Improving deconvolution at low frequencies

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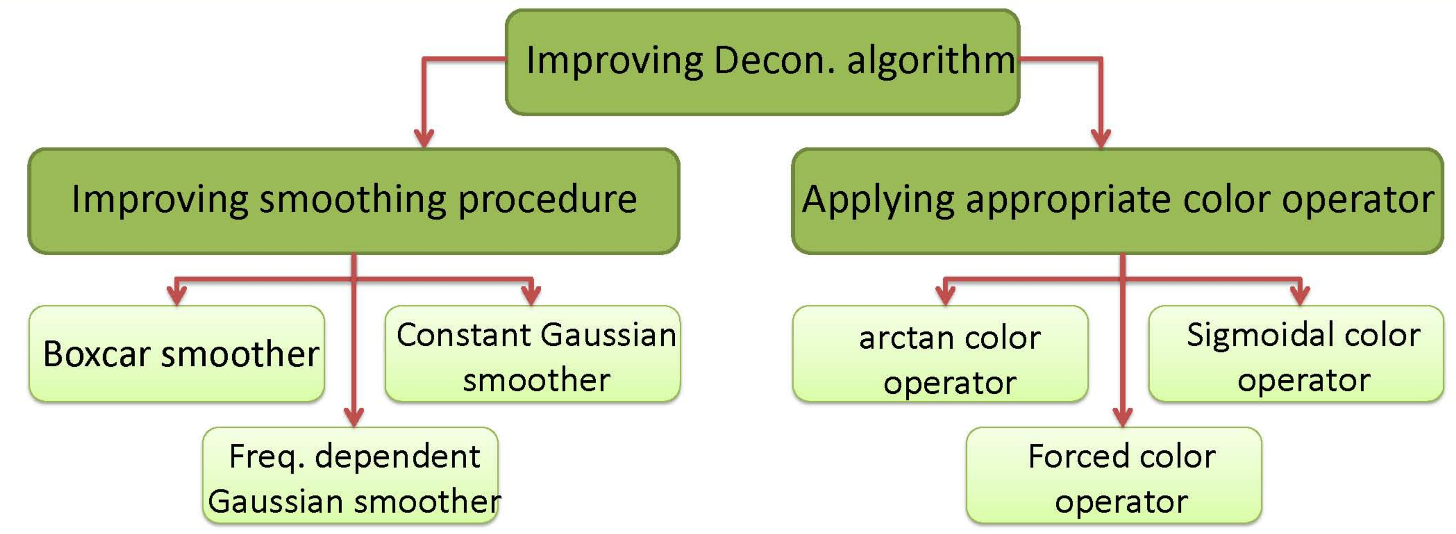
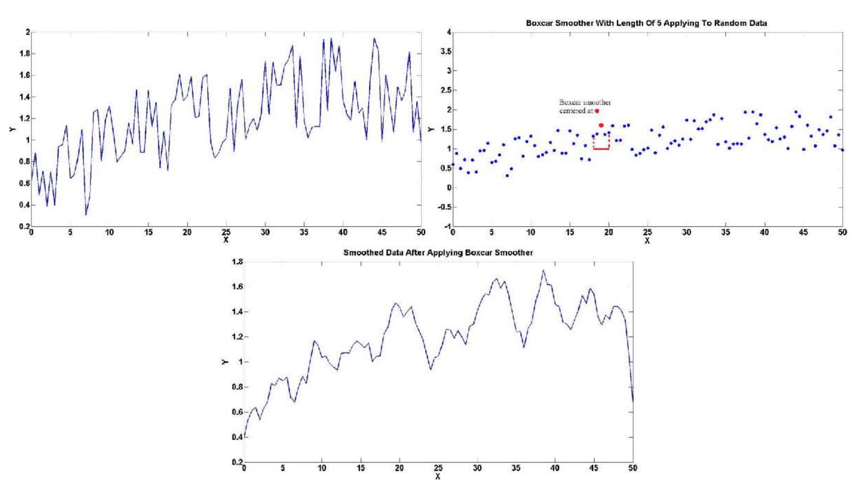
Introduction

- ❖ Conventional deconvolution shapes the spectra to a white reflectivity while the real reflectivity always has colored spectra.
- ❖ There are different ways to smooth the spectrum of seismic data to estimate embedded wavelet in frequency domain deconvolution.
- ❖ Boxcar and Gaussian convolutional smoothers with constant width and with frequency dependent width are examined.
- ❖ Once the deconvolution algorithm whitens the spectrum, a color correction operator can shape the reflectivity to that observed in wells.
- ❖ Three different color operators are defined: arctan color operator, sigmoidal color operator and forced color operator.

