USE OF THE KYRGYZ SEISMIC NETWORK TO ASSESS THE PERFORMANCE OF THE INTERNATIONAL MONITORING SYSTEM IN AND AROUND KYRGYZIA

Final Report on Task 1 of DTRA Contract 01-99-C-0019
submitted to

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Task 1: "The contractor shall analyze seismic data from the Kyrgyz regional seismic network to produce a bulletin for the period 1 January 1995 through 30 August 1995. The contractor shall compare this bulletin with the GSETT-3 bulletin for the same coverage area and time period and determine the extent of Kyrgyz seismicity which is not monitored by the GSETT-3 network. The contractor shall complete this Task in the first 12 months of the contract and write a special reports for the Arms Control and Disarmament Agency (ACDA), which is funding this effort. The contractor shall acknowledge ACDA in an appropriate manner in any publications base on this effort."

Summary

In this report we complete Task 1 of Contract DTRA 01-99-C-0019 by comparing the performance of the Kyrgyz broadband seismic network (KNET) and the International Monitoring System IMS (the extension of the GSETT-3 network) in monitoring the regional seismicity of Kyrgyzia and the surrounding areas. Performance parameters include the detection threshold as well as epicentral and depth location capabilities. Although Task 1 defines a time period between 1 January 1995 and 31 August 1995, wherever possible we extended the analysis through 1999 to improve the statistical significance of the conclusions.

We analyzed events reported in the three seismological bulletins listed in Table 1. The KNET Bulletin (KNB) for 1995 - 1999 was provided to us by the KNET Data Center at the Institute of Geophysics and Planetary Physics (IGPP) at the University of California, San Diego (UCSD). The Central Asian Bulletin (CAB) for February - August 1995 was produced by the Joint Seismic Program Center (JSPC) at the University of Colorado at Boulder. The Reviewed Event Bulletin (REB) for 1995 - 1999 was issued by the Prototype International Data Center (PIDC), at the Center for Monitoring Research (CMR), Arlington, Virginia. The KNB does not have magnitude estimates, so the CAB, which was compiled only for seven months in 1995, is used for comparisons that require magnitudes of small events.

This comparison has lead us to the following conclusions.

- The magnitude threshold of the REB is difficult to determine rigorously because of the absence of magnitude estimates in the KNB and the weak correlation between the REB, CAB, and ISC magnitudes. We estimate, however, that the magnitude threshold of the REB for this region is about 4.2 in 1995 and reduces to about 3.5 (Figure 13) later in the decade. As expected, many local events that appear in the Kyrgyz catalogues (KNB, CAB) are not reported in the REB. This totals more than 70% of the events reported in the KNB from 1995 through 1999 within 1,000 km of the center of KNET. The magnitudes of these events (m_b) range from 2.0 to 3.5.

- The hypocentral locations reported both in the KNB and the CAB in 1995 for the events that occurred within 200 km of the center of KNET differ minimally (Figure 10), but

at larger distances differ systematically and significantly. Thus, we consider the KNB locations from 1995 - 1999 to be reliable for events within 200 km of the center of KNET, and use the KNB to estimate hypocentral reliability of the REB for the full time range.

- There are significant differences in the epicentral location of many events reported both in the KNB and the REB within 500 km of the center of KNET. For events located within 200 km of the center of KNET, these differences are attributable to errors in the REB locations. For events with $m_b \geq 5.0$ errors are less than 20 km up to 500 km from the center of KNET. For events with $4.0 \leq m_b < 5.0$ the errors are less than 40 km (Figures 17 and 18), but for smaller events ($m_b < 4.0$) errors are generally above 45 km and may be as large as 75 km.

- The depths of the events reported both in the KNB and the REB within 500 km of the center of KNET differ by more than 20 km for at least 50% of the events. For some events within 200 km from the center of KNET, these differences may be as large as 60 km (Figure 20), and are attributable to errors in the REB depths.

As a part of this work, we deliver to the CMR and ACDA two relational databases in CSS3.0 format: KNB_Jan_Aug_1995 and CAB_Feb_Aug_1995, containing information about all the events reported in the KNB for Jan. - Aug., 1995, and the CAB for Feb. - Aug., 1995, respectively.

1. Introduction

There are several possible ways to evaluate the detection and location capabilities of the International Monitoring System (IMS). One of them, described in detail by Wüster *et al.* (2000), is to compare the Reviewed Event Bulletins (REB) produced by the prototype of the IMS with bulletins issued by the other agencies monitoring global seismicity. Wüster *et al.* use for these purposes the Preliminary Determination of Epicenters (PDE) bulletins issued by the U.S. Geological Survey.

Another approach is to evaluate IMS performance at the regional scale by comparing the REB drawn from IMS data with local bulletins provided by high quality regional networks. An excellent opportunity to apply the second approach exists for a region in Central Asia centered around the Kyrgyzian Republic. Here, the digital broadband network KNET has been in operation for almost ten years (Vernon, 1994). Following this second approach, we analyzed events reported in three seismological bulletins listed in Table 1.

Table 1. Seismological bulletins used in this study

Bulletin	Acronym	Time interval	Network
Kyrgyz Network Bulletin	KNB	1995 - 1999	KNET
Central Asian Bulletin	CAB	Feb. - Aug. 1995	KNET+KAZNET+GSN (ABKT, NIL)
Reviewed Event Bulletin	REB	1995 - 1999	GSETT-3 & IMS

The comparison of the REB and the KNET bulletins (KNB) for this region was started by D. Harvey (1996), who used a limited data set for February, 1995. In this study, we extend the data set comparing these two bulletins to cover the five year time interval 1995-1999. To estimate the range in which the KNB locations are reliable, we compare them with locations reported in the Central Asian Bulletin (CAB) for seven months of 1995. This Bulletin was produced as a result of a joint analysis of data from KNET, several stations of the GSN Network (NIL in Pakistan, ABKT in Turkmenistan), and the KAZNET network in Kazakhstan (Kim *et al.*, 1995). The number of stations used in the CAB locations is almost twice the number used in the KNB. In addition, the azimuthal coverage of regional events in the CAB is more dense than in the KNB. We will demonstrate that the KNB locations are reliable at distances less than 200 km from the center of KNET. Comparing the REB and the KNB bulletins for events that occurred within this range provides information about the detection and location capabilities of the REB in this region of Central Asia. We compare the regional detection thresholds of the REB and the KNB within the 500 km from the center of KNET. We estimate a detection threshold for the REB between m_b of 3.5 and 4 for the REB and a threshold for the KNB of about 3. We identify common (matched) events in these two bulletins, and evaluate relative mislocations and depth differences. We conclude that the errors in locations reported in the REB for the area around KNET can be as large as 50 km. The errors in source depth are also significant and in several cases reach 100 km.

2. Kyrgyz broadband seismic network

The Kyrgyz broadband seismic network (KNET) was installed in the Kyrgyzian Republic by a team of American, Russian, and Kyrgyzian seismologists in the summer of 1991 as a part of the US-USSR Joint Seismic Program (Vernon, 1994, Pavlis *et al.*, 1994). After the demise of the Soviet Union, this network has continued operation under an agreement between IRIS, in the U.S., and the Academy of Sciences of the Kyrgyzian Republic.

Table 2

Kyrgyz Network Stations

Station Code	Station Name	Latitude, φ^0, N	Longitude, λ^0, E	Elevation, km
AAK	Ala-Archa, Kyrgyzstan	42.6333	74.4944	1.6800
AML	Almayashu, Kyrgyzstan	42.1311	73.6941	3.4000
CHM	Chumysh, Kazakhstan	42.9986	74.7513	0.6550
EKS2	Erkin-Sai, Kyrgyzstan	42.6615	73.7772	1.3600
KBK	Karagaibulak, Kyrgyzstan	42.6564	74.9478	1.7600
KZA	Kuzart, Kyrgyzstan	42.0778	75.2496	3.5200
TKM2	Tokmak, Kyrgyzstan	42.9208	75.5966	2.0200
UCH	Uchtor, Kyrgyzstan	42.2275	74.5134	3.8500
ULHL	Ulahole, Kyrgyzstan	42.2456	76.2417	2.0400
USP	Uspenovka, Kazakhstan	43.2669	74.4997	0.7400

