

# Influence of colour operator on Hussar data

SINA ESMAEILI\*

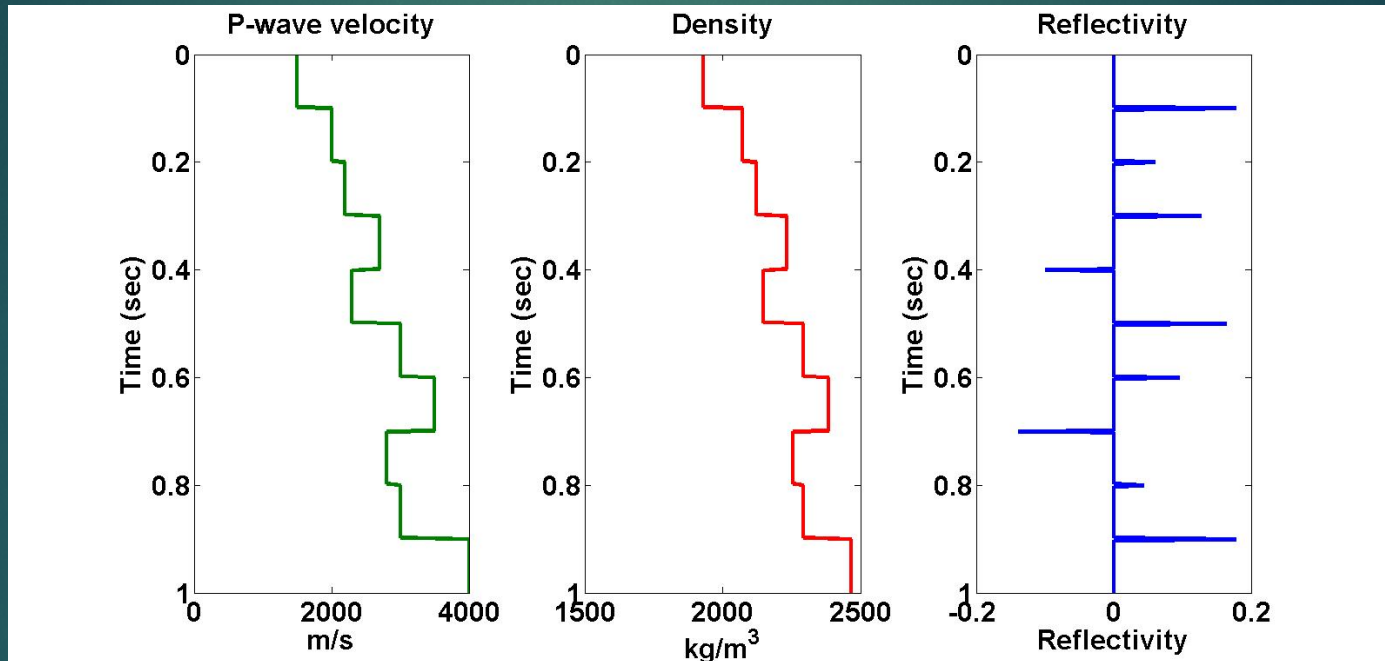
G. F. MARGRAVE



# Outline

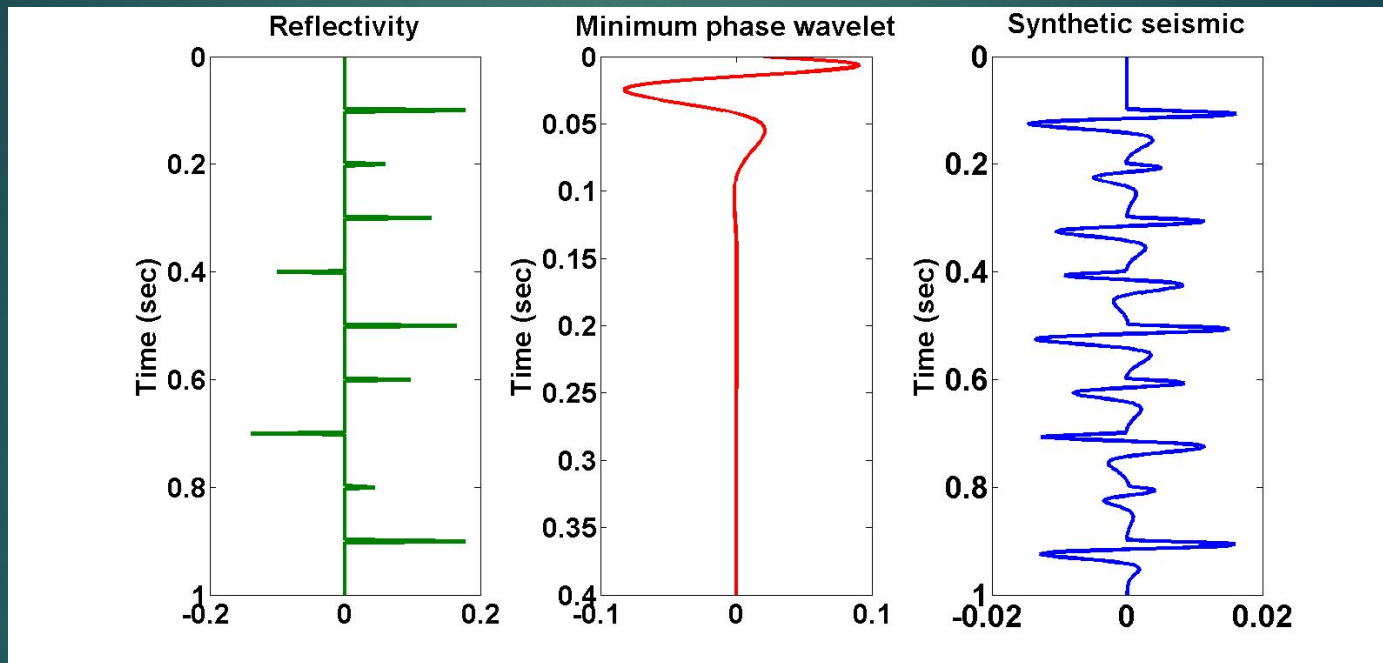
- ▶ Motivation:
  - Why the low frequencies are so important?
  - Why we need colour operator?
- ▶ Defining different colour operators
- ▶ The effect of color operators on real seismic data
- ▶ Impedance inversion results
- ▶ Coloured inversion method
- ▶ Conclusion
- ▶ Acknowledgment

# Simple model

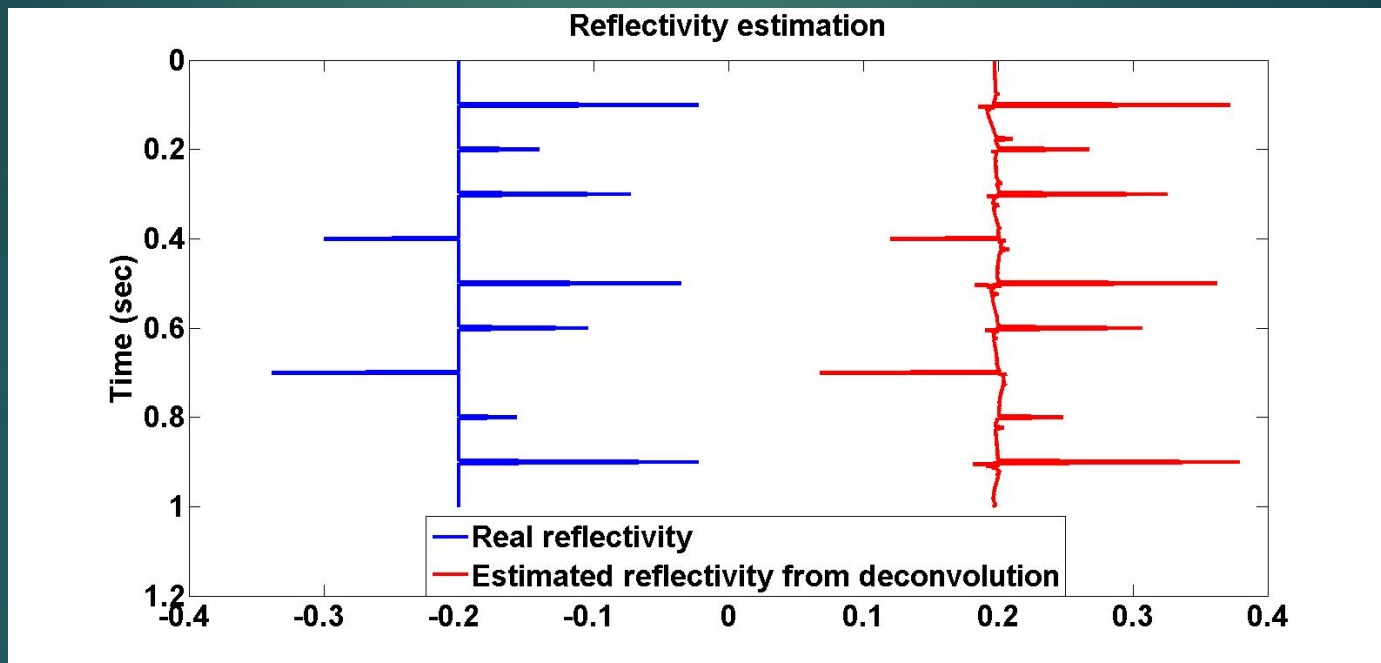




# Synthetic data

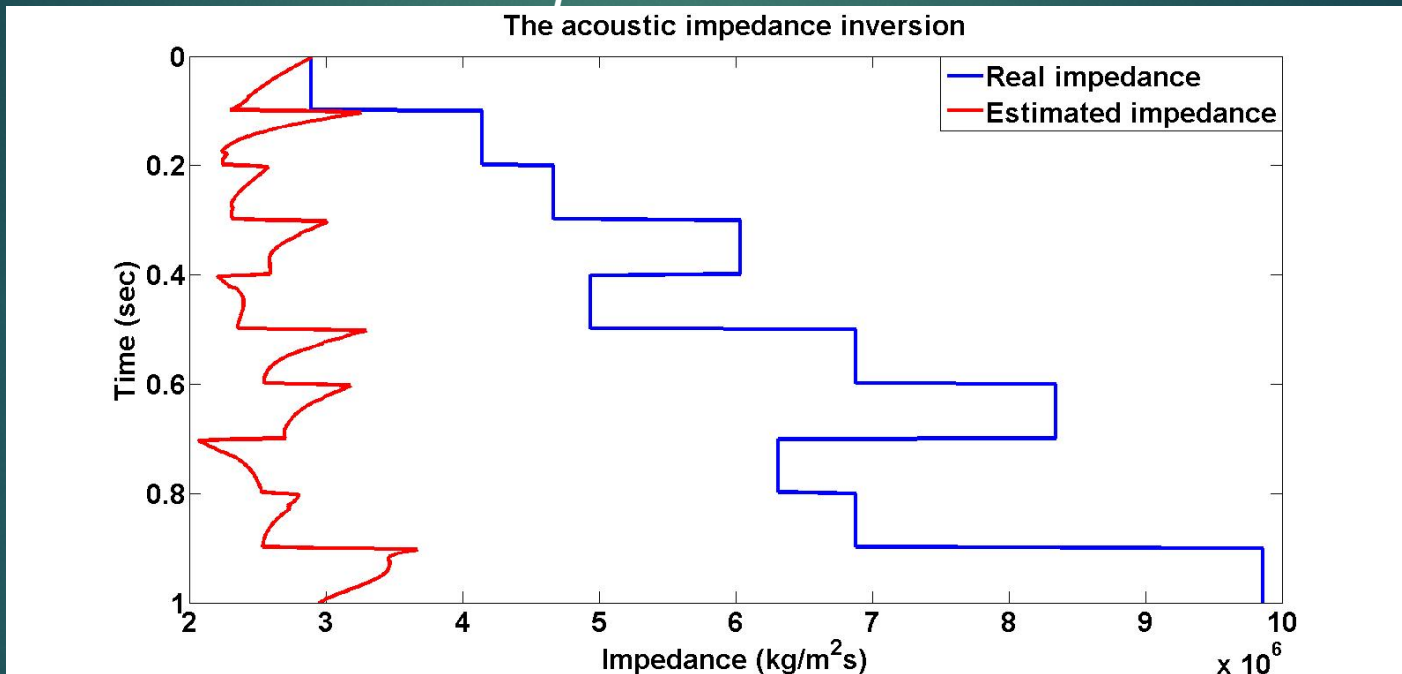


# Deconvolving



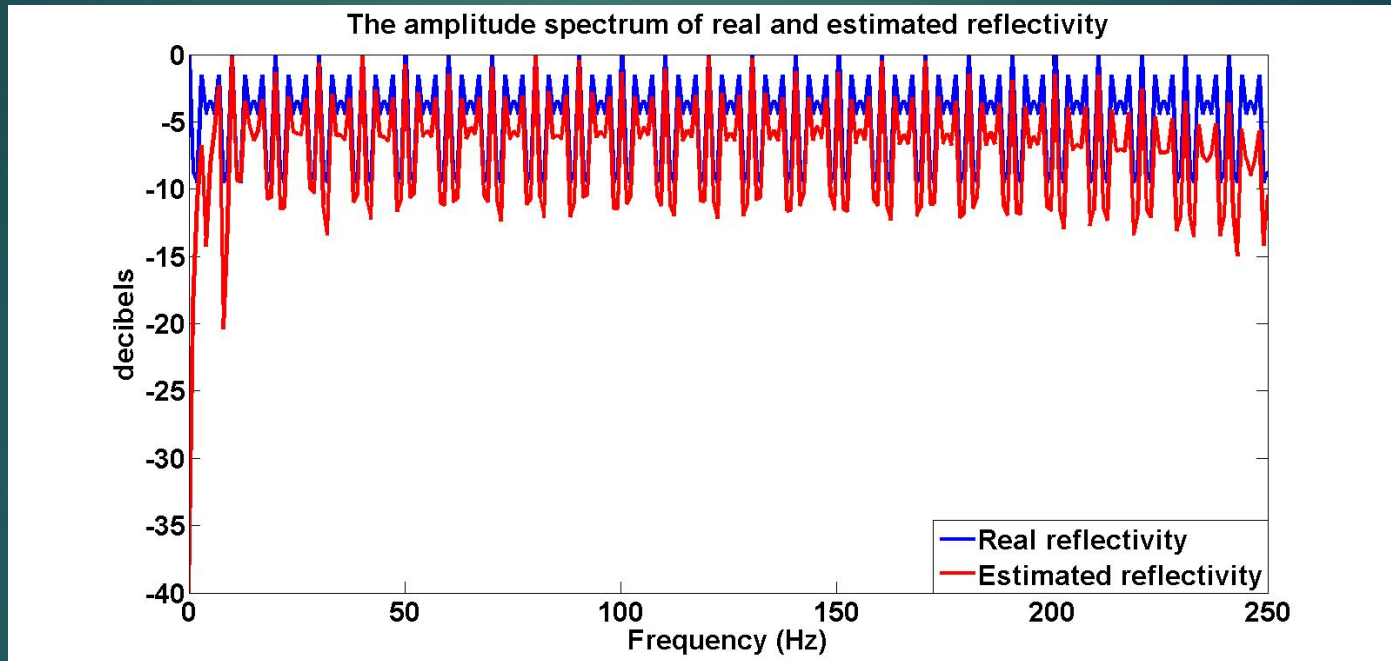
# Impedance inversion (recursion formula)

