Surface Consistent Surface-Wave Inversion
Christine E. Krohn and Partha S. Routh, ExxonMobil Upstream Research Company

A tomographic method (SWIPER) is used to invert surface-seismic data to estimate variable surface-wave properties. Surface consistency of multi-source, multi-receiver data is exploited to decompose the data in the frequency domain into frequency-dependent propagation (i.e., velocity and attenuation) effects and variable source- and receiver-coupling effects. The inversion can be performed for single modes (linear optimization) or simultaneously for multiple modes (nonlinear optimization). Including source- and receiver-coupling variations improves the ability to estimate velocity and attenuation. Further improvements in the estimation are made by constraining the parameters to be a smooth function of frequency. The estimated model parameters, such as velocity dispersion relations, can be used to predict the multi-mode ground roll and subtract it from the data with little damage to reflections or to invert for a near-surface depth model.

The properties of the near-surface vary rapidly in both vertical and horizontal directions. Consequently, the behavior of ground roll also varies both with frequency and with position along the surface. Traditional methods of surface-wave analysis, such as the MASW, have limited resolution because they effectively average properties over the maximum source-to-receiver distance in the gather. For example, because slant stack sums over the traces in the gather, variability within the gather is averaged. Additional limitations arise from the difficulty in picking the maximum amplitudes in the transform domain because of limited velocity resolution, noise, and interference of multiple modes. Fully exploiting the multi-shot and multi-receiver aspect of 3-D surface seismic data allows the determination of variable surface-wave parameters within a fine grid of surface cells using direct-ray tomography. At the higher frequencies, however, multi-mode behavior and their interference must be included. Amplitude and phase effects are coupled and must be determined by a nonlinear optimization method. We show the ability to determine for a receiver-interval sized grid multi-mode velocity and attenuation parameters, which after horizontal smoothing match those determined with a beam-forming method.