TRAVEL TIME RESIDUALS FROM THE NEW AND OLD SEISMIC NETWORKS OF PAKISTAN AND PRELIMINARY HYPOCENTER DETERMINATION

Nasir Mahmood* **Supervisor: Tatsuhiko HARA****
MEE07163

ABSTRACT

The Pakistan Meteorological Department has started establishing a new digital seismic network in 2006. We evaluated data from this new network, and performed preliminary hypocenter determination. First, we checked detectability of new stations to find that the detection capability of the Islamabad station seems better than the Peshawar and Quetta stations in new network. Then, we calculated theoretical P and S wave travel times using USGS hypocenters. We compared them to the observed travel times from the new and old Pakistan seismic networks to obtain travel time residuals. For station Quetta in the old analog network, the P and S readings are less accurate than those from the new network. Taking these uncertainties into account, we performed preliminary hypocenter determination of events in the Hindu Kush region using data with relatively smaller residuals. We used two earth models: the one is iasp91 and the other has a crust structure from CRUST 2.0. Most of the events are located in the depth range consistent with USGS focal depths when we used iasp91, while the distances between the epicenters issued by the USGS and those determined using iasp91 are larger (on the order of 50 km) than those when we used the latter model (on the order of 25 km). Probably due to the small number of data and not good station configuration to events in the Hindu Kush region, the dependence of hypocenters on crust models is strong. We expect it will be possible to improve accuracy of hypocenters by expanding our seismic network with carefully checking data.

Keywords: New digital seismic network, Travel time residuals, Hypocenter determination, Hindu Kush Region.

INTRODUCTION

The seismic networks in Pakistan

An advanced earthquake monitoring system is necessary for countries such as Pakistan surrounded by the active seismic zones. At the time of the October 8th 2005 Kashmir earthquake, there was a small analog seismic network of six stations including one digital station at Peshawar, which were operated by the Pakistan Meteorological Department. The performance of this network was not sufficient, and a denser seismic network with modern communication and recording systems is necessary to enhance the monitoring capability.

The Pakistan Meteorological Department has deployed a set of new broadband Guralp sensors (CMG 40T) at Islamabad, Peshawar, Quetta and Balakot in 2006. *Scream 3.0* software was installed for seismic data acquisitioning on a real time basis at each station. Seismic signals

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*Pakistan Meteorological Department, Ministry of Defense, Pakistan.
** International Institute of Seismology and Earthquake Engineering, BRI, Tsukuba, Japan.

were digitized at 24 bits with a sampling rate 100 sps at each station. Both Islamabad and Peshawar stations are linked via telephone line to exchange the seismic data, while other stations were under consideration to be linked. This new seismic network is expected to enhance the earthquake monitoring capability (although it is desirable to increase the number of stations particularly in areas close to seismically active zones). In this study, we evaluated data from this new network, and performed preliminary hypocenter determination. First, we checked event detectability of the new stations.

Event detection capability and data quality of new network

The Islamabad station CMG 40T sensor in new network has recorded relatively a larger number of events, which suggests its better detection capability. The smallest event of magnitude M=3.3 detected at epicentral distance 120 km. An event (M=6.1) with epicentral distance of 728km in the north direction was recorded with clear P and S phases. Detection capability of CMG 40T sensor at Peshawar station was poorer than the Islamabad station. Some of the events in the Hindu Kush region recorded at Islamabad but can not be recorded at the Peshawar station, although they are closer to Peshawar than to Islamabad. At Peshawar, another sensor, S-13, has been deployed, and its detection capability is much better. Many events that are not detected by CMG 40T sensor are recorded by this sensor. Due to unstable power condition, instrument handling and some technical problems only a few events were found from the observed records of CMG 40T sensor of Quetta station. The detection capability of this station is very poor compared to the Peshawar and Islamabad stations. All of the events recorded by the Islamabad, Peshawar and Quetta stations between 2006 and 2007 are shown in Fig. 1.

