

**EXTENSION OF THE CAUCASUS SEISMIC INFORMATION NETWORK STUDY INTO
CENTRAL ASIA**

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ABSTRACT

The Central Asian Seismic Research Initiative (CASRI) is an extension of the Caucasus Seismic Information Network (CauSIN). Both projects seek to build knowledge bases of geological, geophysical, and seismic information in their respective regions and to use crustal modeling techniques to create a combined model of the regions to aid in seismic monitoring.

Catalog and phase arrival data from local networks in the CASRI region (Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan) have been collected. The historical catalog contains nearly 11,000 events from 500 AD through the present. The modern catalog of the region includes 469 events from 1991 to 2005.

Participants in the project are validating data quality and preparing phase arrival tables. Because these data have never before been shared with the world-wide seismic community, care is being taken to use consistent station naming and descriptions for each station. The phase arrival data from Kazakhstan includes 2,991 seismic phases for 71 events in Kazakhstan and 2,257 phases for events in other countries in the region. Kyrgyzstan's phase data include 2,500 arrivals picked from roughly half of the events in the country; local scientists are continuing to make picks from the rest of their data and will eventually expand to pick times from events in the other CASRI countries.

Other new acquisitions include newly released explosion data in paper print-out format, which provide ground truth and are invaluable to crustal tomography and validation of earth models. These data include 600 records from 177 events and 33 stations. Event-station separations range from 450 to 2,500 km. These data are in the process of being digitized.

This seismic travel time data, combined with the available geophysical and tectonic information, will be used for the tomographic modeling of the CASRI region.

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OBJECTIVE

The primary goal of this project is to develop a database of geology and active tectonics in the Caucasus and Central Asian regions. With this new database, we will be able to improve earthquake locations and identify potential “ground truth” (GT) events. The dense network, calibration events (mining and quarry blasts), improved models, and better location algorithms (including multiple-event grid search, and double difference) will improve the event locations. Scientists at collaborating countries are very eager to assist with this task, since improved locations will aid in the identification of active faults.

With the GT events to serve as validation, we will obtain a detailed crust/upper mantle structure in Central Asia, using data from newly installed seismic stations as well as GSN and other stations operated as part of the national networks.

RESEARCH ACCOMPLISHED

Event Catalog

Figure 1 shows locations of events in the unified catalog from local networks in the CASRI region. It includes almost 11,000 events from historic times through 2005.

Phase Arrival Data

Phase arrival tables have been received from CASRI participants (Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan). Because these data have not previously been shared with the world-wide seismic community, care is being taken to use consistent station naming and descriptions for each station, and to ensure the quality of the phase picks. The data are still undergoing this processing.

The National Nuclear Center (NNC) in Kazakhstan operates a number of stations, (listed in Table 1 and shown in Figure 2) most of which are analog stations still operating from the Soviet era. Scientists at the NNC have put a great of effort into picking travel times from analog records and have contributed over 5,000 phase picks to the CASRI database; 2,991 of these picks are from 71 events in Kazakhstan, 2,257 are from events in other countries in the region.

Table 1. Coordinates of NNC station network, Kazakhstan. The coordinates of 3-component instruments are shown for the arrays.

Station name	Station code	Elevation, m	Latitude	Longitude
Borovoye (IRIS)	BRVK	315	53.0578	70.2828
Vostochnoye (array)	VOS	300	52.7232	70.9797
Zerenda (array)	ZRNK	384	52.9508	69.0043
Chkalovo (array)	CHKZ	123	53.6762	70.6152
Kurchatov (IRIS)	KURK	240	50.7149	78.6208
Makanchi (IRIS)	MAKZ	600	46.8075	81.9774
Talgar	TLG	1210	43.2487	77.2237
Podgornoye	PDG	1277	43.3274	79.4849
Karatau (array)	KKAR	475	43.1034	70.5115
Makanchi (array)	PS23	554	46.7937	82.2904
Borovoye (array)	AS057	361	53.0240	70.3880
Aktyubinsk	AKTK	360	50.4348	58.0167
Akbulak (array)	ABKAR	362	49.2558	59.9431

Kyrgyzstan operates the Kyrgyz broadband seismic network (KNET), shown in Figure 3. Phase data include 2,500 arrivals picked from roughly half of the events in the country; local scientists are continuing to make picks from the rest of their data and will eventually expand to pick times from events in the other CASRI countries.

