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Short Note

Source parameters from near regional earthquake data recorded at Garm, Tadjikistan

Christine Ecker[1]

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INTRODUCTION

In recent years, numerous efforts have been made to improve the accuracy of regional event location from single station data by using travel time and azimuth information (Magotra et al., 1987; Ruud et al., 1988; Thurber et al., 1989). Ruud et al. (1988), and Thurber et al. (1989) claimed that not only the epicenter but also the source depth can be constrained accurately with this information. Furthermore, Langston (1987), and Dreger and Helmberger (1991) showed that additional waveform modeling can increase the precision of the depth estimates and yield information on focal mechanism. The purpose of my study is to explore the utility of new IRIS data recorded at Garm, Tadjikistan, for locating regional earthquakes and determining source parameters by using travel times, azimuth data and detailed waveform analysis. Three intermediate depth earthquakes from the Hindu Kush seismic zone are used for this purpose. Because relatively little is known of the wave propagation in this region from past geophysical studies, it is essential to investigate the structure effect. This is attempted by performing a receiver function study of four teleseismic events. P, S, SsPmp phases and azimuth data are then used to determine possible depths and distances of the regional events. Travel time curves and synthetic seismograms generated by a wavenumber integration method put constraints on the source parameter estimates. Fault plane solutions are obtained by a grid search comparing relative amplitudes in the real data with those in the synthetic Green's functions.

[1]**email:** not available

SOURCE PARAMETER DETERMINATION

Receiver Function Study

In order to get accurate source parameter estimates from single station information, the whole waveform has to be analyzed. In this process, knowledge of the local velocity structure is essential. To investigate the local structure directly, a one-dimensional receiver function study of four teleseismic events was performed. A receiver function study isolates the local structure response from all other factors which interact to form the observed seismogram (Langston, 1979). The information in these so-called receiver functions is then translated into a simple model of local velocity structure by using an inversion method developed by Ammon et al. (1990). The initial crustal model for this analysis was adapted from Soviet Deep Seismic Sounding surveys.

The receiver function data showed large tangential components, with the radial components showing large scattered phases directly after direct P. The scattered phases appear to be composed of Rayleigh waves, based on particle motion. In order to examine possible topographic scattering indicated by the Rayleigh phase, synthetic seismograms were constructed using the T-matrix method. This method uses the extinction theorem to derive two matrices that relate the incident waves to the scattered waves, and to the waves on the surface (Lakhtakia et al., 1984; Clouser, 1992). The resulting scattered phases, however, were not large enough to explain the data. Therefore, the observed data have to be caused mainly by crustal scattering. The complexity of the receiver functions suggests that the crustal structure near Garm has significant lateral heterogeneities. The receiver function method, however, gets accurate results for homogeneous layers, a fact which makes the finding of an accurate crustal model from the teleseismic data impossible. Since it was not possible to determine the crustal structure directly, I used the initial model that was given by the DSS surveys in the following location study.

Regional Earthquake Study

Three deep Hindu Kush events were then analyzed to explore the utility of data from Garm for locating regional earthquakes and determining source parameters. Since the previous receiver function study indicated complex crustal structure at Garm, attenuation caused by scattering and anelasticity was investigated by a spectral ratio study. Attenuation is potentially important in controlling the differential amplitudes of P and S waves which are needed in the source mechanism study. The results, however, showed that waves from all events traversed areas of high Q_s (which is the frequency independent S wave quality factor) indicating that attenuation has nearly no effect on the amplitudes. A following sensitivity study using synthetic Green's functions showed the same result.