$$I_n = I_1 \prod_i^n (e^{2R_j}) = I_1 e^{2 \sum_{j=1}^n (R_j)}$$

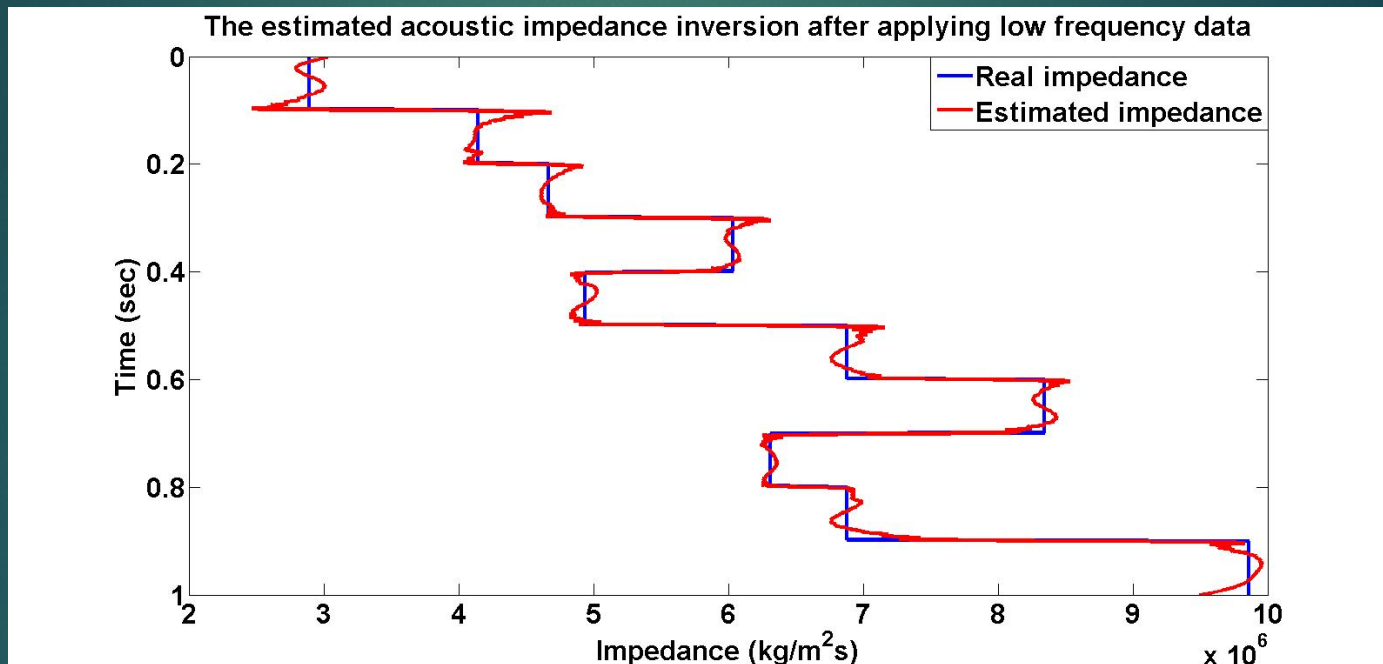




# Amplitude spectrum

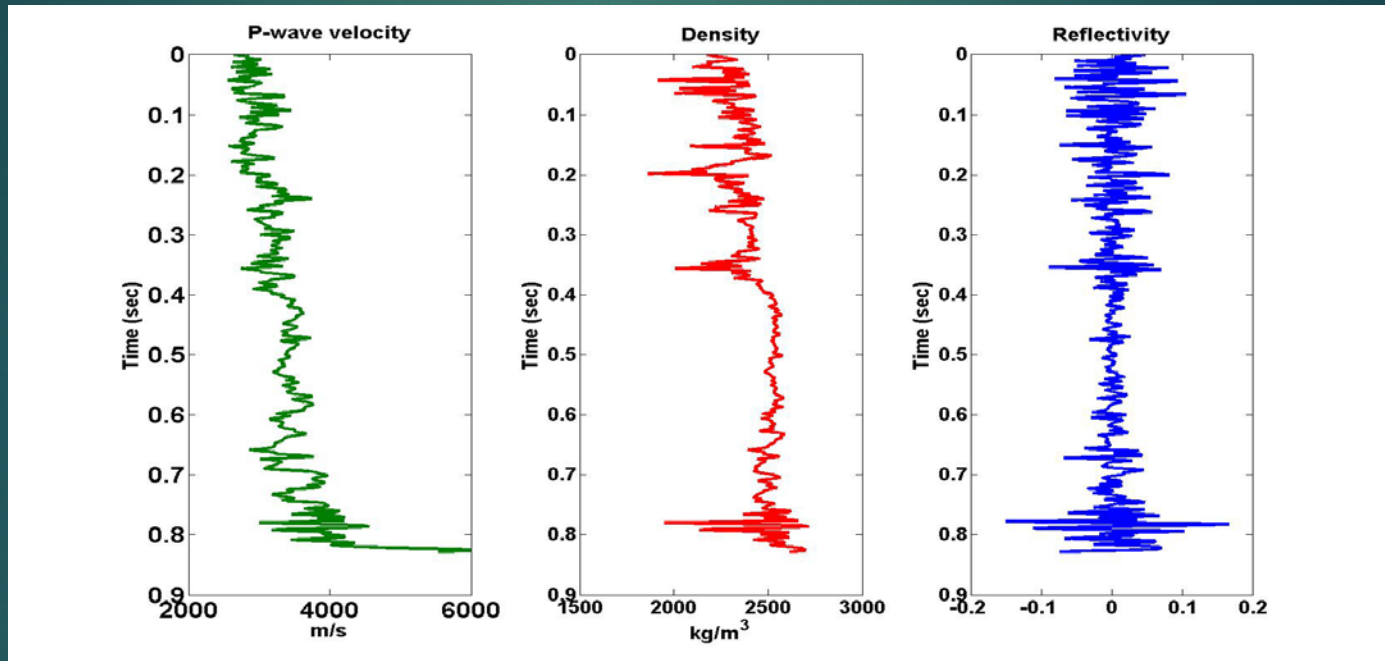


# Taking the low frequencies from the impedance model (e.g. well info)

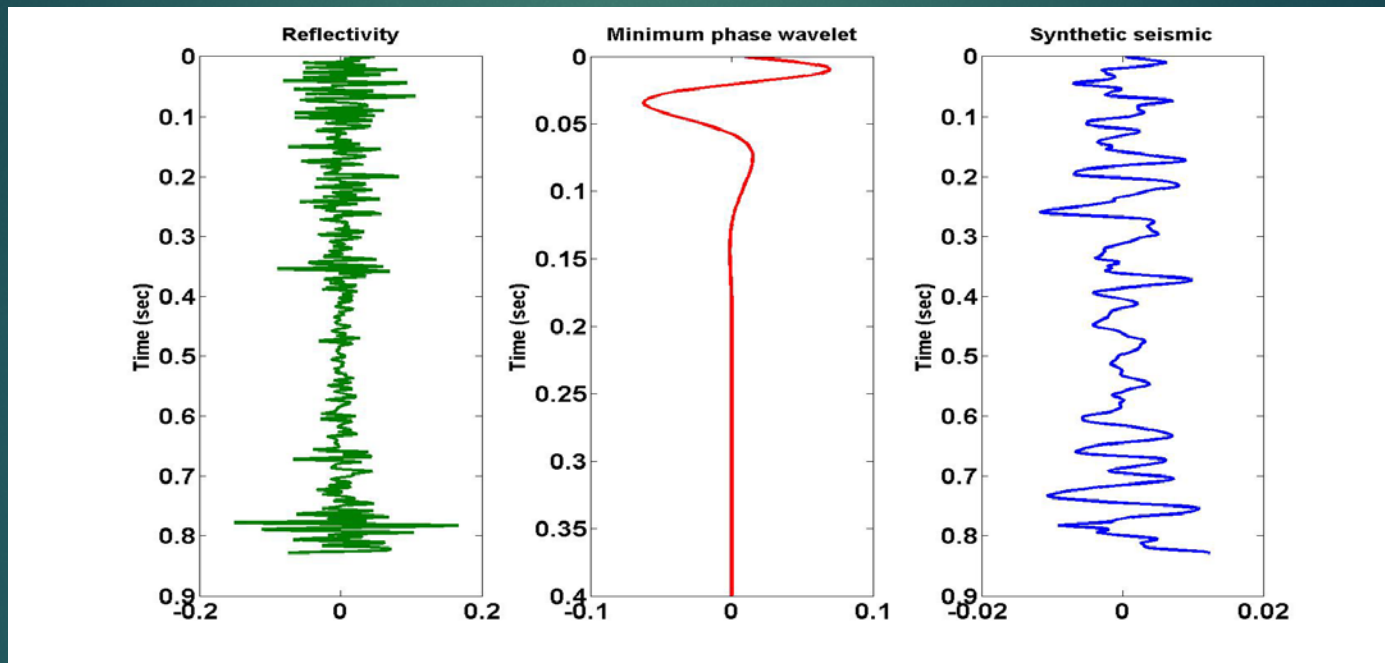




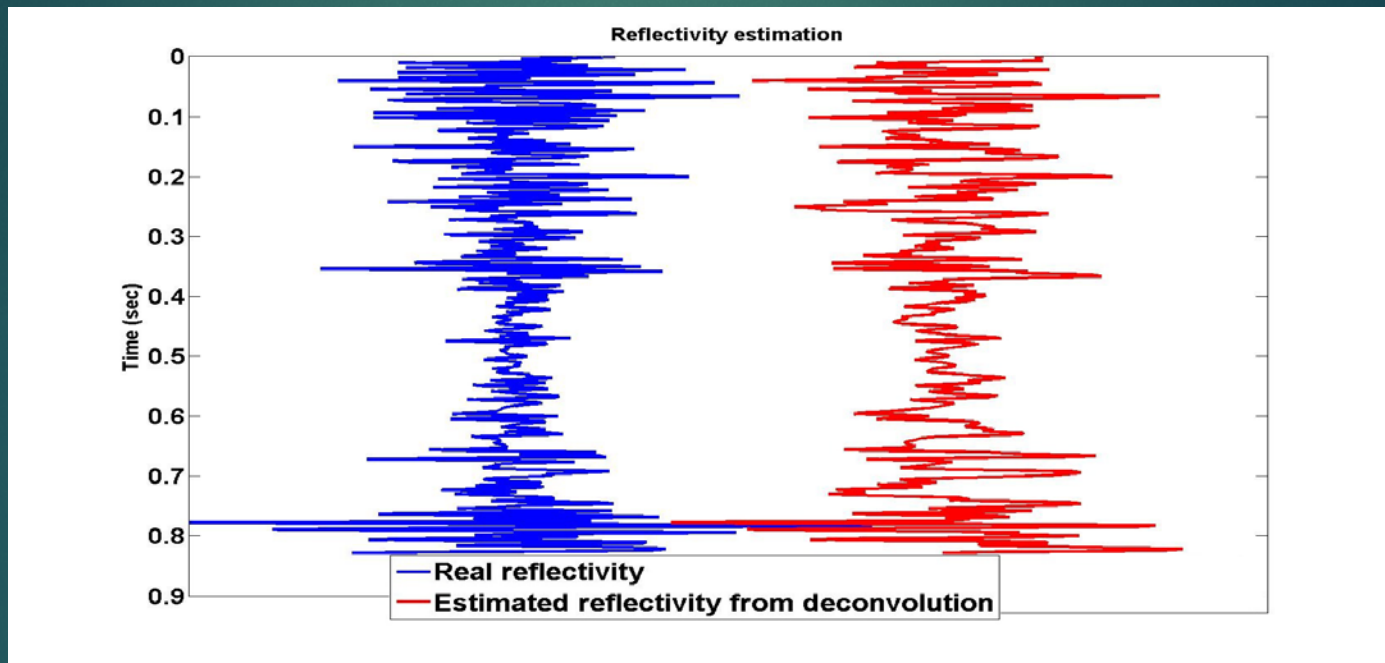
# Well log data



# The synthetic data created from well log data

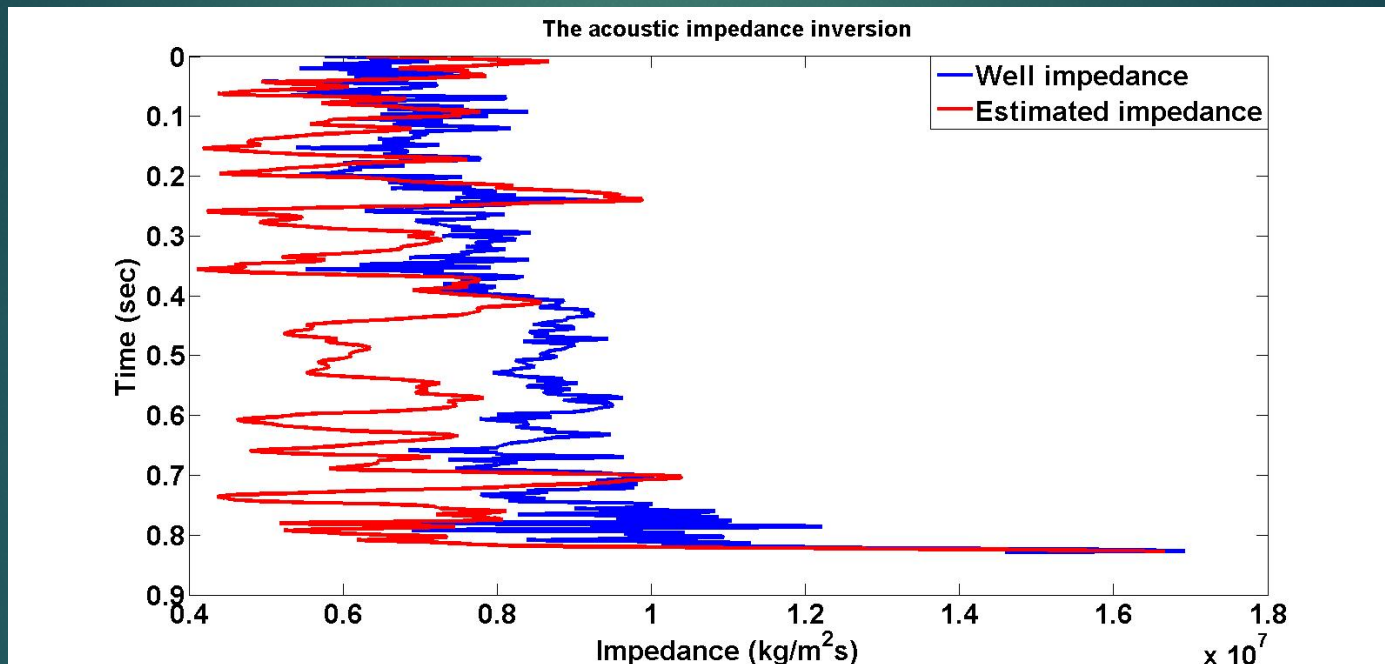


# Deconvolving

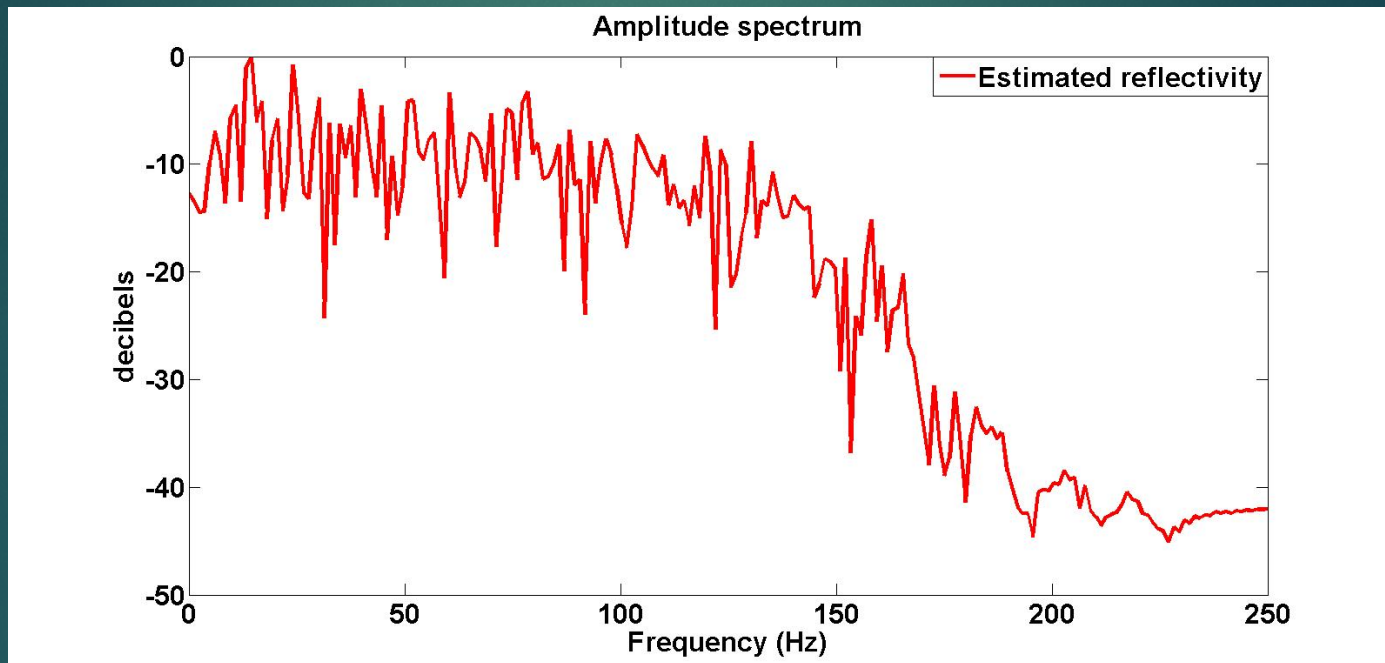




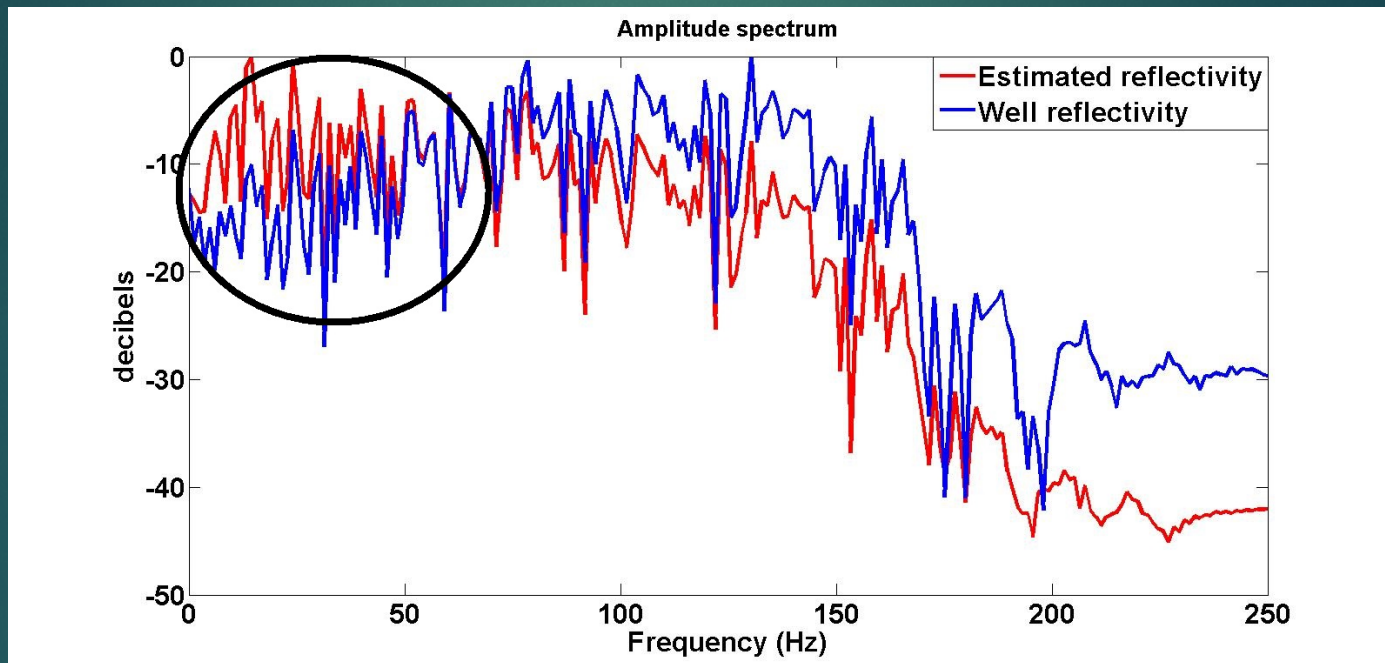
# Impedance inversion (recursion formula)



# Amplitude spectrum



# Amplitude spectrum



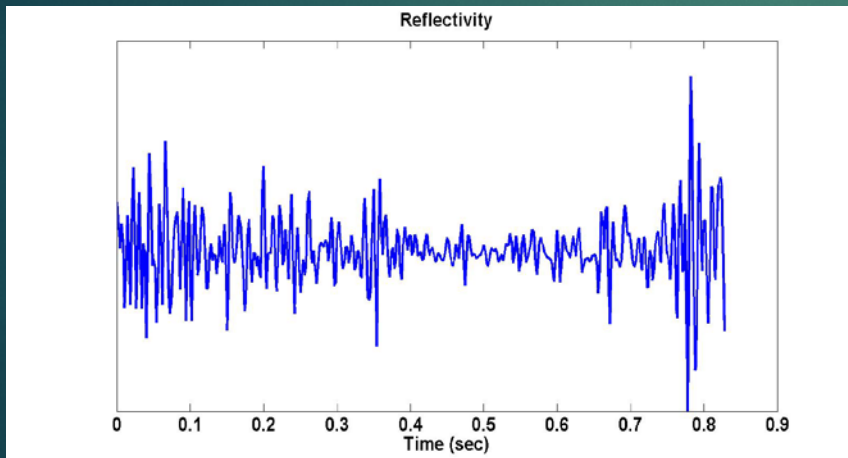