Method

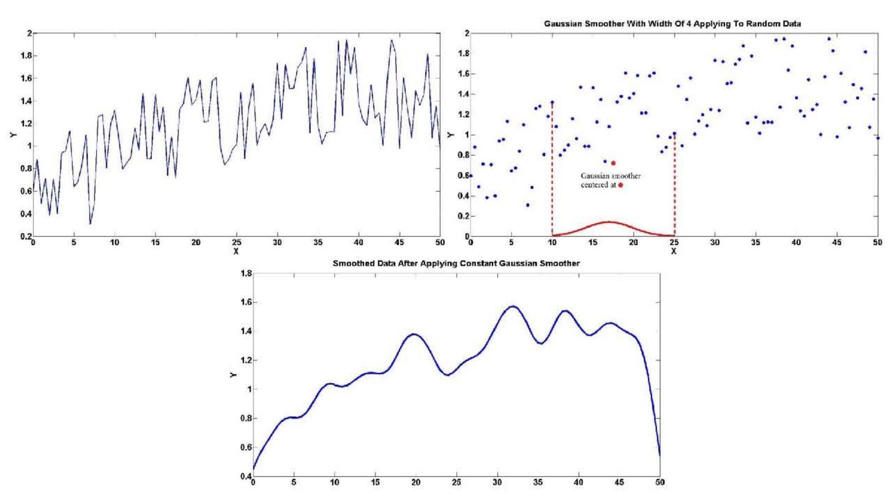


➢ Boxcar smoother (BS)



$$\bar{x}[i] = \frac{1}{2M+1}\sum_{j=-M}^{M} x[i+j]$$

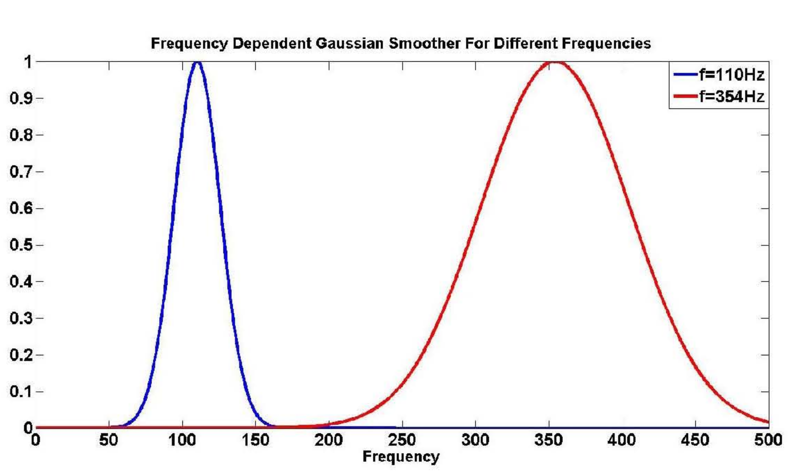
➢ Constant Gaussian smoother (CGS)



$$\bar{A}_j = \frac{\sum_k A_k g_{j-k}}{\sum_k g_k}$$

$$g_k = e^{-(k\Delta f)^2/\sigma_f^2}$$

➢ Frequency domain Gaussian smoother (FDGS)



$$\sigma_f = \frac{f}{n} = \frac{k\Delta f}{n}$$

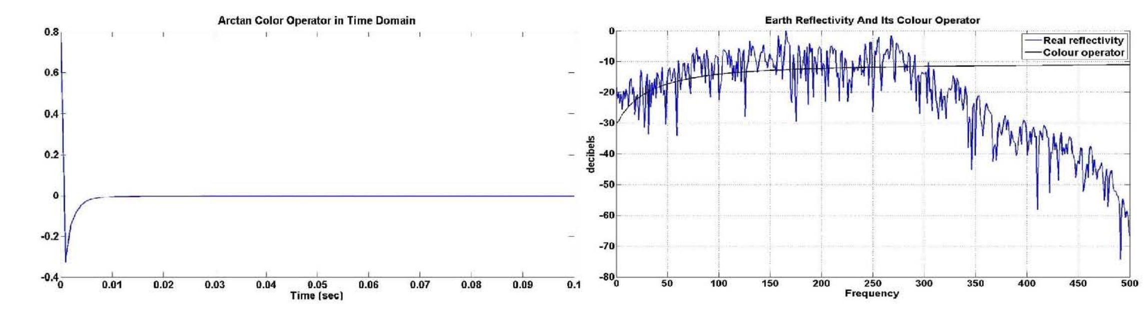
❑ Minimum phase spectral color operator

- The amplitude spectrum of color operator can be derived by fitting any appropriate function to the amplitude spectrum of well reflectivity.
- The phase can be calculated by Hilbert transform of the logarithm of the amplitude spectrum.

