Estimation of Near Surface Shear Wave Velocity Using CMP Cross-Correlation of Surface Waves (CCSW)

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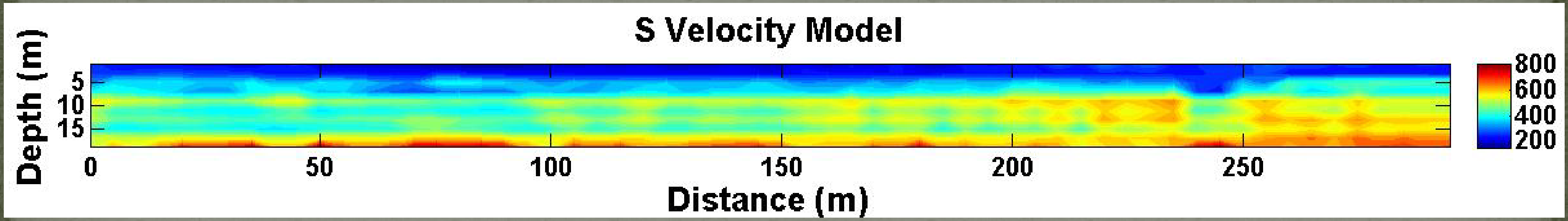
Outline

- Objective of this study
- SASW method
- MASW method
- CMP Cross-Correlation of Surface Waves (CCSW)
- Application of estimated shear wave velocity to the static corrections of converted waves
- Conclusion

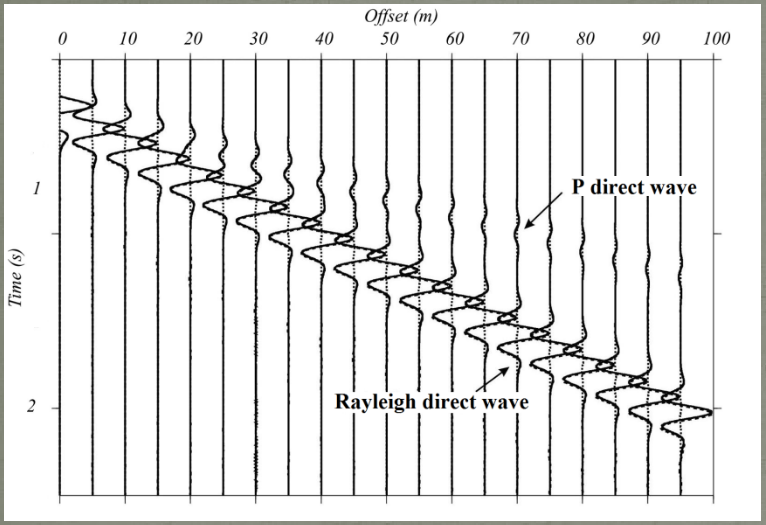
Objective of this study

The Objective of this study is to develop a method to optimize the estimation of near surface shear wave velocity applicable to the static corrections of converted waves in multi-component studies.



Surface Wave Analysis

Surface Wave Analysis is a procedure for estimating shear wave velocity based on dispersed surface waves.



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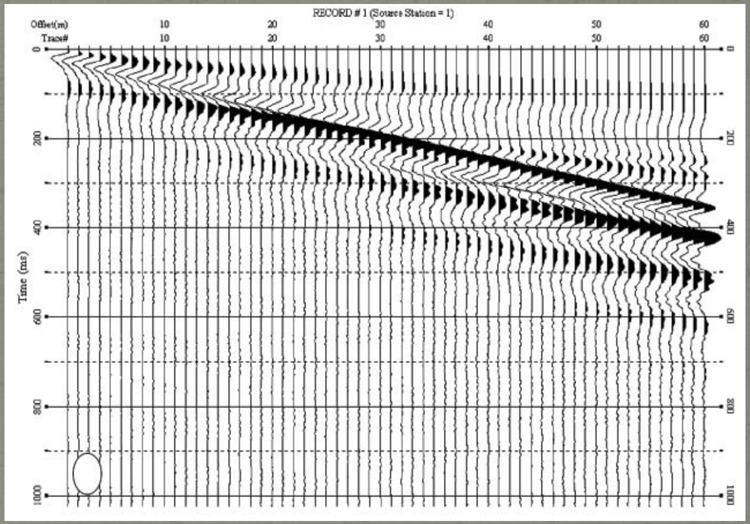


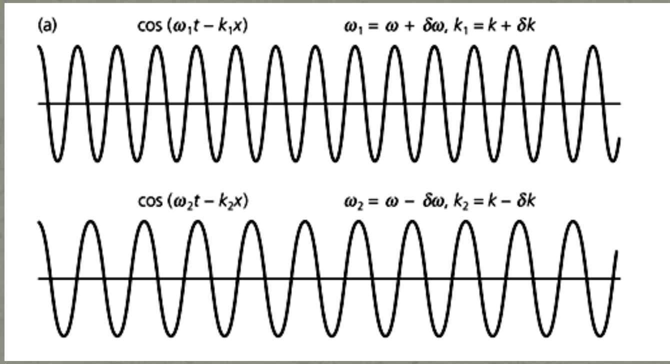
B

Luo et al., 2008
Gelis et al. 2005

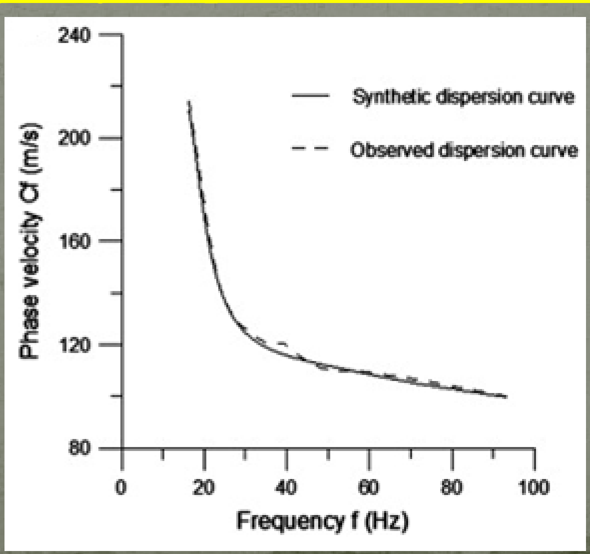
Phase Velocity

Phase velocity is the velocity of each frequency component of dispersed surface wave which is defined as

$V_p(f) = f/k$.



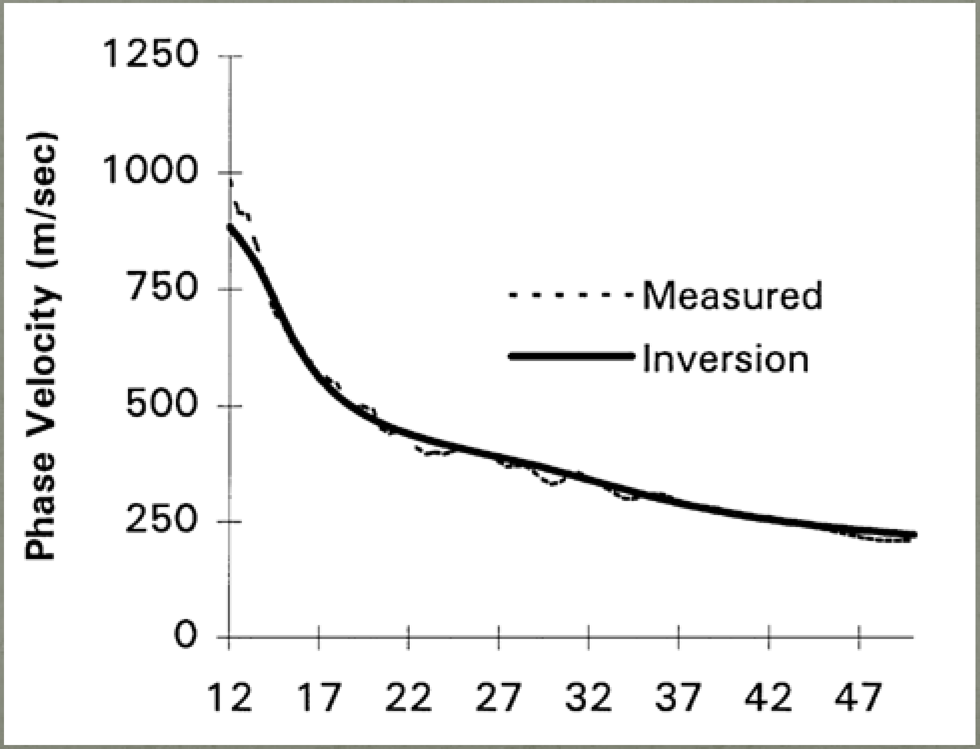
Dispersion Curve: As a function of frequency the phase velocity is displayed by a curve so-called Dispersion Curve



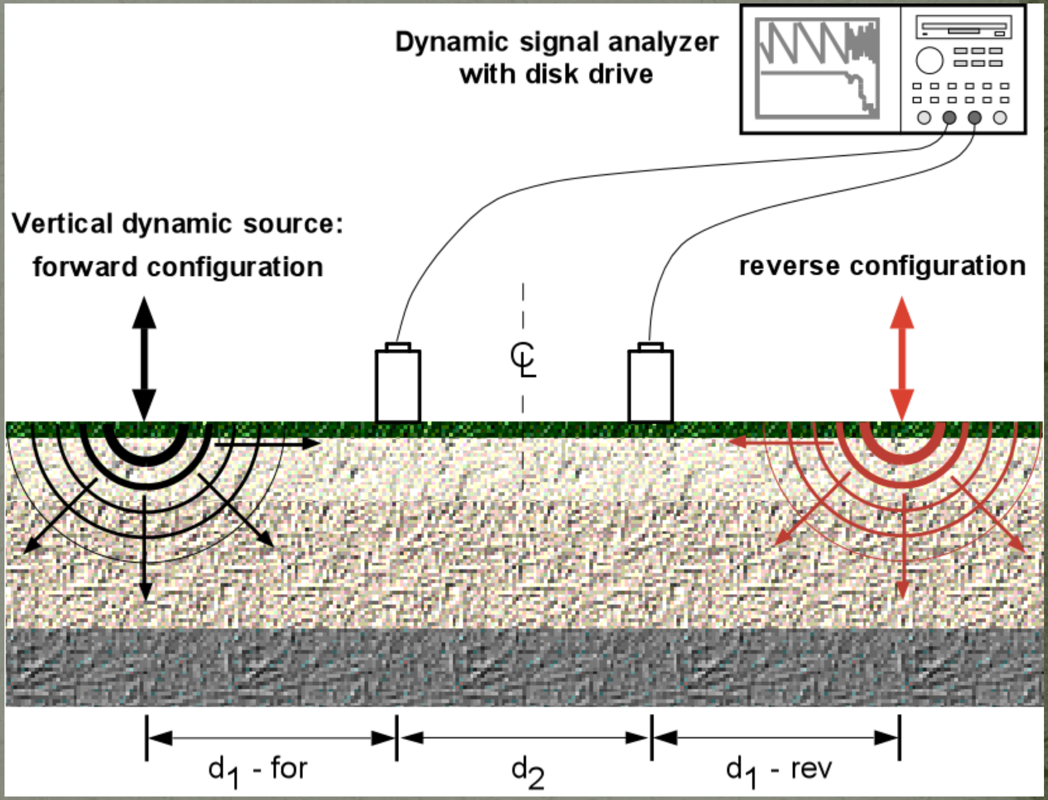
SASW Method

One of Methods for estimating shear wave velocity is the Spectral Analysis of Surface Waves (SASW) method.

