Residual dependent FWI sensitivities based on direct nonlinear inverse scattering

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Gauss Newton FWI generalizes linear AVO inversion

...with the former reducing to the latter in the special case of reconstruction of a single horizontal interface. In this research we work towards derivation of extended FWI algorithms, whose purpose is to generalize a range of *nonlinear* AVO and impedance inversion schemes. New forms are needed, because no descent based method can incorporate nonlinearity within an individual update. We introduce nonlinear sensitivities, by varying the wave field G with respect not to the current model, s_n, but the model s_{n+1} we are in the process of constructing. A series sensitivity is produced:

$$\left(\frac{\partial G(s_{n+1})}{\partial s(\mathbf{r})}\right) = \left(\frac{\partial G(s_{n+1})}{\partial s(\mathbf{r})}\right)_0 + \left(\frac{\partial G(s_{n+1})}{\partial s(\mathbf{r})}\right)_1 + \ldots$$

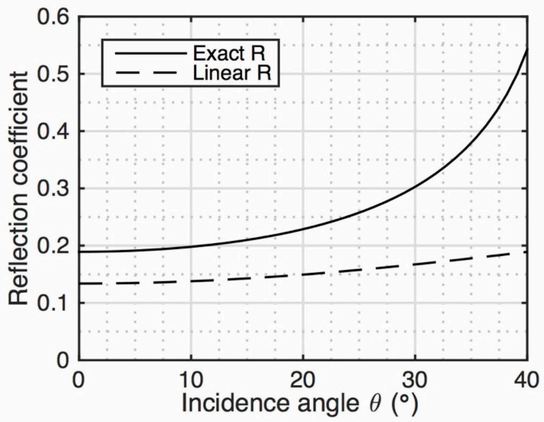

Fig. 1. We exemplify the need for nonlinear sensitivities with an AVO inversion procedure. Here a reflection coefficient is plotted in comparison with its linearized approximation. We compare iterative linear vs. iterative second order inversion, focusing on convergence rate, accuracy and stability.

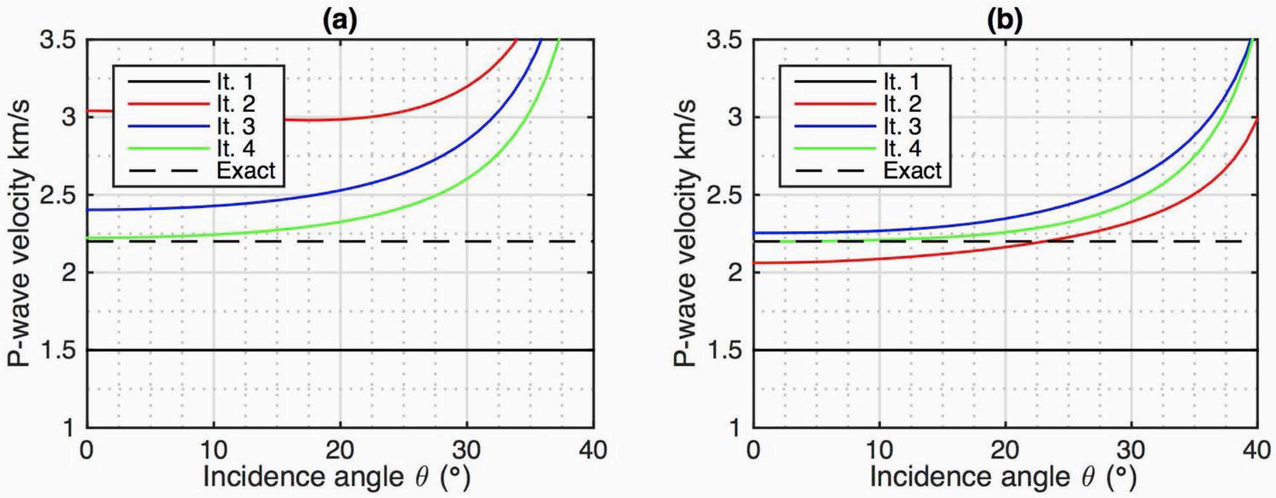

Fig. 2. (a) Iterative linear inversion of R in Figure 1, compared against (b), an iterative nonlinear (2nd order) AVO scheme. Upticks in convergence rate, stability, and angle range are notable. This motivates the search for extended FWI theories: currently no Newton type update generalizes iterative nonlinear AVOI.