# Colour operator

- ▶ Hunt, L., Gray, F. D., & Wallace, R. A. (1993). Using Reflectivity to Produce a Superior Deconvolution. *Canadian SEG Convention Technical Abstracts*, 95-96.

# Colour operator

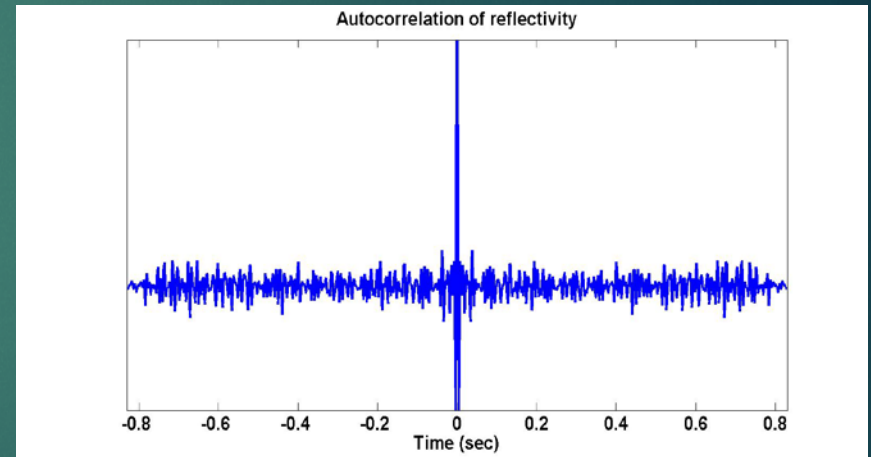
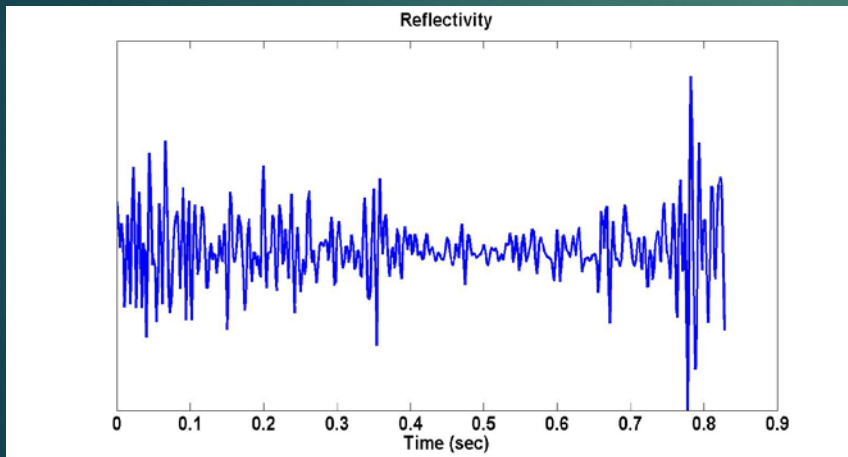
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# Colour operator

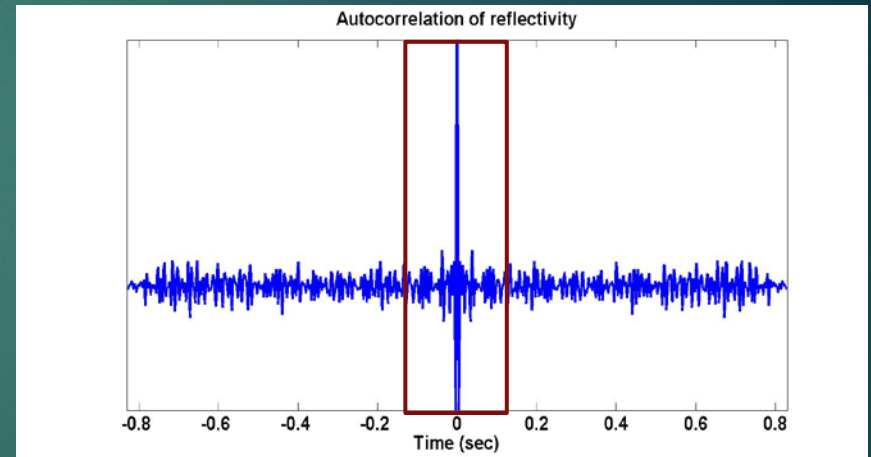
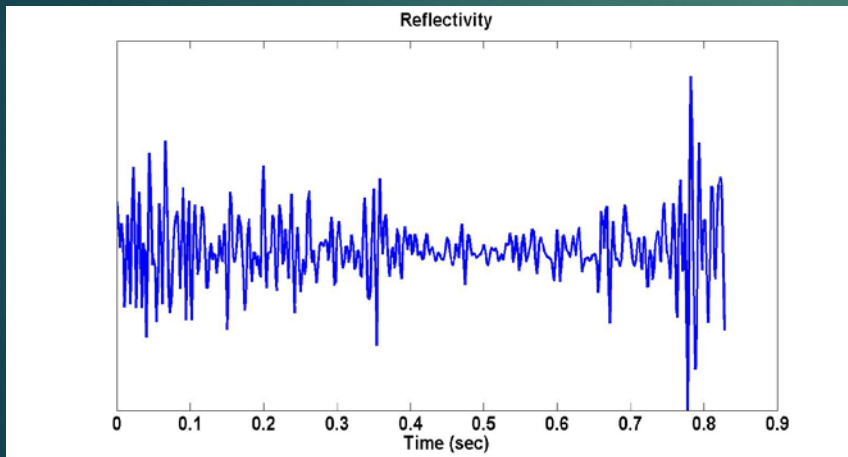
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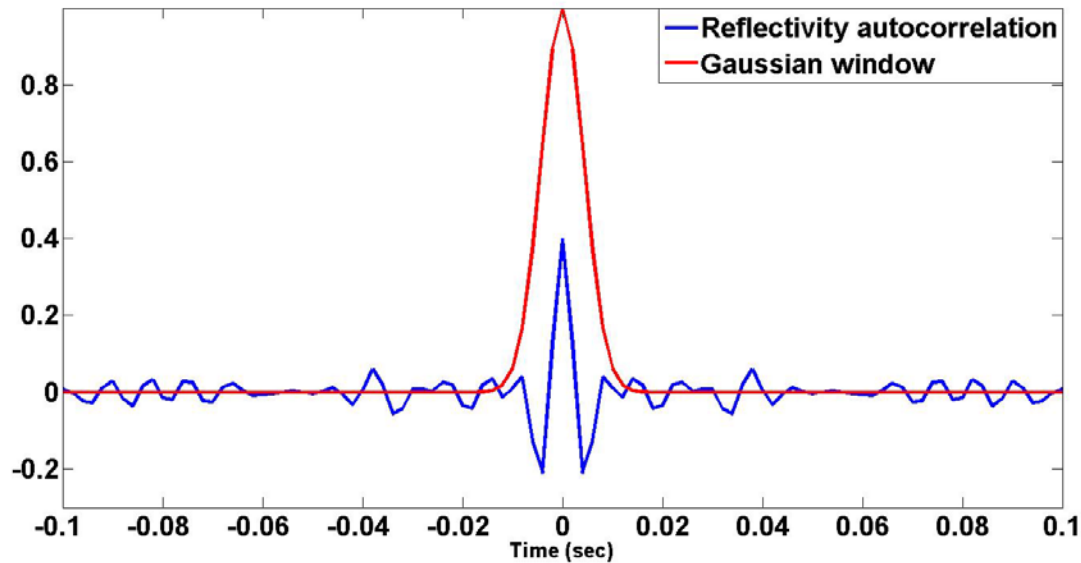
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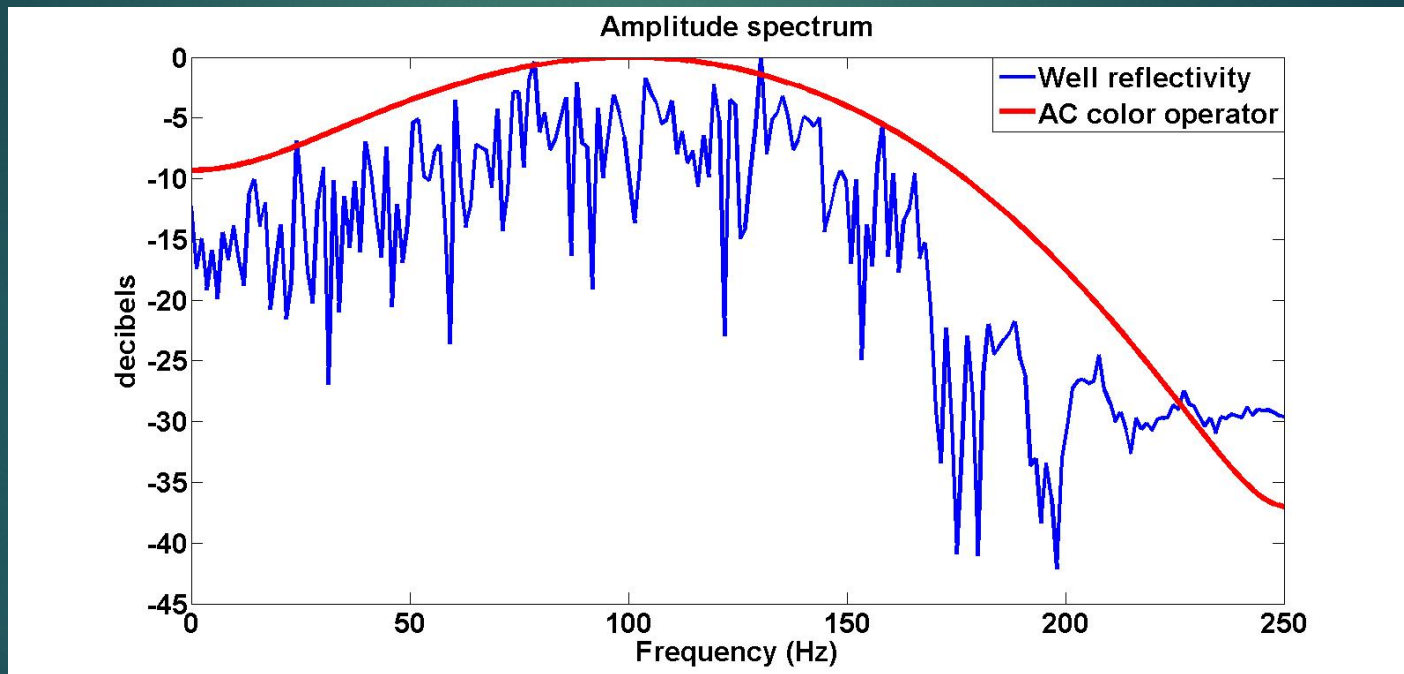
# Colour operator

