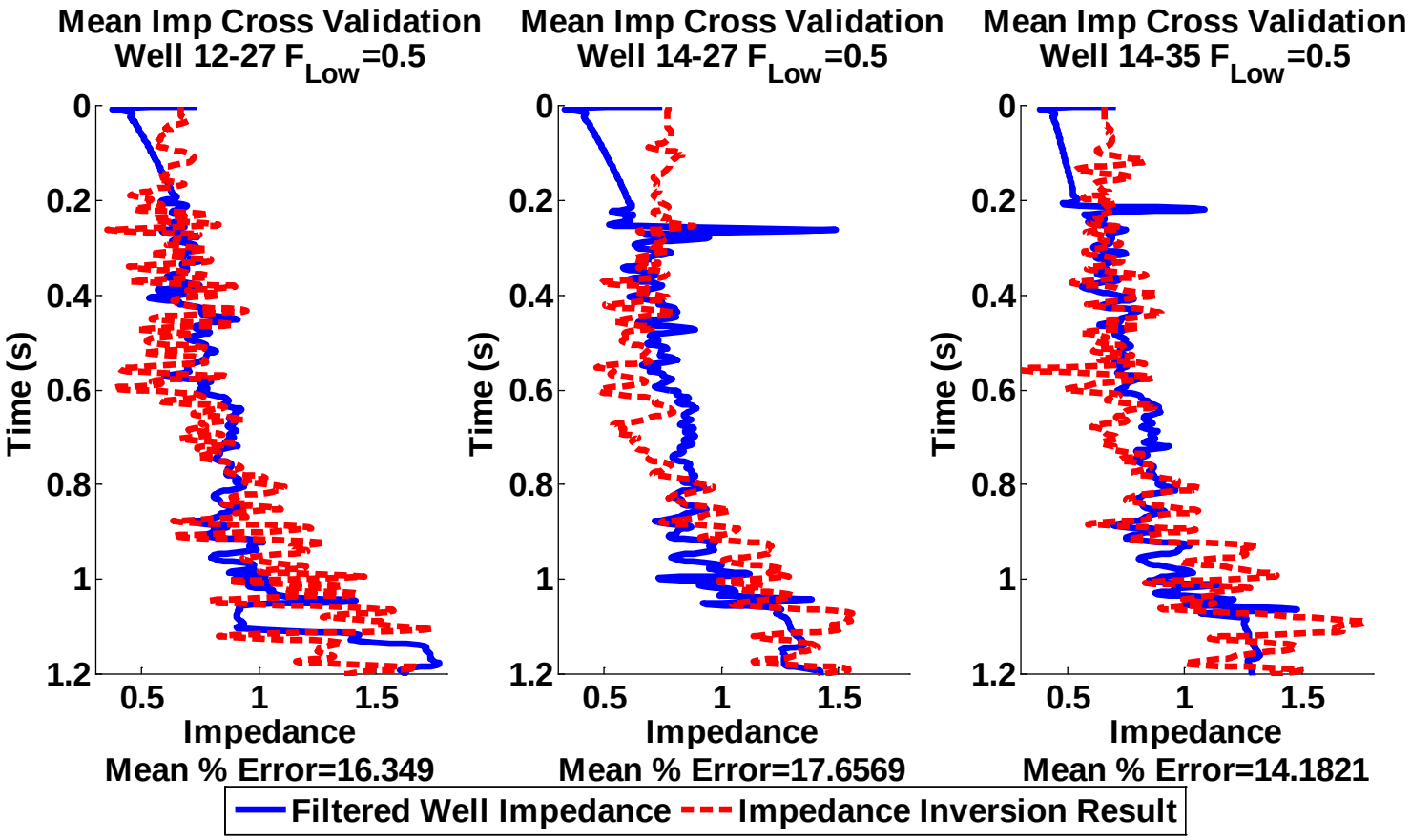
Low Frequency Source: Average Well



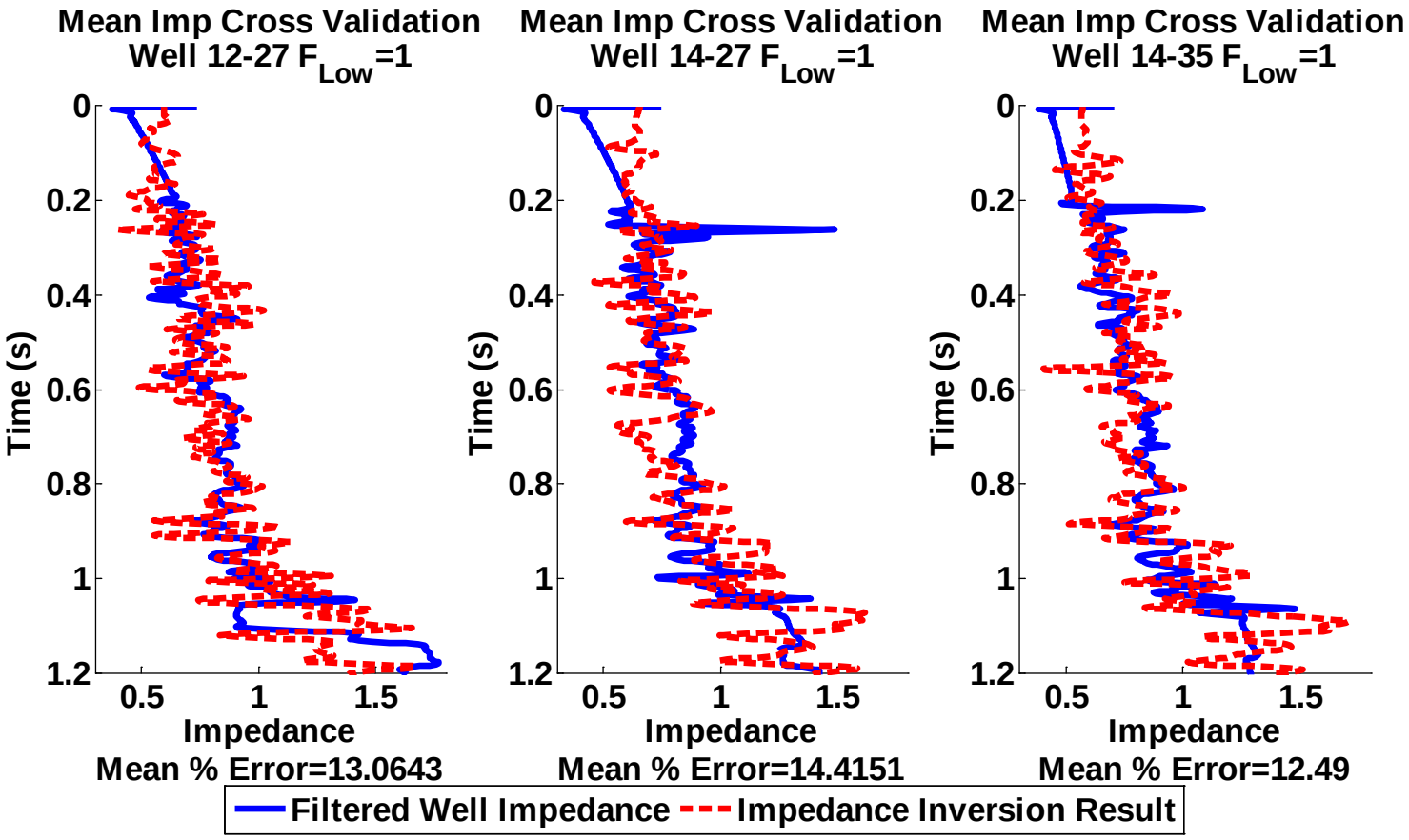

Cross Validation % Errors
Well 12-27
12%
10%
10%
9%
Time (s)
0
0.2
0.4
0.6
0.8
1
1.2
I1227
I1427
I1435
IMean
Cross Validation % Errors
Well 14-27
11%
10%
10%
9%
Cross Validation % Errors
Well 14-35
10%
9%
9%
8%
50
40
30
20
10
0