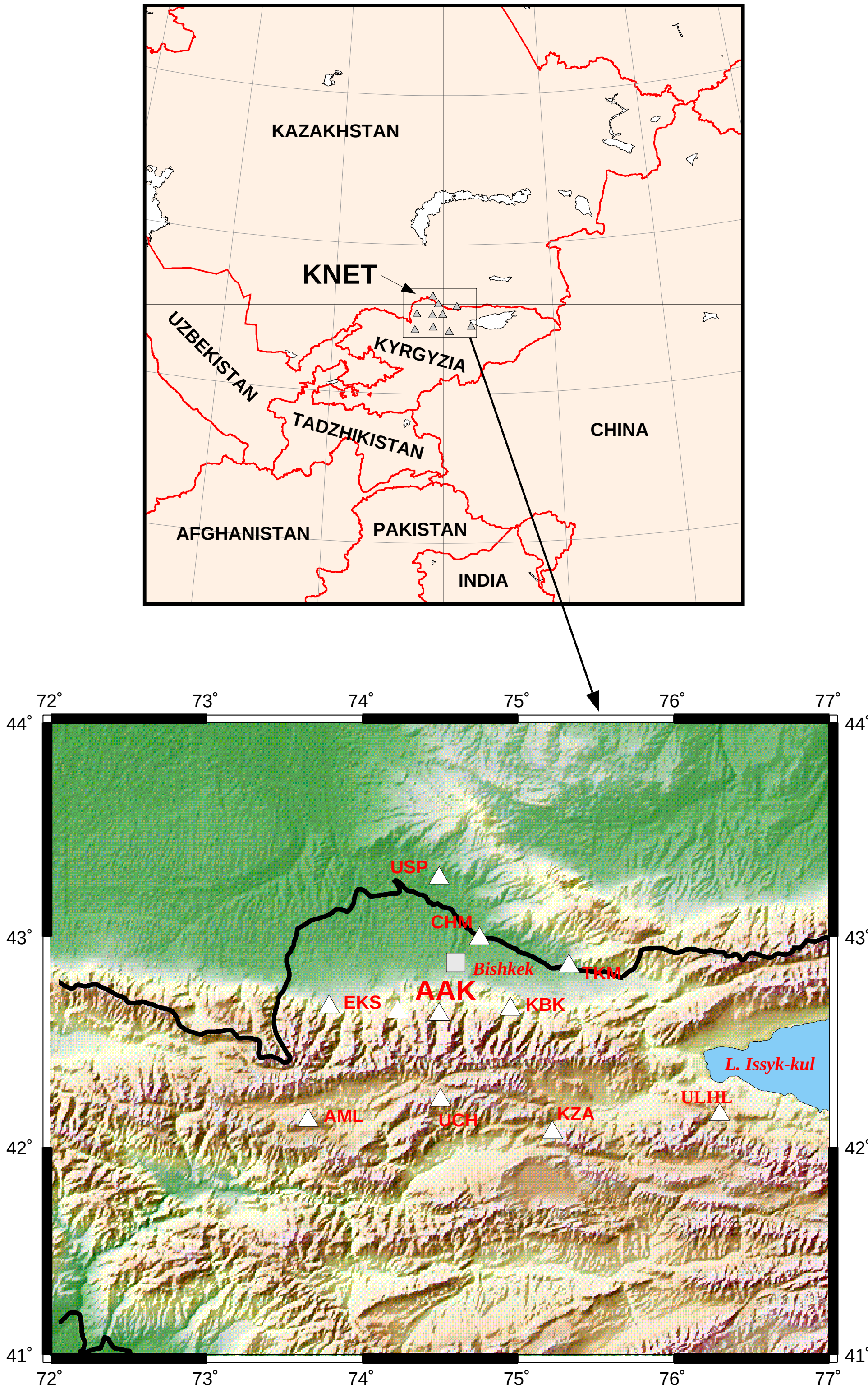

Figure 1: Kyrgyz Network (KNET). AAK is used to represent the center of KNET.

Through August 1999, KNET consisted of ten stations located near the city of Bishkek, the capital of Kyrgyzia. The network is situated in the transition zone between the Kazakh Platform and the high mountain ranges of the Tien Shan. Three stations (CHM, USP, and TKM) sit on the crystalline Paleozoic rocks of the Kazakh platform. The other seven stations lie close to the northern Tien Shan mountain foothills (EKS2, AAK, KBK) or further south in the northern Tien Shan (AML, UCH, KZA and ULHL). Two new stations (NPRT and EPRT) were deployed in August 1999. Information about the network is summarized in the Table 2 and Figure 1 .

Each KNET station is equipped with a Streckeisen STS-2 3-component broadband sensor and a Reftek RT72A-02 datalogger, which creates 100 sps and 40 sps data streams for three high-gain and three low-gain channels. The instrument responses are shown in Figure 2. The amplitude response is flat for ground velocities in the range of 0.01-10.00 Hz. The two data-streams are continuously transmitted by VHF digital telemetry to CHM, the central relay site, and then via microwave link to the Kyrgyz Institute of Seismology in Bishkek. There they are recorded in both triggered mode and continuous mode. The three southern stations must use one of two repeaters to communicate with CHM. This is necessary because there is a mountain range with elevations exceeding 4,800 m that obstructs the direct line-of-site from these stations to CHM. The Kyrgyz Institute of Seismology Data Center in Bishkek is linked to the Internet through a dedicated phone line and satellite link to the KNET Data Center at IGPP, San Diego.

All seismometers in KNET are mounted using mini-vaults designed by IGPP, San Diego. All stations are located at hardrock sites. Some of these stations are among the quietest stations in the world. Only three stations (CHM, KBK, and TKM) are known to be slightly influenced by cultural noise produced by local traffic.

3. Event Detection, Association, and Location

To detect events, associate seismic phases, and locate events, data are processed at the KNET Data Center, at IGPP, San Diego. Analysts use the software package 'Datascope' developed at the Joint Seismic Program Center (JSPC) at the University of Colorado at Boulder (Quinlan, 1995). We will briefly mention the basic stages of the procedure.

Database

First, the 16-bit integer data is extracted from field tapes. Then the CSS3.0 relational database (Anderson *et al.*, 1990) is filled in with complete and accurate site and instrument characteristics.

Detection and Measurements

The detection program developed at the JSPC (Harvey, unpublished, 1994) is routinely applied to all continuous records in the database. The detection program looks for arrivals in waveform files from the input database. Then it estimates the onset time and adds new records to the arrival table in the output database. This detection program differs from the standard

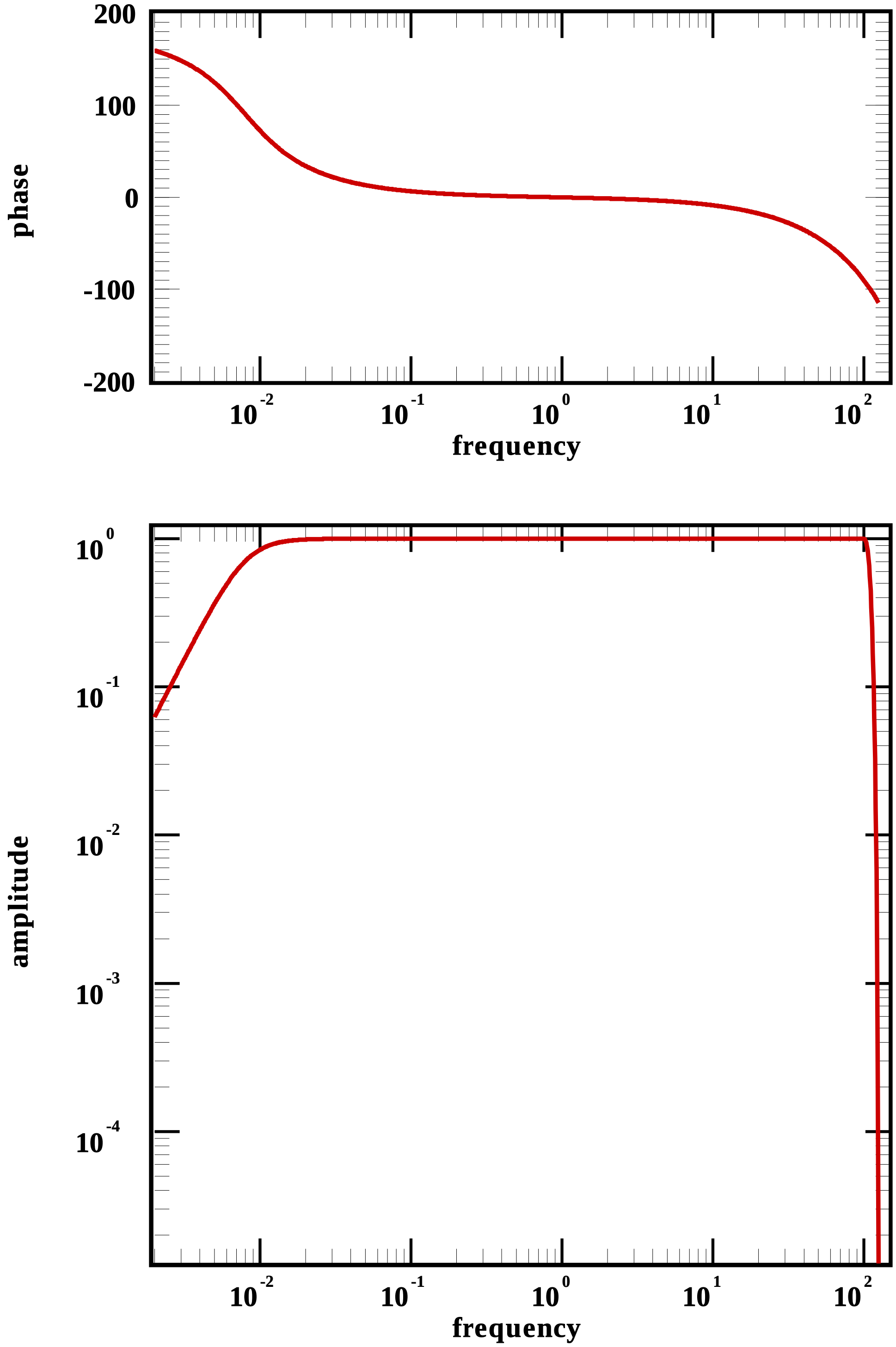

Figure 2: Instrument response of KNET broadband channels.

technique, which uses the ratio of rms amplitudes in short and long time windows. The JSPC program applies a similar operation to several filtered streams of original broadband record and also combines a decision function from the different streams.