Observed direct P, S and SsPmp phases and times were then used to infer back-azimuth, depth and distance, locating the events. The SsPmp phase appeared to be the major secondary phase that could be identified in the regional seismograms. ”S” represents the direct S wave traveling from the source. The small s is the S wave after transmission at the moho. After the conversion at the free surface, the wave travels as P down to the moho where it is reflected. The small p is the upgoing P wave from the moho. Possible focal mechanisms were obtained by a grid search program that uses arrival amplitudes of synthetic Green’s functions as an input. The Green’s functions were generated by a wavenumber integration method developed by Barker (1984) using the determined depth and distance of each event. By integration over horizontal wavenumber or slowness, a complete seismogram is obtained. To increase the accuracy of the source parameter estimates, synthetic seismograms were computed and the waveforms were compared with the observed data. The synthetics were generated by combining the obtained Green’s functions with the focal mechanisms. Using time versus depth and time versus distance synthetic moveouts, the change of the P, S and SsPmp phases in shape and timing to each other could be determined. In this way, constraints could be put on the source parameter estimates. Figure **??** shows the observed data of the three Hindu Kush events and the synthetics generated by the wavenumber integration method.

The first event is the event of the 16th of April 1991. Three clear distinct phases, namely direct P, direct S and SsPmp, could be identified in the data. Based on this information the event could be located at a backazimuth of 161°, a depth of 110 km and a distance of 320 km. The uncertainties were only ±5 km in depth and ±2 km in distance. The PDE (Preliminary Determination of Epicenters) location of this event gives a backazimuth of 164.4°, a depth of 127 km and a distance of 296 km. Considering the fact that PDE locations can have an error of up to ±50 km, the respective location lies within the probable error of the PDE location. One possible focal mechanism was obtained for a determined depth of 110 km and a distance of 320 km. It had a strike of 350°, a dip of 10° and a rake of 165°. Its T-axis was plunging 46.8° to the north. The variations in this mechanism are small, being only ±15°. Due to the three different phases used in the grid search, this event is reasonably well constrained.

The second event is the event of the 4th of June 1991. It was located less accurately than the first event due to the fact that the SsPmp phase interfered with the direct S phase so that clear identification of its arrival time was not possible. This increased the uncertainties in the results. The event was located at a depth of 208 km which could vary from 190 km to 225 km. The resulting distance was 283 km and could vary from 275 km to 288 km. The backazimuth was determined to 198.5°. The original PDE location gives a backazimuth of 194.5°, a depth of 160 km and a distance of 283 km. Still, both locations are in good agreement. The obtained focal mechanism had a strike of 45°, a dip of 20° and a rake of 205°. The deviations in the mechanism are slightly higher than those of the first event.

The third event occurred on the 11th of February 1991. Its analysis showed that the coda level is very large, dominating over small amplitude phases. This large coda level is caused by the lateral heterogeneities around Garm. Due to the fact that the coda is masking low amplitude phases, only first P and S could be identified in the data. This makes an accurate location estimate impossible. Based on only the S-P travel time, the event was located at a depth of 180 km or deeper, a distance of 275 km or less and a backazimuth of 187°. Considering these limits, the source parameters could still agree with the PDE depth of 217 km, distance of 256 km and backazimuth of 183.3°. Many different focal mechanisms could be obtained for the determined range in depth and distance. They varied essentially in the T-axes, but the P-axes were in fairly good agreement with each other plunging approximately to the south. These large variations are based on the very limited phase information in this event.

Possible Error Sources

The possible error sources in this study can be summarized as follows:

- measurement errors in backazimuth and travel times
- errors in the backazimuth due to the complex three-dimensional structure around Garm caused by arrivals off-azimuth
- large coda levels that mask small amplitude phases
- one-dimensional velocity model
- possible variations in the velocity model, e.g. velocity variations or variations in the thickness of the crust

An additional study showed, however, that a change in the velocities does not affect the result very much. A decrease in the crustal thickness of 20 km results in a change of ±10 km in the event depth. This would still be a reasonable result. Furthermore, it is unlikely that the thickness varies as much as 20 km. Therefore, the error caused by possible variations in the crustal model should not be too large.

CONCLUSIONS

It can be concluded that the utility of data recorded at Garm for analyzing location and source parameters of regional earthquakes is good as long as the data are not too much affected by the heterogeneities in the crust. If three different, distinct phases can be identified, the depth can be constrained within 10 km and the distance within 4 km. Identification of two distinct phases and one indistinct phase results still in an accuracy of approximately ±18 km in depth and ±7 km in distance. High coda level and indistinct phases, however, destroy accuracy.