LOW-FREQUENCY INVESTIGATION

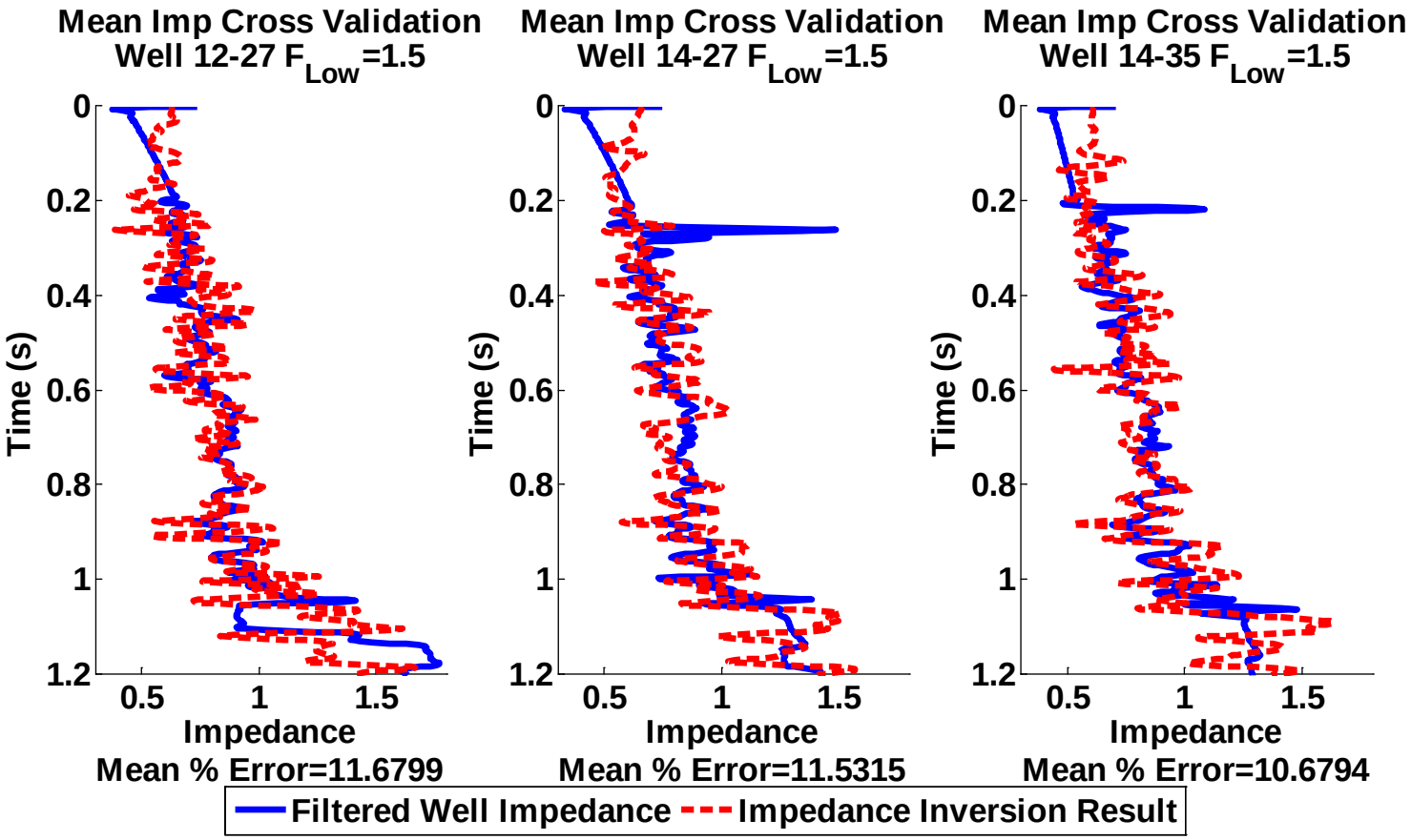
0.5 Hz Cut-off


Mean Imp Cross Validation
Well 12-27 F Low =0.5
Mean Imp Cross Validation
Well 14-27 F Low =0.5
Mean Imp Cross Validation
Well 14-35 F Low =0.5
Time (s)
0
0.2
0.4
0.6
0.8
1
1.2
0.5
1
1.5
Impedance
Mean % Error=16.349
Mean % Error=17.6569
Mean % Error=14.1821
Filtered Well Impedance
Impedance Inversion Result