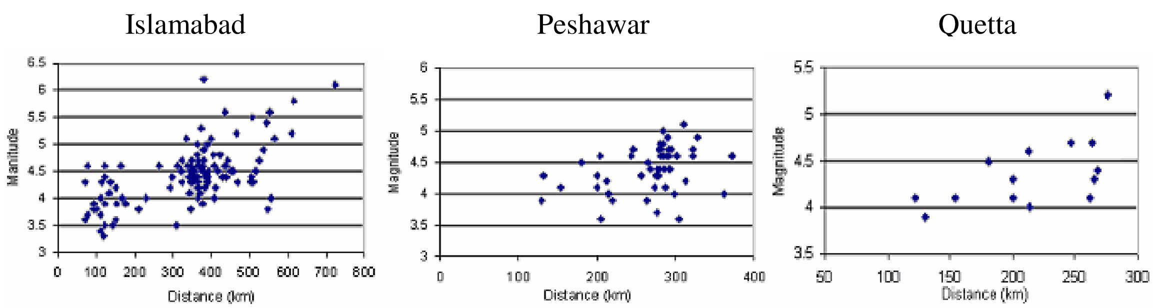

Figure 1. Events detected by CMG 40T sensors at Islamabad, Peshawar and Quetta stations

However the WWSSN system at Quetta recorded more events, and we used these data in the following part of this study. Similarly quality of seismic data from the Islamabad station was found comparatively better than those of the other stations in new network. Noise level of the observed records of Islamabad (CMG 40T) was quite low. A local event of M=3.5 was recorded with clear arrivals of P and S waves. For Peshawar station (CMG 40T), larger noise level observed and it was difficult to pick P arrivals for smaller events of magnitude M ≤ 4.0 only S phase was clear. Similarly it was difficult to pick S phase for smaller events from the CMG 40T records of Quetta station. A possible problem of noise levels may come from the local site condition of the sensor for both these stations.

TRAVEL TIME RESIDUALS FROM NEW AND OLD SEISMIC NETWORKS

In this study we used data from the new network of Guralp sensors (CMG 40T) at Islamabad and Peshawar stations, S-13 sensor of Peshawar station and the old WWSSN system of Quetta station for the period 2006-2007. The main aim was to check the accuracy of data from the observed record of the new and old networks and investigate factors causing discrepancies in the data. We used the SEISAN version 8.1 (Havskov and Ottmoller, 2005) software to manipulate and analyze the digital waveform data. The digital data obtained from the new network was first converted from Guralp (GCF) to SEISAN format. Arrival times for P and S waves were picked for all possible events from each station. Observed travel times for P and S waves were obtained by subtracting origin times (issued by the USGS) from observed arrival times for each station. Theoretical travel times for P and S waves were calculated using TauP toolkit software (Crotwell et al., 1999) and iasp91 model (Kennett and Engdahl, 1991). Travel time residuals for P and S waves as well as S-P times residuals were computed using the observed and theoretical travel times. In this way we compared observed and theoretical travel times to check the accuracy of data from the new and old networks and found following results for three stations Islamabad, Peshawar and Quetta.

Data from Islamabad station

Figure 2(a) shows a comparison between observed and theoretical P wave travel times for the Islamabad station. There was a general agreement between them, while they differ considerably for some events. Figure 2(b) shows the comparison for events whose magnitudes are equal to or greater than 4.5. Most of the data which show large differences are removed. This suggests that there are many misidentifications for smaller events. We made similar comparisons for S travel times and S-P times and find a general agreement between observed and theoretical times.