The method is based on the inversion of the phase velocity (a dispersion curve) of Rayleigh waves to a shear wave velocity model.



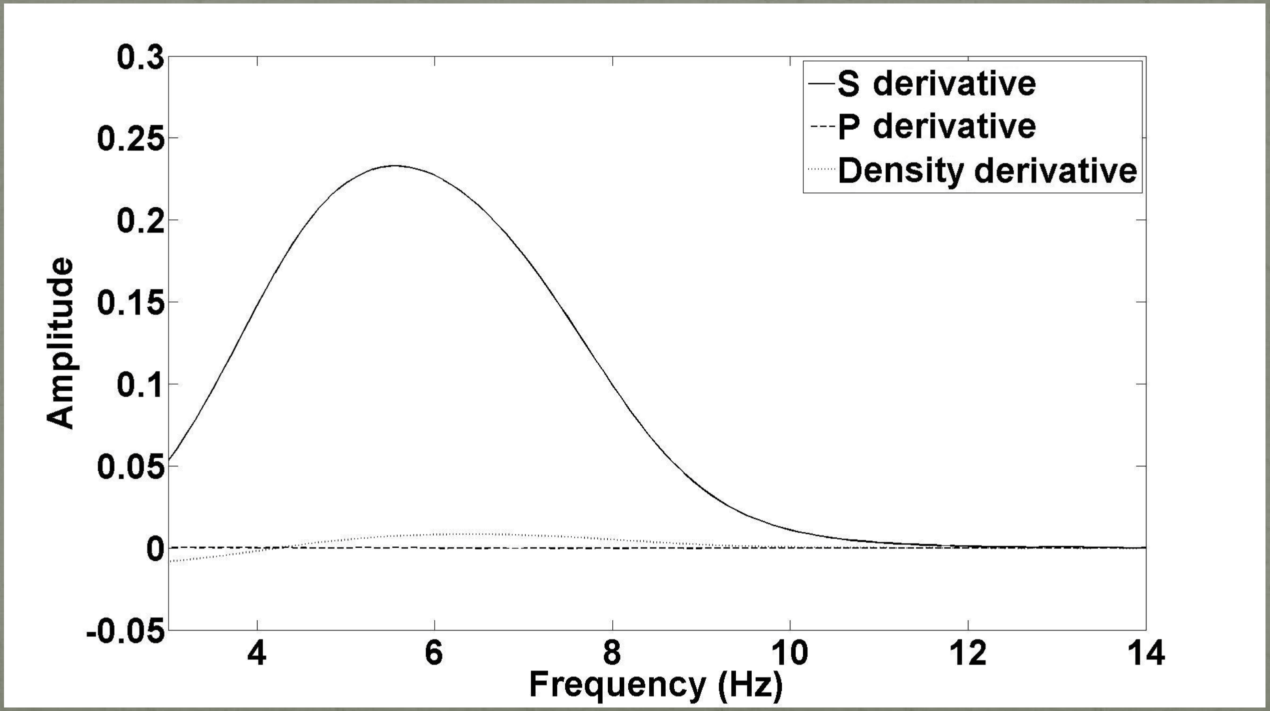
In SASW, the dispersion curve of Rayleigh waves is determined by measuring phase spectrum differences of two adjacent receivers (Geophones) with respect to forward-reverse configuration of two shots.



The Theory of SASW

Method: Using Knopoff's method, Rayleigh-wave dispersion curves can be obtained for a layered earth model.

Analyses show dispersion curve of Rayleigh waves is more sensitive to vs and h (Xia et al., 1999).