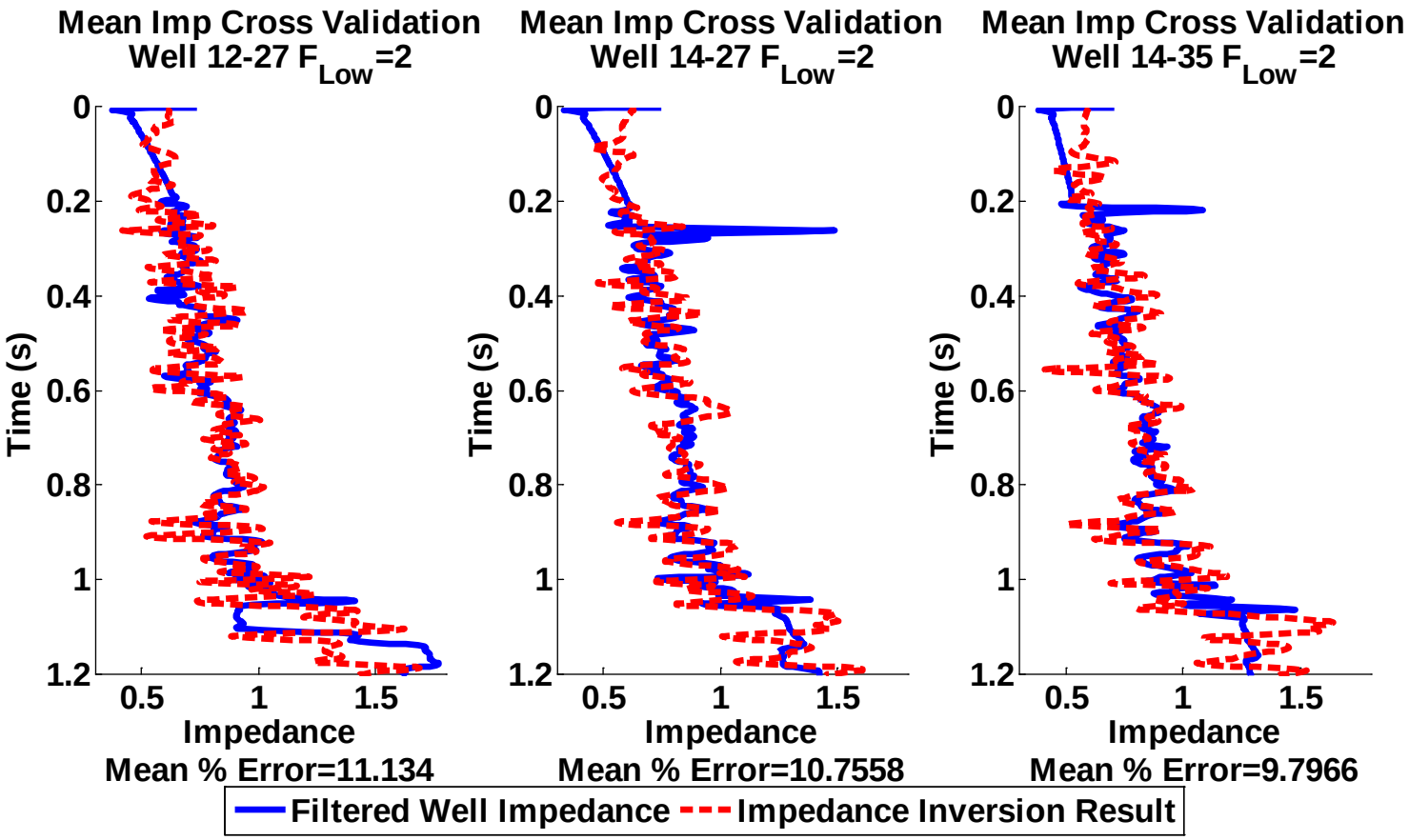
1 Hz Cut-off


Mean Imp Cross Validation
Well 12-27 F Low =1
Mean Imp Cross Validation
Well 14-27 F Low =1
Mean Imp Cross Validation
Well 14-35 F Low =1
Time (s)
0
0.2
0.4
0.6
0.8
1
1.2
0.5
1
1.5
Impedance
Mean % Error=13.0643
Mean % Error=14.4151
Mean % Error=12.49
Filtered Well Impedance
Impedance Inversion Result