➢ arctan color operator

The arctan function can be fitted to the amplitude spectrum of well reflectivity:

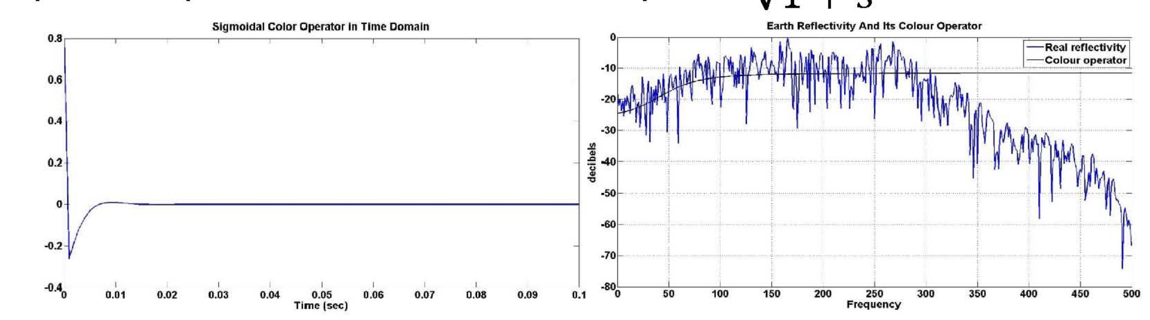
$$a + b\arctan(f) = R(f)$$



➢ Sigmoidal color operator

The sigmoid function can also be fitted to the amplitude spectrum of well reflectivity:

$$\frac{a+bs}{\sqrt{1+s^2}} = R(f) \quad ; \quad s = \frac{f - f_0}{f_0}$$



➢ Forced color operator

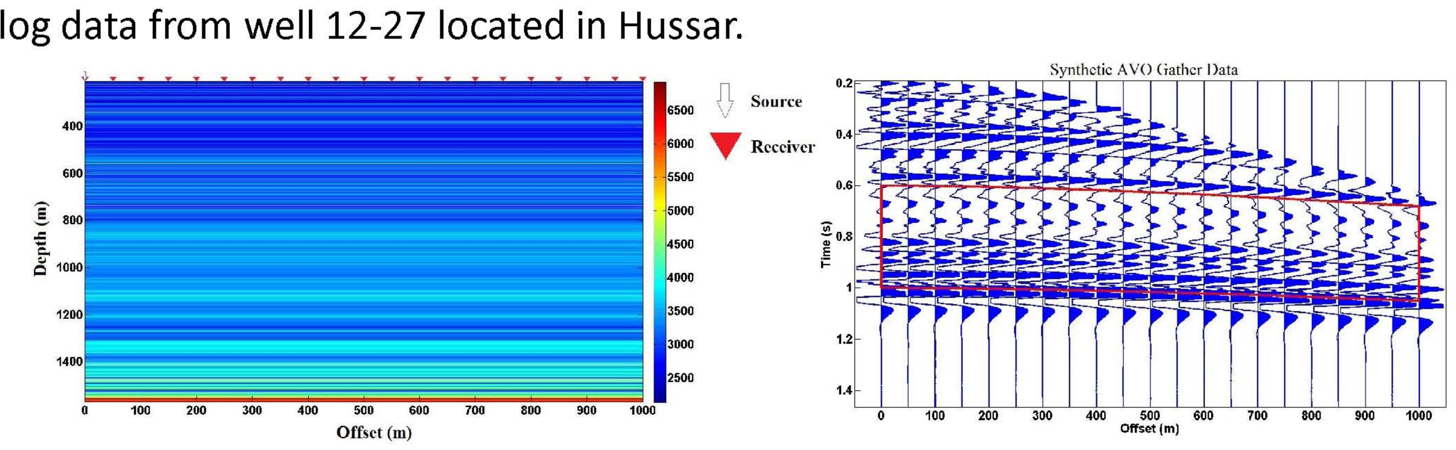
- Choose a zero-offset recording very near the well. Since all the information such as velocity, density and depth are available at the well location, we can form the ratio of the amplitude spectrum of the reflectivity divided by that of the deconvolved trace.
- After smoothing this ratio we will use it to construct a third minimum-phase color operator.
- The designed operator at zero-offset can be used for non-zero offset traces.