Uzbekistan's store of seismic records are still being analyzed by local scientists. There have been 75 analog stations operating at different times within the country from 1901 to the present. Uzbek scientists have identified 46 stations that have recorded for a consistent period (others were for special deployments), and currently have 19 analog seismic stations operating. Phase arrivals from 21 events have been identified in the Tashkent station, and records from the Ferghana station are being analyzed now. Phase-arrival data from these records will be added to the CASRI database as soon as they are available.

Tajikistan's seismic network includes only strong motion stations. These records are useful to the seismic hazards assessment carried out by project participants at Lawrence Livermore but do not contribute to the crustal tomography studies, which are the focus of this report.

GT Event Data

On October 9, 2006, at 01:35, North Korea carried out an underground nuclear test. This event was registered by nuclear monitoring seismic stations network of Kazakhstan's NNC; the clearest signals were recorded by Akbulak stations, Borovoye large aperture array (Vostochnoye, Zerenda, Chkalovo stations), shown in Figure 4. These stations are located 3,750–4,500 km away from the explosion epicenter.

Seismic event parameters: North Korea nuclear test

Origin time 01:35:28 41.311

Coordinates: latitude 41.311, longitude 129.114

Magnitude 3.6–4.2

Another GT event is the crash of the "Dnepr" carrier rocket, which fell to earth during a failed launch in June 26, 2006. Two seismic arrays in the National Nuclear Center monitoring network registered the seismic signature of the event. Akbulak is in Western Kazakhstan and Karatayu located in Southern Kazakhstan; these stations were 571 km and 625 km away from the event, respectively. Figure 5 shows the detected signals. The Center for Acquisition and Processing of the Special Seismic Information, Almaty, calculated the event energy to correspond to an earthquake with a magnitude of $M = 3$, energy class 6.

A third source of GT data is a series of underground nuclear explosions that were carried out in Kazakhstan. A total of 177 events were recorded on 33 stations in Central Asia at distances from 450 to 2500 km, resulting in approximately 600 photographic paper records, which are currently being processed.

Tomography: Expanding on the CauSIN Project

One of the main goals of this project is to use phase-arrival times to form tomographic images of the crust and upper mantle. The approach we are using is the same as that applied in the CauSIN region, which utilized data from local networks in the Central Caucasus countries of the Republic of Georgia, Armenia, and Azerbaijan, in combination with data from the International Seismological Centre (ISC) and the Army's Space Missile Defense Command (SMDC), to form images of unprecedented resolution.

During the CauSIN project, a 3-D P-wave velocity model was developed for the crust and uppermost mantle of the Caucasus and the surrounding area by applying the tomography method of Sun and Toksöz (2006); 300,000 high-quality P-wave first arrivals from 43,000 events between 1964 and 2005 were used. This tomographic method accommodated velocity discontinuities, such as the Moho, in addition to smooth velocity variations. The spatial resolution was $1^\circ \times 1^\circ$ in the horizontal direction and 10 km in depth.

Figures 6 and 7 shows Pn and P wave imaging results from the CauSIN project. Strong P-wave velocity variations of more than 6% found in the study area indicate the existence of significant structural heterogeneities in the crust and uppermost mantle in this region. The Pn velocities shown in Figure 6 have similar features to those obtained by Al-Lazki et al. (2004). High Pn velocities are dominant under eastern Azerbaijan/southern Caspian and under the eastern Black Sea. The extent of the anomalies require further

confirmation; because of the distribution of earthquake epicenters and stations in the CauSIN database, rays traversing the area are mostly NW-SE, and likely have resulted in “smearing” along the dominant ray direction.

Repeating this imaging process with a joint dataset from the CauSIN and CASRI projects will extend our data coverage to the east, and should improve the image of the high velocity zones under the northern and southern Caspian Sea.

Events, stations, and ray paths in the current CASRI phase arrival time database are shown in Figure 8. This includes ISC data up until 2002 and is currently being updated to include more recent ISC data as well as the data discussed in the previous sections of this report.

CONCLUSION AND RECOMMENDATION

Efforts at improving communication and increasing the availability of seismic data among the countries of the Caucuses have met with success. Progress has been made in building a database that can be used toward the final goal of improving crustal models of the region.

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International Seismological Centre (2001). *Bull, Internatl. Seis. Cent.*, on-line bulletin, <http://www.isc.ac.uk/>.

