Full waveform inversion of multimode surface wave data: numerical insights

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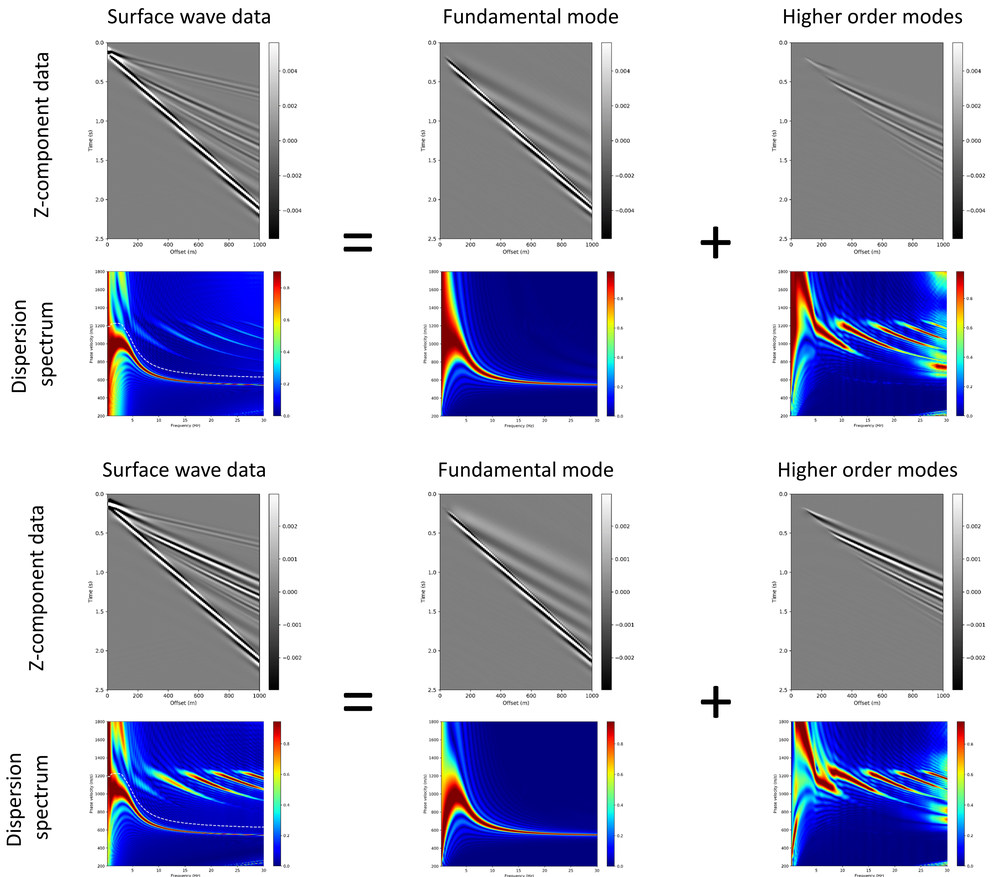
Abstract

The dispersive nature of surface waves is responsible for the amplification of cycle skipping problems during surface wave FWI. We propose decomposing surface waves into their fundamental (FM) and higher order modes (HOM) and inverting them sequentially to mitigate this problem. Even though the fundamental mode amplitudes are typically larger than the higher order modes, the latter ones can travel in the deeper parts of the near-surface at higher frequencies. Therefore, we use the fundamental mode to produce an initial approximation to the near-surface S-wave velocities and then perform another step of FWI using the higher order modes to produce a more detailed velocity profile, particularly at larger depths. Results obtained from synthetic data demonstrate the potential of this approach to avoid cycle skipping and to improve the resolution of inverted S-wave velocity models.

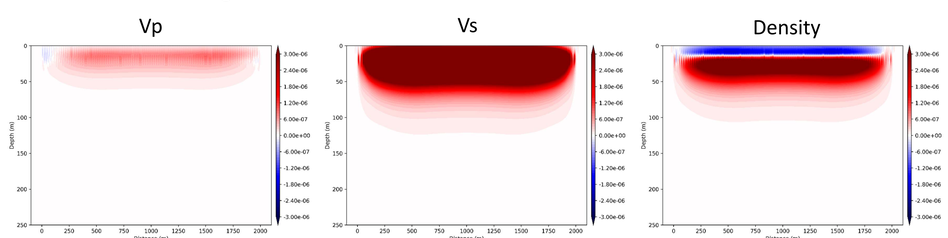
Multimode surface wave data

Surface wave propagation in a layer media is multimode and dispersive process. Mode separation can be achieved by F-K filtering based on dispersion curves.