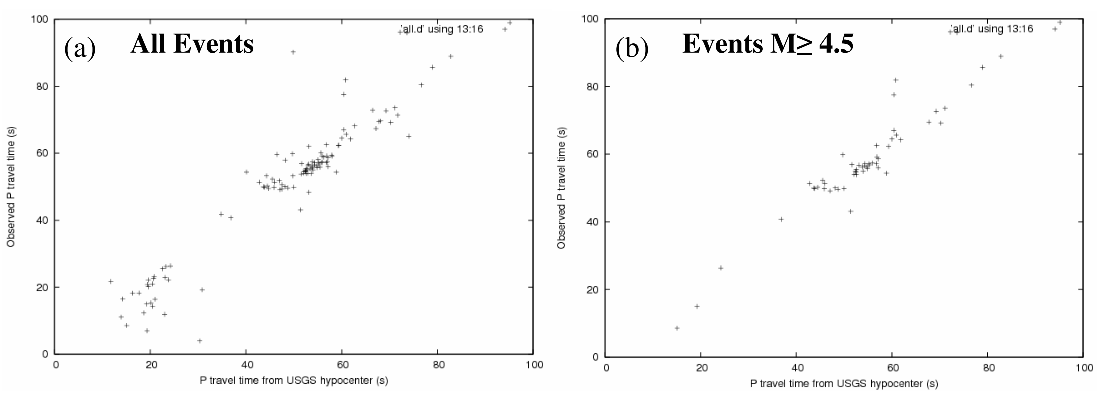

Figure 2. Comparison of observed and theoretical P wave travel times for Islamabad station.

Figure 3 shows the frequency distributions both for P and S travel times and S-P times respectively for the Islamabad station. The P travel time residuals show a peak around 2 sec and most of the observations are within the range of 0 – 5 sec. The S travel time residuals show a larger scatter, and most of the observations are within the range of -3 – 3 sec.

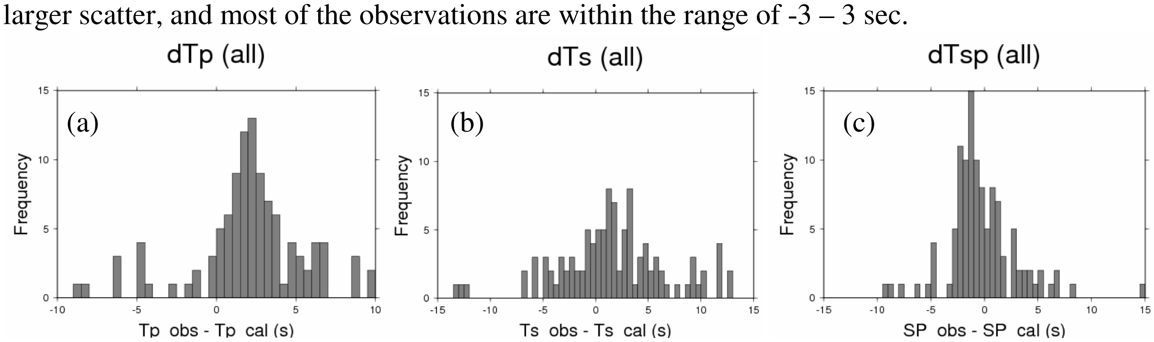

Figure 3. Frequency distributions of P travel time residuals (a), S travel time residuals (b), S-P time residuals (c), respectively, for Islamabad.

Since there is not a large systematic deviation from 0 both for P and S wave travel time residuals, it is possible to use absolute travel times in the following hypocenter determination.

Data from Peshawar station

Figure 4 shows the frequency distributions of the P and S travel time residuals and S-P time residuals for Peshawar station (CMG 40T). P wave travel time residuals show a peak around 2 sec ad most of the observations are within the range of -1 – 5 sec while S wave travel time residuals show a larger scatter and most of the observations are within the range of -5 – 4 sec. S-P time residuals are within the range between -5 – 2 sec. Similarly we used absolute travel times from this station in the following hypocenter determination.

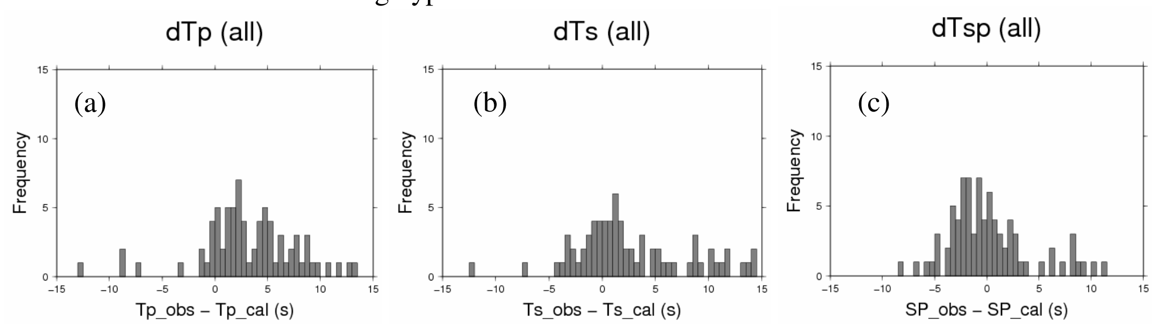

Figure 4. Frequency distributions of P travel time residuals (a), S travel time residuals (b), S-P time residuals (c), respectively, for Peshawar.