Sun, Y. and M. N. Toksöz (2006). Crustal structure of China and surrounding regions from P wave traveltimes tomography. *J. Geophys. Res.* 111: B03310, doi:10.1029/2005JB003962.

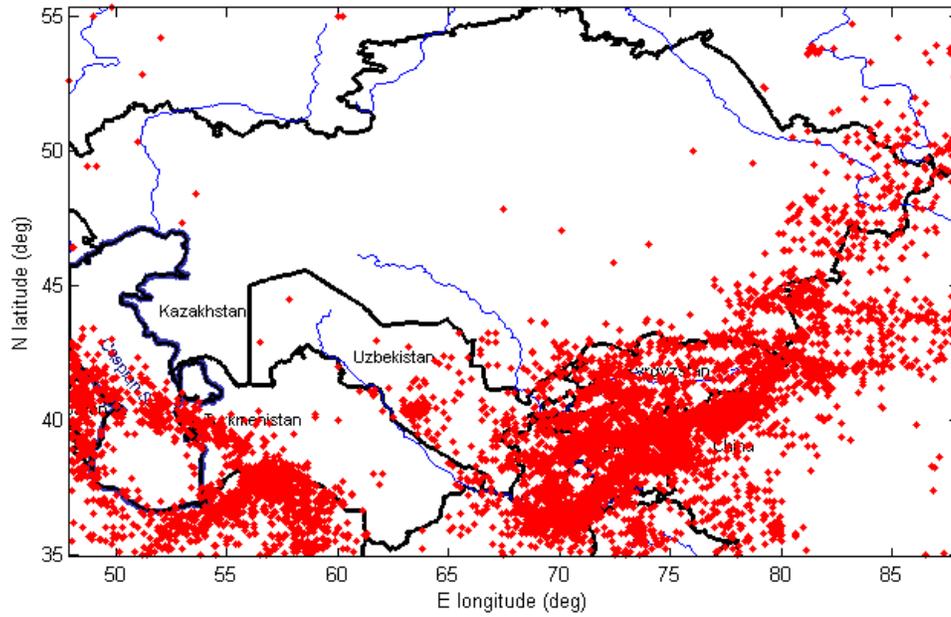


Figure 1. Events in the unified CASRI database, which includes nearly 11,000 events, both historical and from modern records.

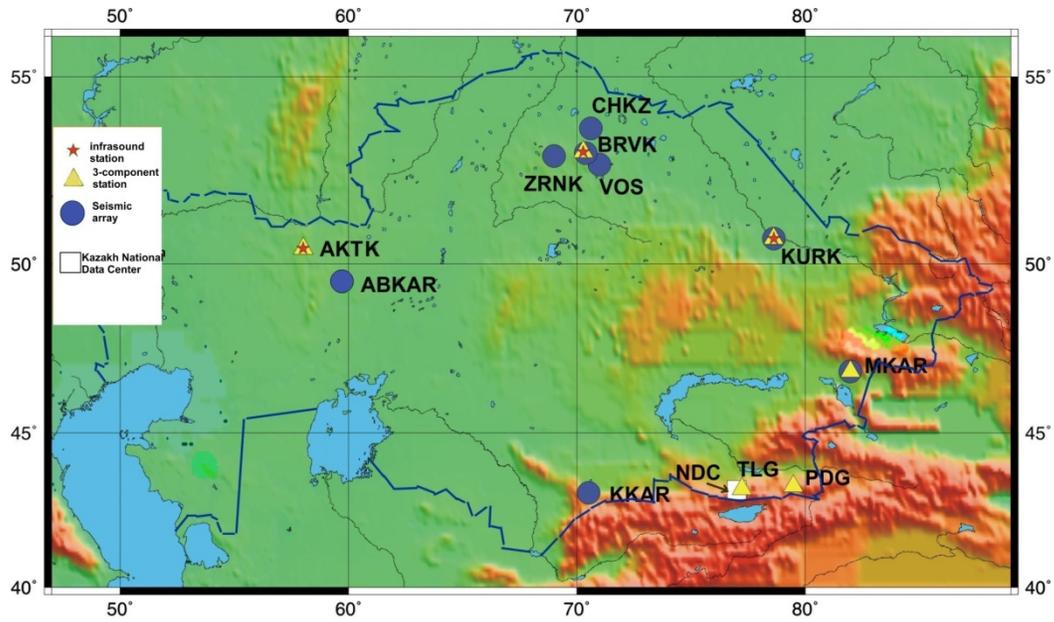


Figure 2. Kazakhstan's seismic array. More information about these stations is given in Table 1.

