Geophysical Research Abstracts
Vol. 12, EGU2010-2108, 2010
EGU General Assembly 2010

Inversion of seismic and georadar reflection data for the spatial correlation structure of subsurface velocity heterogeneity

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An important problem in many geological and geophysical studies is the accurate geostatistical description of subsurface heterogeneity. Boreholes provide detailed information in the vertical direction, but are generally too sparsely distributed to provide useful information in the horizontal direction. As a result, a number of researchers have explored the relationship between the correlation properties of seismic and georadar reflection data and those of the underlying velocity structures. Although some of these efforts have shown promise, the development of an analytically correct and physically realistic model relating the spatial correlation structure of a back-scattered seismic or high-frequency electromagnetic wavefield to that of the scattering medium has so far been unavailable. Here, we address this issue based on the assumption that weak scattering prevails and that the observed seismic and georadar data can be adequately depth-imaged. While testing the developed model, we found that an essential element for its successful application is correctly accounting for the lateral resolution limits of a depth-imaged reflection section. We then use our model within a stochastic inversion framework to recover the nature of the spatial correlation of the underlying velocity structure from synthetic seismic and georadar reflection data scattered from realistic, strongly heterogeneous subsurface models. For this, we employ the Generalized Likelihood Uncertainty Estimation (GLUE) method, which involves repeatedly testing sets of parameters drawn from a prior distribution and then either accepting or rejecting these configurations based on how well they allow us to fit the autocorrelation of the seismic and georadar data. Our results indicate that the newly developed methodology not only provides an effective means for constraining the spatial correlation structure of the probed subsurface region, but also allows for exploring and characterizing the uncertainty and non-uniqueness associated with the inferred parametric models.