- ▶ Hunt, L., Gray, F. D., & Wallace, R. A. (1993). Using Reflectivity to Produce a Superior Deconvolution. *Canadian SEG Convention Technical Abstracts*, 95-96.



# AutoCorrelation (AC) colour operator

The phase spectrum calculated to be minimum phase.







# Arctan and sigmoidal colour operator

- ▶ Esmaeili, S., & Margrave, G. F. (2014). *The optimum colour operator for recovering low frequencies*. CREWES Research Report, Vol. 26.



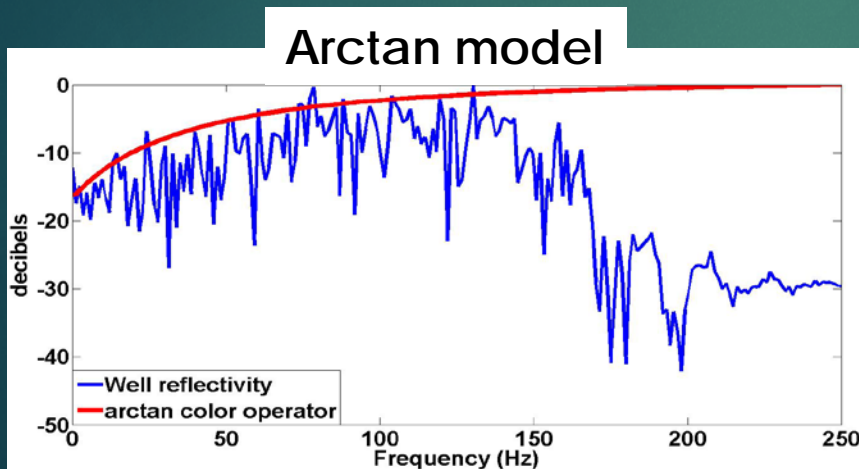
# Arctan and sigmoidal colour operator

- ▶ Esmaeili, S., & Margrave, G. F. (2014). *The optimum colour operator for recovering low frequencies*. CREWES Research Report, Vol. 26.
- Its amplitude spectrum calculated from Curve fitting on amplitude spectrum of well reflectivity.
- The phase spectrum calculated to be minimum phase.



# Arctan and sigmoidal colour operator

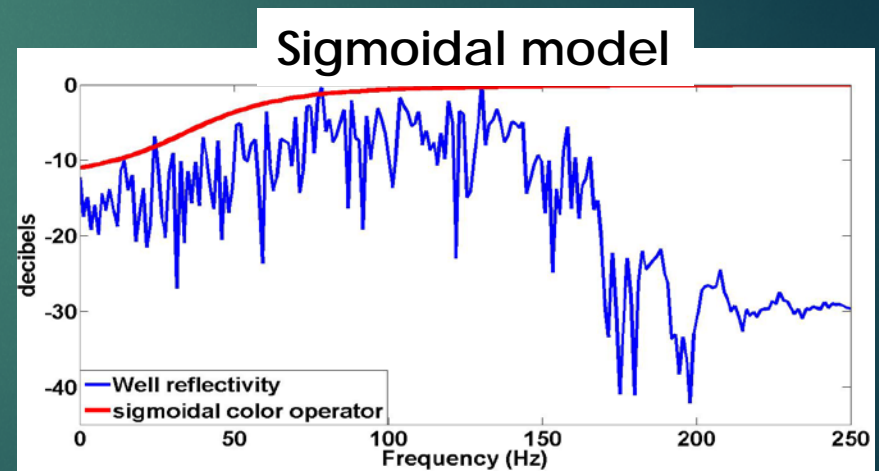
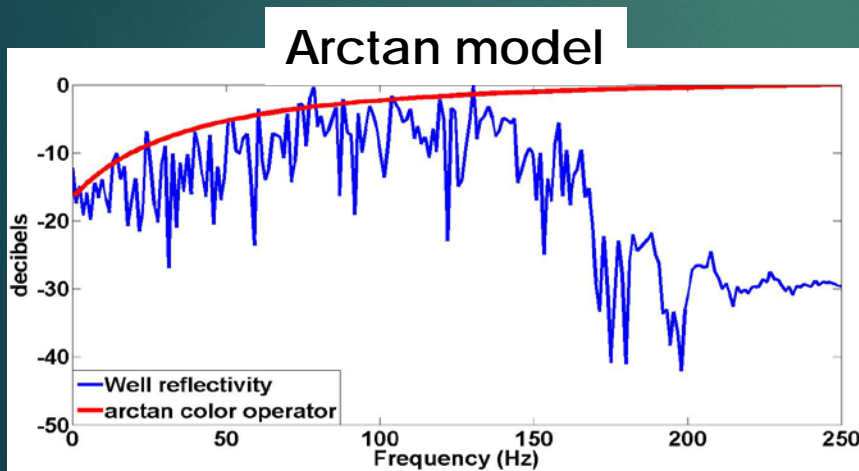
- ▶ Esmaeili, S., & Margrave, G. F. (2014). *The optimum colour operator for recovering low frequencies*. CREWES Research Report, Vol. 26.
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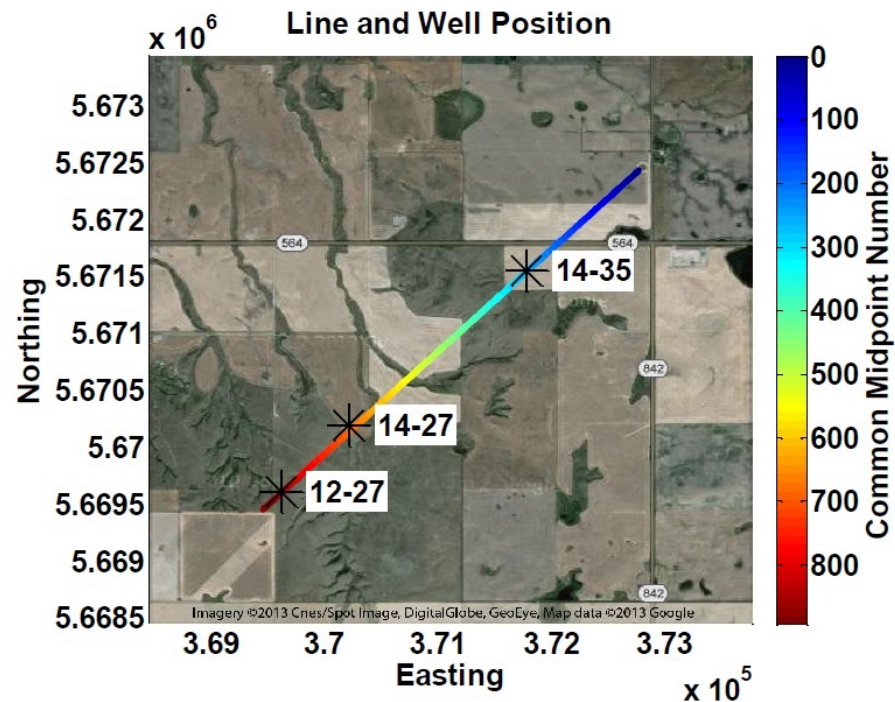
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- Its amplitude spectrum calculated from Curve fitting on amplitude spectrum of well reflectivity.
- The phase spectrum calculated to be minimum phase.



# Hussar Seismic data

- ▶ In September 2011 CREWES initiated a seismic experiment.
- ▶ Located near Hussar, Alberta.
- ▶ The line was 4.5km.
- ▶ Three wells: 14-35, 14-27 and 12-27.

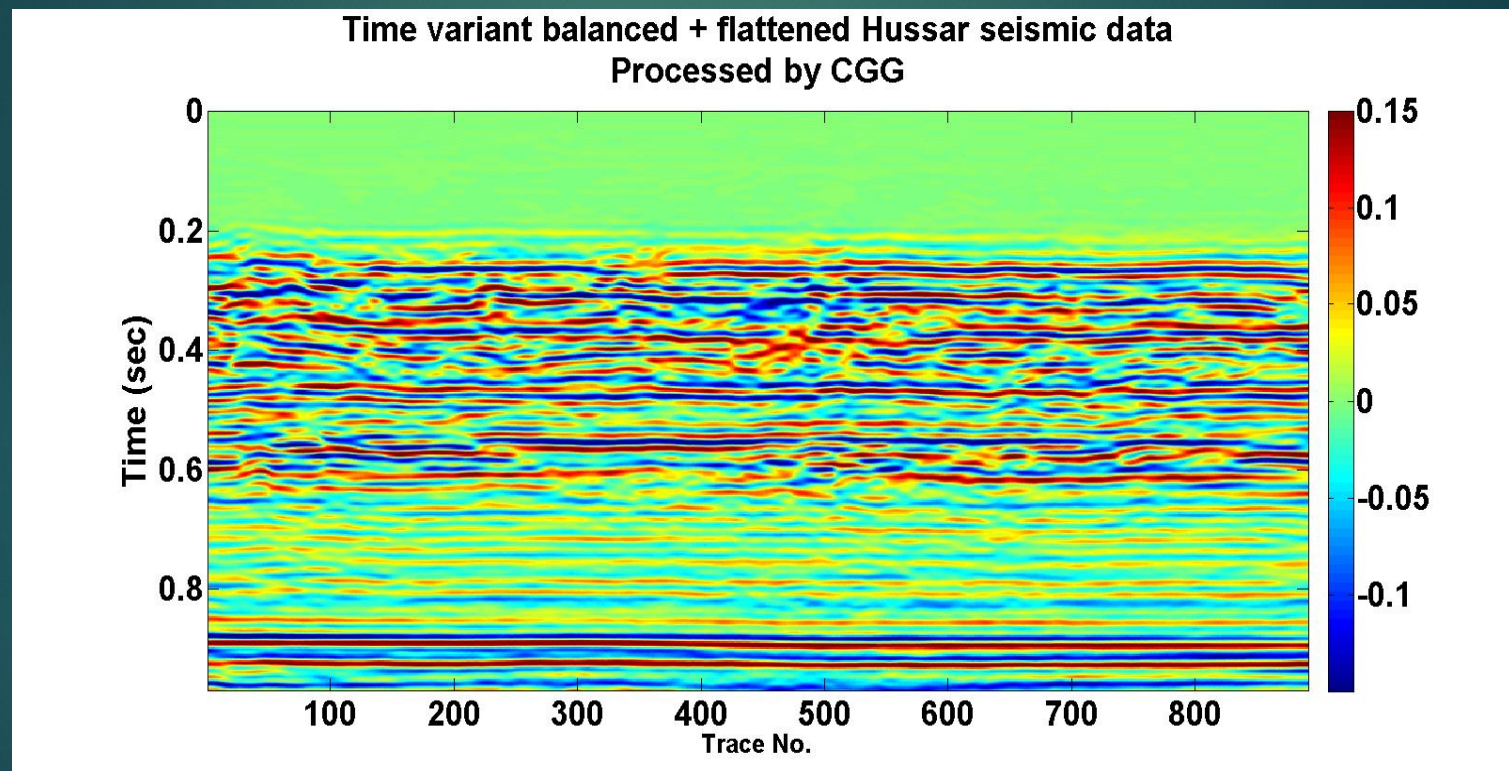


Lloyd, H. J., E., An investigation of the role of low frequencies in seismic impedance inversion. thesis, University of Calgary, 2013