The JSPC detection program produces waveforms and arrival flags from all the selected stations and displays them in an interactive window. An analyst can then change arrival times, relabel them, delete them, and add them. The analyst can also change the arrival grouping parameters and re-establish a candidate association. The analyst can check and optionally change time uncertainty measurements and can measure P-wave amplitudes and periods. These measurements are made on 0.8-5.0 Hz bandpass filtered waveforms by measuring the largest peak-to-peak oscillation in the 5 seconds after the first P-wave onset.

Association

All event associations and locations are made at the KNET Data Center through a set of interactive software utilities that allow extensive review and immediate relocation of events. A simple, time window-based algorithm is used to group P-wave and S-wave arrivals into a candidate association for a single event. The PDE and any other selected catalogs are automatically searched for potential event associations with the candidate group of arrivals. Events that fall within the arrival time residual thresholds are saved in a temporary database and the associations and time residuals are displayed in both text and graphic forms.

Location

The location program used at the KNET Data Center to determine the event hypocenters is a slightly modified version of LocSAT (Bratt & Bache, 1988). The program accounts for receiver elevation that can affect the resulting locations in areas where there are large receiver elevation differences. The distance and depth-dependent travel-time tables are determined using a structural model that consists of a Central Asian crust over an IASPEI91 (Kennett, 1991) mantle (Figure 3). The crustal model assumes a typically thick (50 km) Central Asian crust and is being used by Kyrgyz seismologists in the production of their catalog from local analog instruments. Travel-time tables used for location correspond to the first arriving P and S waves regardless of the type of phase (e.g., P, Pg, Pb, Pn).

The location and association procedures are driven by a computer script that keeps an audit trail on everything the analyst has done. This allows the process to be easily restarted.

If there are enough arrivals to provide a reasonable independent location (at least five P-wave or S-wave arrivals), the analyst executes LocSAT which, upon completion, places the new location along with the location error parameters into the temporary database and displays the errors and time residuals. In addition to the phases used in the location, all other secondary phases are automatically displayed on the screen to aid in location evaluation.

The analyst can change, repick, or regroup arrivals; reassociate arrivals using the PDE catalog; change LocSAT execution parameters (e.g., constraining the depth or using another crustal

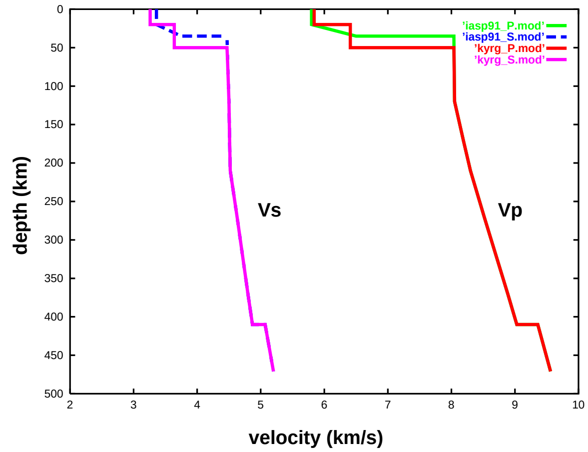

Figure 3: Velocity models used for location.

model); and rerun LocSAT as many times as desired. The results are stored in the temporary database. Once the analyst is satisfied with the results, the location and/or association can be archived into the permanent database. Events that are not locatable and that do not have PDE associations are skipped. The next set of arrivals then are grouped and the process is repeated.

Output Database

Results of this process are stored in the CSS3.0 relational database that contains several relations: *event, origin, origerr, arrival, assoc.* The three first relations contain information about all detected and associated events and estimates of location errors. The two last relations contain information about detected arrivals, arrival times, amplitudes, and association with different seismic phases.

A more detailed description of the database can be found in Anderson *et al.* (1990). The KNET Data Center at UCSD provided us with their database of KNET measurements for the five years 1995 to 1999. We refer to this database as the KNET Bulletin or, for brevity, KNB. We provide as the electronic Appendices to this report the two databases, namely:
(1) KNB_Jan_Aug_1995 - the subset of the database KNB for January-August 1995;
(2) CAB_Feb_Aug_1995 - the CAB database for February - August 1995.

4. Comparison of event detection and location capabilities of KNET (KNB and CAB) and GSETT-3 (REB) for January - August, 1995

Detection

The KNB for this 8-month interval is based only on triggered records from KNET. A total of 852 events were reported in KNB during the period. The KNB for these events is provided in electronic Appendix 1. The REB drawn from GSETT-3 contains 13,111 total events. The REB is missing 316 events present in KNB. The KNB is missing 12,575 events present in the

REB. To limit the comparison of the KNET and the REB performances to the territory around KNET, we introduced several range limits: 1,000 km, 500 km, and 200 km from the center of KNET at the AAK station at Ala-Archa, Kyrgyzia. The corresponding numbers are presented in Table 3.

These numbers indicate (as expected) the relative increase of KNET detection capabilities by shortening the distance from the center of KNET. Nevertheless, there are a significant number of events relatively close to KNET that appear in the REB but did not appear in the KNB. Figures 4 and 5a illustrate these facts. Figure 5b shows very similar results for the CAB. Approximately twice the number of events are reported in the CAB than are reported in the KNB. The increase in the number of reported events in the CAB is due to two circumstances: more stations are used, and both triggered and continuous records are processed.

Table 3. Comparison of KNB and REB Performance for January - August, 1995

	KNB		**REB**	
range, km	total	in KNB only	total	in REB only
any	852	316	13111	12575
$\leq 1,000$	401	290	236	125
≤ 500	277	247	42	12
≤ 200	146	142	4	0

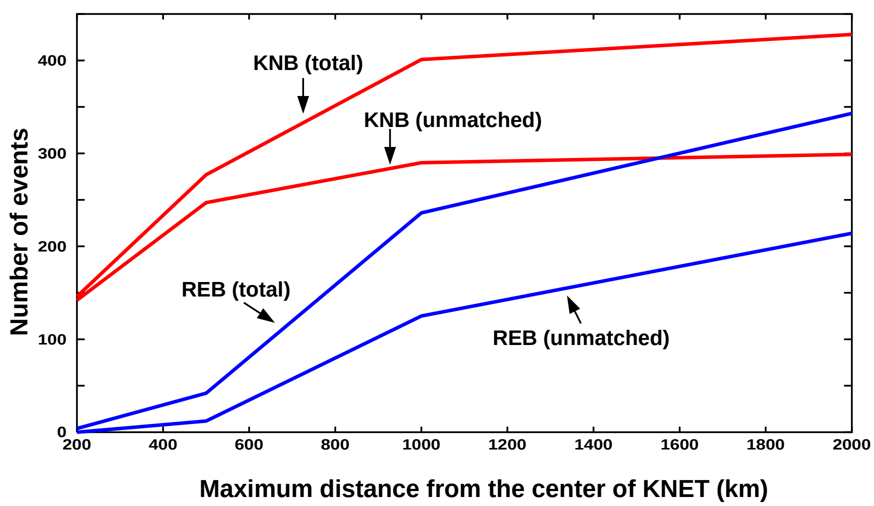

Figure 4: Number of events reported in the KNB and the REB versus distance interval from the center of KNET (January - August 1995).

In the KNB, only 24 events within 1,000 km of the center of KNET have magnitude estimates (provided by the REB or the PDE). In order to estimate the threshold of detection for KNET and GSETT-3 for this region, we selected 183 matched events that occurred between February and August 1995 within 1,000 km of the center of KNET which were reported in both the CAB and the REB (Figure 6a). We consider events in the REB and the KNB bulletins to match if the difference between origin times is less than 60 s, and the distance between epicenters is less

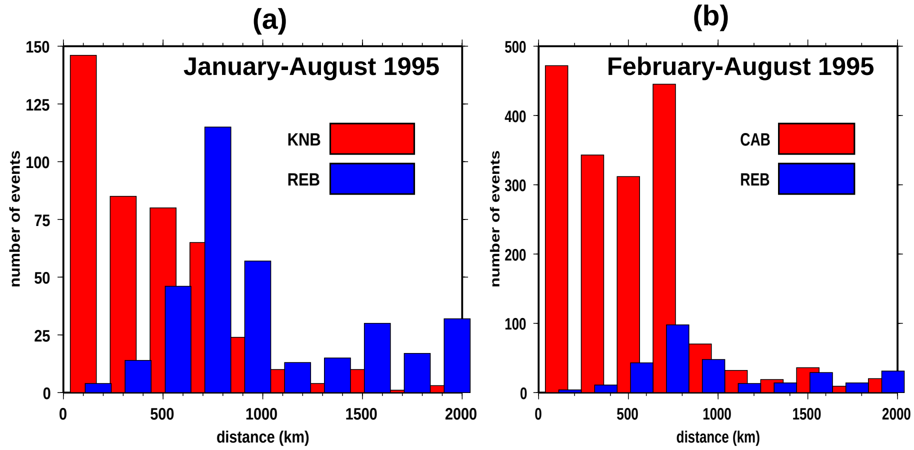

Figure 5: Number of reported events versus range from the center of KNET: (a) KNB and REB (January - August 1995); CAB and REB (February - August 1995).

than 200 km. If these "matching" parameters are decreased by a factor of two, the statistics are not changed appreciably. The magnitude distribution of these matched events is shown in Figure 6a. The magnitude distribution of events which were missing from the REB but reported in the CAB is presented in the same Figure.