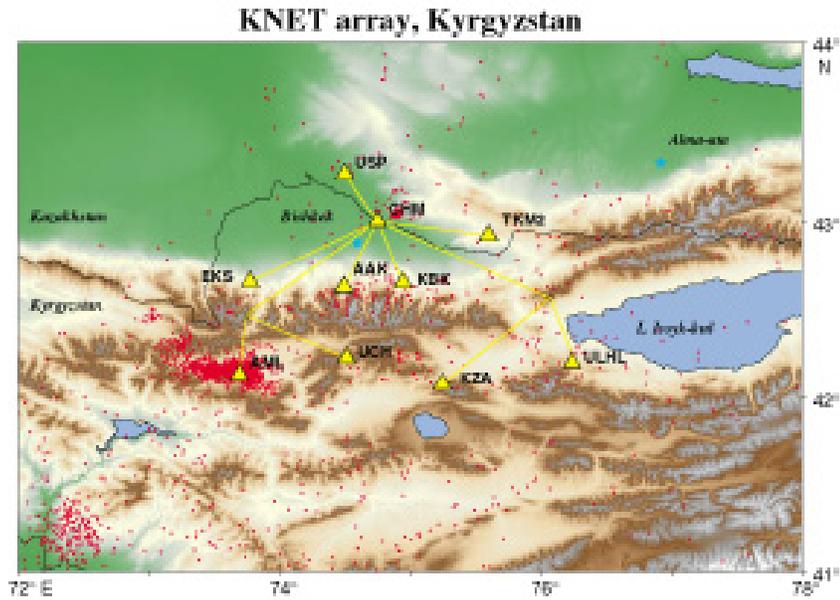


Figure 3. Kyrgyzstan's KNET seismic array.

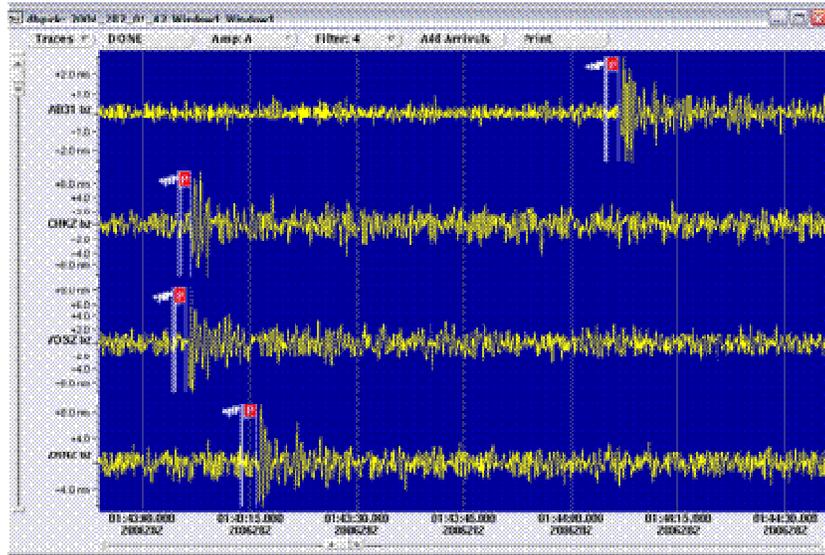


Figure 4: Records of the underground explosion carried out by North Korea on October 9, 2006. These are from Akbyulak stations, Borovoye large aperture array in Kazakhstan (Vostochnoye, Zerenda, Chkalovo stations.)