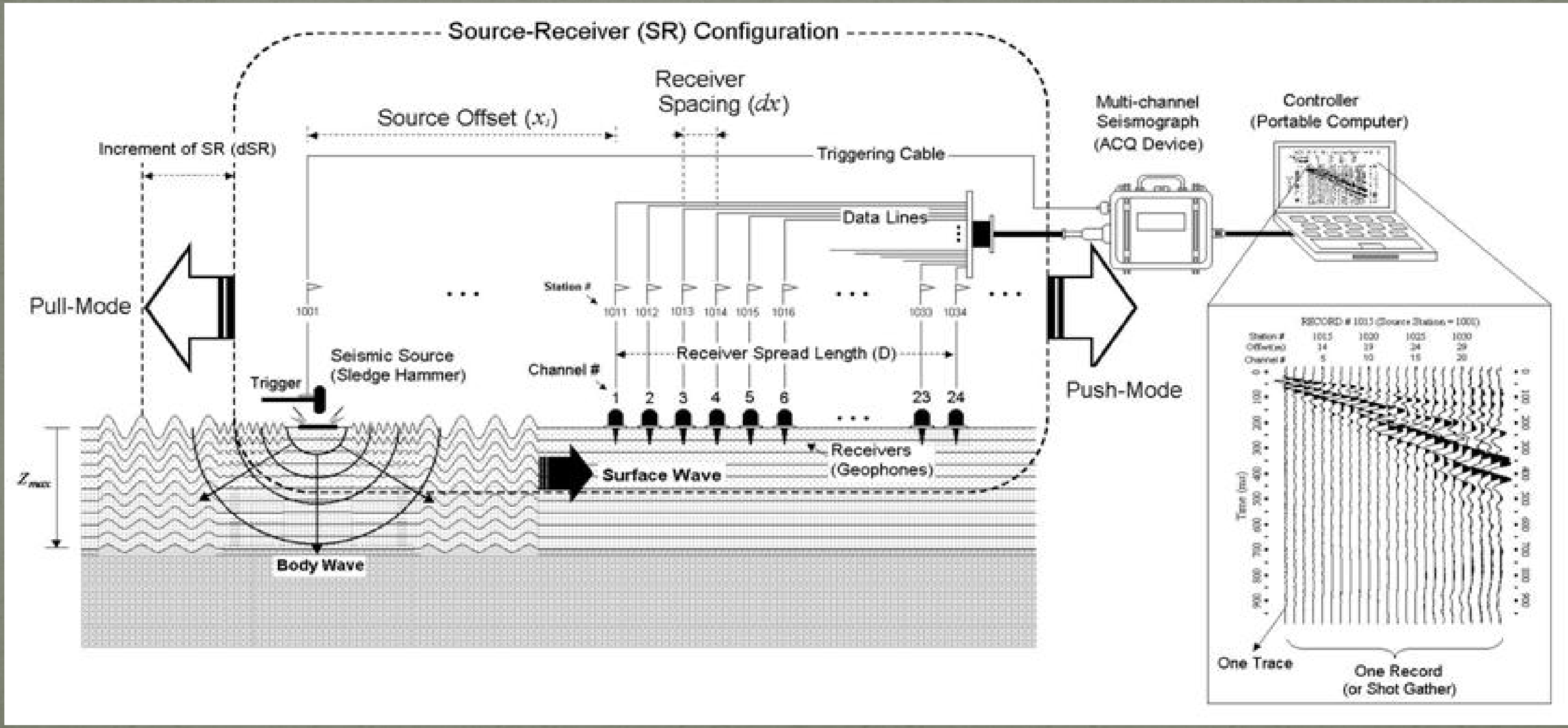


SASW Withdraw

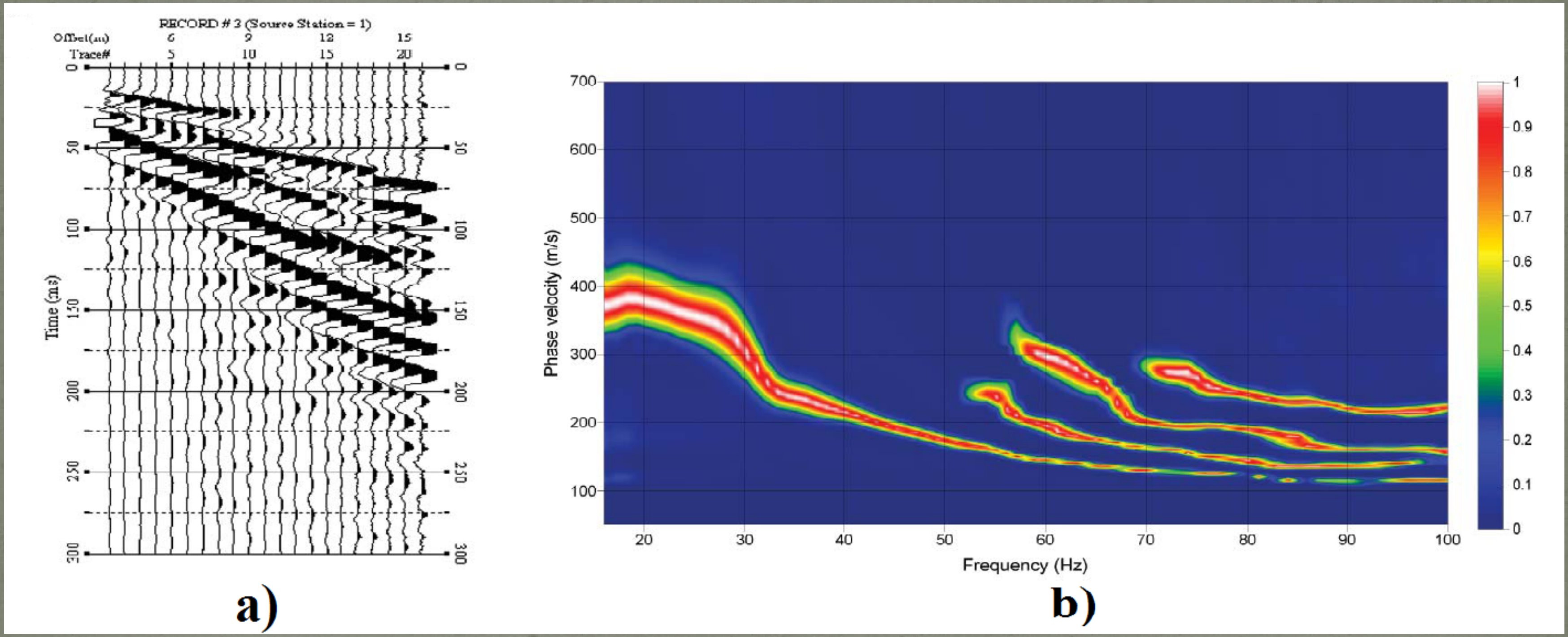
- **Although providing a good lateral resolution, SASW is very sensitive to coherent noise and individual geophone coupling.**

MASW Method

- **The Multichannel Analysis of Surface Waves (MASW) is a robust method to separate different wave types and to overcome the sensitivity of coherent noise.**



Using mutli-channel recording system, different modes are detectable. Therefore, the method does not suffer from other coherent noises as well as ambient noise. Dispersion curves are pretty obtainable in the cost of lateral resolution.

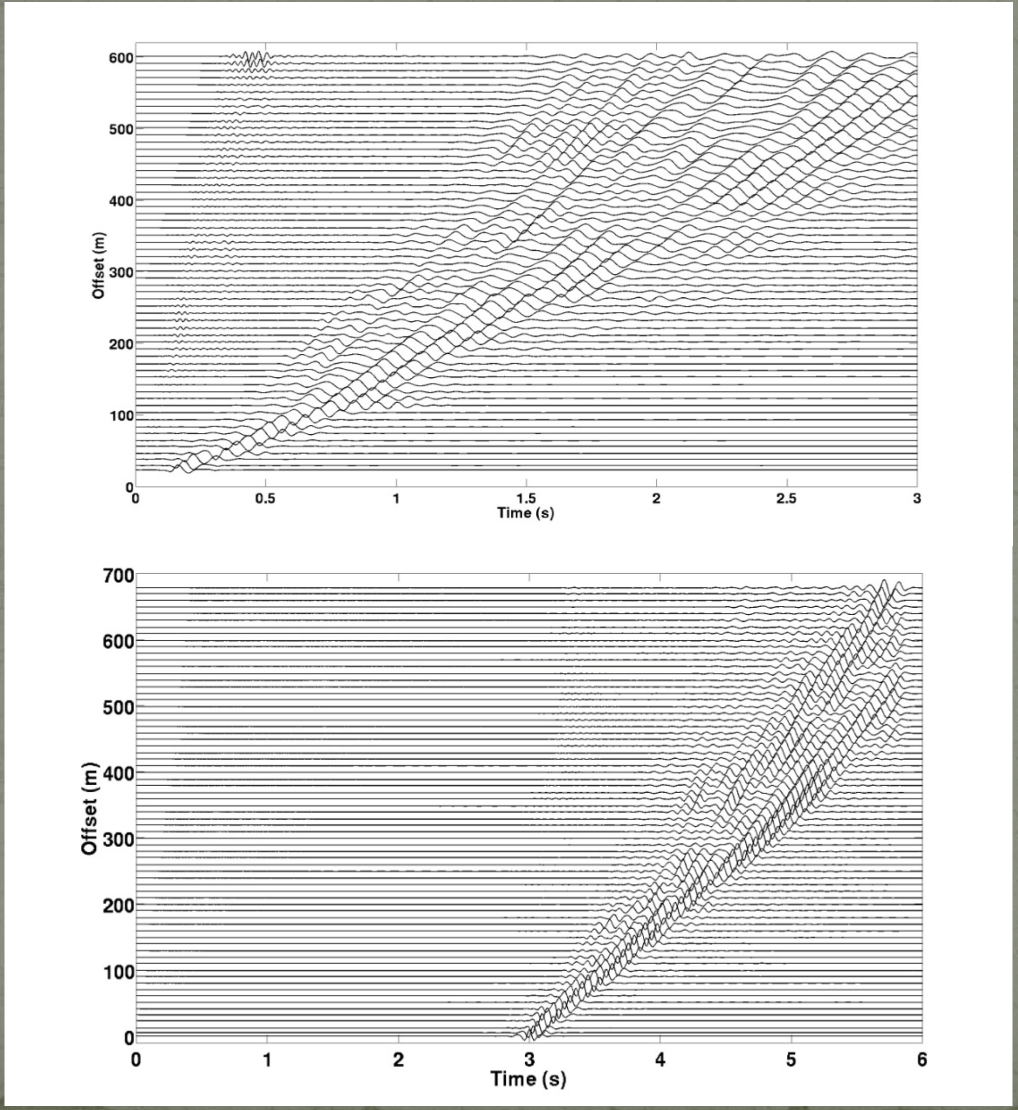


CMP Cross-Correlation of SurfaceWaves (CCSW)

- The method combines two ideas of SASW and MASW to improve the estimation of the phase velocity and lateral resolution simultaneously.