Figure 6a implies that some large events with $m_b > 4.5$ that occurred near KNET are missing in the REB. There are actually 24 such events. However, the comparison of magnitudes of the matched events reported in the REB and the CAB (Figure 6b) shows very strong scatter in the magnitude estimates reported in these two bulletins. Similar results are obtained when we compare the magnitudes of the 203 matched events reported in the CAB and the bulletin of the International Seismological Center (ISC) (Figure 6c) for the same region and the time interval. There could be several reasons for such discrepancies between different bulletins: the use of different algorithms for determining magnitudes; much larger scatter of the CAB magnitudes due to the smaller number of stations, the predominance of small epicentral distances in the CAB, and large azimuthal gaps. It is, therefore, likely that the CAB magnitudes attributed to the events missing in the REB are too high. The absence of a strong correlation between the magnitudes in these two bulletins does not allow us to make statistically supported estimates of the detection threshold of the REB for this region (Ringdal, 1975; Wüster *et al.*, 2000). The approximate lower estimate of the detection threshold for the REB may be found from the fall off in the number of events with decreasing magnitude (Figure 6d). Thus, the threshold for the GSETT-3 appears to be $m_b \approx 4.2$ for this time interval in 1995. The same value is inferred for the ISC bulletin. For the CAB, the threshold is much lower, $m_b \approx 3.0$, for distances less than 500 km from the center of KNET, and $m_b \approx 3.5$ for distances less than 1,000 km. After 1995, the magnitude of events that appear in the REB reduces and we estimate for these later times that the magnitude threshold reduces to about 3.5 in this region. See Figure 13.

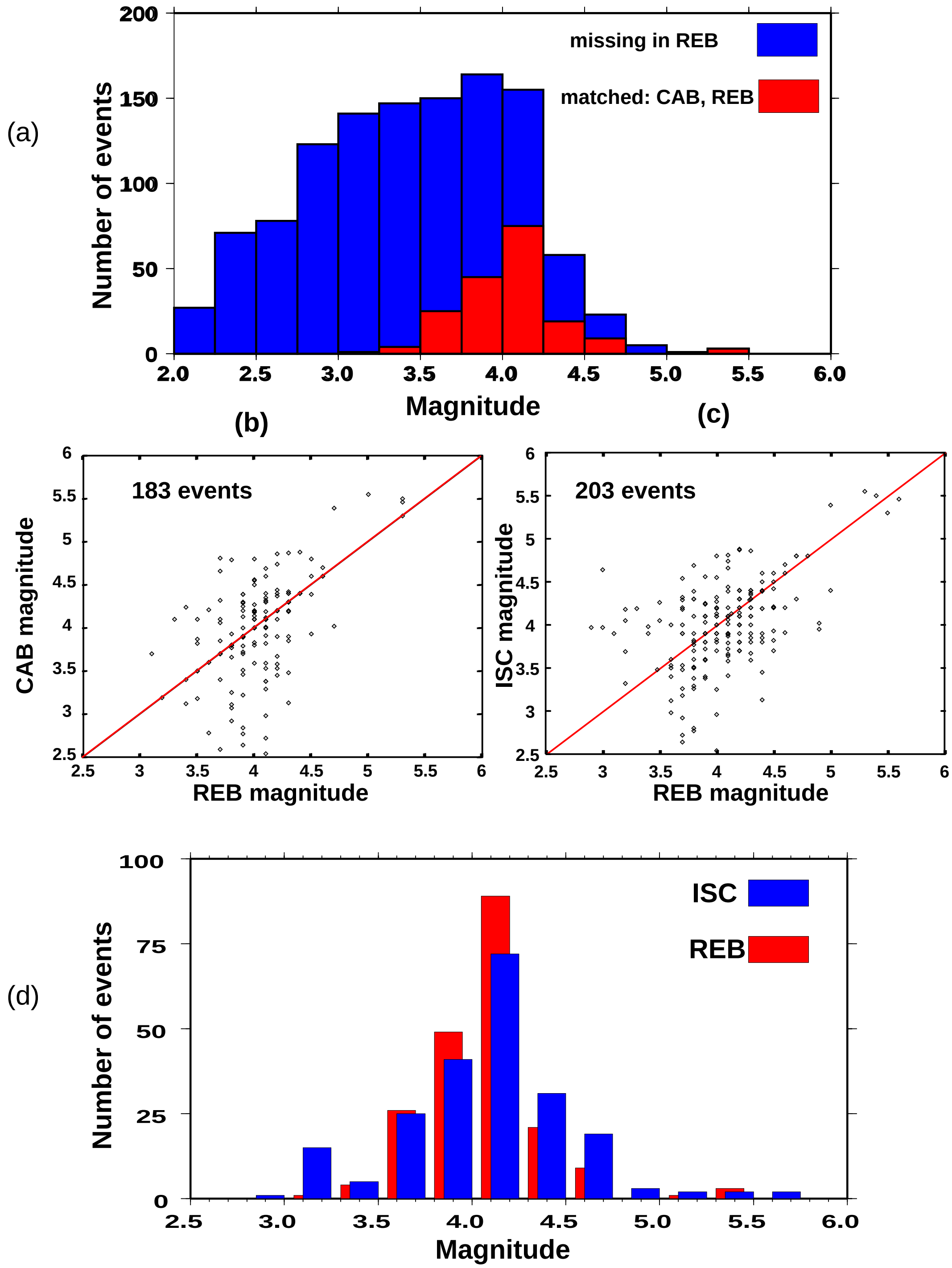

Figure 6: (a) Histogram of the total number of events in the CAB indicating numbers of matched and unmatched events in different magnitude ranges within 1,000 km of the center of KNET for Feb. - Aug. 1995. (b) Correlation between magnitudes of matched events in the REB and the CAB. (c) The same as (b) but magnitudes are from the ISC and the CAB. (d) Histograms of magnitudes of the all events reported in the ISC and the REB for the same territory and time interval.

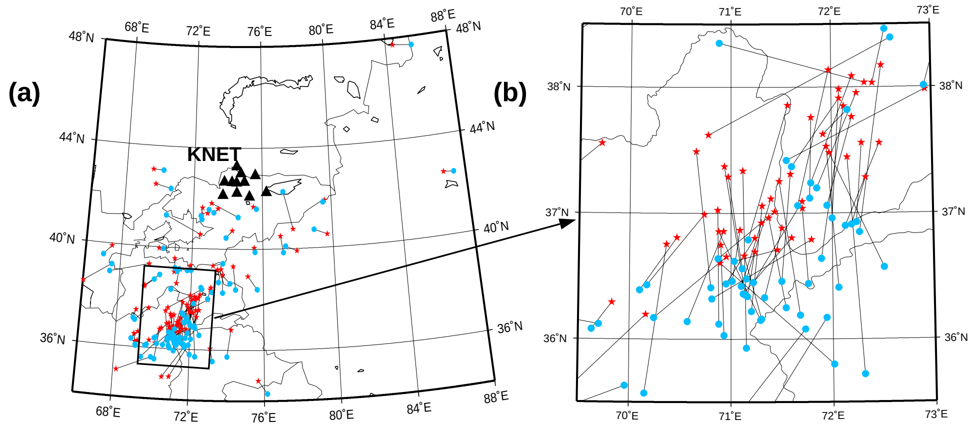

Figure 7: Mislocation of events reported in the KNB relative to the REB for January-August 1995. Red stars: KNB locations, blue circles: REB locations. (a) range 0-1,000 km from the center of KNET; (b) details for the Hindu Kush region.

Location

Among the 852 events reported in the KNB, 402 events (all inside a range of 2000 km) were independently located by the KNET analysts. The locations in the PDE or the REB were accepted by the analysts for 450 events. Figure 7 illustrates the difference in locations between matched events in KNB and REB: (a) less than 1,000 km from the center of KNET; (b) for the Hindu Kush area where there are significant systematic differences between the KNB and the REB locations. These are caused by the effect of a high-velocity slab dipping north under the Hindu Kush and by the one-sided deployment of the KNET stations, relative to the Hindu Kush epicenters (Billington *et al*, 1977; Mellors, 1995). The presence of this slab is not accounted for by the models used for location. A histogram of the distance between epicenters for all the matched events is shown in Figure 8. It is evident from these figures that there are significant differences between location results in the two bulletins. The location results are strongly dependent on the magnitude and azimuth of an event. However, the number of matched events is too small to estimate this dependence reliably.

To estimate possible errors in the KNB locations, we compared the KNB and CAB locations for the 200 matched events which occurred in February - August 1995 within the 500 km range from the center of KNET. Results are shown in Figure 9 and Figure 10. It is evident that within 200 km from the center of KNET differences in epicentral positions and source depths reported in the KNB and CAB are very small. As we said before, the number of stations reporting to the CAB is larger than the number used for the KNB. This fact allows us to consider the KNB hypocenters within about 200 km from the center of KNET as reliable. However, the differences between the KNB and CAB locations increase with distance from the center of KNET, indicating that at distances of more than 200 km, the KNB becomes less reliable.