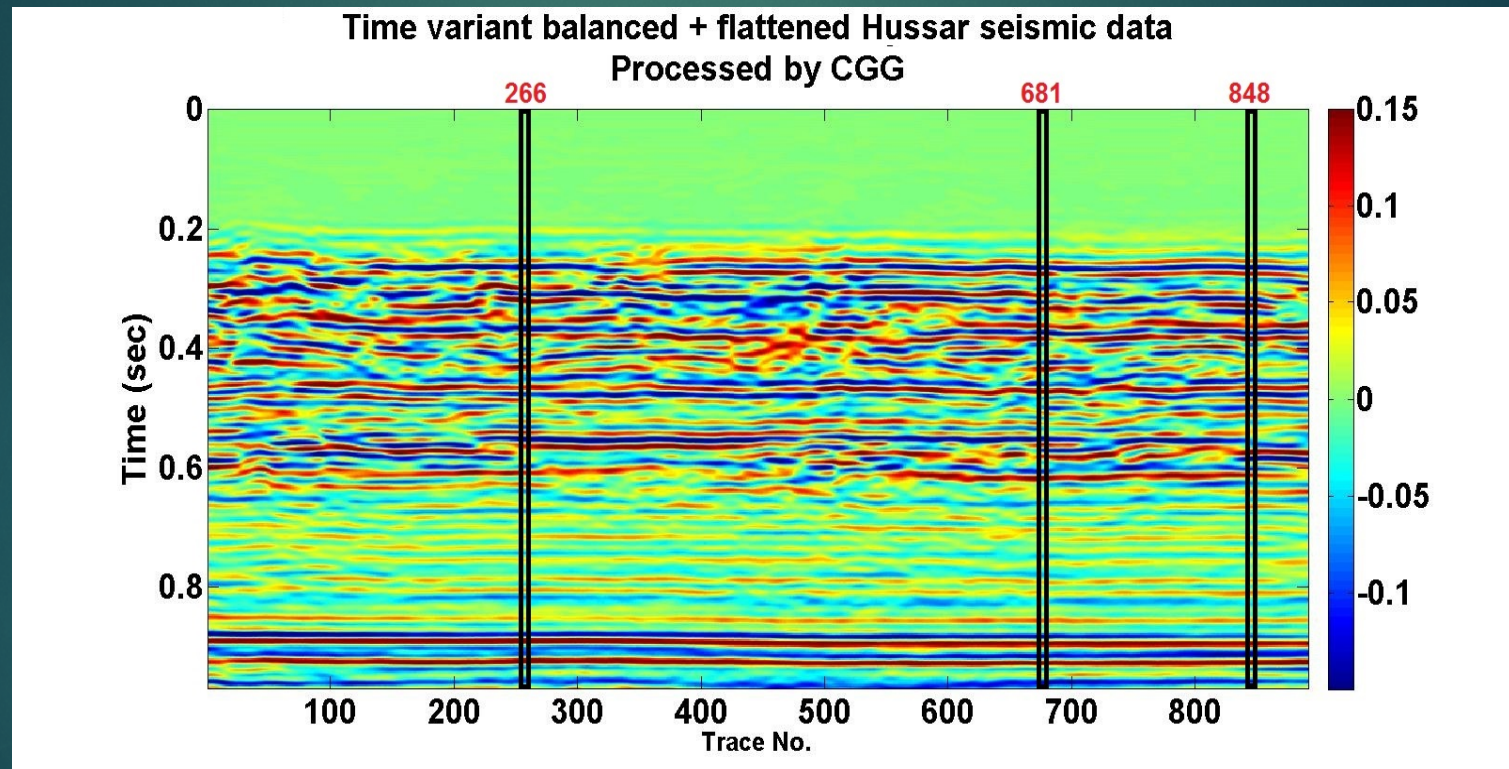
# Hussar Seismic data:

Time variant balanced + Flattened



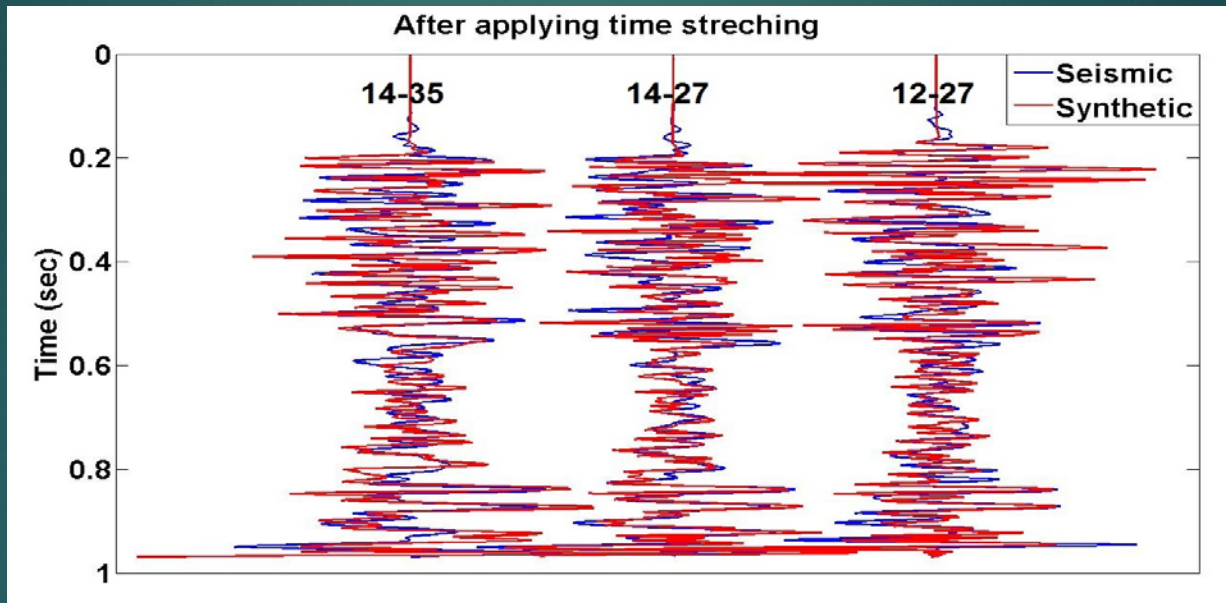


# Tying synthetic data on seismic



# Tying synthetic data on seismic:

Time shift + time stretch



	14-35	14-27	12-27
Time shift	0.002	0.044	-0.014
Phase shift	No phase shift		

	14-35	14-27	12-27
Max corr	0.5561	0.4701	0.5588
Lag	0	0.1	0

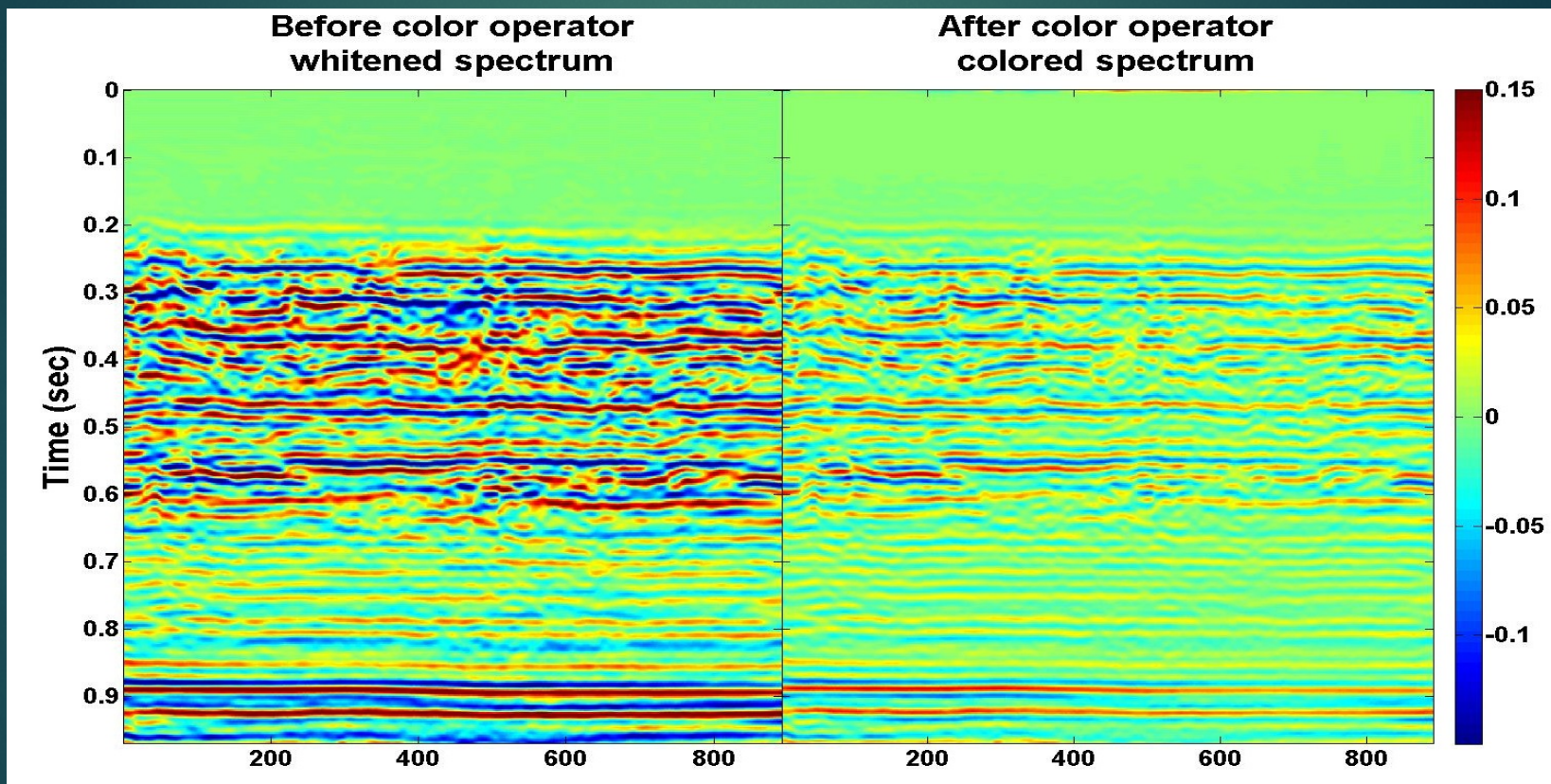


# Applying colour operator

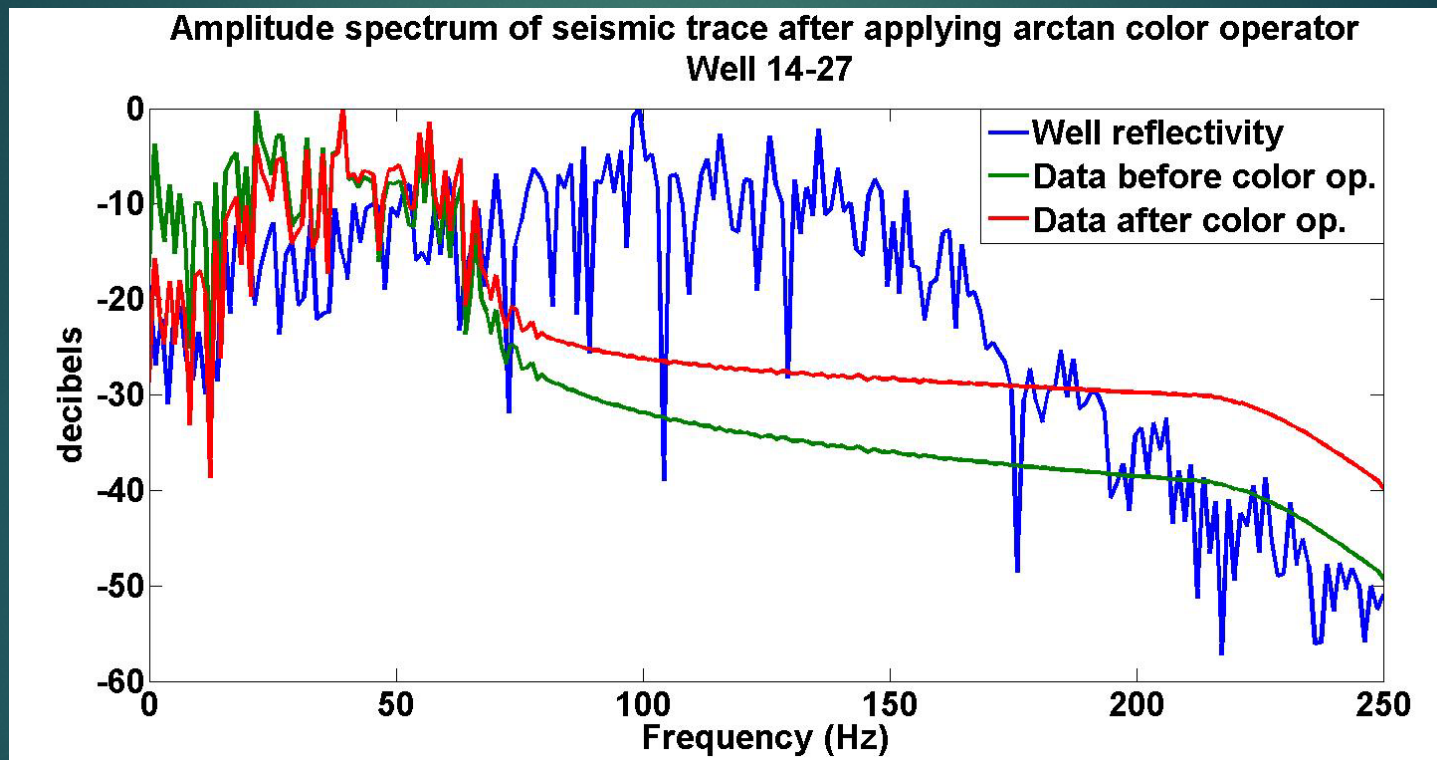
- ▶ For each well, different time-domain colour operators have been calculated. These assume that the seismic data has been whitened by deconvolution.
- ▶ Each trace has a unique colour operator computed by spatial interpolation from the well operators.
- ▶ The coloured seismic section can be calculated via convolution of each trace with its colour operator.