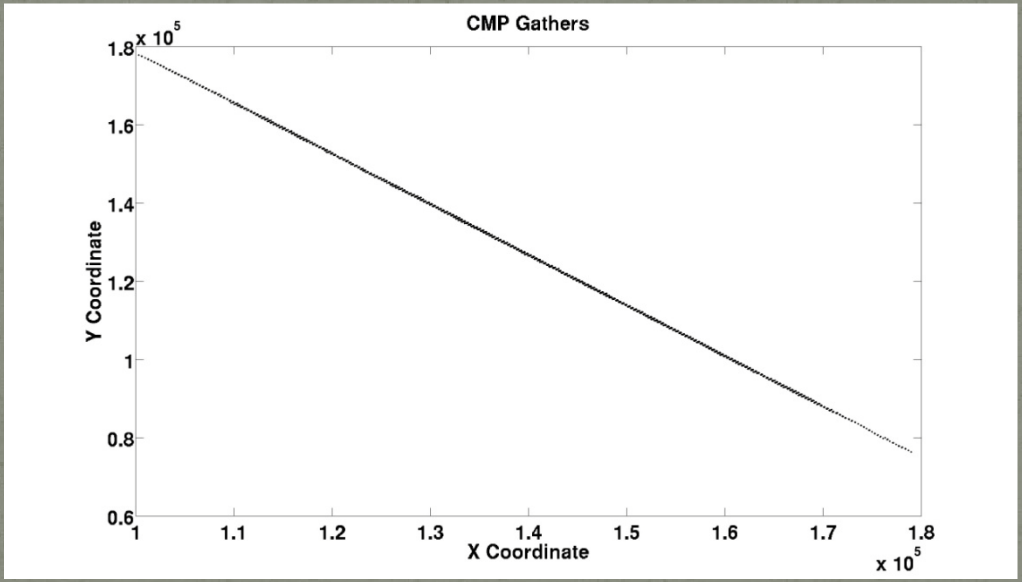
First Step of CCSW

Cross-correlation of traces with a reference trace

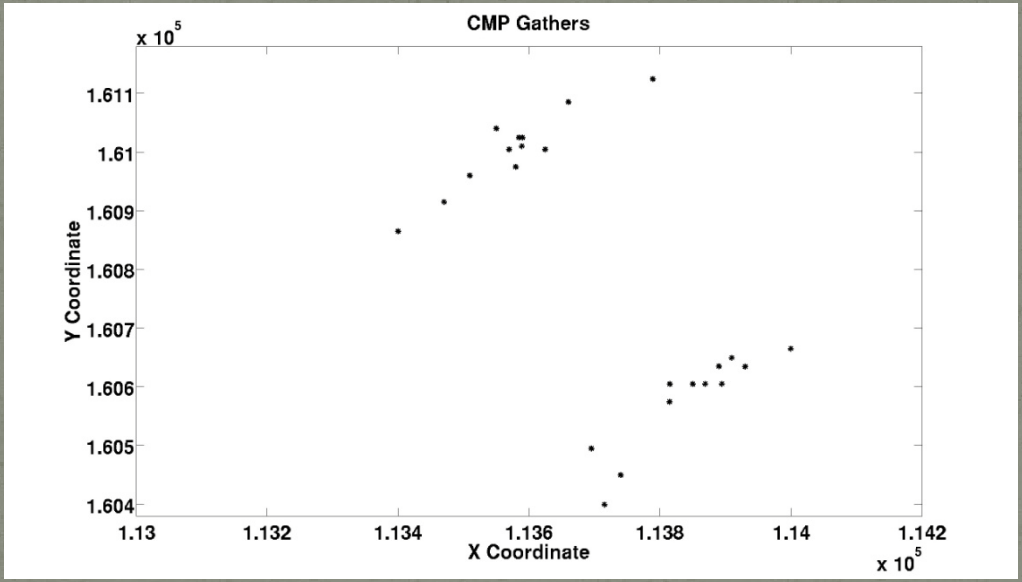


Second Step of CCSW

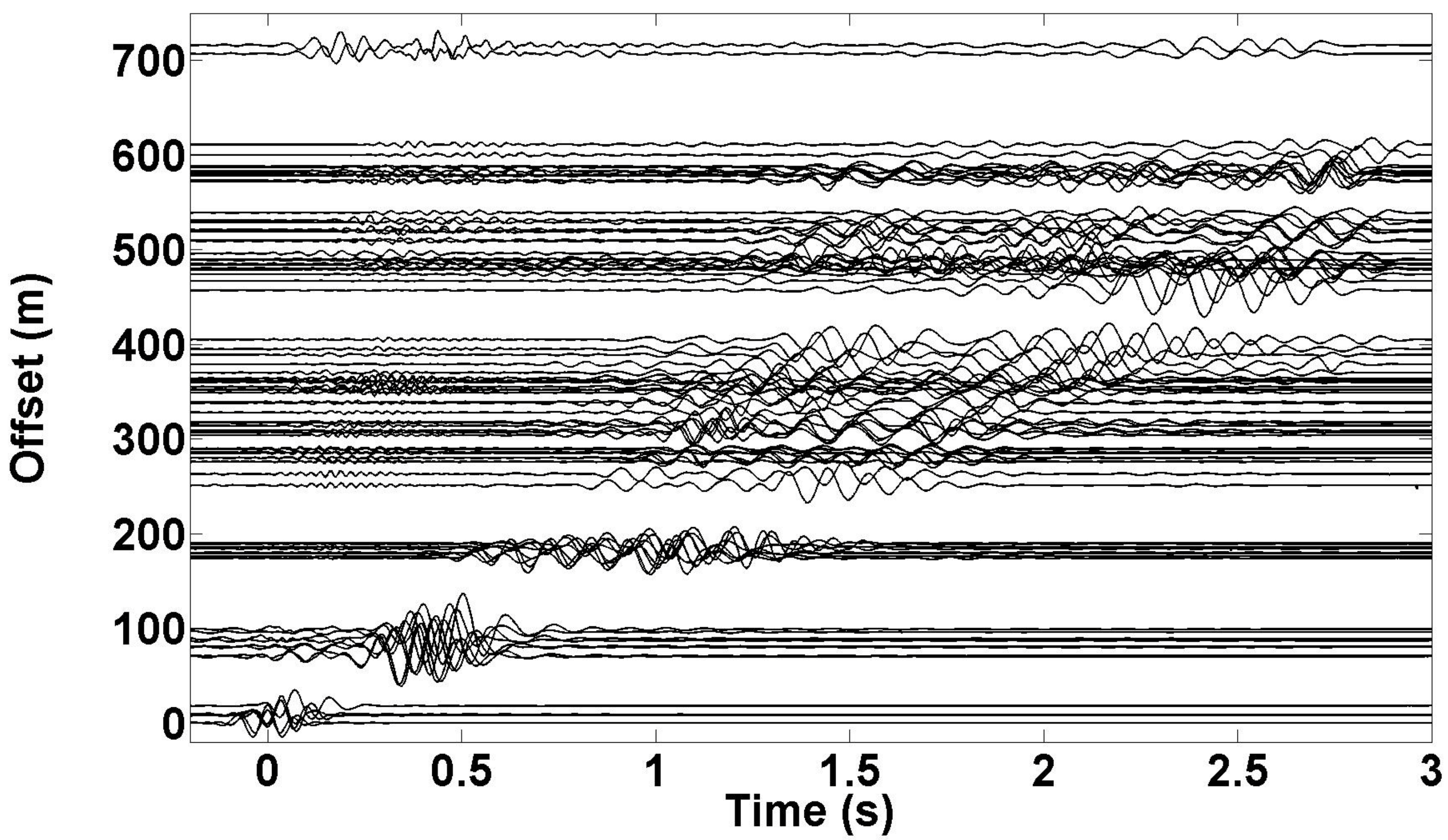
The cross-correlated traces from all shots sorted to CMP gathers.