The data set in KNB for January - August 1995 is not large enough to characterize the performance of KNET in detail. In addition, the KNB was not operating normally during these 8

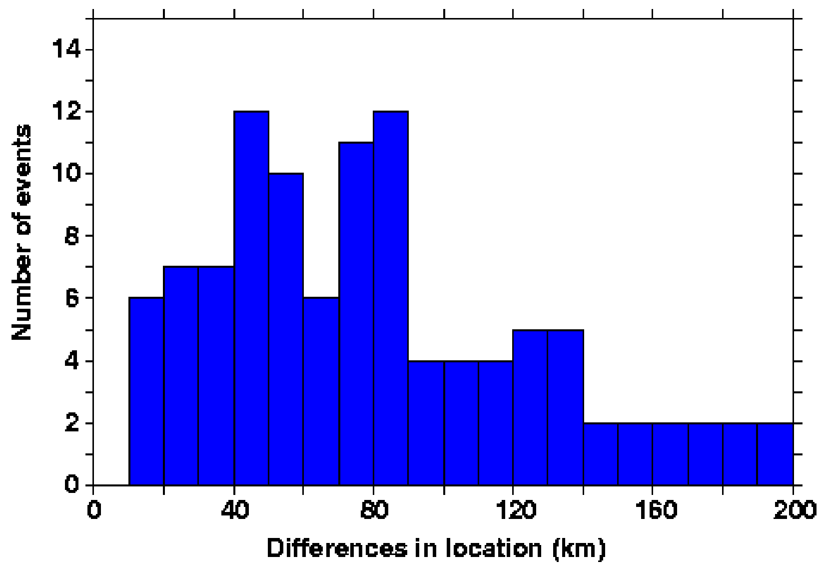

Figure 8: Histogram of the distances between epicenters of the matched events reported in the KNB and the REB (January - August 1995).

months: (1) the KNB for this period is based only on triggered data and does not contain events which can be detected on the continuous records; (b) the performance of several stations during this time period was worse than in following years. Moreover, the GSETT-3 network reporting to REB underwent significant development after 1995. After this development this network became known as a part of the International Monitoring System (IMS). These considerations stimulated us to extend our analysis to a much longer time interval than prescribed by Task 1 of our Contract, namely, from January 1995 to December 1999. Results of this analysis are presented below.

5. Comparison of event detection and location capabilities of KNET (KNB) and IMS (REB) for 1995-1999

Detection

Table 4 contains the number of events reported in the KNB and the REB bulletins for each year from 1995 to 1999. It shows total numbers of events for the 5 year interval for different ranges from the center of KNET and includes the number of unmatched events in both bulletins. We see that within 500 km from the center of KNET, 93% of events reported in the KNB are absent from the REB while 17% of events reported in the REB are absent from the KNB. The relative number of unmatched events in the KNB is decreasing, and the relative number of unmatched events in the REB is increasing as the range from the center of KNET widens. In the range 0-1,000 km, corresponding numbers are 84% and 31%. This is illustrated by Figure 11.

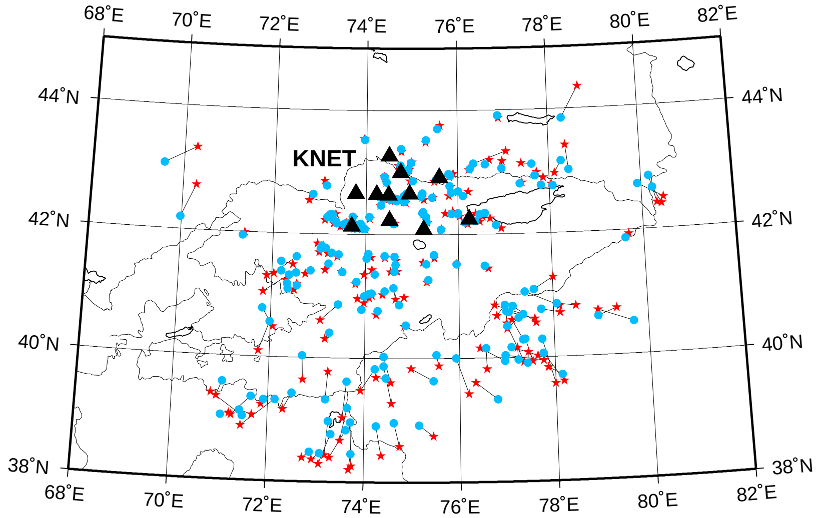

Figure 9: Mislocation of events reported in the KNB relative to the CAB for the 200 matched events reported in the KNB and the CAB (February - August 1995). Red stars: CAB locations, blue circles: KNB locations; black triangles: KNET stations.

Table 4. Comparison of KNB and REB Performance for 1995-1999

	KNB		**REB**	
range, km	total	in KNB only	total	in REB only
		1995		
$\leq 1,000$	563	394	396	227
≤ 500	384	341	65	22
≤ 200	201	194	7	0
		1996		
$\leq 1,000$	3,113	2,260	599	82
≤ 500	1,822	1,886	112	16
≤ 200	994	984	12	10
		1997		
$\leq 1,000$	2,801	2,432	589	217
≤ 500	2,210	2,034	218	42
≤ 200	478	474	8	4
		1998		
$\leq 1,000$	1,716	1,287	670	239
≤ 500	1,009	901	143	35
≤ 200	343	338	6	1
		1999		
$\leq 1,000$	1,931	1,574	447	85
≤ 500	1,151	1,077	90	16
≤ 200	439	437	5	2
		1995-1999		
$\leq 1,000$	11,940	10,089	2,701	850
≤ 500	7,321	6,802	628	109
≤ 200	2,455	2,427	38	10

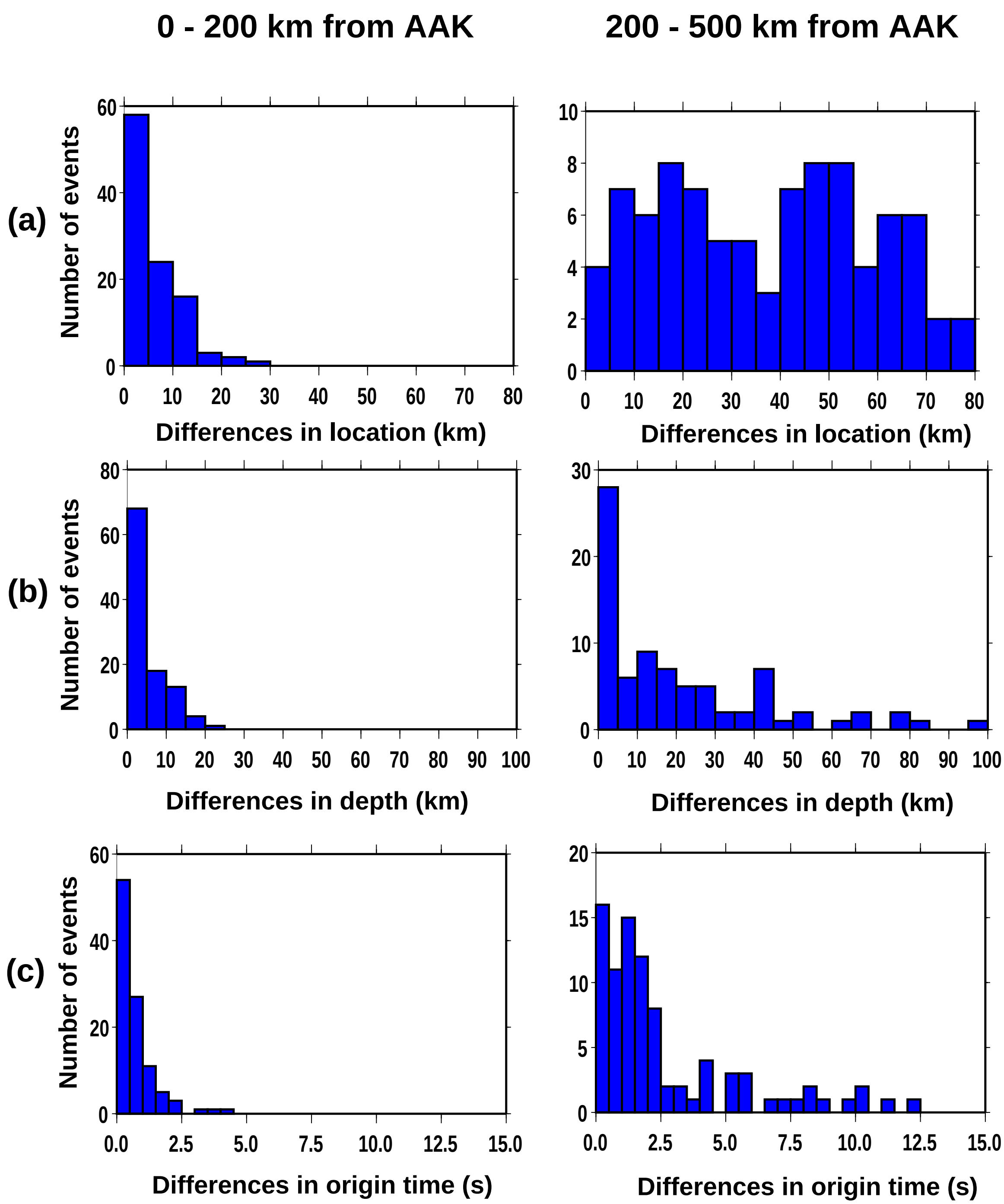

Figure 10: (a) Histogram of the distances between epicenters of the matched events reported in the KNB and the CAB within the two different ranges from the center of KNET; (b) Histogram of the differences in depths for the same events; (c) Histogram of the differences in origin times for the same events.

