AASPI

Variational Mode Decomposition – Power of Data-driven Decomposition

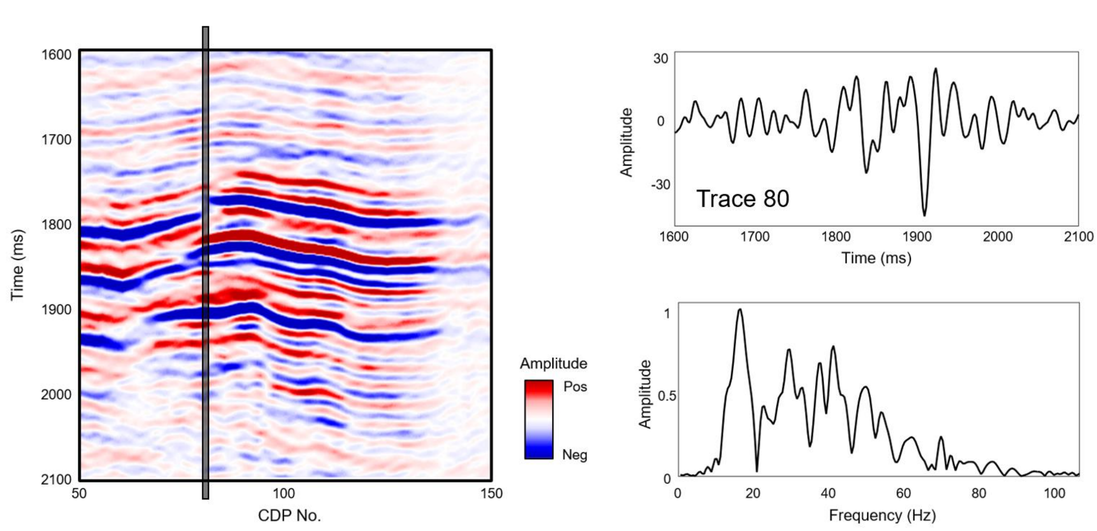
Fangyu Li* and Kurt J. Marfurt, University of Oklahoma

The UNIVERSITY of OKLAHOMA
Mewbourne College of Earth and Energy
ConocoPhillips School of Geology and Geophysics
ConocoPhillips