In order to have a better fold number, we merge two CMPs to one bin

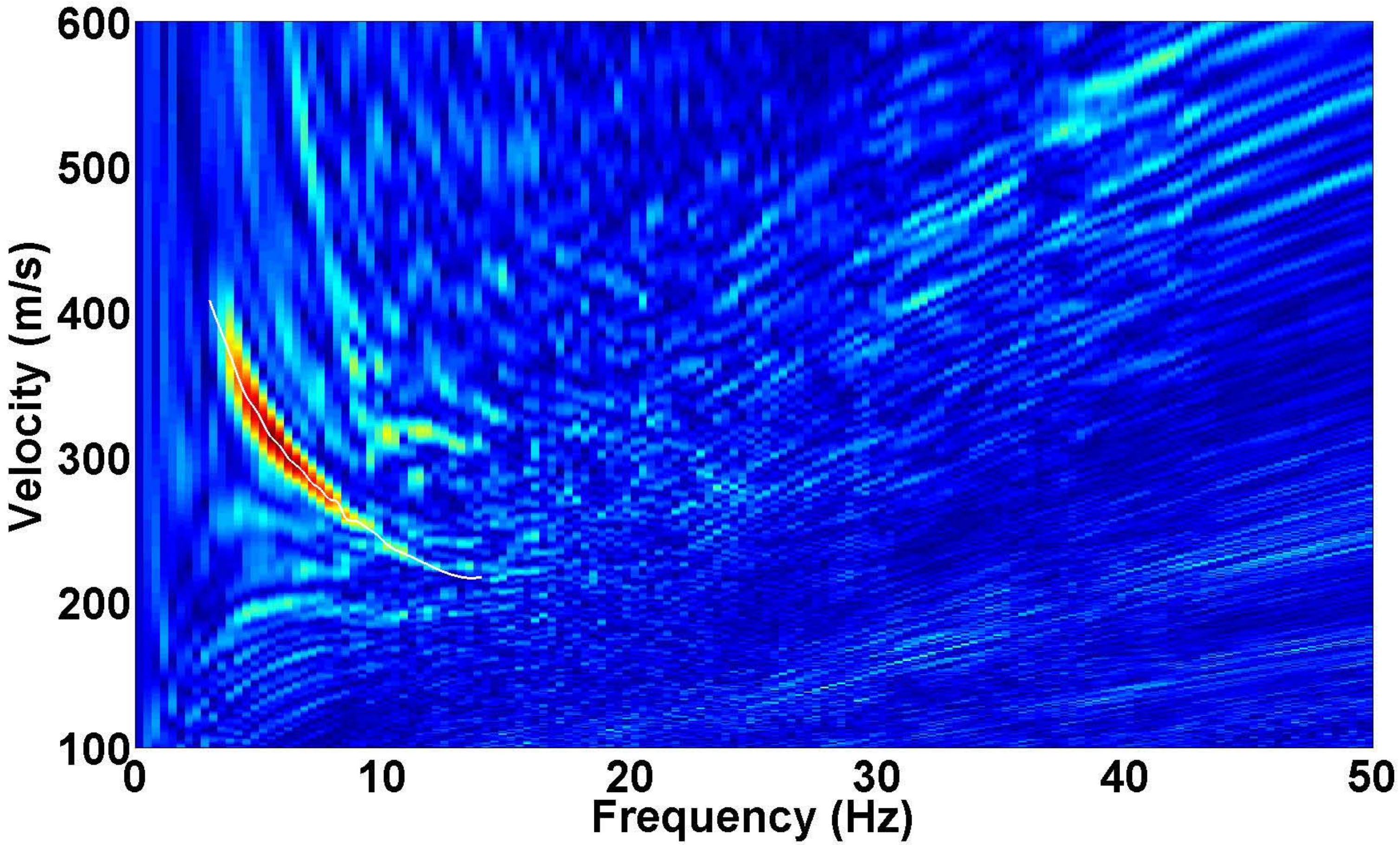


Traces in a bin

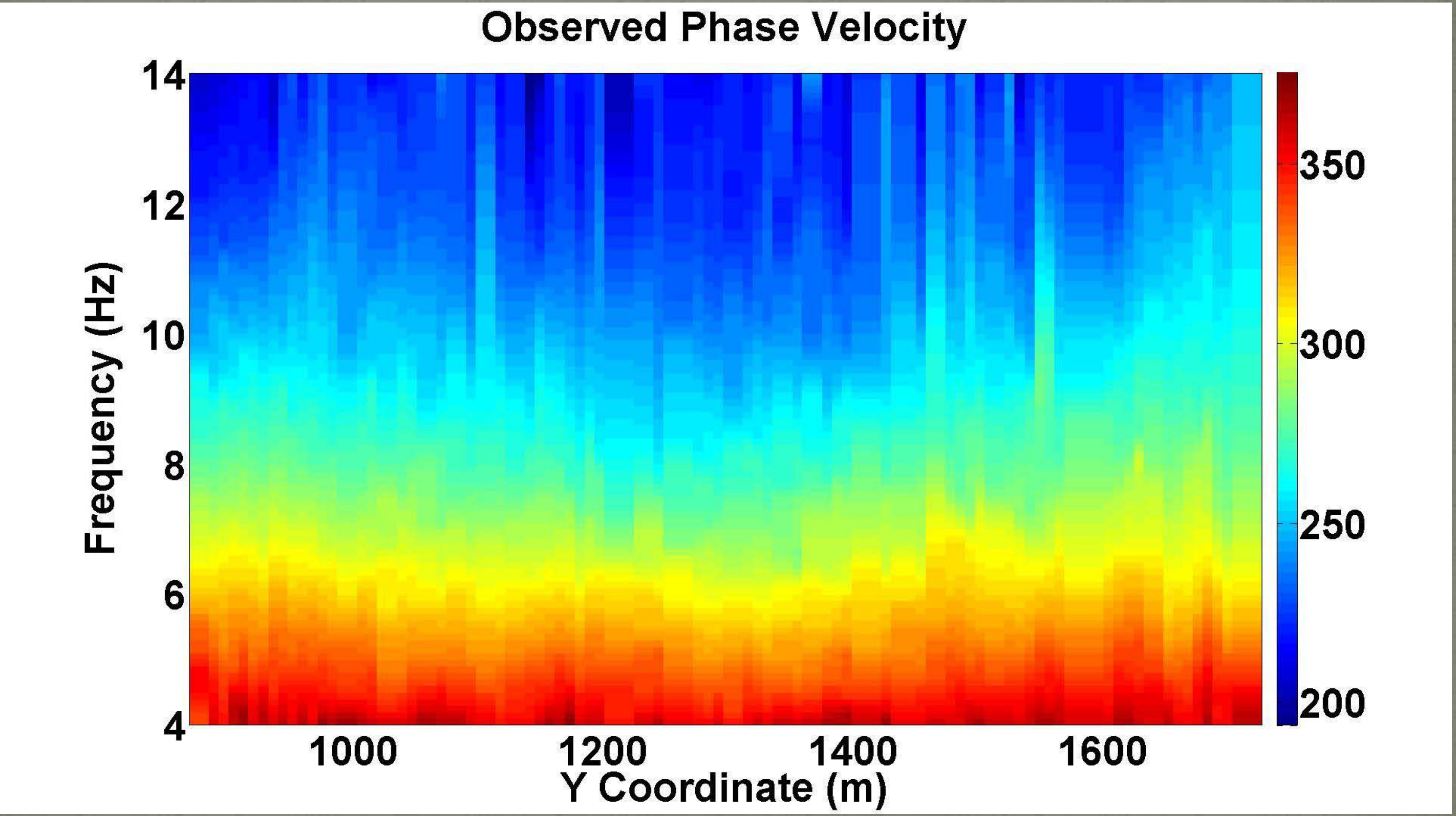


Third Step of CCSW

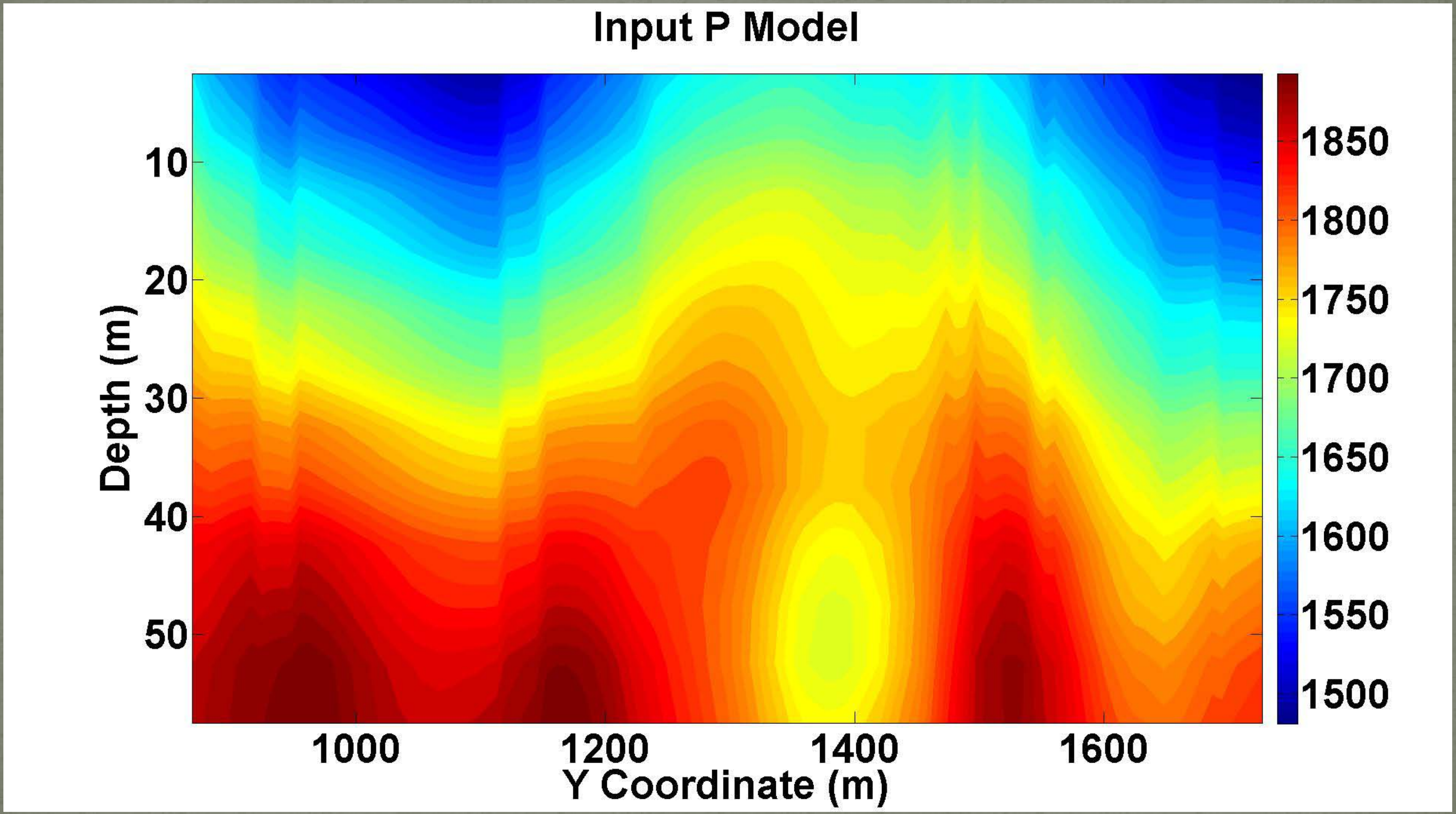
Estimation of a dispersion curve for the traces in a bin



The observed phase velocity for all the bins in the line.



The P velocity model used in this study.



Density and layer thicknesses

- Based on several log data, constant density 2000 kg/m^3 is assumed for near surface.
- For inversion, we assume layers with constant thicknesses of 5 m but with variable S velocity. This thickness is obtained from try and error.

Model covariance

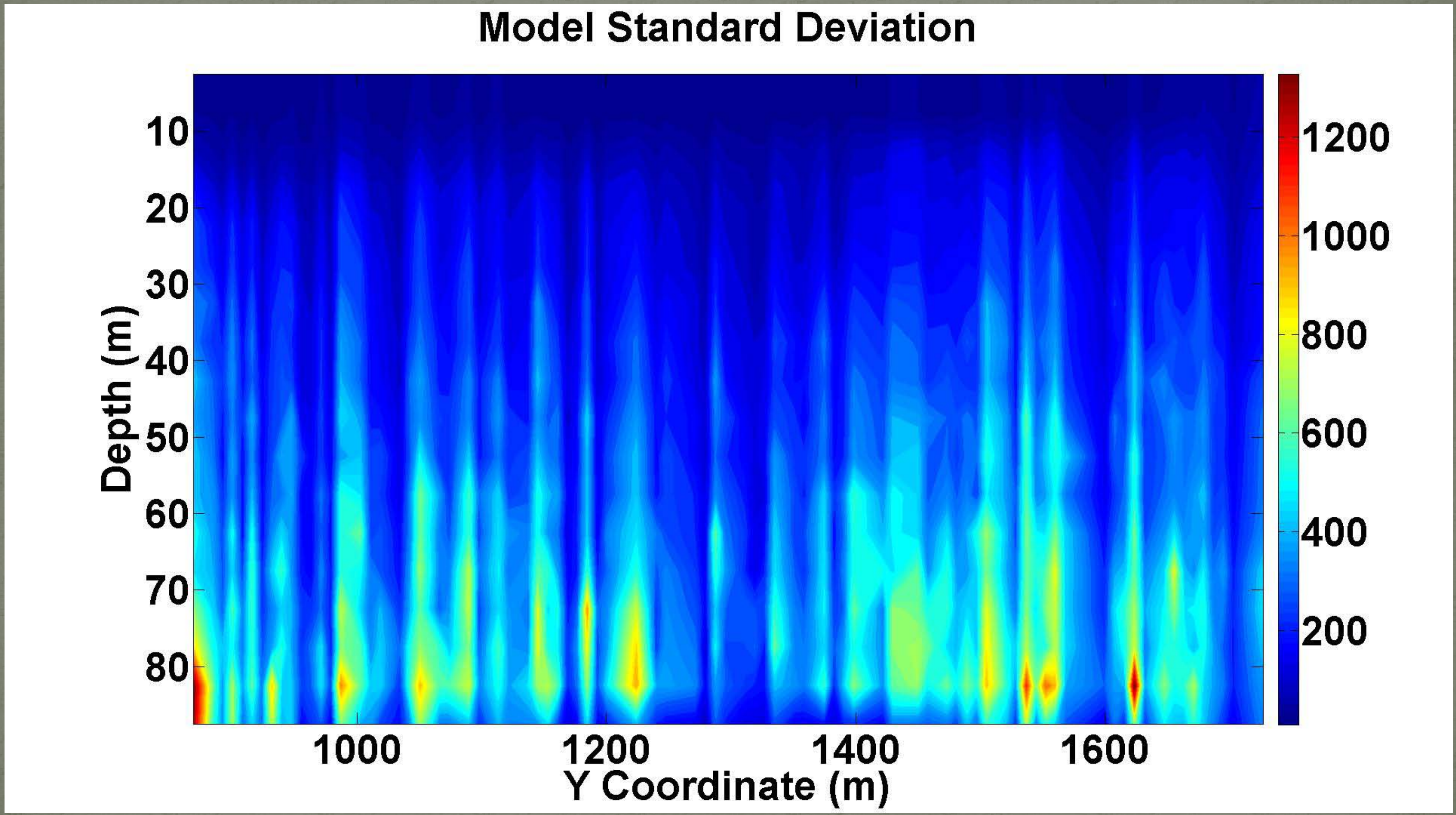
In order to evaluate the reliability of the results, we calculate model covariance using (Zeidouni. 2011)