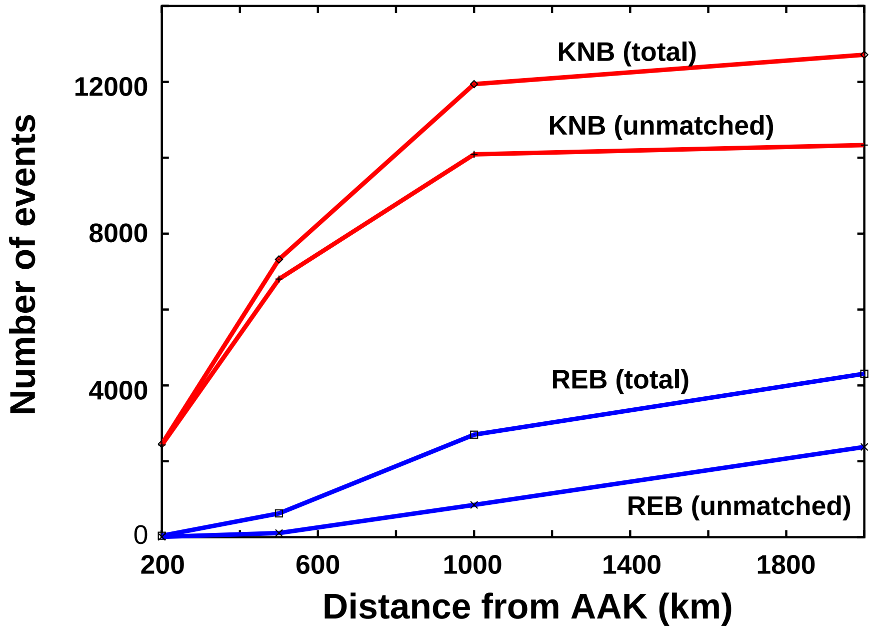

Figure 11: Number of events reported in KNB and REB as a function of the range from the center of KNET (1995-1999 years).

Figure 12 shows the location of epicenters which appear only in the KNB and only in the REB within 500 km from the center of KNET. The absence in the KNB of 109 events reported in the REB at such short distances from KNET may be explained only by gaps in the KNET stations' performance for various periods of time. Absence of magnitude information for most of the events located by KNET does not allow us to evaluate the magnitude threshold of KNET from this data set.

Magnitudes of events detected by IMS and reported in the REB for this area vary from 2.9 to 5.7 (Figure 13). However, the number of events with m_b below 3.5 is very small. Again, the fall off in numbers of detected events with decreasing magnitude may be considered as an indicator of the detection threshold value. For the IMS, this threshold is about 3.5 which is higher than the estimate based on data for January-September 1995. This reflects significant improvement of the IMS over time. Based on the CAB data, we may assume that the magnitudes of the events reported in the KNB but not in the REB are of the order 2.0-3.5, which is in agreement with Harvey (1996) based on the much smaller data set for February, 1995.

Location

There are 482 matched events in the range 0-500 km from the center of KNET found in both the KNB and the REB bulletins for these years. Positions of their epicenters according to the REB are shown in Figure 14.

Histograms of distances between epicenters of the same events in the KNB and the REB for two different magnitude ranges are shown in Figure 15. Significant differences in location are present in both magnitude ranges. However, the events with higher magnitudes are char-

(a)

(b)

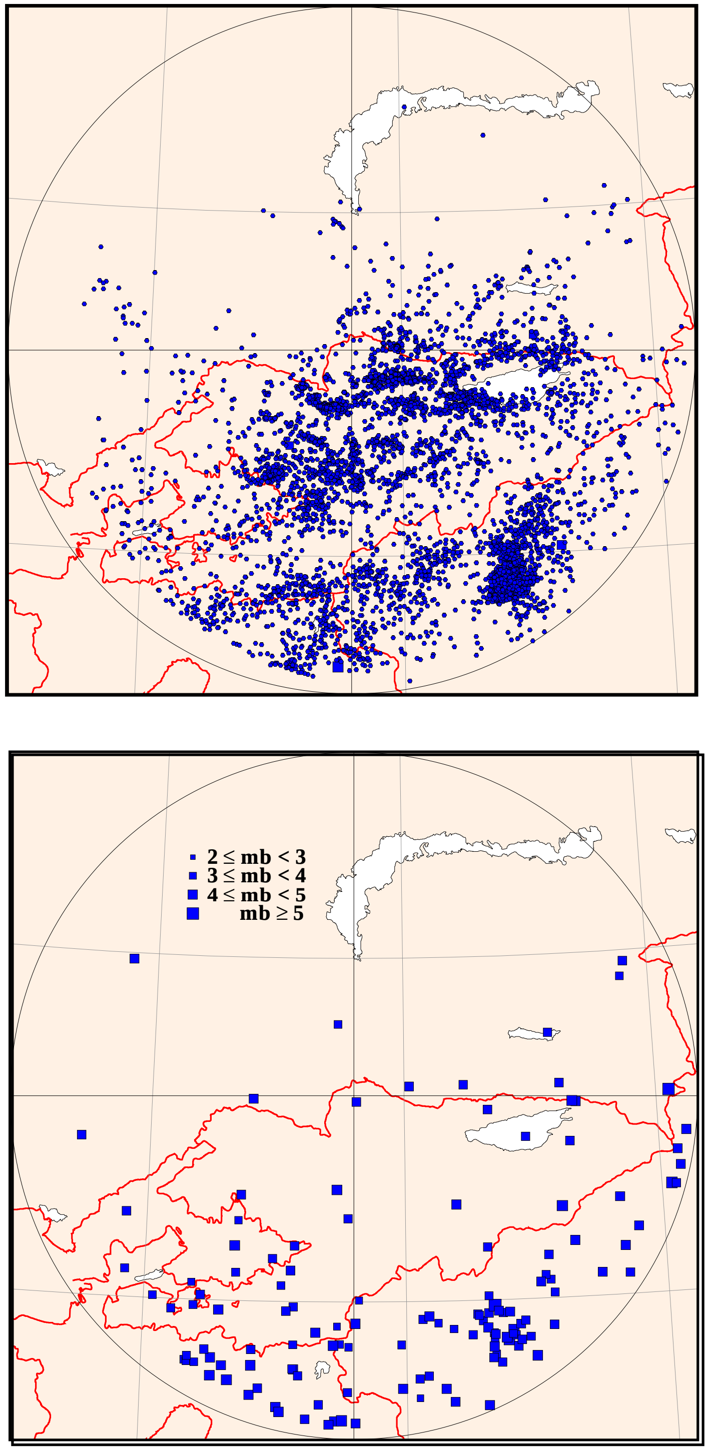

Figure 12: Epicenters of unmatched events reported in (a) the KNB and (b) the REB in the range 0-500 km from the center of KNET.

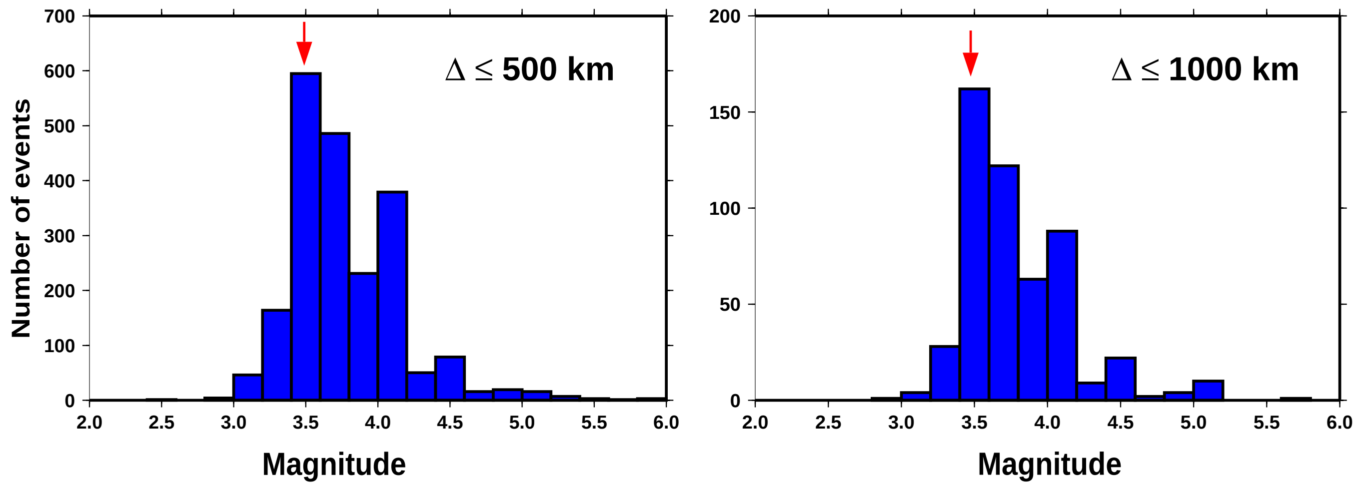

Figure 13: Histograms of magnitudes of events in different ranges from the center of KNET reported in the REB. Red arrows indicate the detection threshold for the REB at this region.