Synthetic AVO gather data

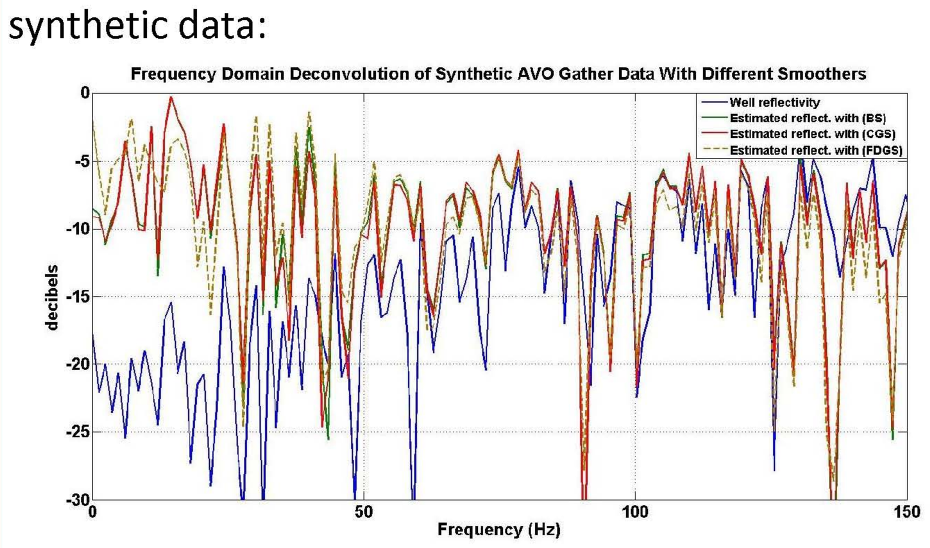
Flowchart of processing synthetic AVO gather data:

Synthetic shot gather with NMO → Deconvolution → Removing NMO and stacking → Impedance inversion

The synthetic data are created by *Syngram* with 15Hz minimum phase wavelet and log data from well 12-27 located in Hussar.



Amplitude spectrum of stacked data deconvolved with three Decon. algorithm to the synthetic data:

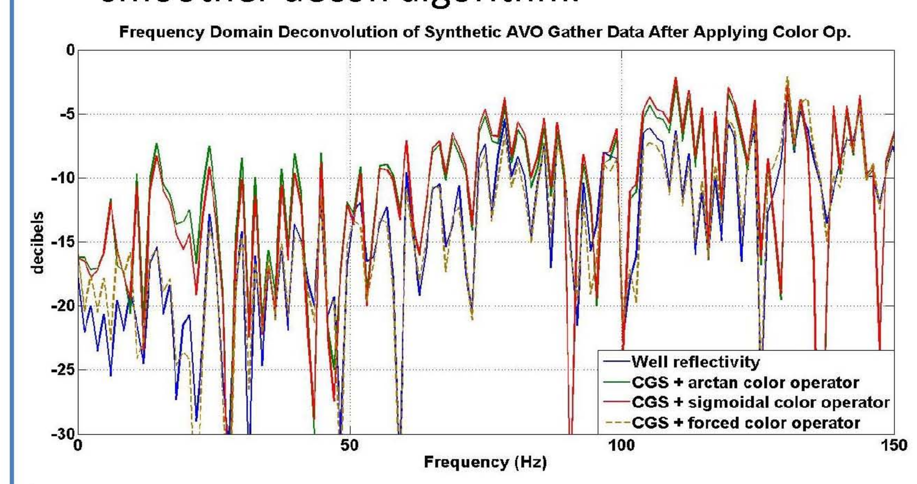


Decon. Algorithm Type	Max Correlation of stacked and real reflc.
Decon algorithm with BS	0.5592
Decon algorithm with CGS	0.6401
Decon algorithm with FDGS	0.6324