$$\mathrm{Cov}(m) = s^2([J^T][J])^{-1}$$

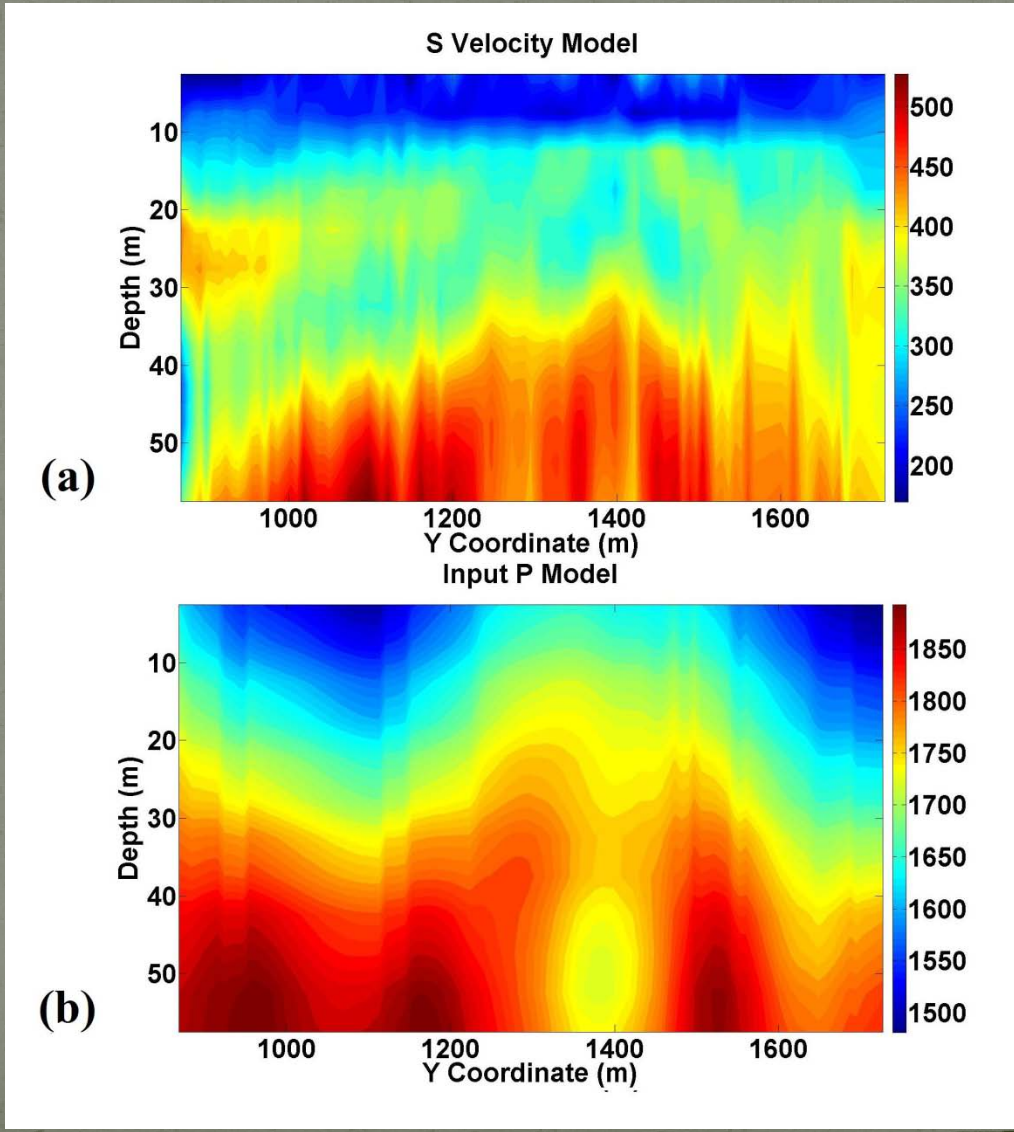
where, J is a Jacobean Matrix and s is the standard deviation of data which is obtained by

$$s = \sqrt{\frac{\|c_{obs} - c_{est}\|^2}{(n-m)}}$$

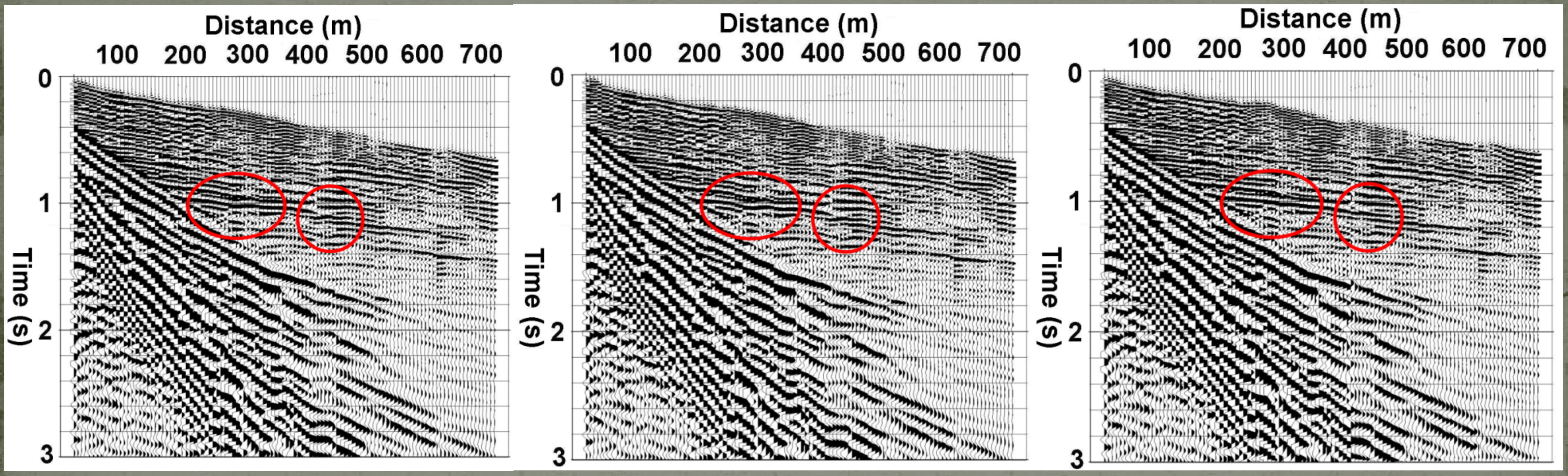
Standard deviation of the model parameters



S velocity model obtained from inversion



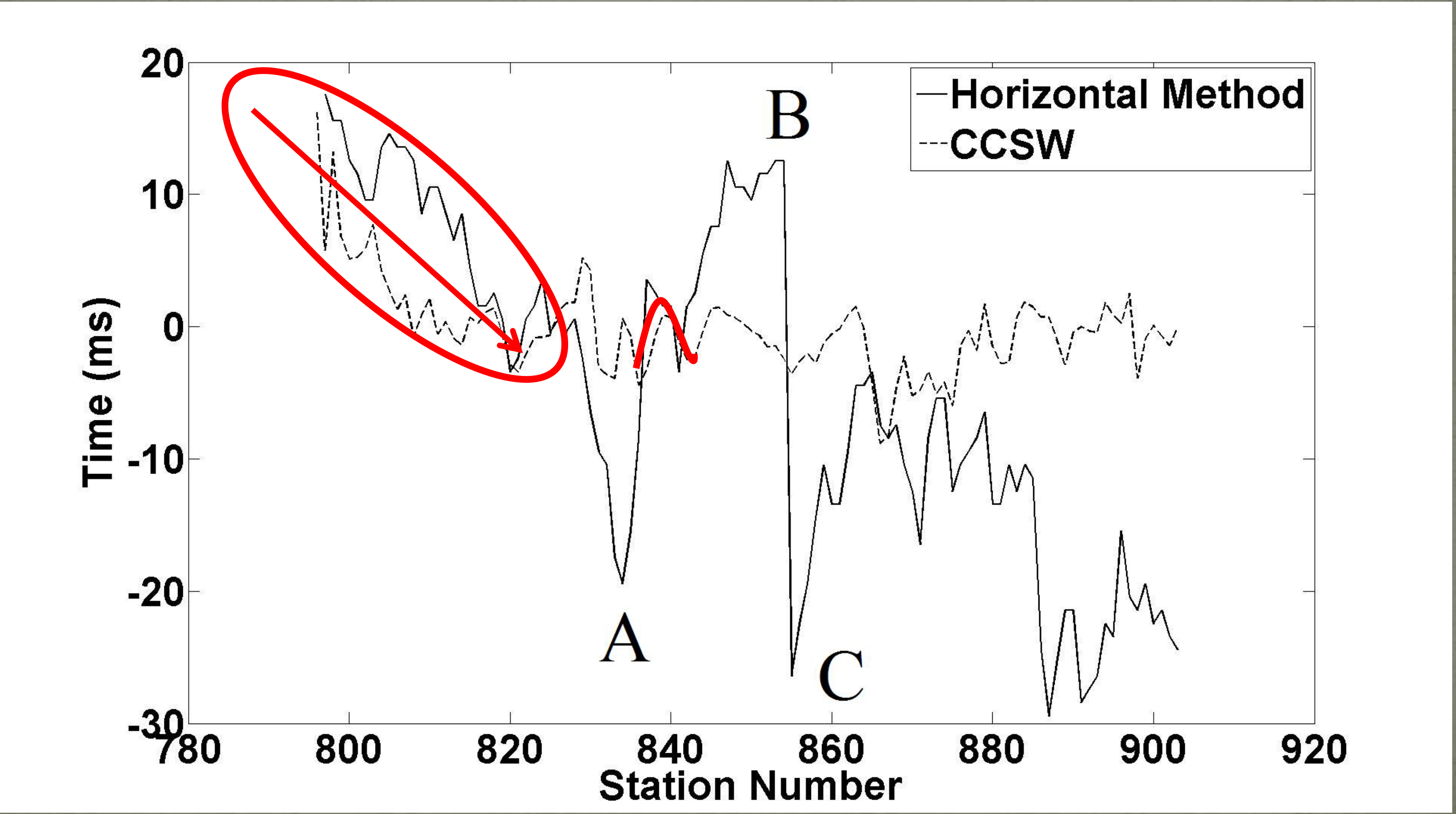
Static correction



A B C

(A) A shot record without correction, (B) CCSW static corrected and (C) Non-physical Horizon based trim static corrected.

Static corrections obtained from the non-physical horizon based trim static and CCSW methods respectively.