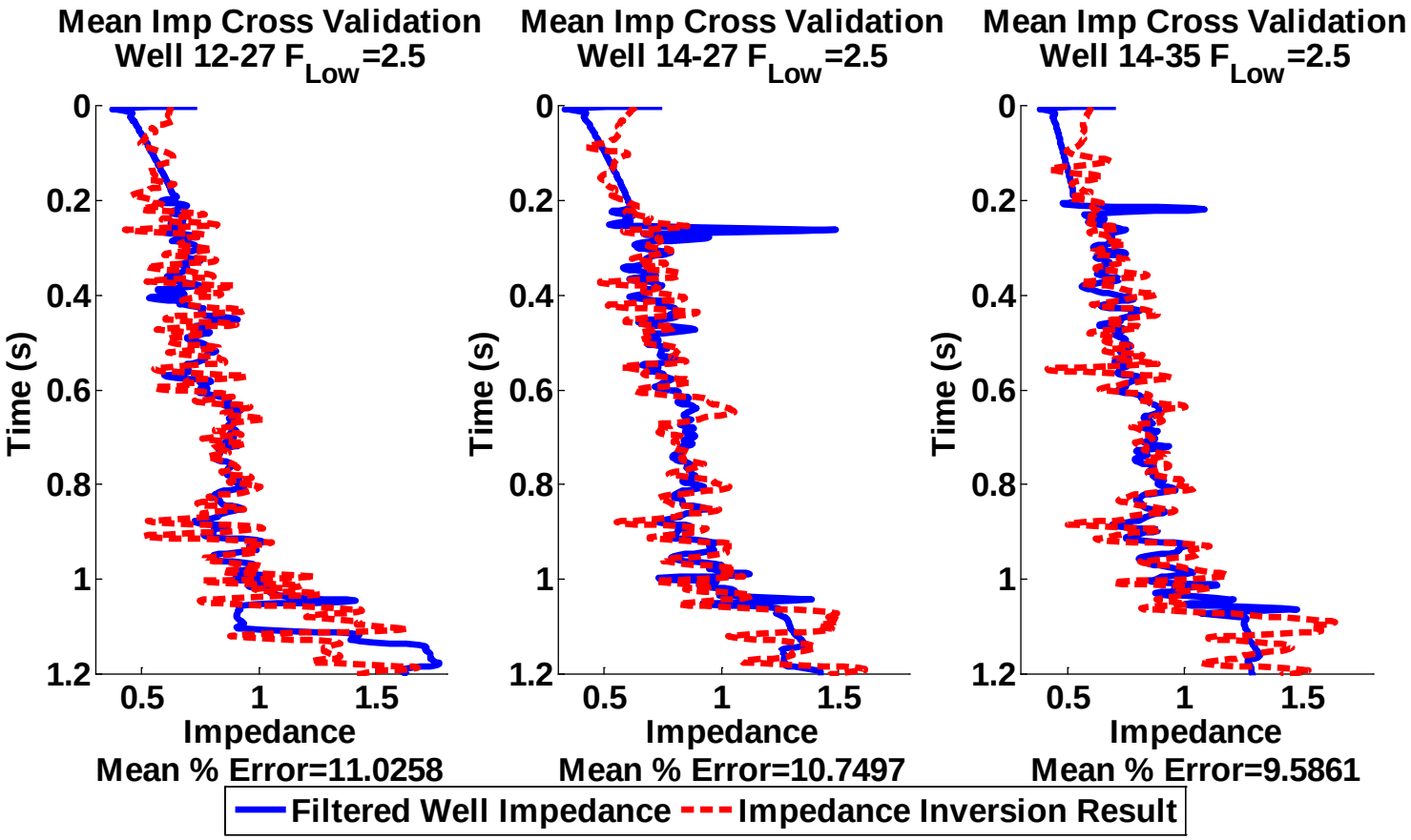
1.5 Hz Cut-off


Mean Imp Cross Validation
Well 12-27 F Low =1.5
Mean Imp Cross Validation
Well 14-27 F Low =1.5
Mean Imp Cross Validation
Well 14-35 F Low =1.5
Time (s)
0
0.2
0.4
0.6
0.8
1
1.2
0.5
1
1.5
Impedance
Mean % Error=11.6799
Mean % Error=11.5315
Mean % Error=10.6794
Filtered Well Impedance
Impedance Inversion Result