# Arctan colour operator

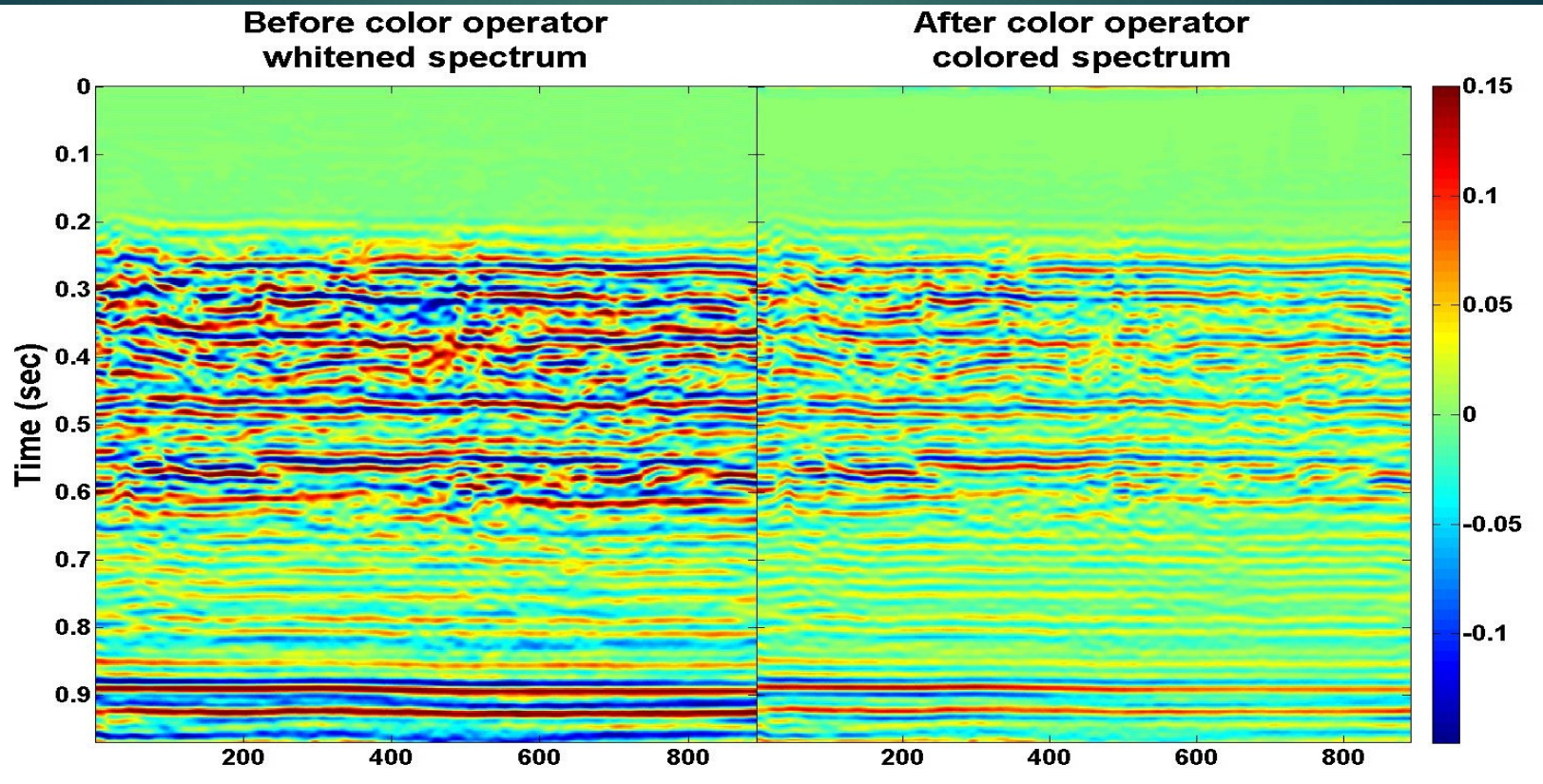


# Amplitude spectrum



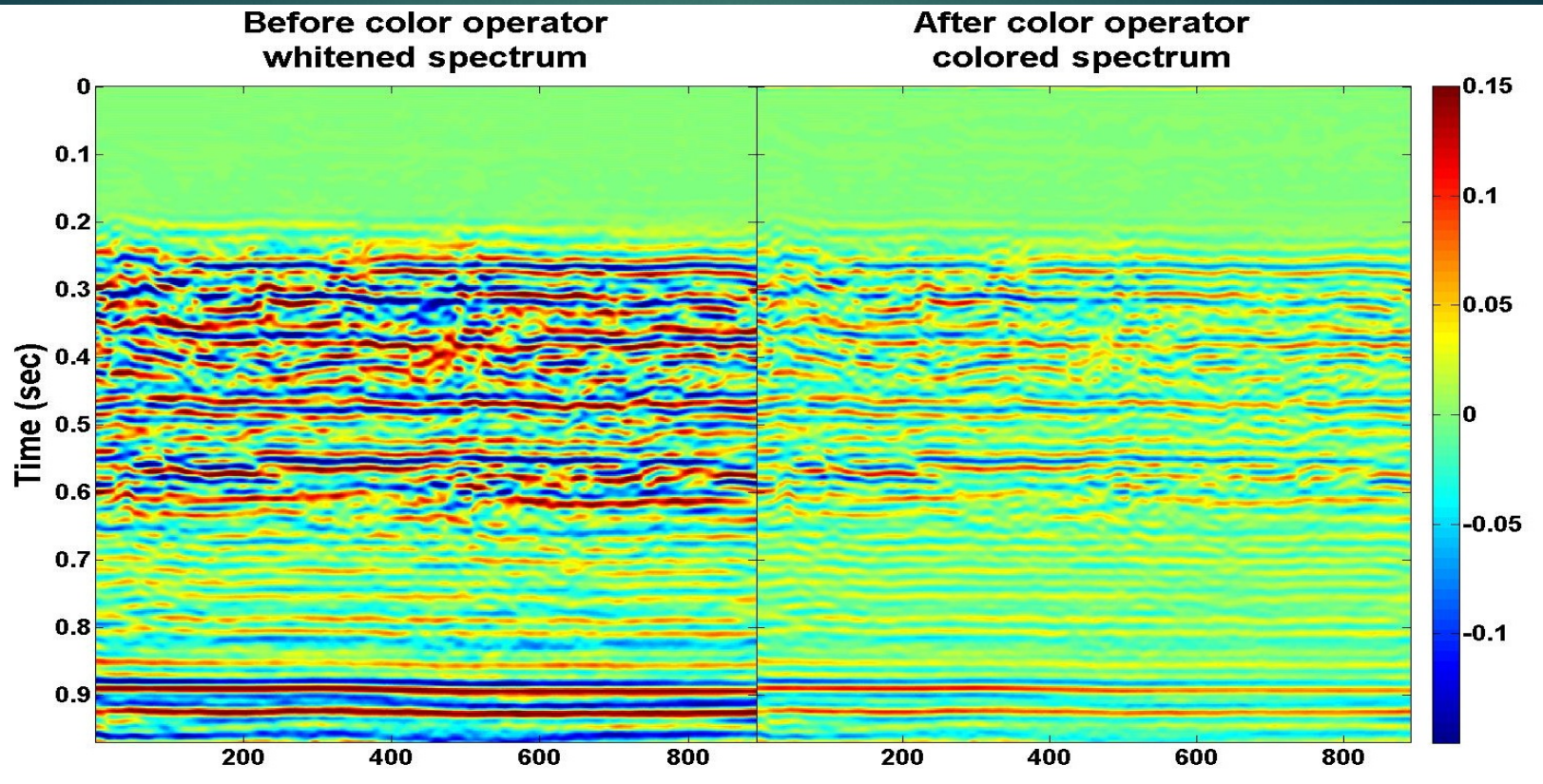


# Sigmoidal colour operator





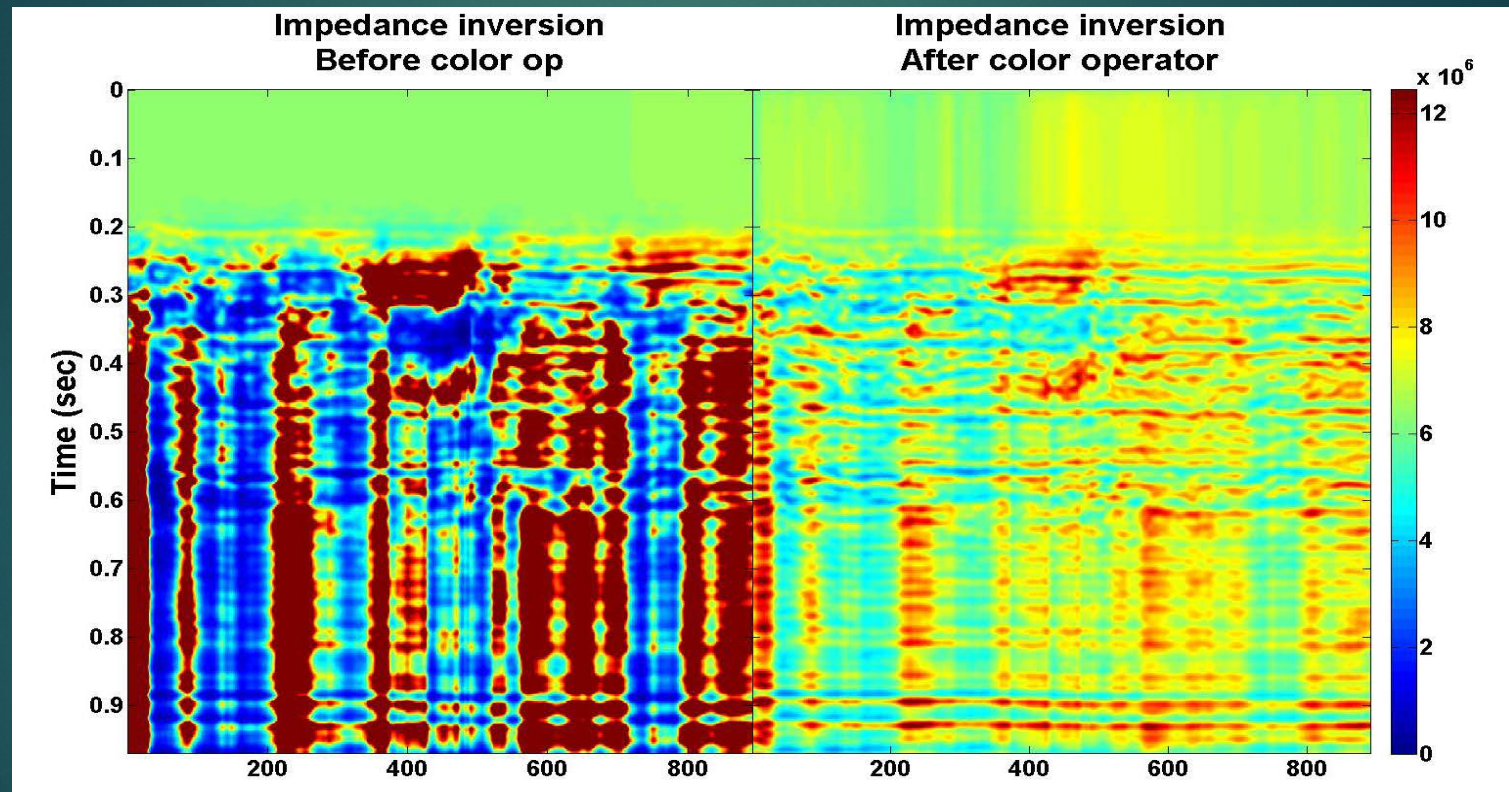
# AC colour operator



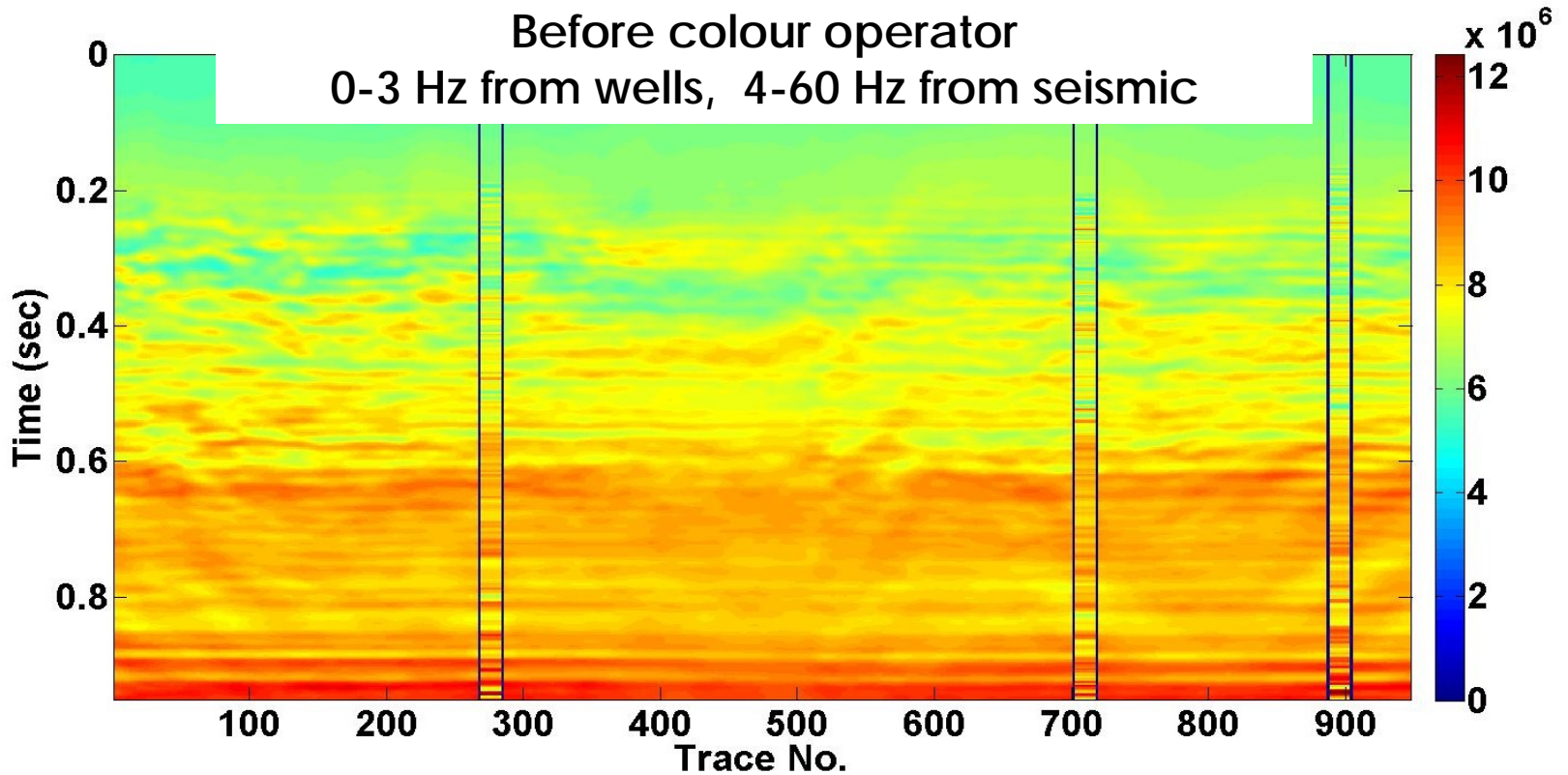


# Impedance inversion:

Just using recursion formula