Data from Quetta station

Figure 5 show the frequency distributions of the P and S travel time residuals and residuals of the S-P times for WWSSN of Quetta station. Both P and S wave travel time residuals show larger scatters. S-P time residuals are comparatively better. We preferred S-P times from this station.

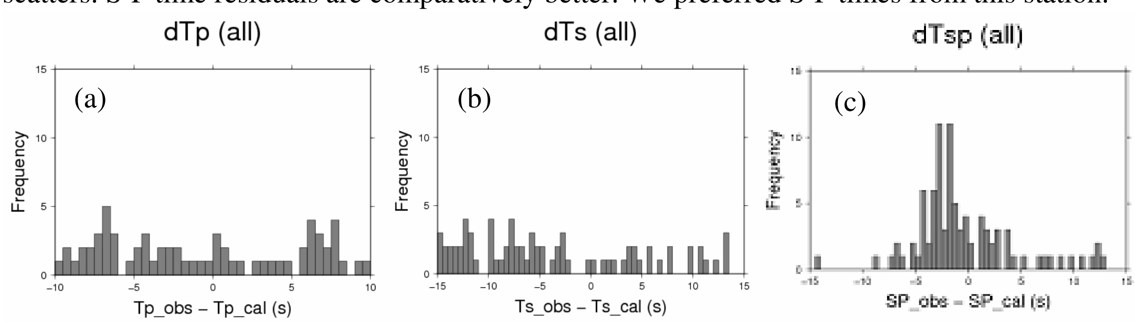

Figure 5. Frequency distributions of P travel time residuals (a), S travel time residuals (b), S-P time residuals (c), respectively, for Quetta.

HYPOCENTER DETERMINATION

In installation of the new digital network, the primary emphasis was to increase the number of stations. Seismic data analysis was mostly carried out manually including earthquake location, and sometimes manual results were not satisfactory or very poor. One of the main objectives of this study was to improve the techniques of hypocenter determination to obtain better results. Since data for an event from all the three stations of the new network were not available, we used data from the analog network as well. Arrival time data from the Islamabad, Quetta and Peshawar stations were used for hypocenter determination.

Software

We used earthquake analysis software SEISAN 8.1 (Havskov and Ottemöller, 2005). After putting data into SEISAN database, we converted waveform data format from Guralp format (GCF) to SEISAN format. Mulplt command is used to plot waveform data for picking P and S phases.

We used HYPOCENTER 3.2 program (Lienert et al., 1986) under SEISAN environment for hypocenter determination. This program has the capabilities to locate earthquakes locally, regionally and globally. Least-squares method works behind this program, in which arrival-time residuals are minimized to get a new set of location parameters. The procedure is repeated through an iterative process till an acceptable error criterion is met. The final adjusted parameters are then accepted as the best possible estimate of the source location.

Crustal Structure

Because there is no velocity model which has been built beneath the country, and most of the analysis carried out manually before, it is necessary to search for a velocity model to carry out earthquake location. We used two models: the one is iasp91 (Kennett and Engdahl, 1991) and the other is the P6 type from CRUST 2.0 (Bassin et al., 2000). This model is available at http://mahi.ucsd.edu/Gabi/rem.dir/crust/crust2.html. Initial guess for hypocenter was set to 15 km.

Analysis and Results

We selected 12 events of the Hindu Kush region for the period 2006-2007 and performed hypocenter determination using arrival time data for P and S waves from the new and old seismic networks of Pakistan. As for data from the Quetta station, based on the results of travel time residuals, we used S-P times. Figure 6 shows comparison between the hypocenters determined using the P6 type from CRUST2.0 and iasp91 with those determined by the USGS.