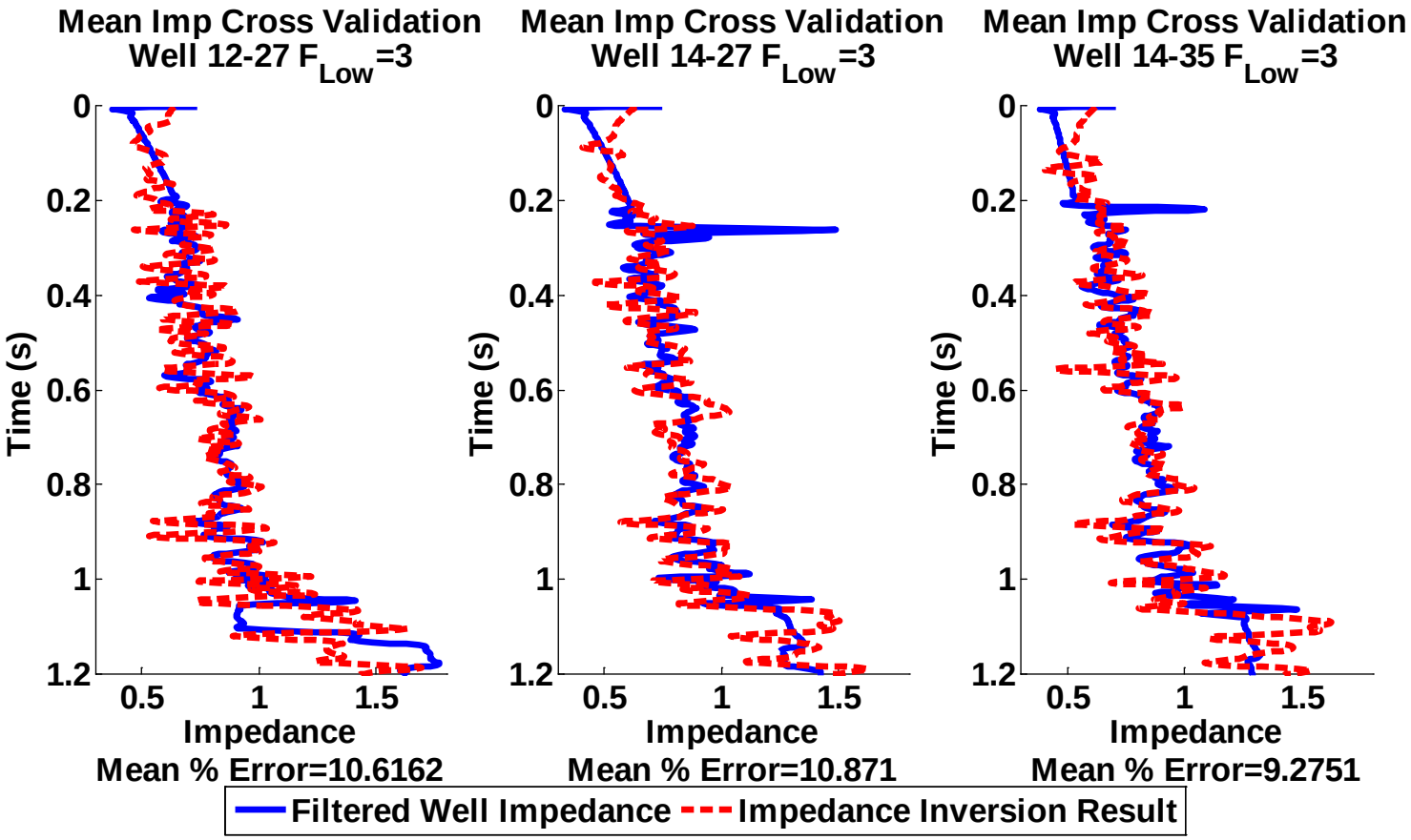
2 Hz Cut-off


Mean Imp Cross Validation
Well 12-27 F Low =2
Mean Imp Cross Validation
Well 14-27 F Low =2
Mean Imp Cross Validation
Well 14-35 F Low =2
Time (s)
0
0.2
0.4
0.6
0.8
1
1.2
0.5
1
1.5
Impedance
Mean % Error=11.134
Mean % Error=10.7558
Mean % Error=9.7966
Filtered Well Impedance
Impedance Inversion Result