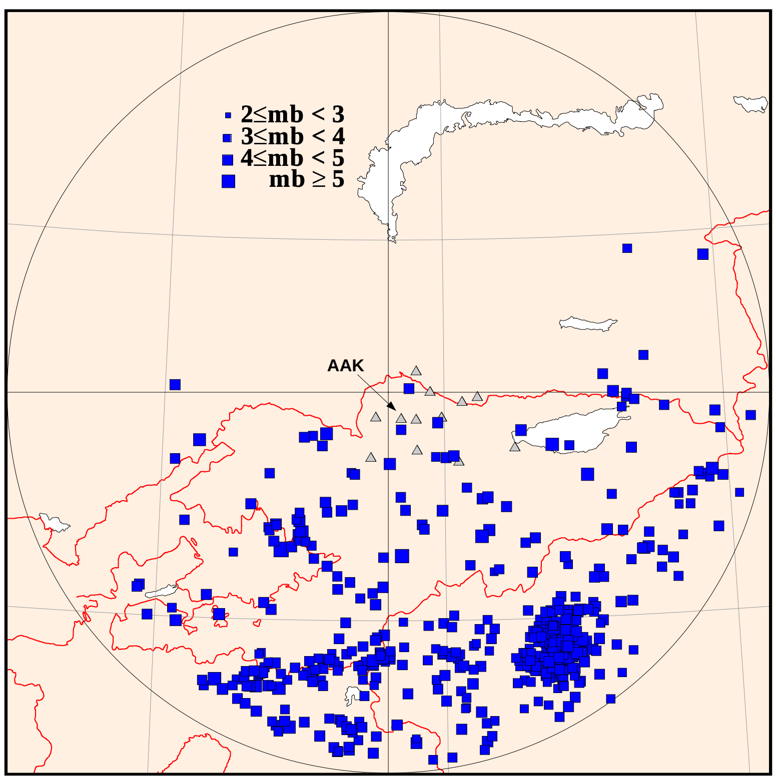

Figure 14: Epicenters of the matched events reported in (a) the KNB and (b) the REB in the range 0-500 km from the center of KNET for 1995-1999.

acterized, on average, by a smaller number of large mislocations. Figure 16 provides a pattern of differences in epicenter locations between the REB and the KNB with special detailization for the Pamir and N.W. China (Kashgar) regions. Figure 16 provides a pattern of differences

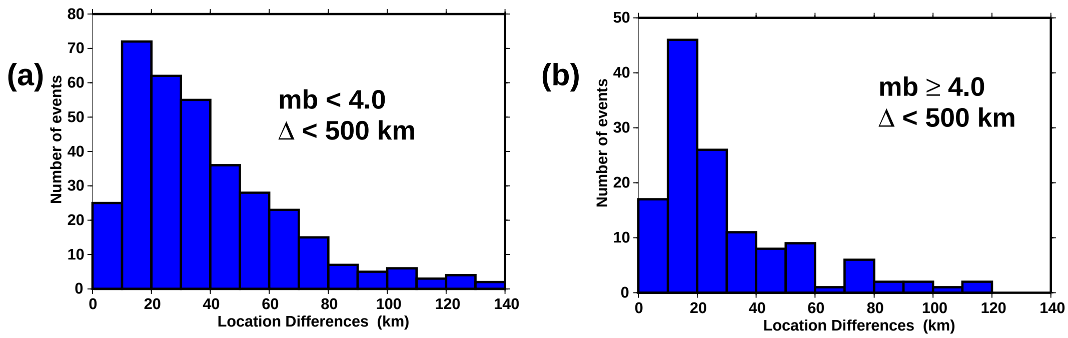

Figure 15: Histogram of location differences for matched events in the REB and the KNB events in the range 0-500 km from the center of KNET: (a) events with $m_b < 4.0$; (b) events with $m_b \geq 4$.

in epicenter locations between the REB and the KNB with special detailization for the Pamir and N.W. China (Kashgar) regions.

From data in these figures it seems that mislocation of events is strongly region-dependent. For example, events in Pamir reported in the KNB are mostly moved to the North relative to the REB location. Events in Kashgar are more closely concentrated around 39.5°N, 77°E than matched events in the REB. Figure 17 demonstrates differences in location change with the magnitude level. For magnitudes higher than 4, the differences in the range less than 200 km from the center of KNET are quite small: less than 20 km. This means that the REB locations for these events are almost as good as the KNB locations. When the distance from the center of the network increases, KNB locations become less reliable. For smaller events, differences are quite large, even inside the network (Figure 18). This can be interpreted as meaning the REB locations for events with a magnitude less than 4 are less reliable than the KNB locations, and location errors could be on the order of 40 km or more.

Depth Determination

Comparison of depths reported in the KNB and the REB for 482 matched events shows that in many cases there are significant differences between the depths reported in the two bulletins for the same event. Figure 19 presents the histograms of these differences within the range 0 - 500 km from the center of KNET: (a) for events with $m_b < 4$; (b) for events with $m_b \geq 4$. No significant changes in distribution of differences with magnitude level are seen.

Differences in depth for all the matched events within the 0-200 km range are shown in Figure 20. There are still significant differences in depths for at least half of the matched events. Taking into account the closeness of KNET to event epicenters, it is reasonable to assume that the REB determinations of source depth are far from accurate.

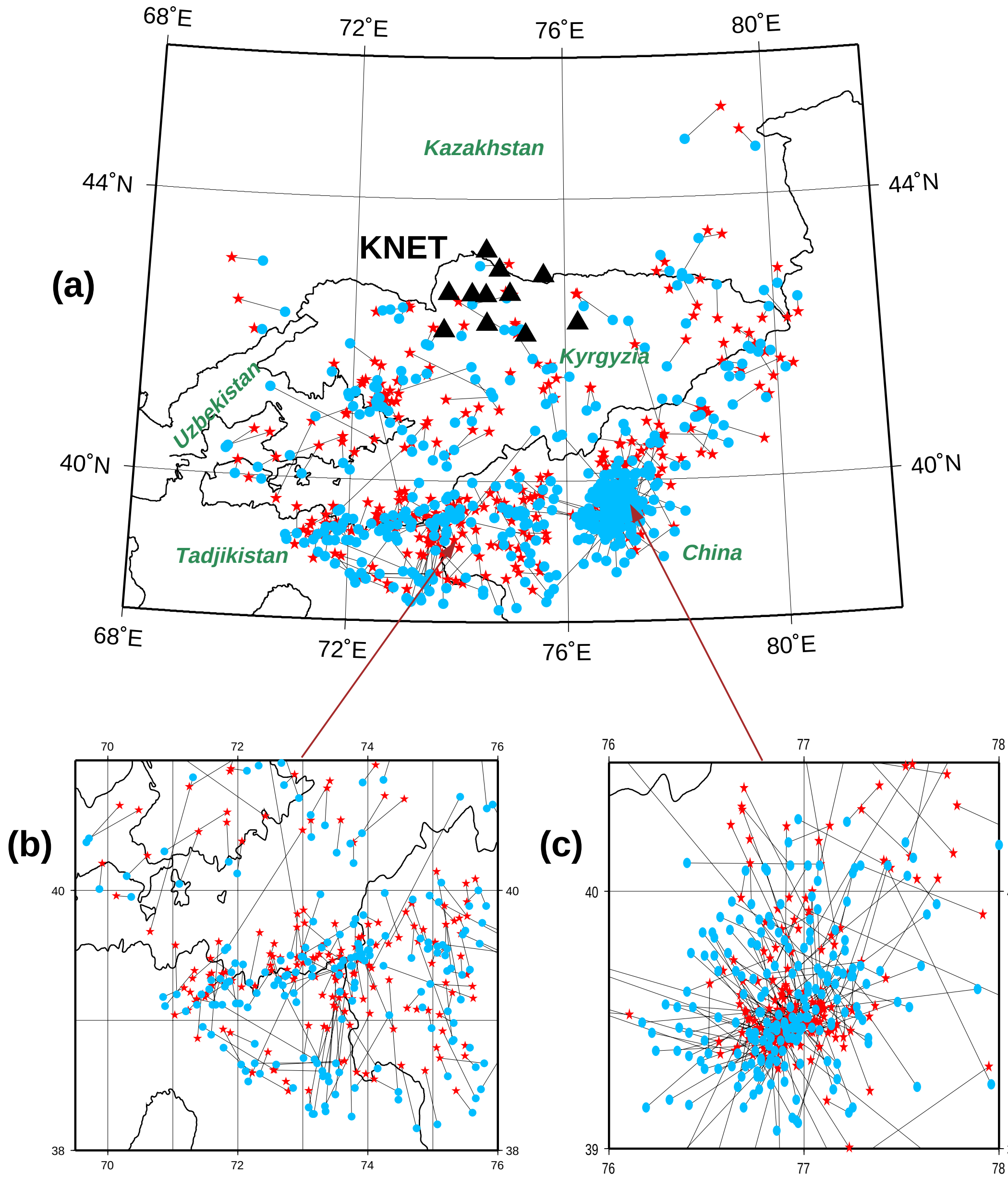

Figure 16: Differences in location of 482 matched events in the range 0-500 km from the center of KNET. Red stars: KNB locations; blue circles: REB locations. (a) All events; (b) Pamir; (c) Kashgar.

