Application of Regional Phase Amplitude Tomography to Seismic Verification


Abstract — We have applied tomographic techniques to amplitude data to quantify regional phase path effects for use in source discrimination studies. Tomography complements interpolation (kriging) methods by extending our ability to apply path corrections into regions devoid of calibration events, as well as raising levels of confidence in the corrections because of their more physical basis. Our tomography technique solves for resolvable combinations of attenuation, source-generation, site and spreading terms. First difference regularization is used to remove singularities and reduce noise effects.

In initial tests the technique was applied to a data set of 1488, 1.0 Hz, $P_p/L_p$ amplitude ratios from 13 stations for paths inside a 30’ by 40’ box covering western China and surrounding regions. Tomography reduced variance 60%, relative to the power-law distance correction traditionally applied to amplitude ratios. Relative $P_p/L_p$ attenuation varied with geologic region, with low values in Tibet, intermediate values in basins and high values for platforms and older crust. Spatial patterns were consistent with previous path effect studies in Asia, especially local earthquake coda-$Q$. Relative spreading was consistent with expected values for $P_p$ and $L_p$. Relative site terms were similar to one another, yet some tradeoff with attenuation was evident.

Tomography residuals followed systematic trends with distance, which may result from the evolution from direct to coda phases, focusing, model tradeoff or data windowing effects. Examination of the residuals using a kriging interpolator showed coherent geographical variations, indicating unmodeled path effects. The residual patterns often follow geological boundaries, which could result from attenuating zones or minor blockages that are too thin to be resolved, or that have anisotropic effect on regional phases. These results will guide efforts to reparameterize tomography models to more effectively represent regional wave attenuation and blockage. The interpolated residuals also can be combined with predictions of the tomographic model to account for path effects in discrimination studies on a station by station basis.

Key words: Discrimination, tomography, path correction, $L_p$ blockage.

Introduction

Removing the effects of propagation path on seismic amplitudes allows us to isolate source signatures, which should lead to more effective discrimination between natural and man-made events. The Comprehensive Nuclear-Test-Ban Treaty (CTBT) requires us to monitor small events, which increases the importance of

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recordings collected at regional distances. Path variations are strong at regional distances because ray paths sample the heterogeneous crust and upper mantle. Thus quantification of regional path effects is a crucial effort for extending Test Ban monitoring techniques to small events.

Path effects include intrinsic attenuation of different crust and upper mantle media, scattering or blockage by structural discontinuities, lateral refraction and multipathing. Seismograms from Tibet and from the Baikal rift, recorded at Lanzhou (LZH) in central China demonstrate the effects different paths can produce on phase amplitudes in a tectonically complex region (Fig. 1). Note the large and impulsive \( L_g \) phase from the Baikal event, compared to the lack of \( L_g \) from the Tibet event, relative to the \( P \) phases. Such behavior has been well documented in China and surrounding regions (e.g., RUZAIKIN et al., 1977; McNAMARA et al., 1996; RAPINE et al., 1997).

Our strategy is to predict path effects on earthquake data by whatever means, and use this information to improve event identification and magnitude estimates on a station by station basis. To facilitate the event identification, corrections are expected to reduce the scatter in the earthquake population of discriminant ratios such as \( P_n/L_g \) (e.g., TAYLOR et al., 1989). In addition, the corrections eliminate the effect of path on any separation between earthquake and explosion populations, and may act to increase or decrease that separation. Decreasing the separation is not necessarily detrimental; otherwise, we employ a practice of identifying events based on their path effects, which in many cases, is just a complicated way to discriminate based on event

![Figure 1](image)

Sample, vertical component, broadband seismograms from the Baikal rift (top) and from eastern Tibet (bottom), recorded at LZH. The seismograms have been high-pass filtered at 0.5 Hz and aligned on their \( P_n \) arrival times. The \( L_g \) arrival is marked at its expected position in the Tibetan event record. Event (circles) and station (triangle) locations are indicated on the map.