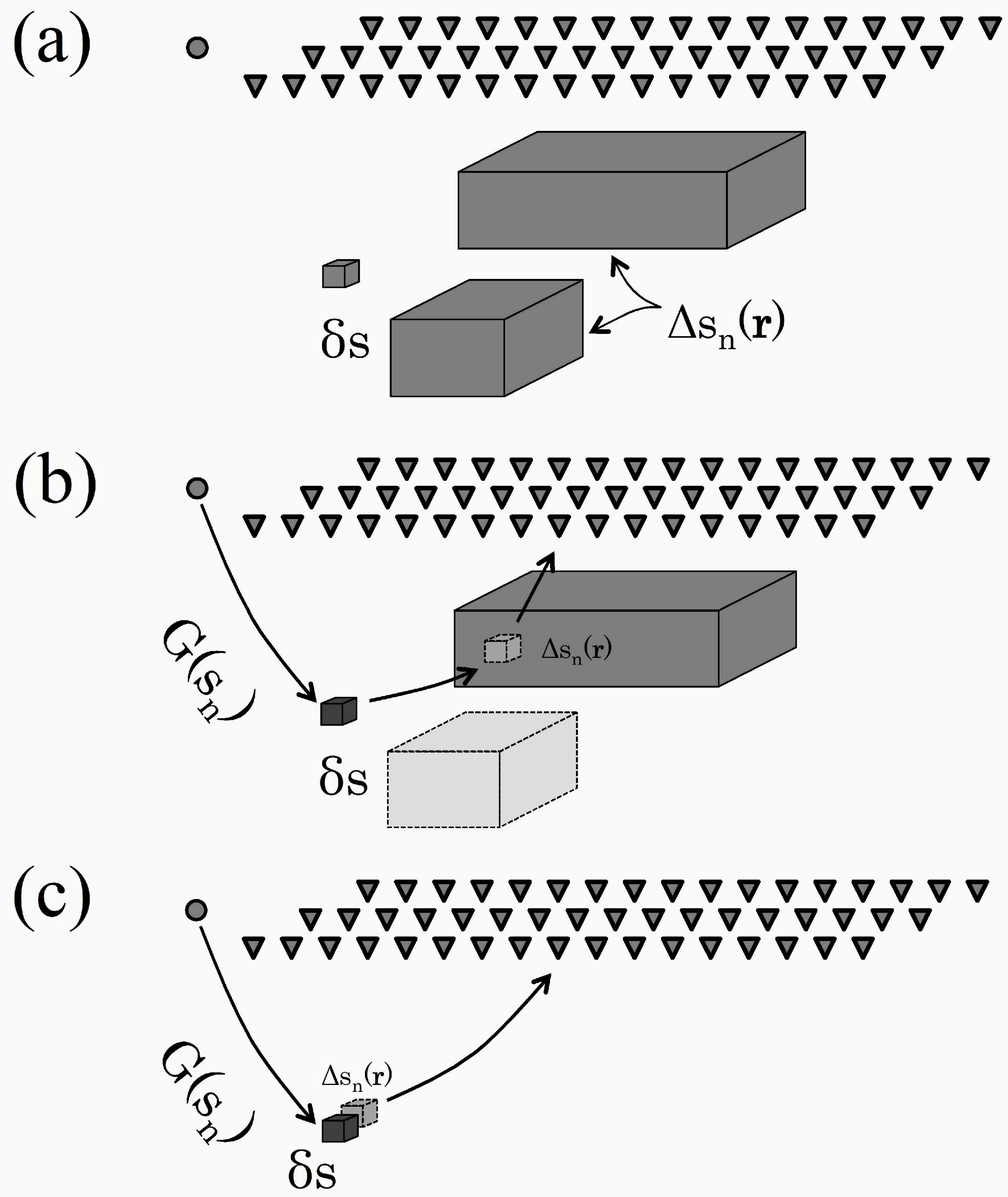

Fig. 3. The current theory generates sensitivities by varying the field G in orders of both the output point δs and the update currently being constructed, Δs. (a) Scattering processes between these two types of perturbation are gathered to generate extended sensitivities. Then, inverse scattering techniques are used to exchange Δs with the current residuals. This results in residual dependent FWI updates which are shown to reproduce at least two familiar nonlinear direct inverse results. Nonlinear impedance inversion is recovered by constructing a gradient which is sensitive to the unreconstructed component of the overburden (b); nonlinear AVO inversion is recovered with collocated update and variational positions (c).

Full development, citations, and acknowledgments, are in the CREWES report.