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# Full model wavenumber inversion

# Petroleum keynote paper

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**SUMMARY**

The promise of full waveform inversion (FWI), granted we could (completely) simulate the conditions in which our field data were acquired, including an accurate representation of the physics involved, is a model of the Earth capable of generating synthetic data that resembles (fits) our field data; No deghosting, no filtering, in fact, no processing is theoretically required as the goal in this case is a model of the Earth, not a seismic section. However, we still have a long way to go, as we usually resort to approximate physics and many assumptions, and yet, we still fail to converge to that promise. The high nonlinearity of the inversion problem with the large number of model points necessary to properly represent the resolution of interest (or need) in our model are prime reasons for the ill convergence.

The long wavelength components of the velocity model usually constrain the general geometrical behavior of the wavefield (the kinematics), observed in our data, while the short wavelength components are responsible for the scattering (the reflections themselves as events in our data). Since FWI is based on comparing the observed and modeled data, free of wavefield geometrical utilization, it usually requires that the long (and at depth and with complex media, the middle) wavelength components of the model be accurate enough to provide modeled data that is within a half cycle of the observed data. These long wavelength components are usually estimated from tomography or migration velocity analysis (MVA) methods. They, however, usually contain too low of a wavelength to fit the cycle skip criteria for all reflections in the data, especially those reflections corresponding to deeper reflectors. We are, specifically, missing the "middle" model wavenumbers necessary to help us transition from the geometrical features of the wavefield to the scattering ones. The analysis of the sensitivity of our conventional (and even FWI-in-mind enhanced) data to the model points show that such lack of middle wavenumbers is a serious problem at depth, and specifically the depths we tend care about in our industry.

In this presentation, we investigate two potential solutions to this problem, beyond requiring low frequency to be acquired. To combat this problem we shift our focus from the data domain to the model domain in which we devise an approach to explicitly control the wavenumbers that we introduce to the model at different stages of the inversion. Such controls are admitted naturally by scattering angle filters. An explicit control on the model wavenumbers provided by the scattering angle of the FWI gradients can help us maneuver model wavenumber gap. This is especially true in anisotropic media where such filters are applicable to the individual parameter models necessary to represent such the anisotropic model; A feature not accessible though data domain decimation and data hierarchical implementations, as all parameters share the same data. Though the physics involved in creating the data and the obvious acquisition limitations will eventually impose bounds on the model wavenumbers we may be able to extract, a proper integration of image domain analysis to the FWI objective will help us widen the model wavenumber spectrum that we can extract from the data. Thus, the combination of scattering angle filtering and an objective that utilizes MVA and FWI are at the heart of making FWI work, and hopefully help us converge to it's promise. During this presentation, I will share many examples that demonstrate the assertions made in this summary.