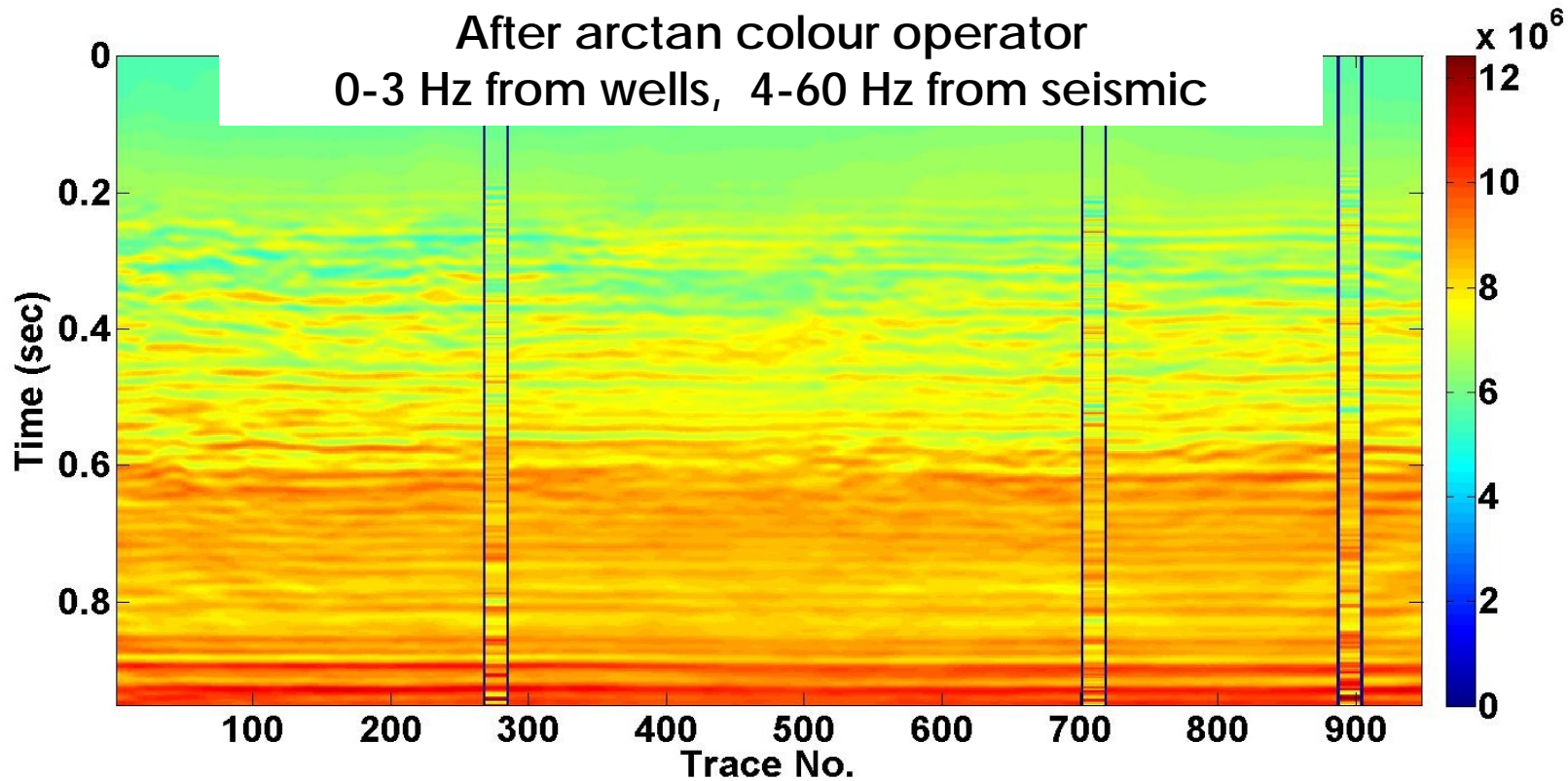


# Impedance inversion (BLIMP)

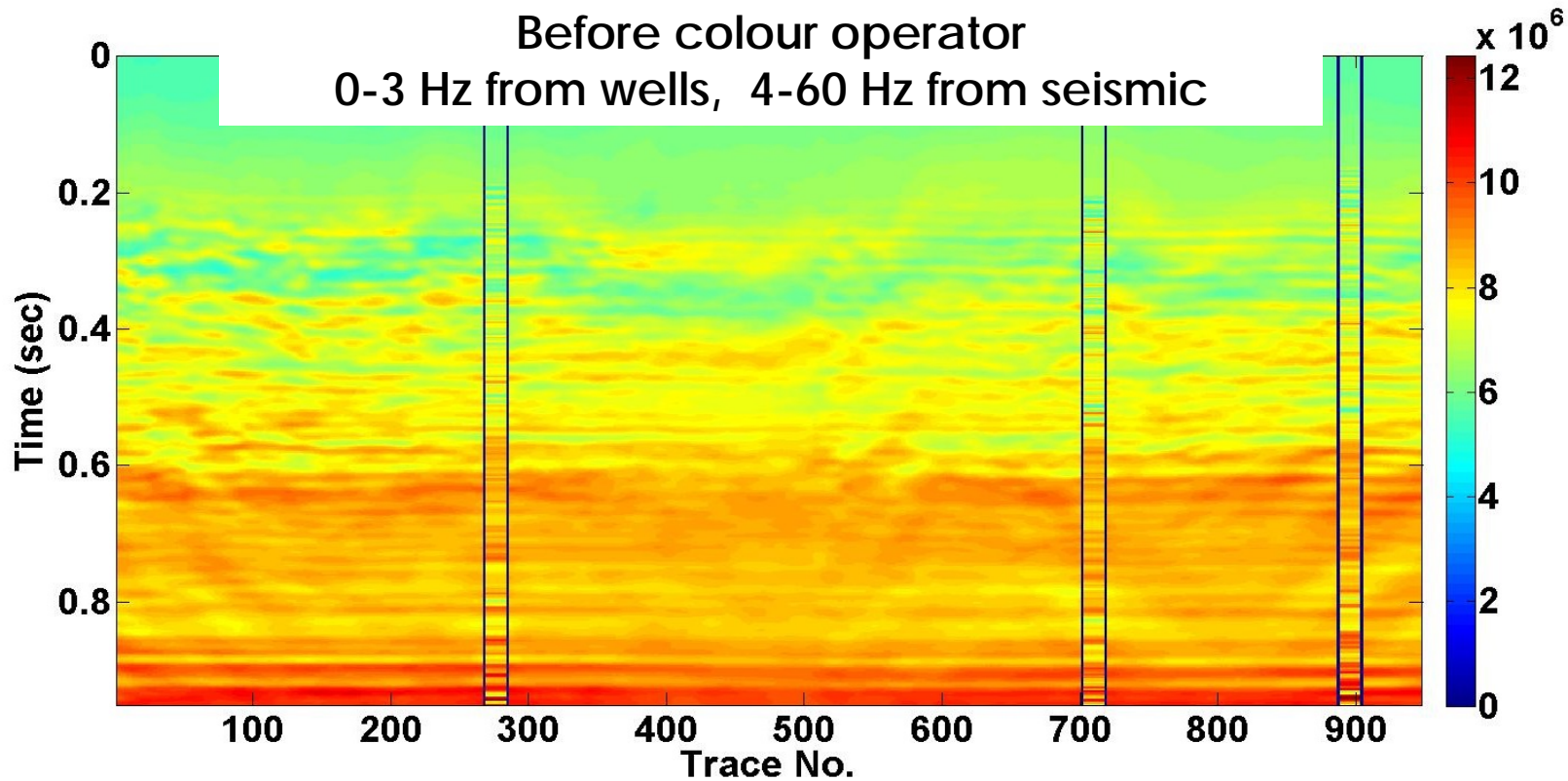




# Impedance inversion (Blimp)

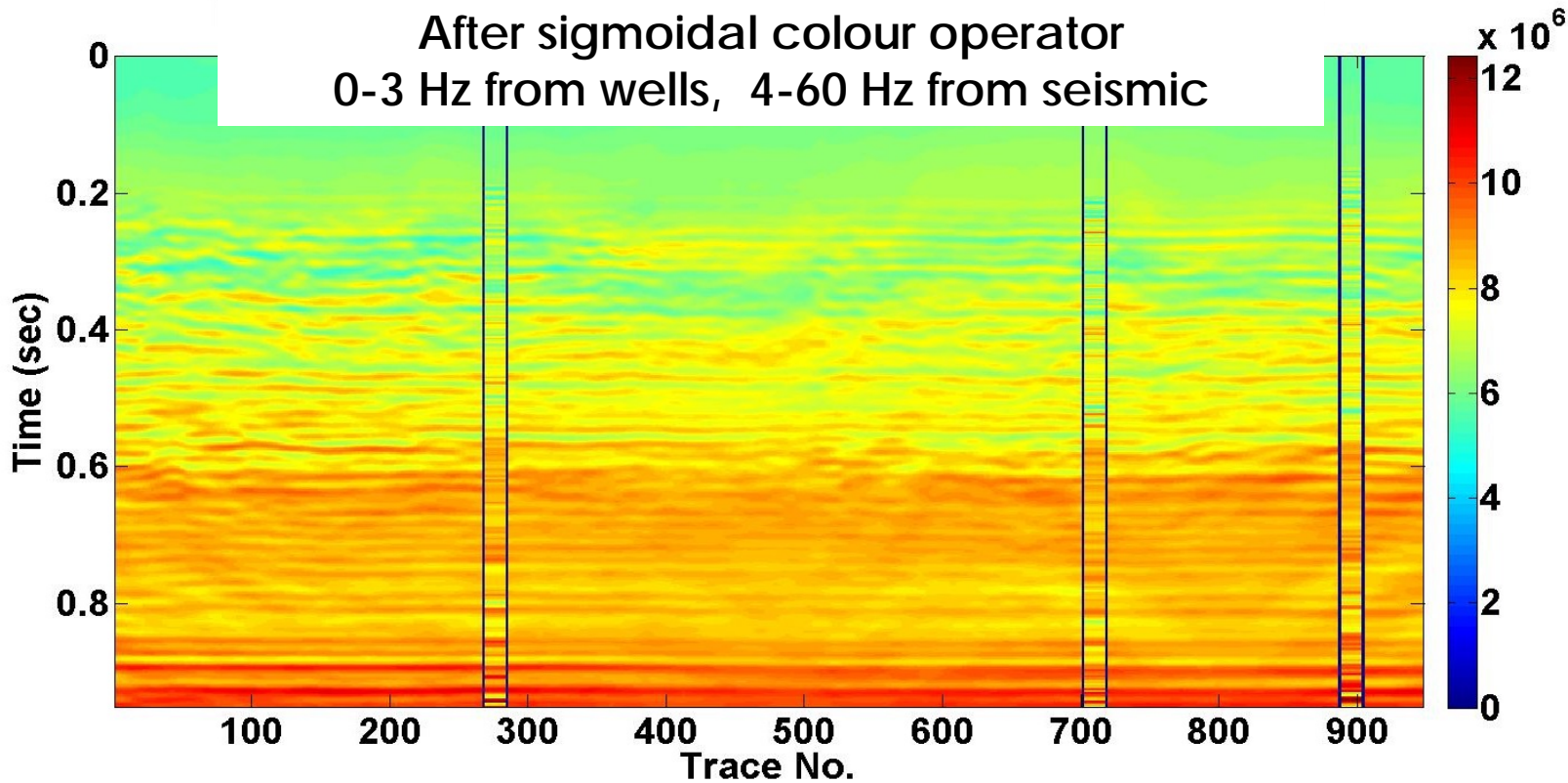


# Impedance inversion (Blimp)



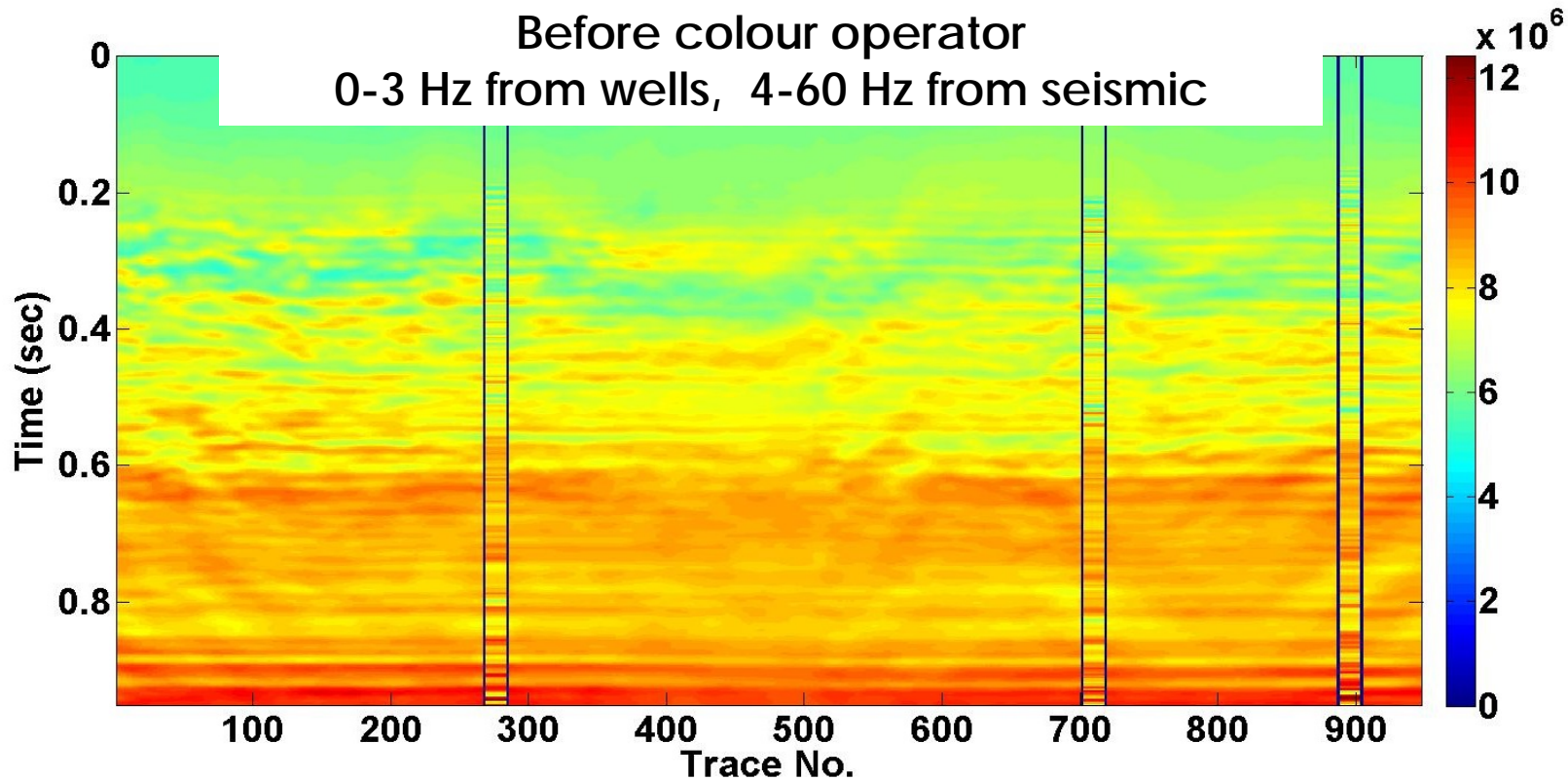


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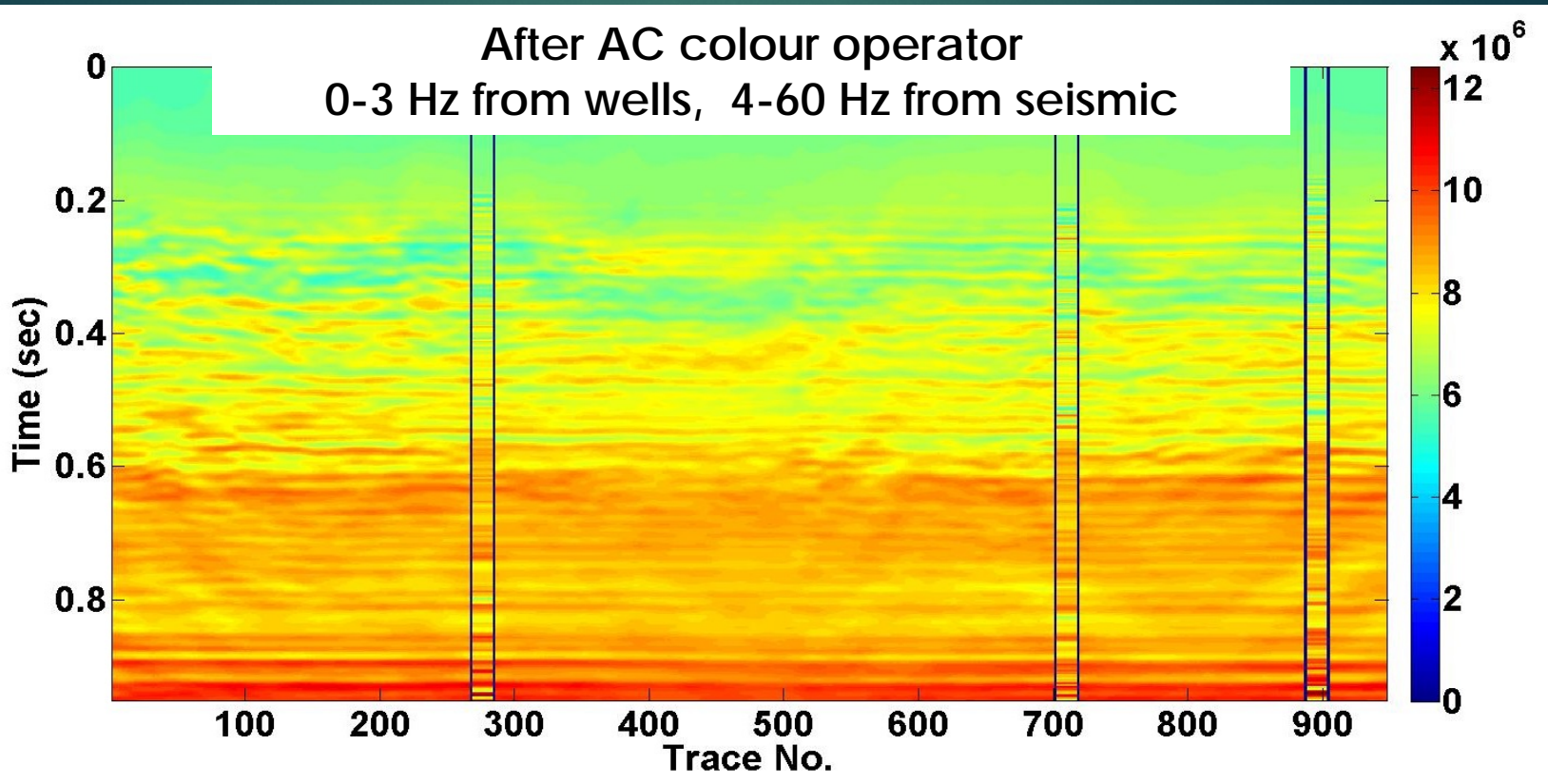