Summary

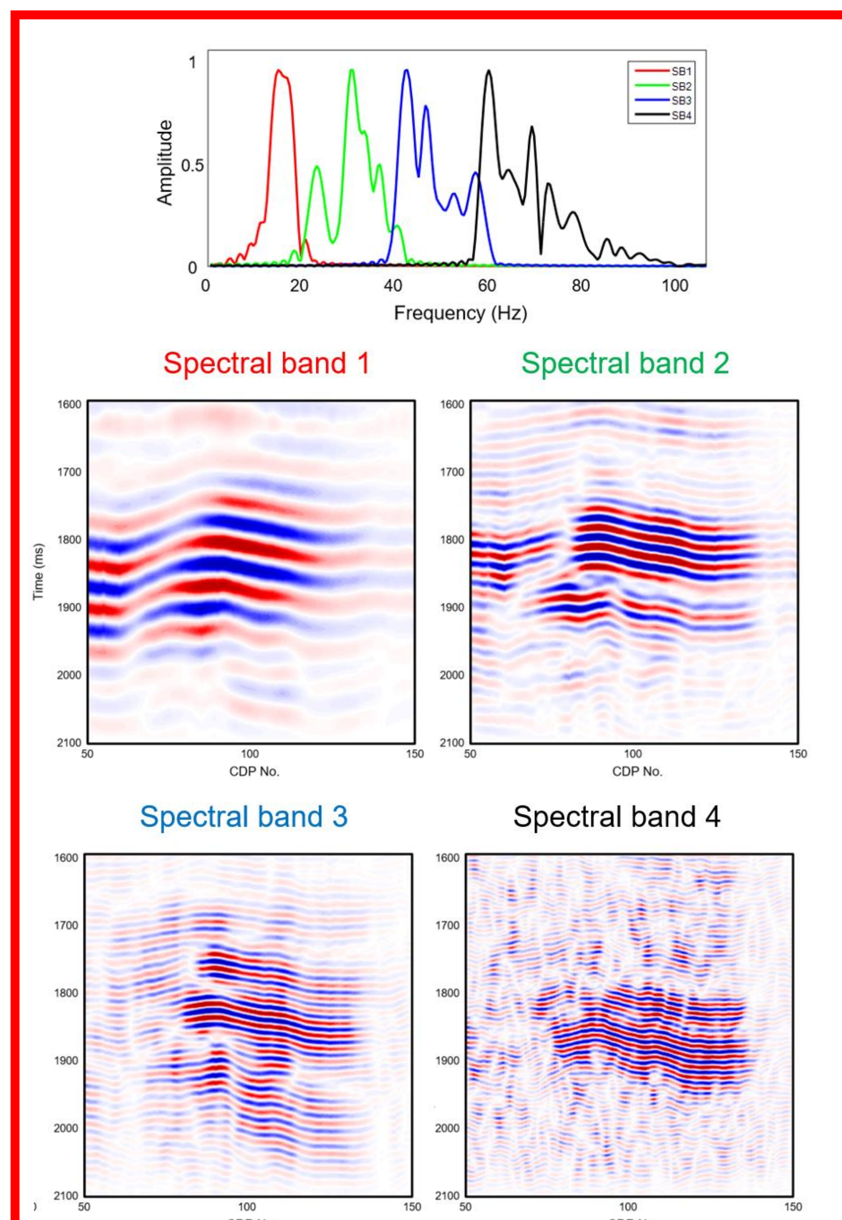
Spectral decomposition discriminates different geological expressions by isolating seismic signals of particular spectral ranges. One goal is to enhance the periodic depositional events that help interpret sedimentary processes. Variational mode decomposition (VMD) is a novel data-driven signal decomposition method and exhibits advanced features compared with the classic time frequency analysis (TFA) methods. Rather than using predefined spectral bands, VMD adaptively decomposes a signal into an ensemble of band-limited intrinsic mode functions (IMFs) with their respective center frequencies. We define our technique using synthetic depositional cycle examples, and then apply VMD to map seismic sequence stratigraphy identification for a survey acquired in Dutch Sector, North Sea.