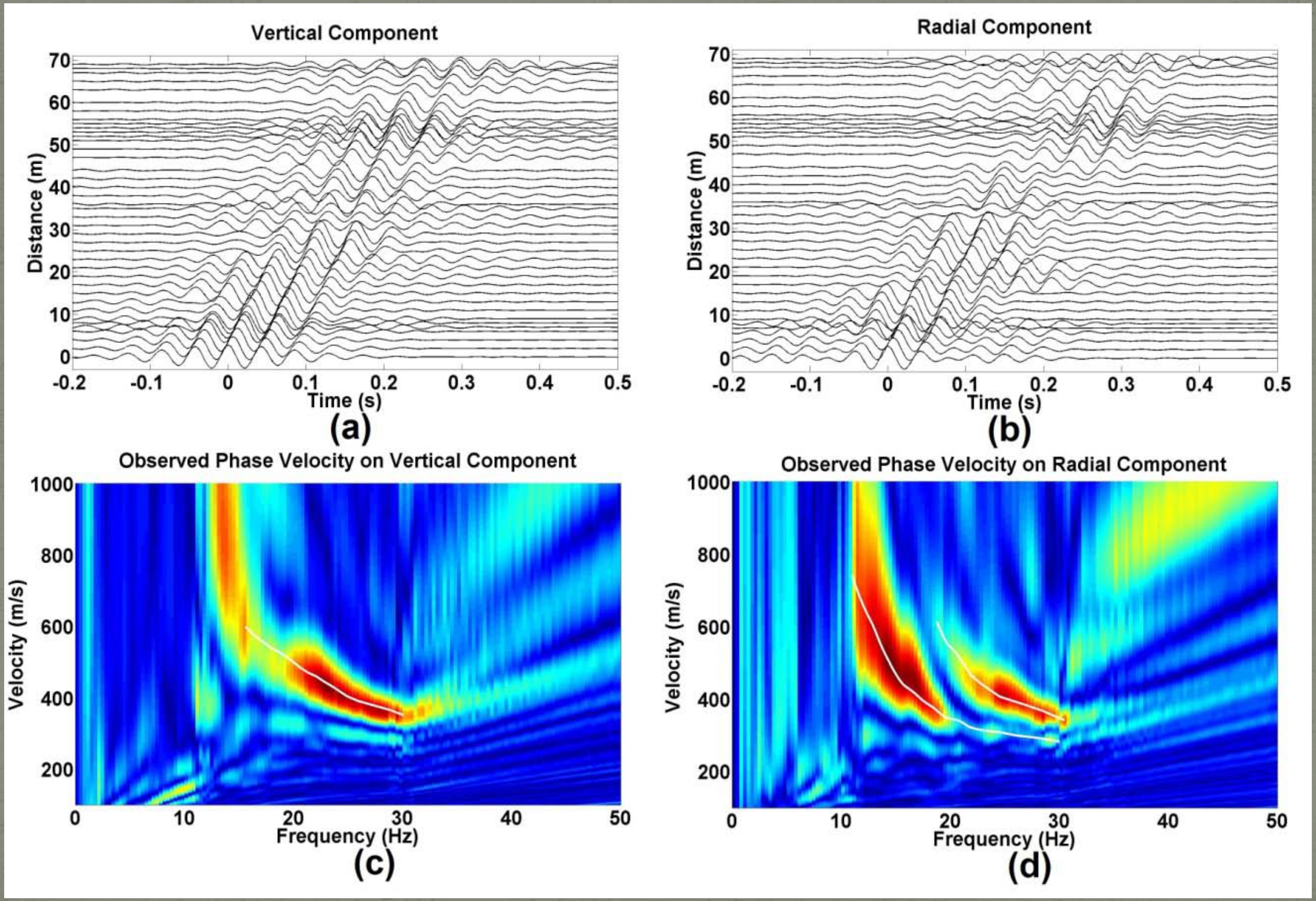
First Observation

- **The CMP Cross-Correlation of Surface Wave takes advantages of SASW and MASW methods, and also is faster more robust in the presence of variable source wavelet and noise.**
- **The S velocity model obtained from the method shows a good coherency to the P velocity model. This shows the potential use of the method for a better lateral resolution of S velocity imaging.**
- **The Static Corrections obtained from CCSW are as good as trim statics. We think this is mostly due to the weak acquisition with respect to shallow low velocity targets.**

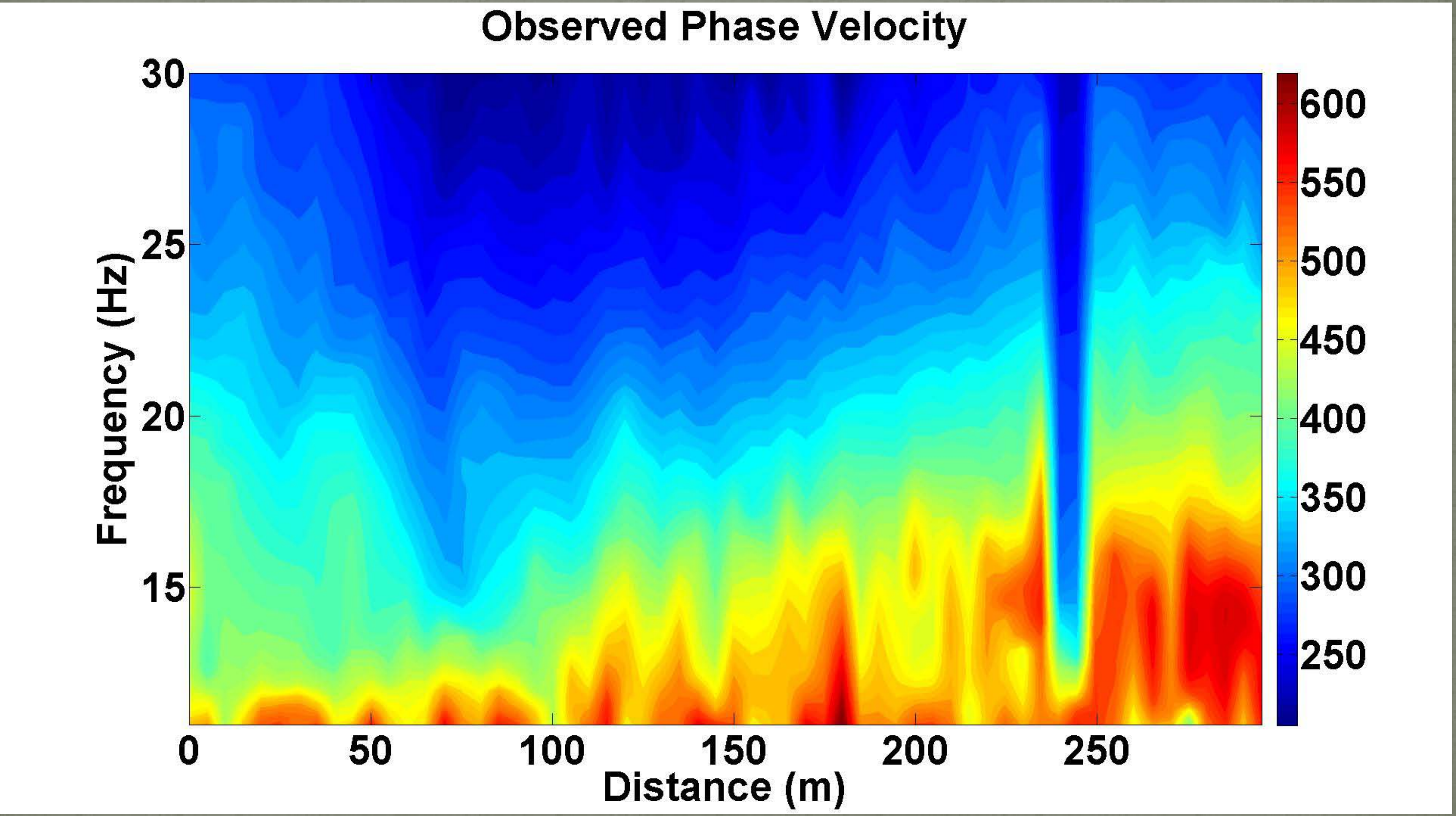
Priddis Data (2012)

- The second data set used in this study is acquired from a site near Priddis, Alberta, about 30 km southwest of the city of Calgary.
- The geophones are 3C SM7 with 2m geophone spacing and 1ms time sampling.
- Vibroseis is used in each 4m. The sweep frequency varies from 10Hz to 120Hz and duration time is 10s.

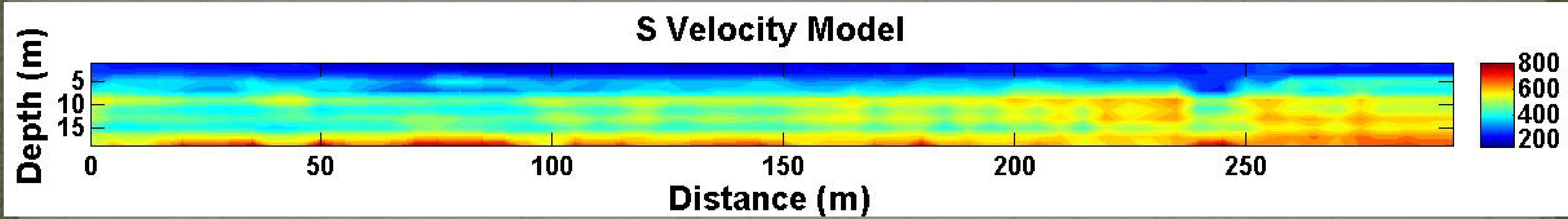
(a) and (b) Vertical and radial components of a bin respectively, (c) and (d) observed phase velocity in (a) and (b)respectively.