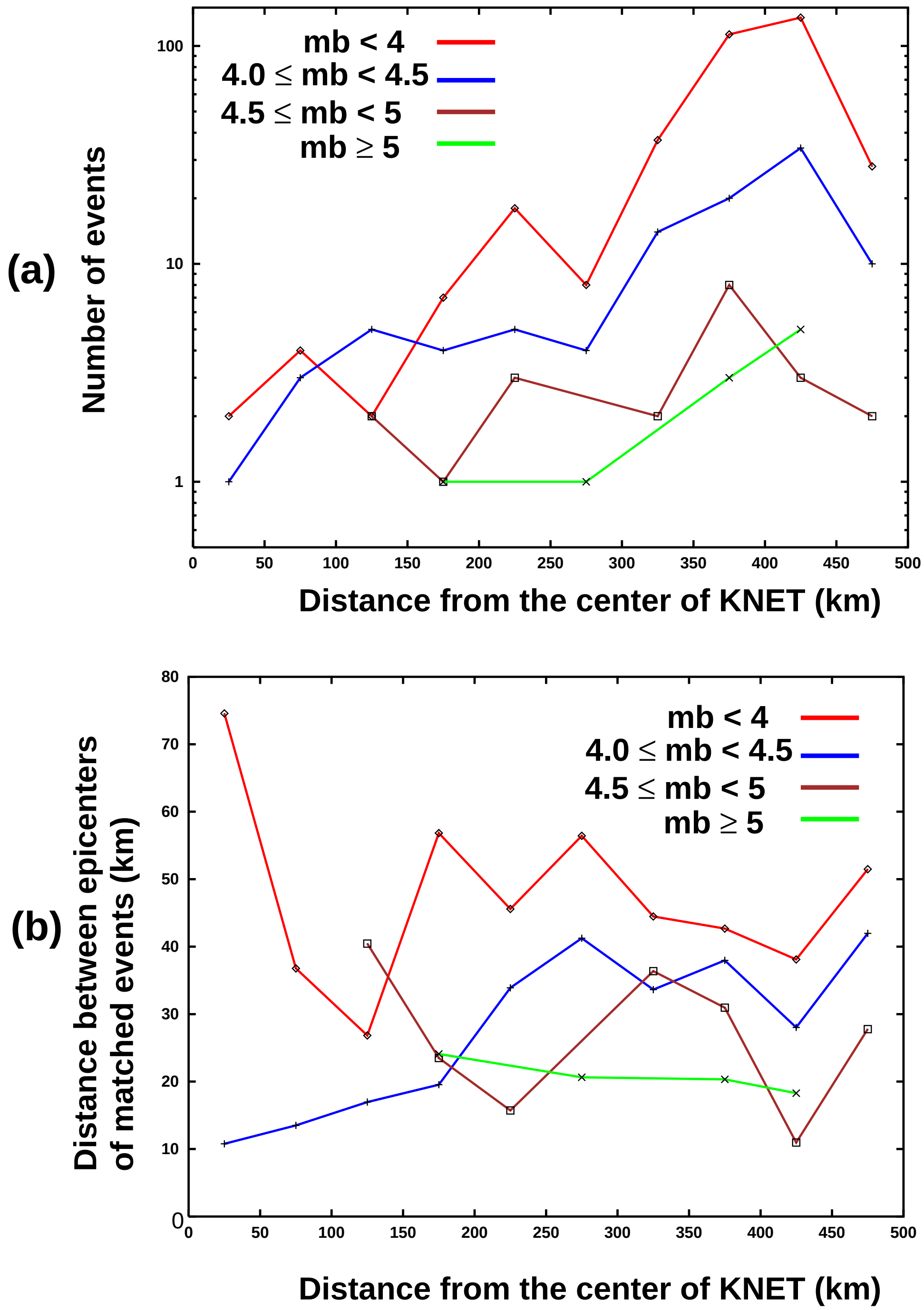

Figure 17: Distance between epicenters of 482 matched events reported in the KNB and the REB as a function of distance from the center of KNET. (a) Number of events at different magnitude levels; (b) Distances between epicenters for all events, events with $m_b \geq 4$, and events with $m_b \geq 5$.

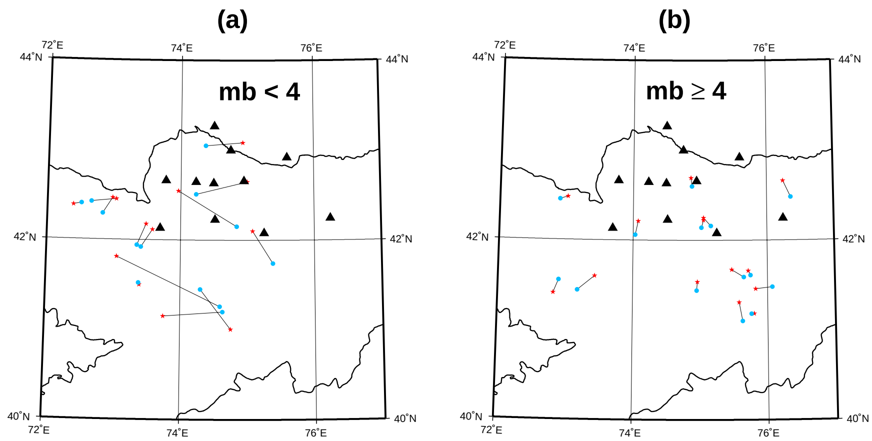

Figure 18: Differences in location of the matched events in the range 0-200 km from the center of KNET. Red stars: KNB locations; blue circles: REB locations. (a) $m_b < 4$; (b) $m_b \geq 4$.

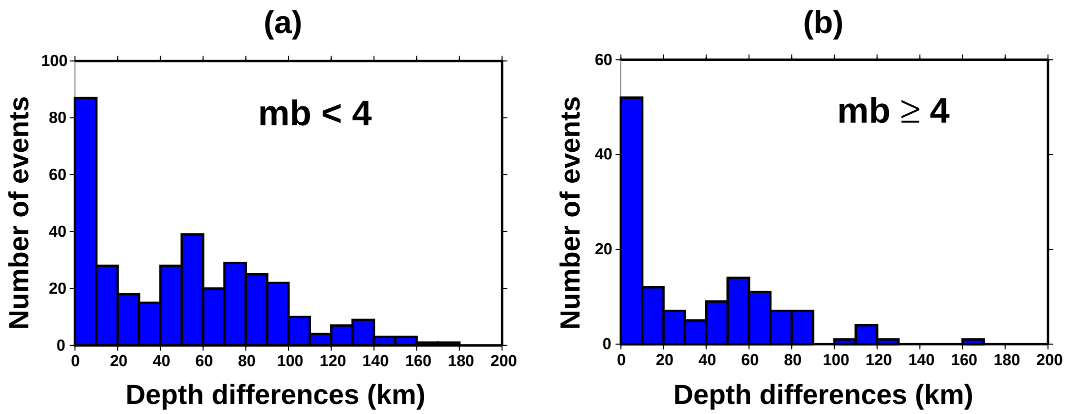

Figure 19: Differences in depths of the matched events reported in the KNB and the REB within 500 km from the center of KNET. (a) events with $m_b < 4$; (b) events with $m_b \geq 4$.

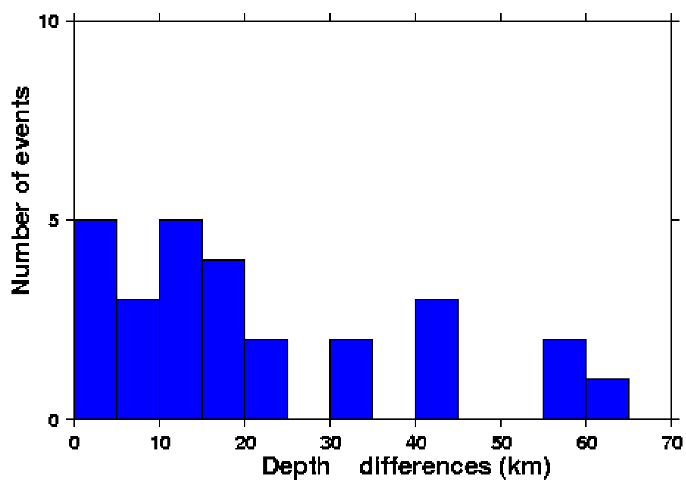

Figure 20: Differences in depths of the matched events reported in the KNB and the REB within 200 km from the center of KNET.

6. Conclusions

The comparative analysis of the Kyrgyz Network Bulletin (KNB) using data from KNET and the Reviewed Event Bulletin (REB) using data from IMS for the 5-year period from January 1, 1995 to January 1, 2000 leads us to the following conclusions:

- **Detection**. The magnitude threshold of the REB is difficult to determine rigorously because of the absence of magnitude estimates in the KNB and the weak correlation between the REB, CAB, and ISC magnitudes. We estimate, however, that the magnitude threshold of the REB for this region is about 4.2 in 1995 and reduces to about 3.5 (Figure 13) later in the decade. As expected, many local events that appear in the Kyrgyz catalogues (KNB, CAB) are not reported in the REB. This totals more than 70% of the events reported in the KNB from 1995 through 1999 within 1,000 km of the center of KNET. The magnitudes of these events (m_b) range from 2.0 to 3.5.

- **Location**. There are significant differences in the location of many events reported both in the KNB and the REB within 500 km from the center of KNET. For events located within 200 km of the center of KNET, these differences are attributable to errors in the REB locations. For events with $m_b \leq 5.0$ errors are less than 15 km, for events with $4.0 \leq m_b < 5.0$ the errors are predominantly less than 25 km (Figures 17 and 18), but for smaller events ($m_b < 4.0$) errors may be as large as 75 km.

- **Depth determination**. The depths of the events reported both in the KNB and the REB within 500 km of the center of KNET differ significantly for at least 50% of the events. For events within 200 km from the center of KNET, these differences may be as large as 60 km (Figure 20), and are attributable to errors in the REB depths.

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