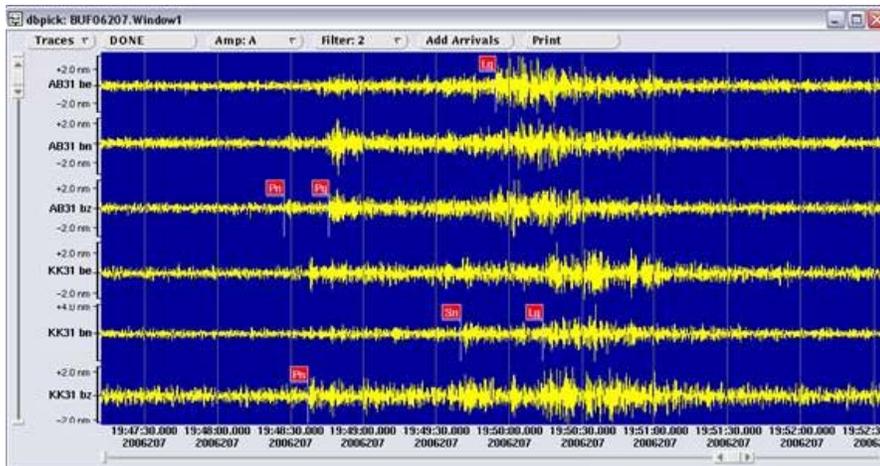


Figure 5. Records of the fall of the “Dnepr” carrier rocket on the territory of Kazakhstan. The upper three traces are recorded at the Akbulak station, and the lower three are at Karatayu. Both are in the Kazakhstan seismic array.

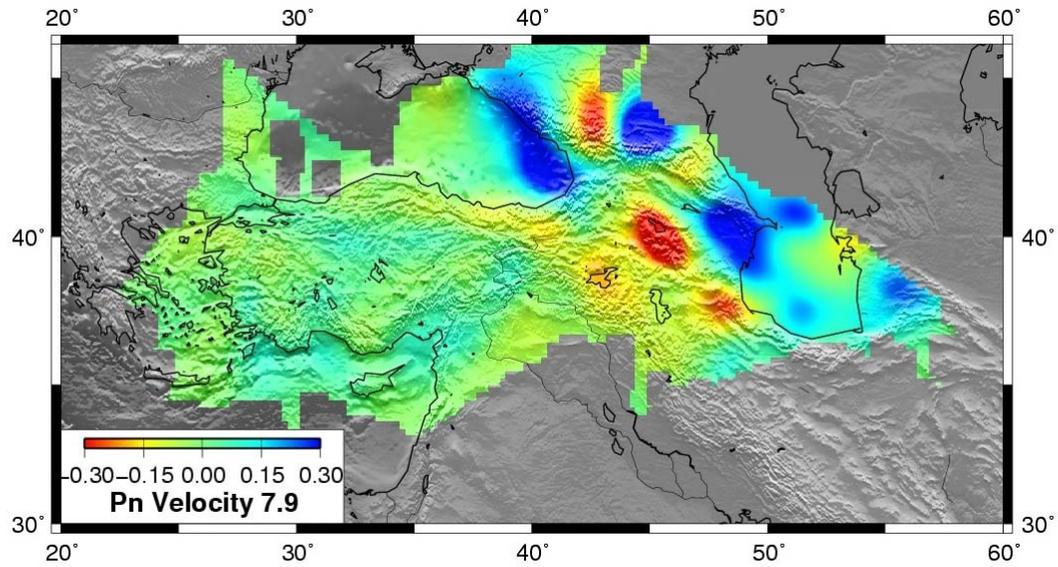
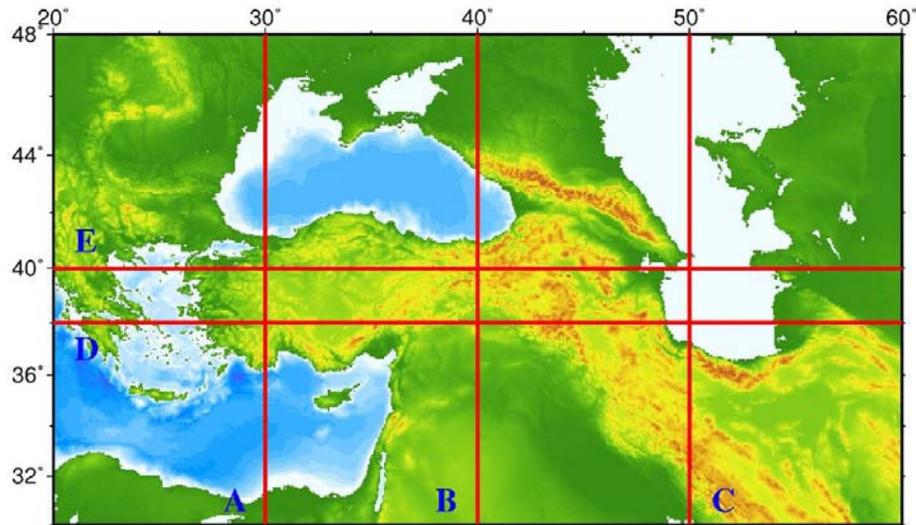


Figure 6. Imaged Pn velocity lateral variations in the CauSIN region. Average Pn velocity is 7.9 km/s, and variation corresponds with color. Red represents lower velocity than the average, and blue denotes higher velocity.