Motivation

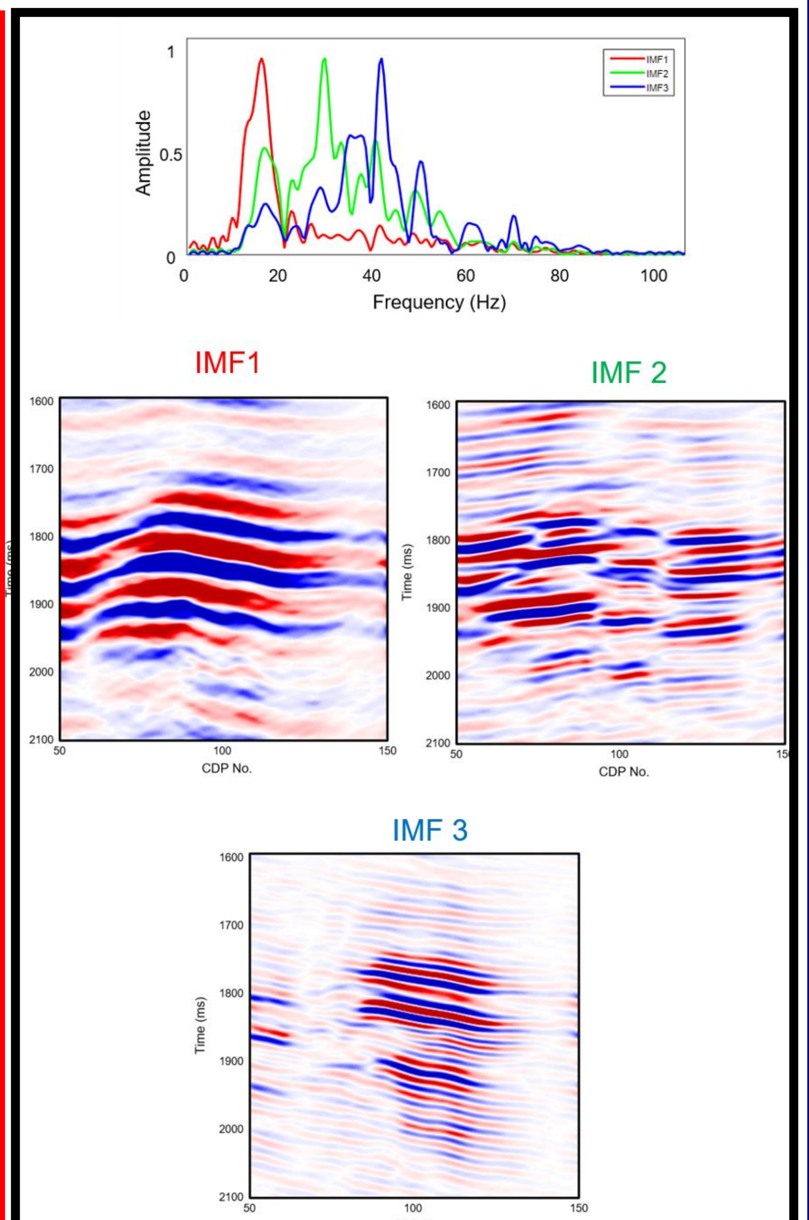


Vertical seismic section (left)
Extracted trace (upper right)
Traditional spectrum (bottom right)

Spectral Bands

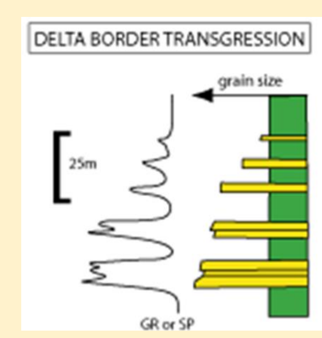


IMFs

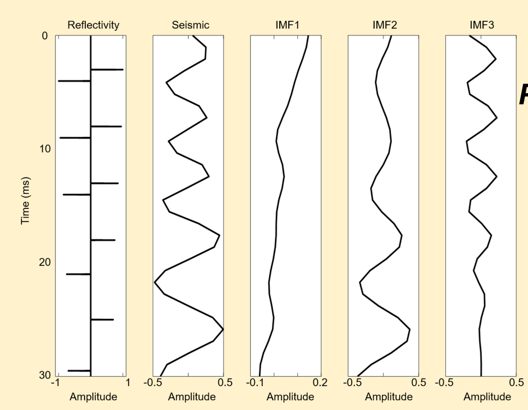


Synthetic Depositional Sequence Model

Sequence stratigraphy interpretation can be made based on rock composition, grain size characteristics, spontaneous potential, and gamma ray log shapes (Rider, 1999). Transgressive/regressive facies recognition is the key for the stratigraphic sequence division. Following Rider (1999), we build a depositional cycle model, e.g. Delta border transgression model. The thickness of sandstone increases with depth; while the grain size of sediment changes from fine to coarse; and the sandstone is interbedded with similar thickness shale layers. The gamma ray log, which increases upward, and depositional settings are shown. The synthetic reflectivity series and seismic traces are also shown. In order to match the scale of the depositional model, the synthetic trace is 30ms long. The reflectivity series follow the same pattern, and because the grain size changes, the seismic reflectivity between shale and sandstone also changes with depth.



