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Determination of Source Parameters at Regional Distances With Three-Component Sparse Network Data

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We find remarkable similarities between regional body waves recorded by the TERRAscope network of broadband stations and synthetics constructed from a standard southern California velocity model. This model is shown to be effective for a variety of azimuths and ranges throughout southern California. At short periods some of the relative timing of the body waves are discordant, but at longer periods this becomes less of a factor. Thus we have developed a waveform inversion technique to rapidly determine source parameters using stored Green's functions for events out to 500 km, well outside the TERRAscope network. Often, only the three-component records of a single station are required because the ratio of SV to SH energy is dependent upon source orientation. Sensitivity analyses examining the effects of source mislocations and velocity model on the inversion results show that the long-period body waves appear relatively insensitive to lateral mislocations but are sensitive to source depth. However, the choice of velocity model can be a factor in obtaining reliable estimates of source depth. In this study the October 24, 1990, ($M_w = 5.2$) Lee Vining and the December 3, 1991, ($M_w = 5.1$) Baja California events are used to demonstrate the effectiveness of the inversion method. For the Baja event, we obtained unique results using a single station. For the Lee Vining event, inversions using a single station were not as stable. However, we found that using two stations with only a 24° aperture provided enough constraint to obtain unique results.

INTRODUCTION

The regional networks of broadband instrumentation currently being installed are expected to improve our understanding of wave propagation and source problems. Progress has been made in studying wave propagation at regional distances using the broadband, whole waveform data [*Helmberger et al.*, 1992*a,b*; *Zhao and Helmberger*, 1991]. These studies are providing information about both the P wave and S wave velocity structures. At local distances the study of wave propagation is further complicated by the greater influence of near-surface lateral heterogeneity and the small time separations between direct, reflected, converted, and surface wave phases; however, it seems possible to model the data broadband with simple, regionalized upper crustal models [*Dreger and Helmberger*, 1990].

The broadband characteristics of the high-quality data are especially useful because they allow the selection of the bandwidth which is the most sensitive to the problem at hand. Long-period data have traditionally been found to be particularly useful in source problems. There are numerous examples of the use of teleseismic body waves to obtain estimates of source parameters of large earthquakes ($m_b \geq 6.0$) in the literature. Smaller events, however, are recorded with poor signal-to-noise ratios at distances greater than 30°. This is especially true for strike-slip earthquakes that have a P wave radiation node for diving energy. In addition, surface wave studies at teleseismic distances are also subject to poor signal-to-noise ratios for moderate sized earthquakes. To circumvent this problem, data recorded at regional distances ($1° - 12°$) are used. Although the regional waveforms are relatively more complicated, the long-period P_{nl} waves are relatively stable (i.e., change slowly with distance) [*Helmberger and Engen*, 1980] and have proven to be quite successful in source inversions [*Wallace et al.*, 1981]. *PL* waves propagating in the upper crust (along a shallow interface at approximately 4 to 6 km depth) also appear to be stable and are useful in obtaining source parameters of earthquakes in the near-regional distance range (100 km to 300 km) [*Dreger and Helmberger*, 1991*a*]. There is evidence that source depth can be resolved with the long-period data [*Dreger and Helmberger*, 1991*a,b*], but source time histories and other higher-order source processes such as directivity and/or distributed rupture require shorter-period information and an Earth structure that adequately explains the short-period propagation characteristics. The wide dynamic range of these systems allows studies of both small and large earthquakes in a given source region enabling the isolation of source and

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