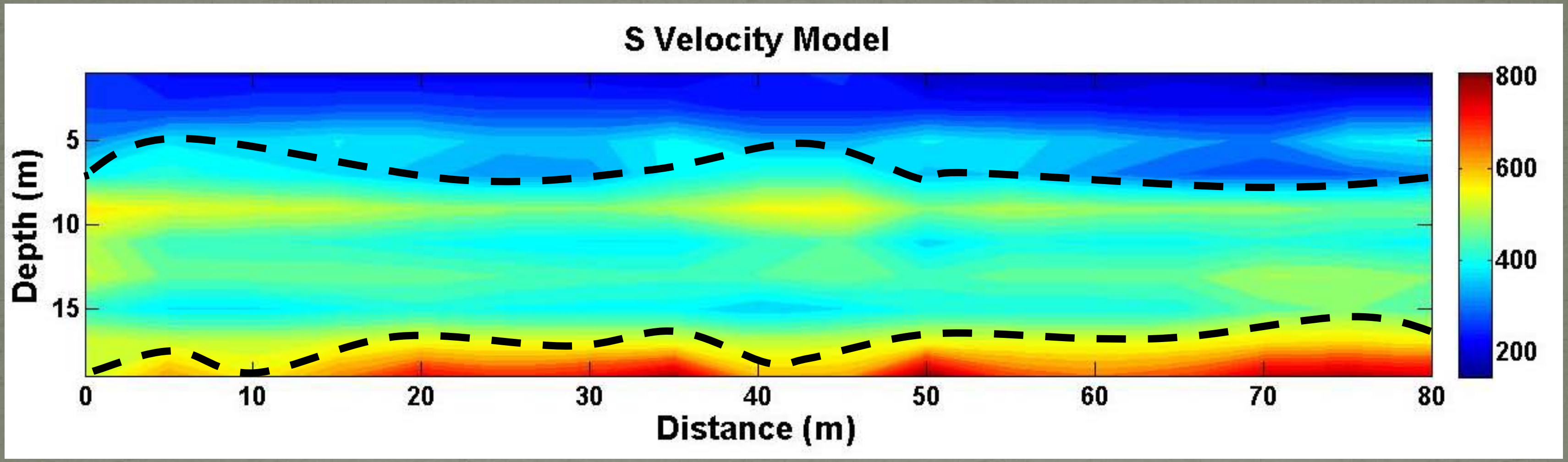
Observed Phase Velocity for Priddis Data

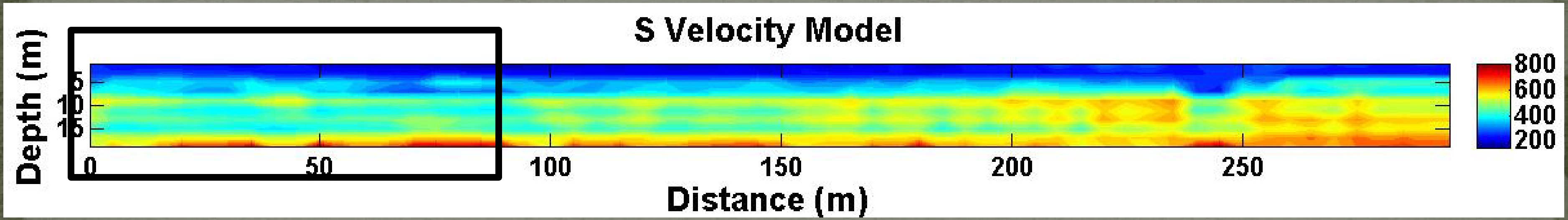


S Velocity Model for Priddis data

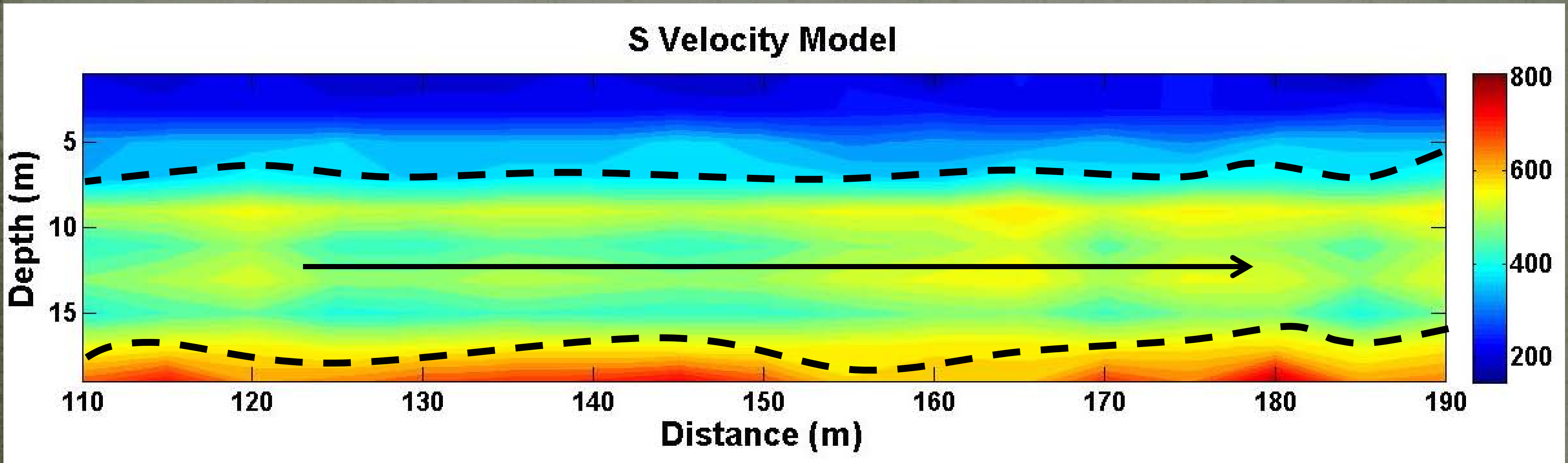


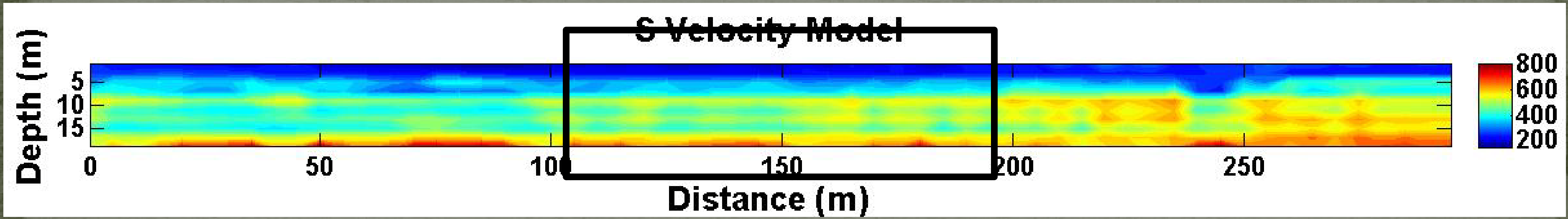
S Velocity Model for Priddis data



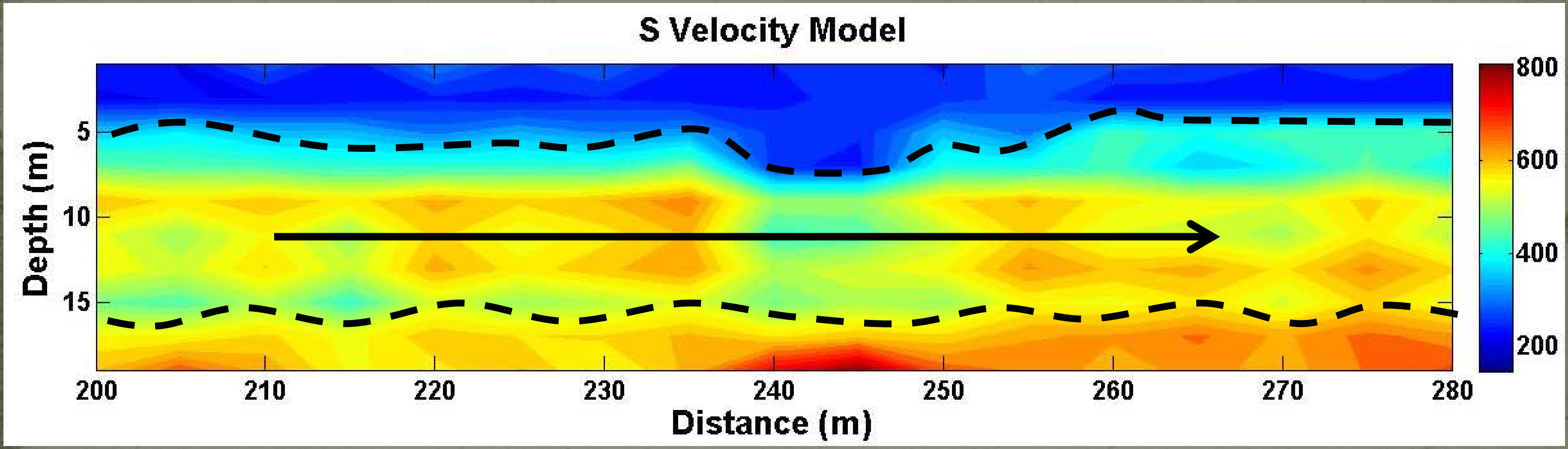


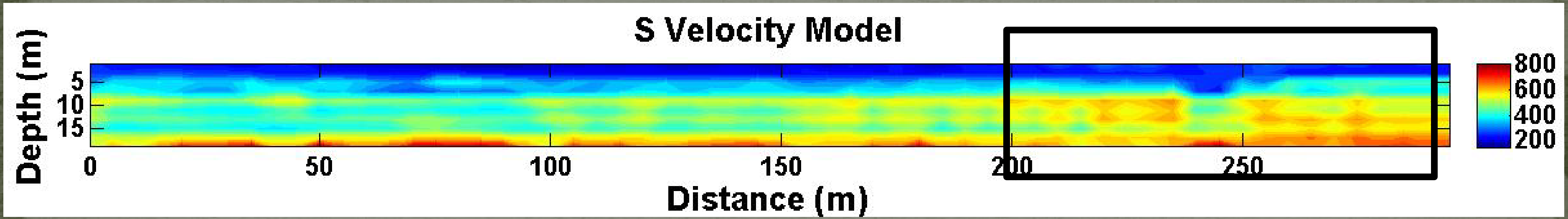
S Velocity Model for Priddis data





S Velocity Model for Priddis data





Conclusion

- Our ability to successfully extract information from converted waves and S-waves is dramatically hampered by our lack of understanding of the near-surface S-wave velocity.
- Surface waves provide information on the earth's layers nearest to the earth's surface.
- Detailed S velocity maps obtained from CCSW demonstrate the high potential of the method to be utilized in seismic exploration.
- This is exactly why the surface wave methods should be taken into account by the oil and gas industry.

Acknowledgements

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S Velocity Model for Priddis data