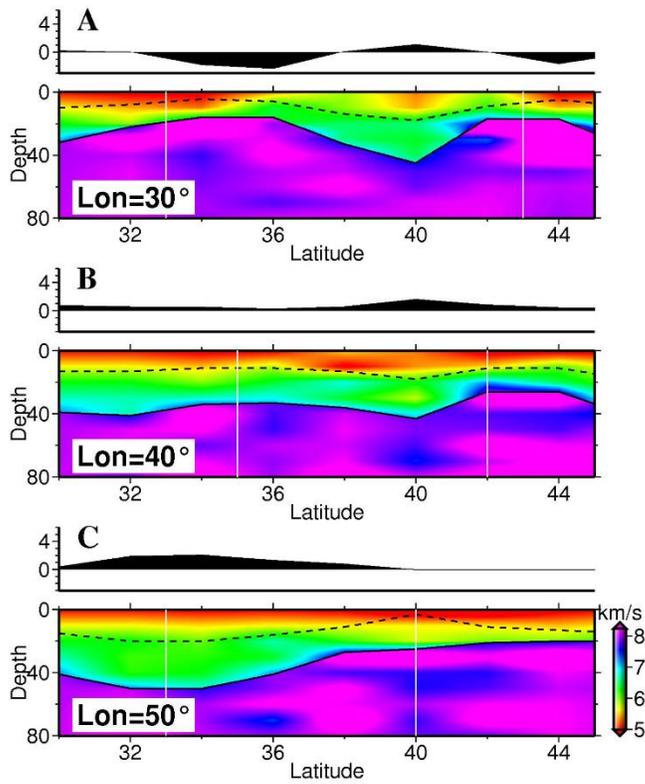


Figure 7: The tomography image produced during the CauSIN project. The top plot shows locations of vertical cross sections. Cross sections in the bottom plot are N-S slices at longitudes of 30°, 40°, and 50°. (The E-W slices D and E aren't shown here.) The surface topography along each profile is shown on the top of each cross section. The black curved lines show the Conrad (dashed) and Moho (solid) discontinuities. See text for discussion.

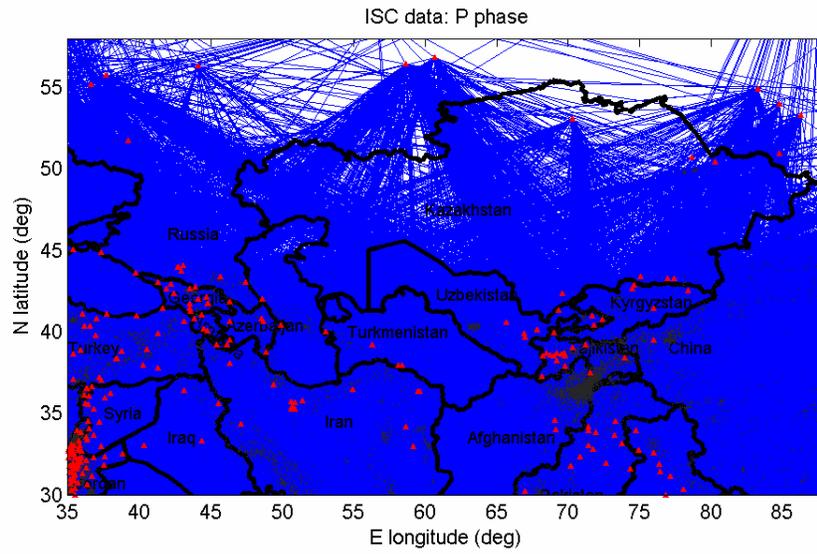


Figure 8: P raypaths in the CASRI region, from the ISC database for the years 1964–2002. This includes nearly 120,000 picks from over 14,000 events and 1200 stations but does not yet include data from local networks in the CASRI countries.