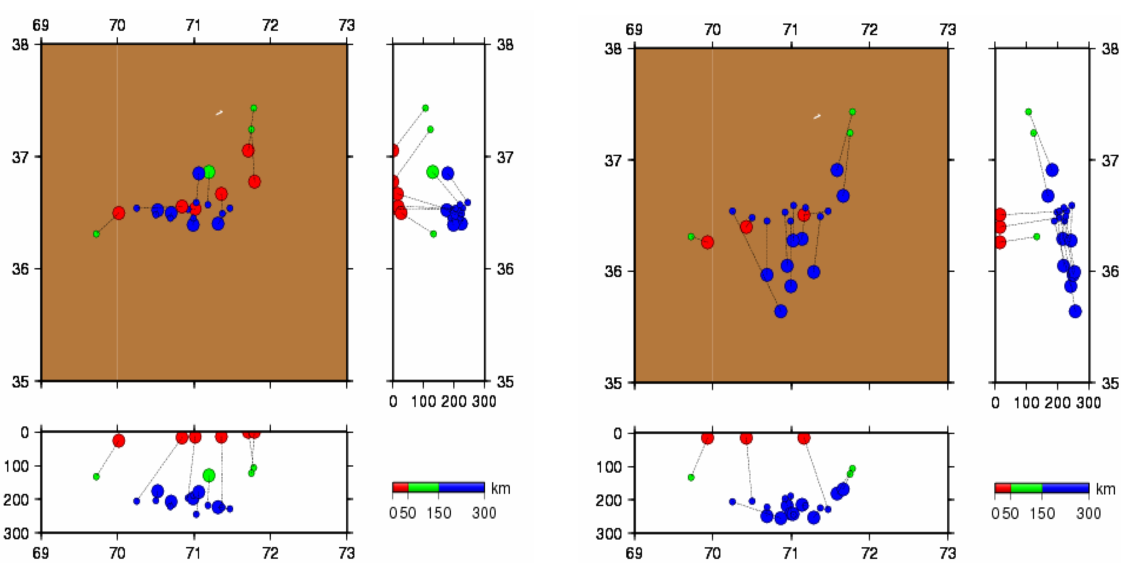

Figure 6. Comparison between the hypocenters obtained for the P6 type from CRUST2.0 (left) and for iasp91 model (right) with those determined by the USGS. Larger and smaller circles denote hypocenters of this study and the USGS, respectively.

The focal depths of the analyzed events determined by the USGS are in the range from 100 to 250 km. Most of the events are located in this range when we used iasp91 model, while the distance between the epicenters issued by the USGS and those determined in this study using iasp91 are larger (on the order of 50 km) than those when we used the P6 mode (on the order of 25 km). Probably due to the small number of data and not good station configuration to events in the Hindu Kush region, the dependence of hypocenters on crust models is strong. We expect it will be possible to improve accuracy of hypocenter determined by expanding our seismic network with carefully checked data.

CONCLUSIONS

In this study, first, we investigated detectability of events. Our results suggest that the detection capability of the Islamabad station seems better than those of the Peshawar and Quetta stations in new network. Then, we calculated theoretical P and S wave travel times using hypocentral parameters of USGS and compared them to those calculated using data from the new and old Pakistan seismic networks to obtain the distributions of travel time residuals. For station Quetta in the old analog network, the P and S readings are less accurate than those from the new network, which resulted in larger travel time residuals.

Considering these uncertainties, we performed preliminary hypocenter determination of events in the Hindu Kush region using data with relatively smaller residuals. When we used iasp91 as an earth model, most of the events are located in the depth range consistent with the USGS estimates. The distance between the epicenters determined by the USGS and those determined using iasp91 are larger (on the order of 50 km) than those when we used the model from CRUST 2.0 (on the order of 25 km). Probably due to the small number of data and not good station configuration to events in the Hindu Kush region, the dependence of hypocenters on crust models is strong.

RECOMMENDATIONS

Based on the results of this study, we recommend the followings.

- The sites of Peshawar and Quetta stations should be examined with appropriate noise level and further site survey while installation of new stations to enhance the quality of data.
- Continuous evaluation of data from stations of the new network will enhance the detection capability and accuracy of hypocenter determination. Therefore, such evaluations as were done in this study should be applied to stations which will be installed in the near future.
- There is a timing problem at the Peshawar station, which should be checked and corrected.
- After collecting enough data, it is desirable to construct an appropriate velocity model for Pakistan

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