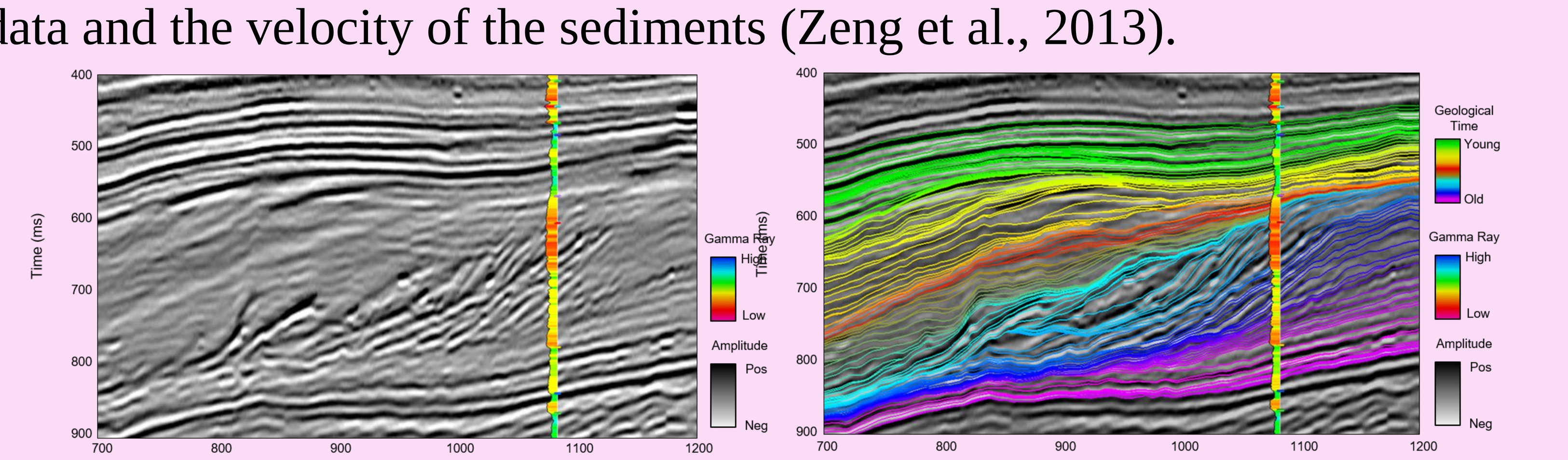
Gamma ray log shape and depositional setting of deltaic transgression facies, modified from Rider (1999). The grain size is fining upward, and the thickness of sandstone is increasing downward. The gamma ray value is enlarging upward.

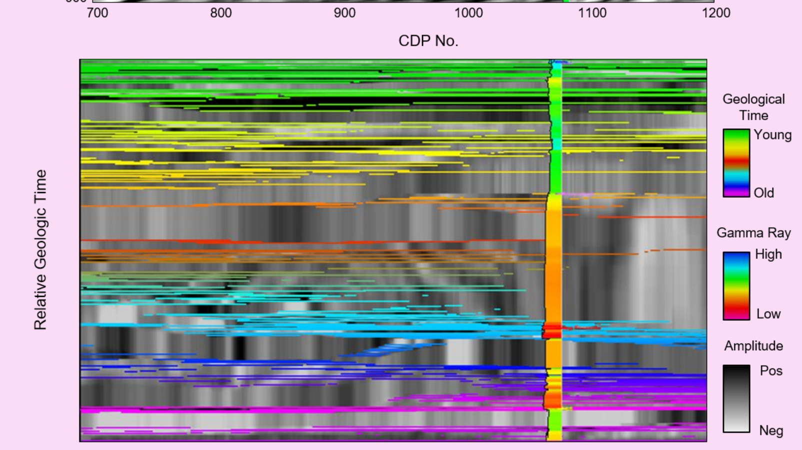


Reflectivity series, seismic traces and IMF 1,2 and 3 from VMD of the deltaic transgression model. The amplitude of IMF 1 increases upward like the gamma ray log