➢ Applying color operator after deconvolution

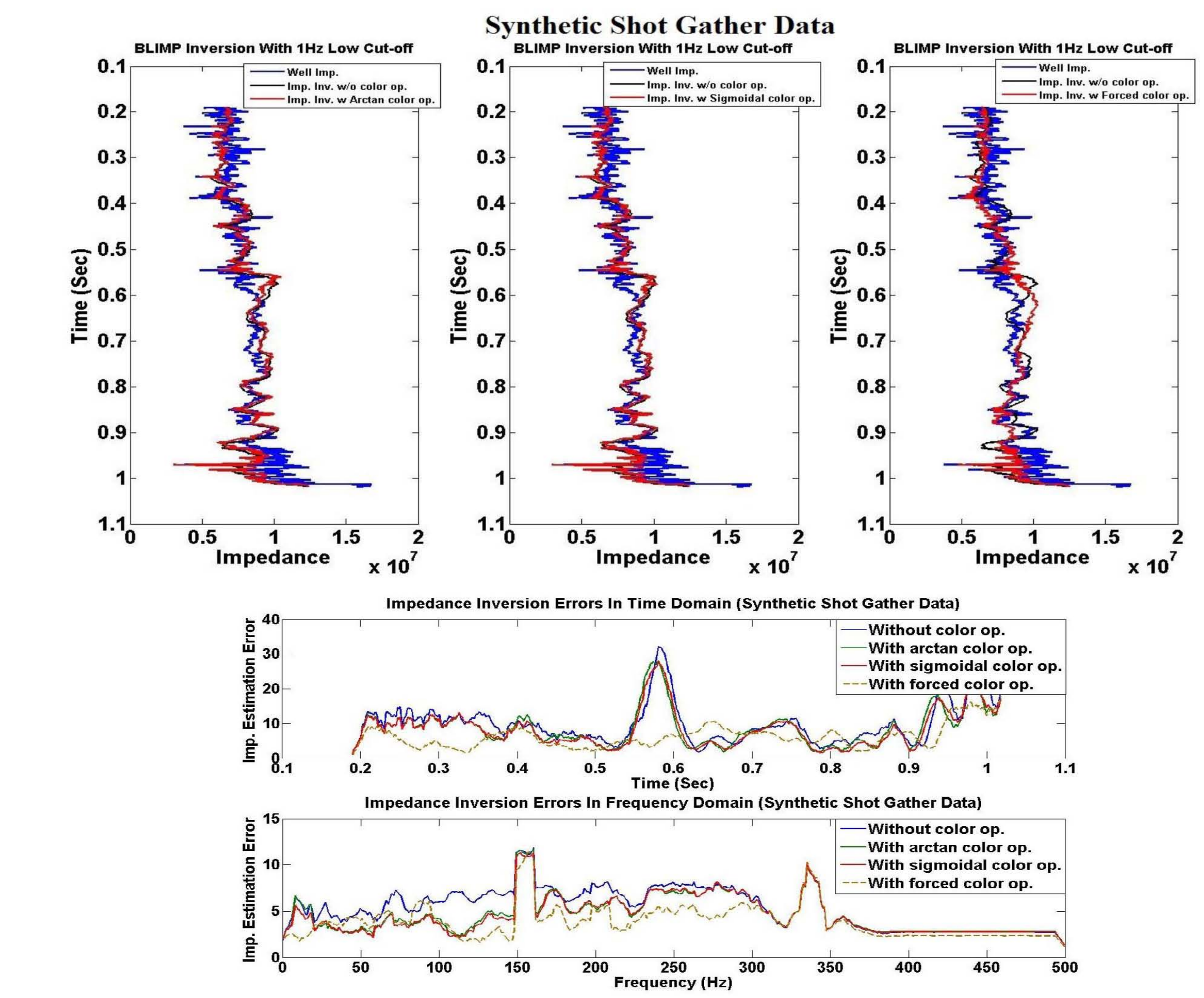
Synthetic shot gather with NMO → Deconvolution + colour operator → Removing NMO and stacking → Impedance inversion

- Three color operators have been applied to deconvolved data with CG smoother decon algorithm.



Color Operator Type	Max Correlation of stacked and real reflc.
arctan color operator	0.8139
sigmoidal color operator	0.8151
Forced color operator	0.9353

➢ Impedance inversion results



Conclusion

- Deconvolution can be affected by choosing different smoothers but the differences are not significant.
- A deconvolved trace shaped to a while spectrum can be corrected by applying color operator right after deconvolution.
- The result of impedance inversion is greatly improved after applying color correction because this affects the low frequencies.

References

- Esmaeili, S., & Margrave, G. F. (2013). Recovering low frequencies for impedance inversion by frequency domain deconvolution. *CREWES research report, Vol. 25*.
- Margrave, G. F. (2002). *Methods of seismic data processing.* Calgary: Department of Geoscience, University of Calgary.

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