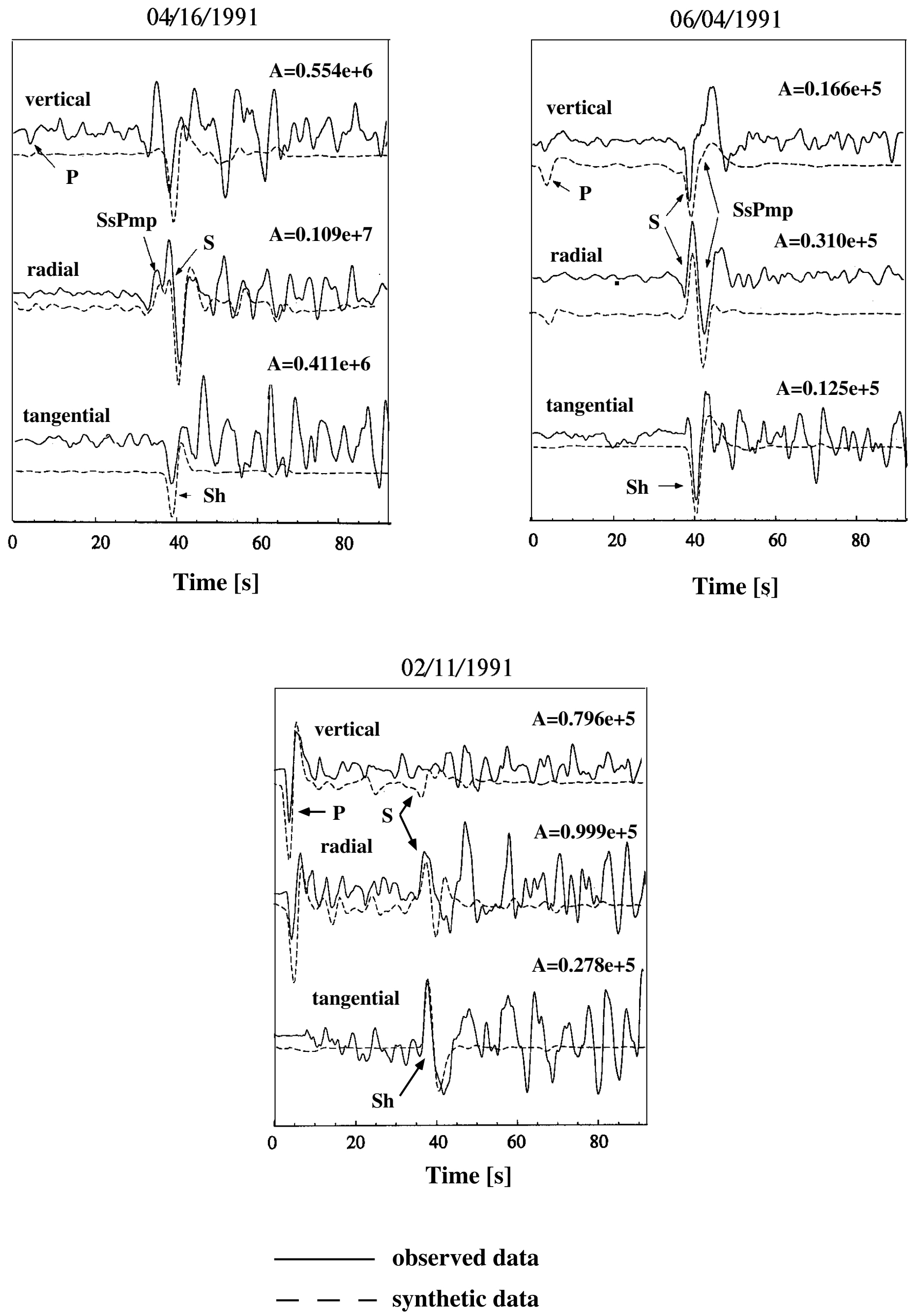

Figure 1: The synthetics of the three events, generated with the determined source parameters, are compared with the observed data of the three events. **A** gives the maximal overall amplitude in units of counts. christine-synth [NR]

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