# Impedance inversion (Blimp)



# Impedance inversion (Blimp)





# Coloured inversion method

- ▶ Lancaster, S., & Whitcombe, D. (2000). Fast-track 'coloured' inversion. *SEG Technical Program Expanded Abstracts 2000*.
- The trend of acoustic impedance spectra can be easily described as  $f^\alpha$ .
- If the  $\alpha$  can be found for a field by curve-fitting to AI logs then the amplitude spectrum of the inversion operator is determined as being that which maps the seismic spectrum to a curve of form  $f^\alpha$ .



# Coloured inversion

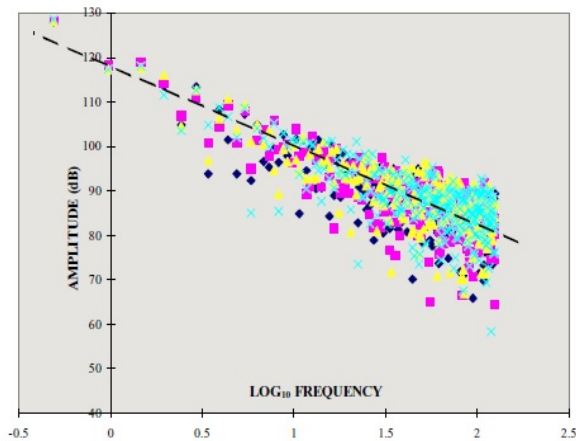


Figure 4: Four AI logs from a North Sea field are displayed on a log-frequency axis to demonstrate the linear trend, equivalently exponential on a linear frequency axis. The gradient of the linear fit determines  $\alpha$ .

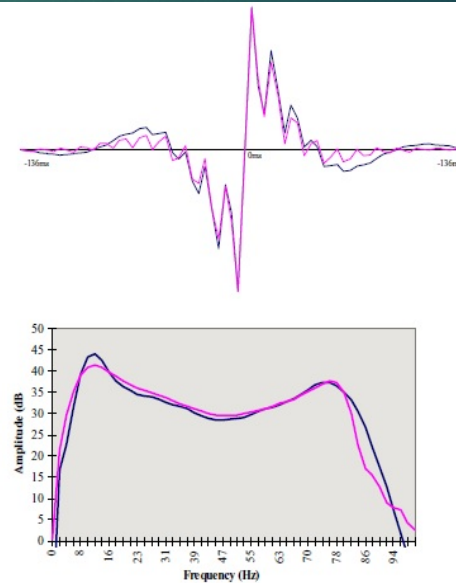


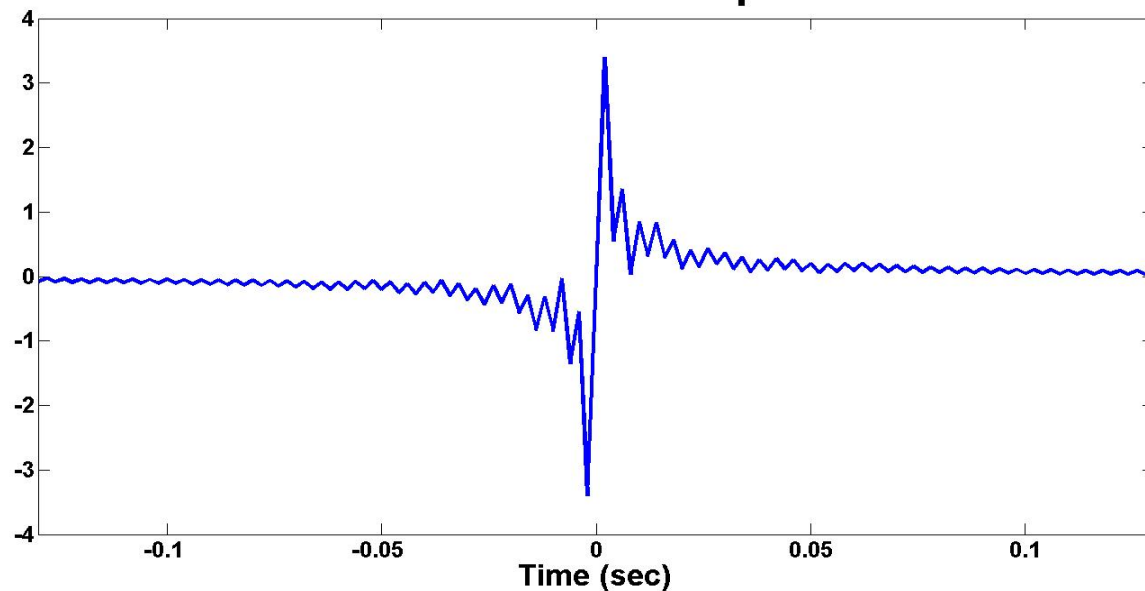
Figure 5: Comparison of the matching operator (pink) and the Coloured Inversion operator (dark blue).

# Coloured inversion for Hussar data

Using:

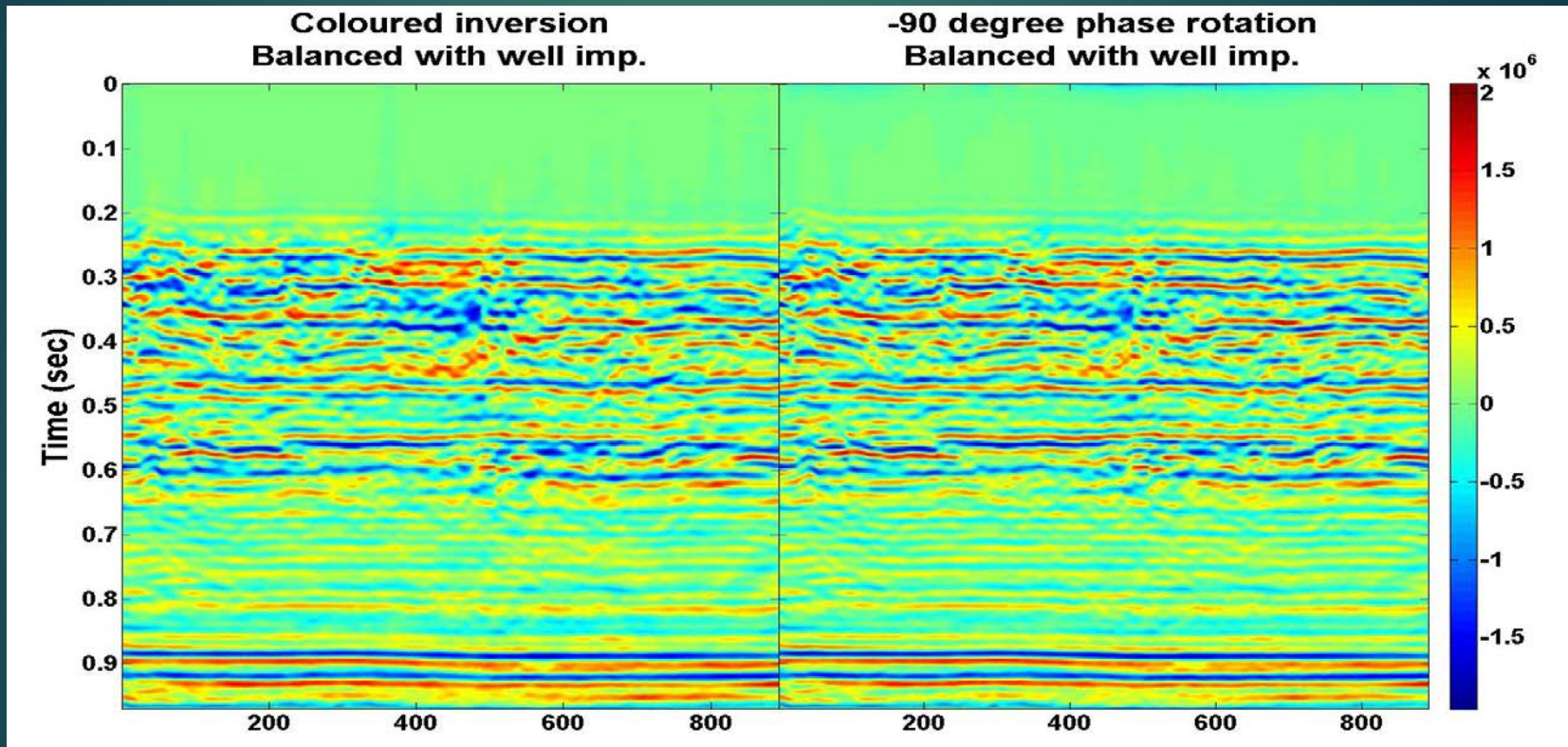
- Mean well impedance
- Mean seismic trace

Coloured inversion operator

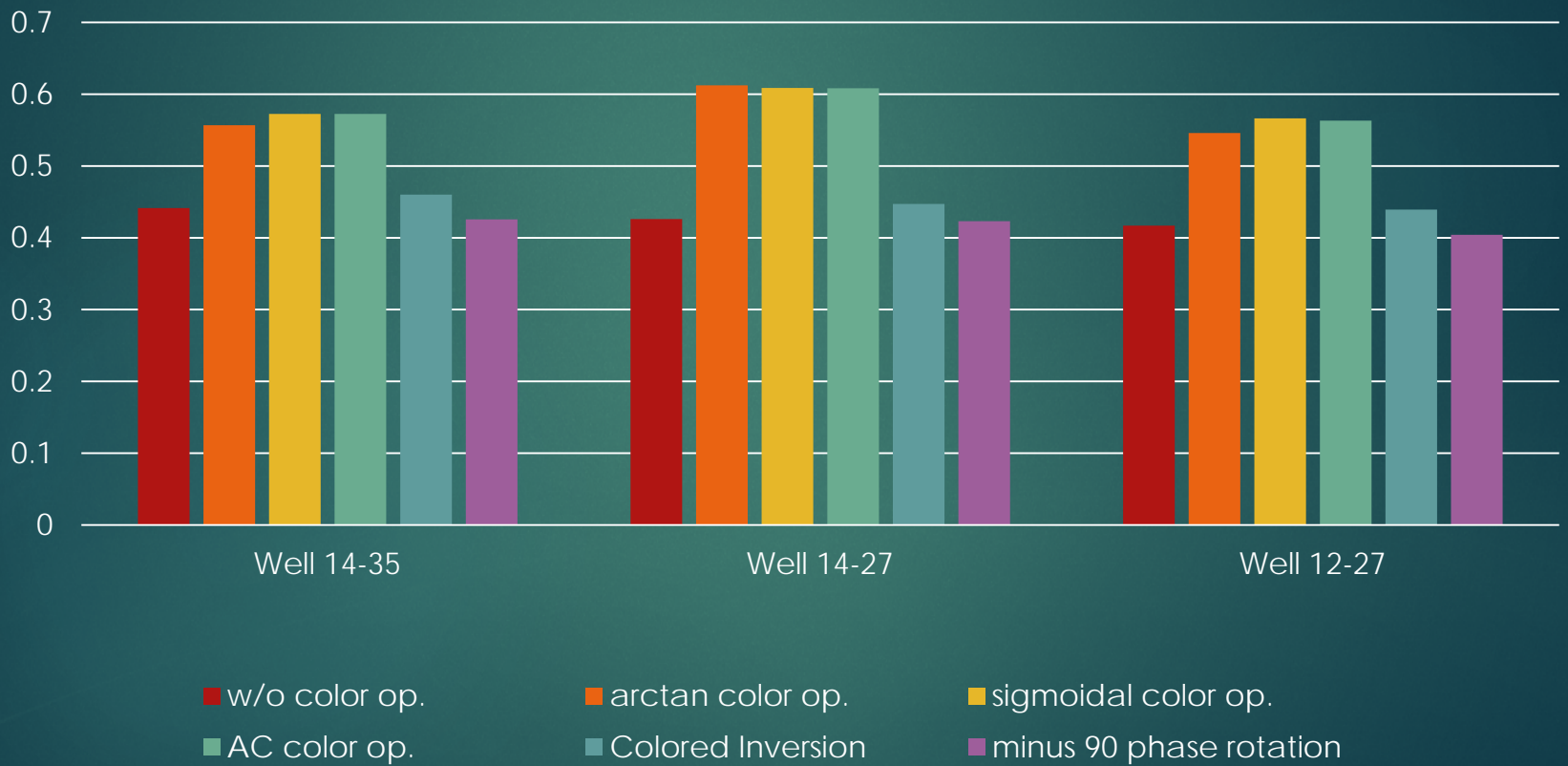




# Coloured inversion vs. $-90^\circ$ phase rotation



# The maximum correlation between estimated impedance and well impedance (frequency range: 14Hz-60Hz)





# Conclusion

- ▶ Accurate acoustic impedance estimation requires low frequencies from well logs.
- ▶ A deconvolved trace shaped to a white spectrum can be corrected by applying a minimum-phase color operator after deconvolution.
- ▶ The result of impedance inversion is greatly improved after applying color correction because this affects the low frequencies and therefore the trend of the inversion.
- ▶ The coloured inversion method is a fast and robust technique to calculate the deviation of acoustic impedance from background trend (e.g. no low frequency information) and it is similar to a -90 degree phase rotation.



# Acknowledgment

- ▶ All CREWES sponsors
- ▶ NSERC
- ▶ CREWES staff and students