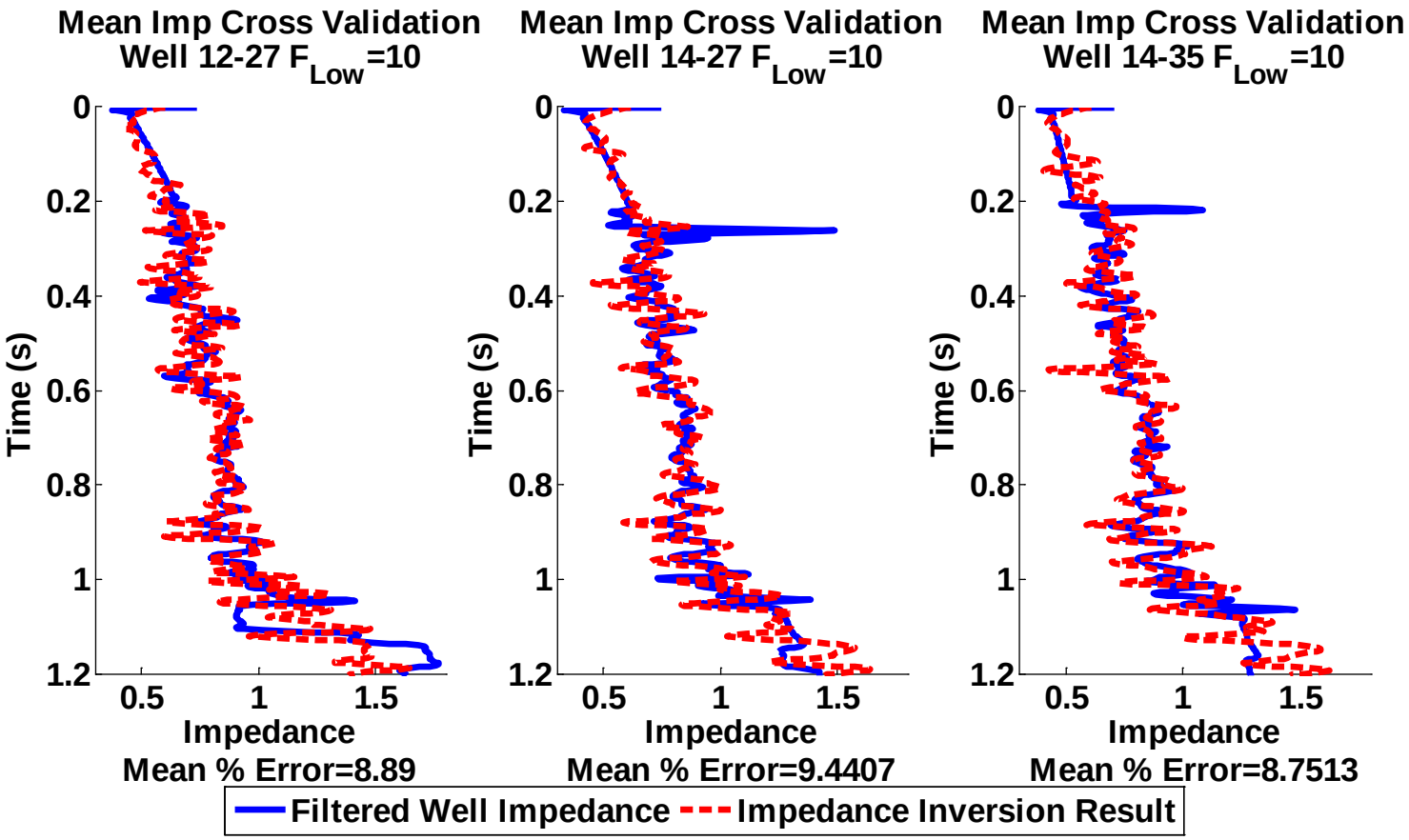
2.5 Hz Cut-off

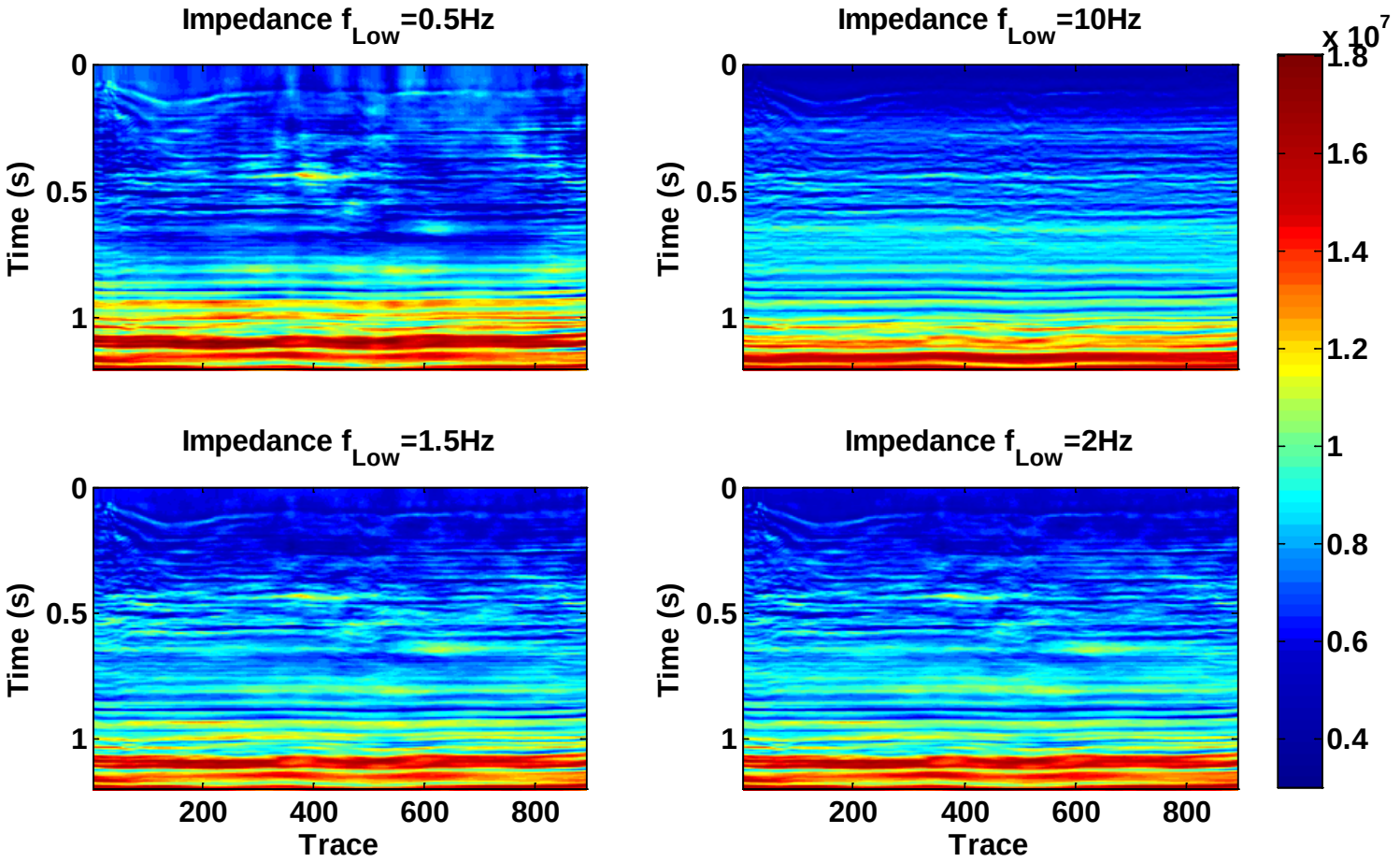

Mean Imp Cross Validation
Well 12-27 F Low =2.5
Mean Imp Cross Validation
Well 14-27 F Low =2.5
Mean Imp Cross Validation
Well 14-35 F Low =2.5
Time (s)
0
0.2
0.4
0.6
0.8
1
1.2
0.5
1
1.5
Impedance
Mean % Error=11.0258
Mean % Error=10.7497
Mean % Error=9.5861
Filtered Well Impedance
Impedance Inversion Result

3 Hz Cut-off


Mean Imp Cross Validation
Well 12-27 F Low =3
Mean Imp Cross Validation
Well 14-27 F Low =3
Mean Imp Cross Validation
Well 14-35 F Low =3
Time (s)
0
0.2
0.4
0.6
0.8
1
1.2
0.5
1
1.5
Impedance
Mean % Error=10.6162
Mean % Error=10.871
Mean % Error=9.2751
Filtered Well Impedance
Impedance Inversion Result

10 Hz Cut-off


Mean Imp Cross Validation
Well 12-27 F Low =10
Mean Imp Cross Validation
Well 14-27 F Low =10
Mean Imp Cross Validation
Well 14-35 F Low =10
Time (s)
0
0.2
0.4
0.6
0.8
1
1.2
0.5
1
1.5
Impedance
Mean % Error=8.89
Mean % Error=9.4407
Mean % Error=8.7513
Filtered Well Impedance
Impedance Inversion Result


Impedance f_Low=0.5Hz
Impedance f_Low=10Hz
Impedance f_Low=1.5Hz
Impedance f_Low=2Hz
Time (s)
0
0.5
1
200
400
600
800
Trace
x 10^7
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4

Conclusions

- Definitive evidence for signal in the Hussar data below 2 Hz
- Time-variant balancing was necessary for a proper inversion
- Well tying is also necessary for a more accurate inversion.
  - New tools are available for this process

Acknowledgements

- CREWES Sponsors
- CREWES Staff
- CREWES Students
- Husky, INOVA, Geokinetics
- Roy Lindseth
- Laura Baird
- Carbon Management Canada