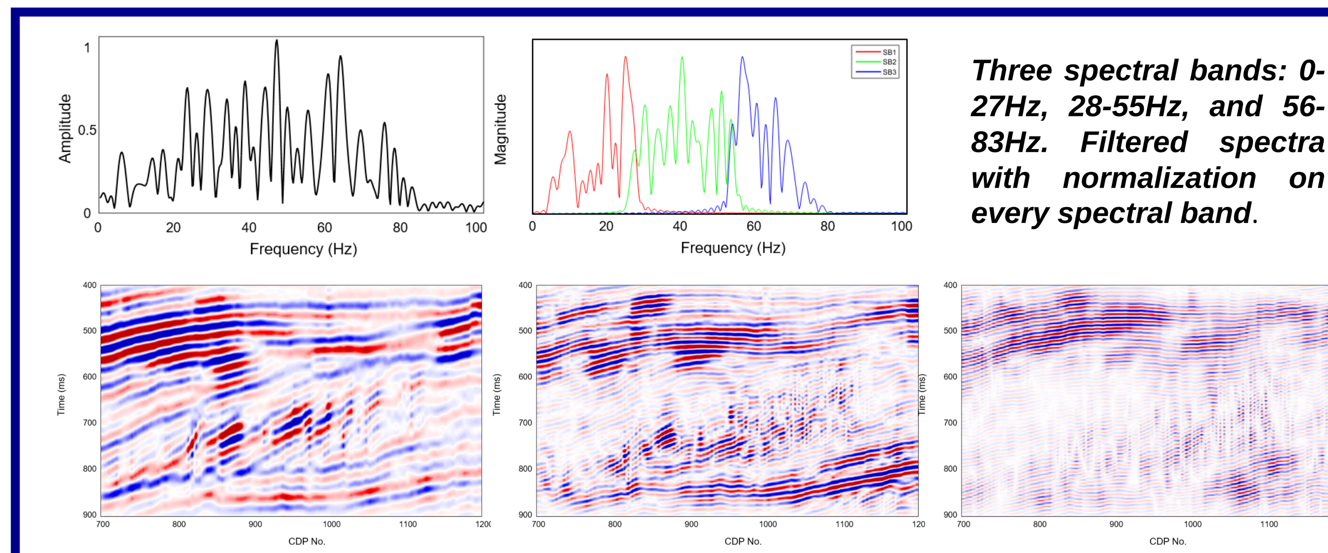
Field Application

The field seismic data set is from the Dutch Sector, North Sea. I show a vertical seismic section, and the colourful curves are auto-tracked horizons, the Wheeler domain relative geologic time section with the auto-tracked horizons shown (Ligtenberg et al., 2006). The deltaic cycles in Dutch sector rang from a river-dominated to a wave-tide dominated stages. These cycles comprise of classic clinoform geometries prograding towards the basin (Petruno et al., 2015). The Wheeler diagram shows the distinct depositional trends; i.e., aggradational, progradational, and retro-gradational. Seismic clinoform detection is usually limited by one wavelength (the thickness of two seismic events) and related to the predominant frequency of the seismic data and the velocity of the sediments (Zeng et al., 2013).