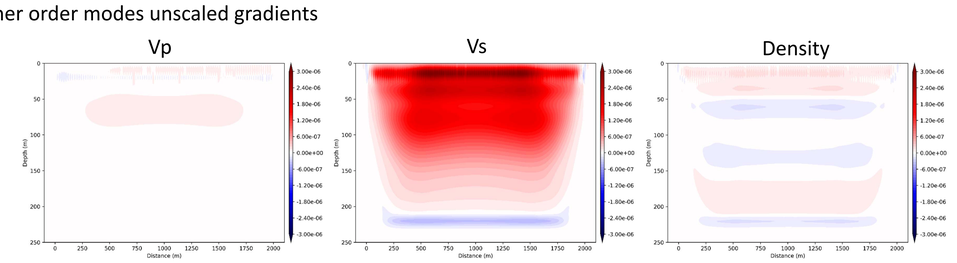


Multimode Elastic FWI kernels

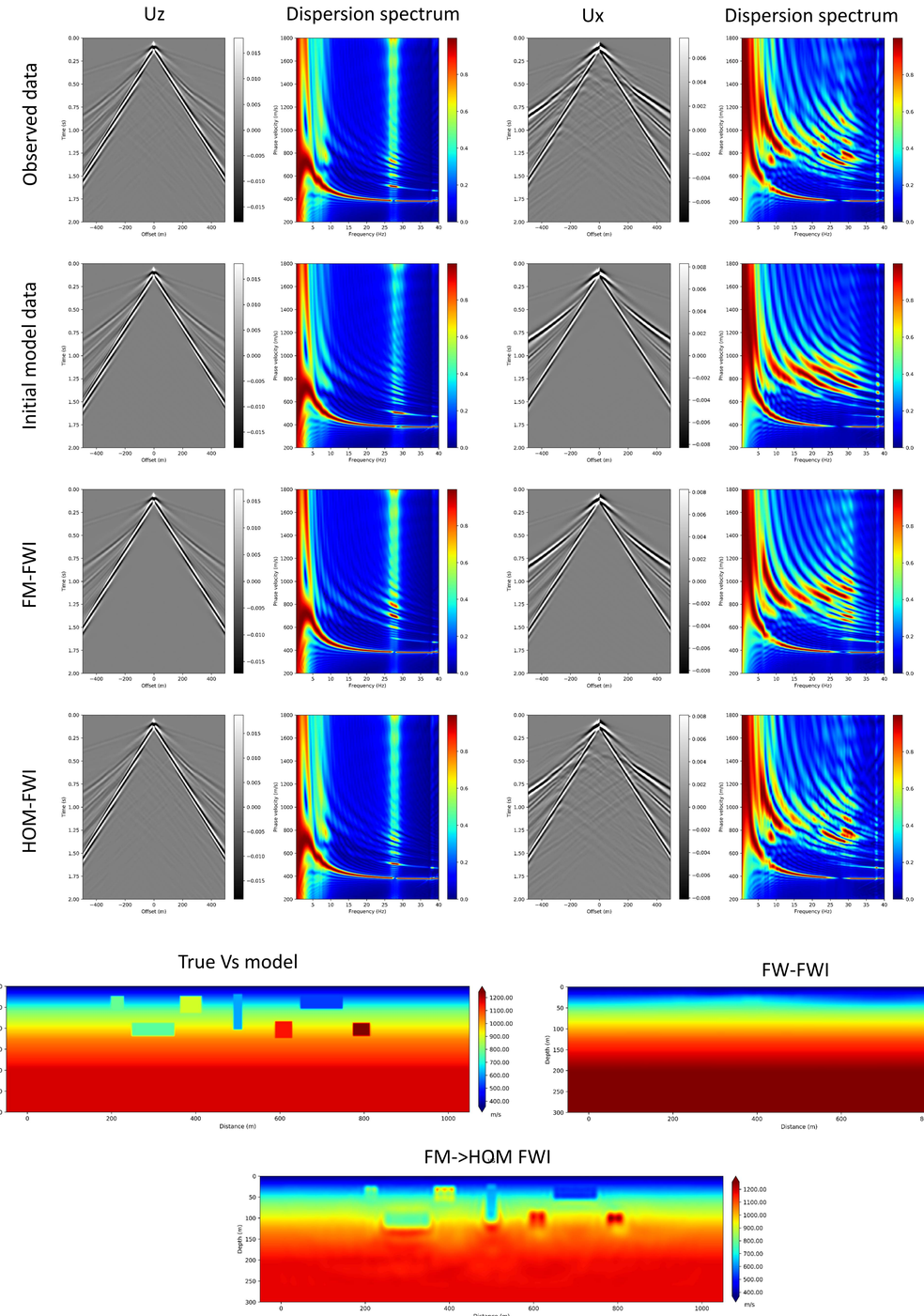
Fundamental mode unscaled gradients



Higher order modes unscaled gradients



Multimode surface wave inversion



Conclusions

- By first inverting the fundamental mode of surface wave data, high-resolution short-wavelength updates can be obtained in the shallowest part of the near-surface while providing long-wavelength updates in the deeper parts of the model.
- Adding the higher order modes at a later stage improves the resolution at the deeper parts of the model.
- Layer stripping is an implicit process in this approach.
- Horizontal component data is critical for this process, since it provides a more balanced measurement of fundamental and higher order modes.
- In the case of inverting vertical component data only, the inversion will be mostly driven by the fundamental mode energy.
- Multimodal surface wave FWI seems to be a promising alternative for inverting surface wave data recorded with DAS fibre. The extremely dense spatial sampling of this technology allows for an unaliased recording of the propagation of the surface wave in all its modes.

Acknowledgements

The authors thank the sponsors of CREWES for continued support. This work was funded by CREWES industrial sponsors, CFREF (Canada First Research Excellence Fund) and NSERC (Natural Science and Engineering Research Council of Canada) through the grant CRDPJ 461179-13. Thanks to Dr. Wenyong Pan for providing the Seiselastic2D FWI codes we used in this study. We are also grateful to Compute Canada for providing the computational resources.

NSERC CRSNG
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