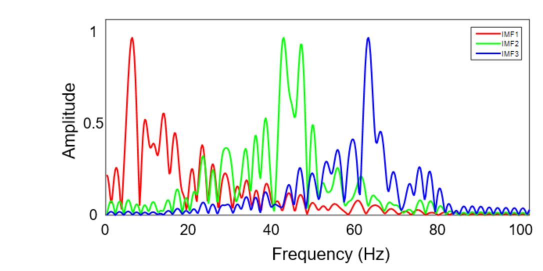




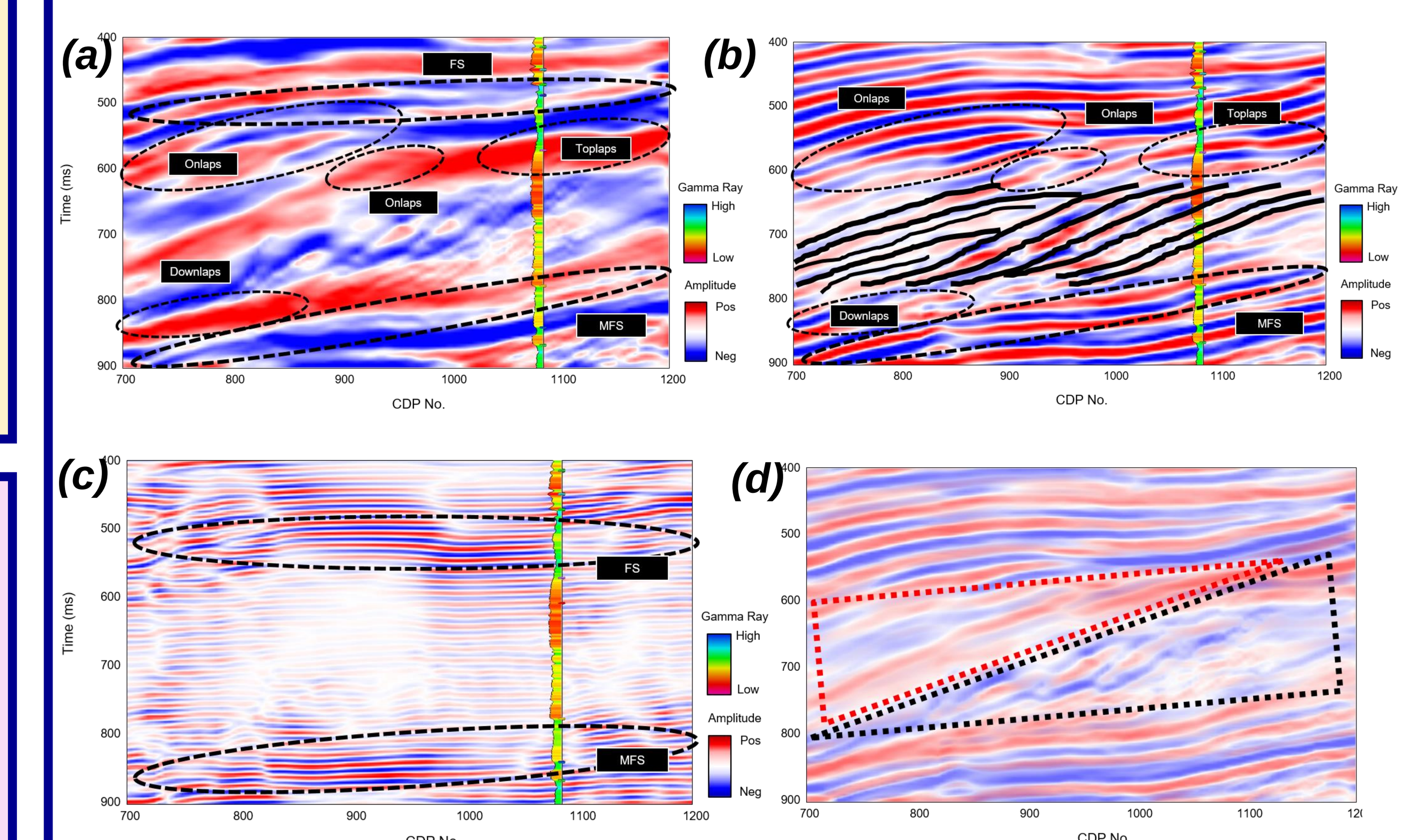
Vertical sections through seismic data (a) without, and (b) with auto-tracked horizons. (c) The resulting Wheeler transform volume. The gamma ray log is shown.



Three spectral bands: 0-27Hz, 28-55Hz, and 56-83Hz. Filtered spectra with normalization on every spectral band.



Spectra of IMFs with normalization on every mode.



Sequence stratigraphy interpretation on (a) IMF-1, (b) IMF-2, and (c) IMF-3. IMF-1 shows a good visual correlation with gamma ray log like the synthetic model. The IMF-2 characterizes the progression and regression sequences more clearly, compared with the seismic section above and bandpass filtered results. The strong amplitudes on IMF-3 highlight the sequence boundaries, FS and MFS. In addition, IMF-1 and IMF-2 are blended on (d) with dotted triangles showing the two depositional sequences.

Conclusion

VMD is a data-driven signal decomposition method, and unveils the hidden information from seismic data.

We estimate the sedimentary cycle by decomposing seismic amplitude signal into a finite number of modes using VMD. However, the geological meaning of such modes is not well understood, and these modes need to be carefully calibrated and evaluated with well logs.

Since the adaptive signal decomposition method can highlight the sequence boundaries, it will be helpful for facies analysis. Please have a look at Tao Zhao's poster.

For communication email: fangyu.li@ou.edu