LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

LLNL-TR-828313

CENTRAL ASIA SEISMIC HAZARD ASSESSMENT (CASHA) "COMPLETE" CATALOGUE OF EARTHQUAKES

T. Onur, R. Gok, K. Mackey

October 25, 2021

Disclaimer

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

CENTRAL ASIA SEISMIC HAZARD ASSESSMENT (CASHA) "COMPLETE" CATALOG OF EARTHQUAKES

TUNA ONUR[1], RENGIN GÖK[2], KEVIN MACKEY[3], KEN ABRAMS[3], ANNA BEREZINA[4], NATALYA MIKHAILOVA[5], BAYAN BEKTURGANOVA[6], SHOKHRUHK MURODKULOV[7], ISTVAN BONDAR[8], AND CARLOS HERRERA[1]

[1] Onur Seemann Consulting, Inc. Victoria, BC, Canada
[2] Lawrence Livermore National Laboratory, Livermore, CA, USA
[3] Michigan State University, East Lansing, MI, USA
[4] Institute of Seismology NAS KR, Bishkek, Kyrgyzstan
[5] Institute of Geophysical Research NNC RK, Kazakhstan
[6] Seismological Experimental Methodological Expedition MES RK, Almaty, Kazakhstan
[7] Institute of Geology, Earthquake Engineering and Seismology NAS RT, Dushanbe, Tajikistan
[8] Research Centre for Astronomy and Earth Sciences of HAS, Budapest, Hungary

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

INTRODUCTION

Probabilistic Seismic Hazard Assessments (PSHA) greatly benefit from reliable earthquake catalogs. Central Asia, while rich in seismic monitoring history, reports a fraction of their earthquake data to international data collection centres. Furthermore, since the collapse of Soviet Union until now, monitoring and data collection efforts in Central Asia have not been centralized, making monitoring and reporting uneven and disconnected in this time period. Lawrence Livermore National Laboratory (LLNL) has undertaken a multi-year effort to systematically work with national seismic monitoring and data centres and seismic networks in Kazakhstan, Kyrgyzstan, and Tajikistan to compile a unified seismological bulletin for Central Asia. In tandem with this effort, an earthquake catalog that is processed to be PSHA ready was also generated. The processing for this effort included further duplicate identification and removal, magnitude harmonization and catalog completeness analyses. This report describes the "complete" PSHA-ready earthquake catalog, including the completeness intervals that were applied.

UNIFIED EARTHQUAKE BULLETIN

The unified earthquake bulletin, which forms the backbone of the earthquake catalog described in this report, includes data collected for the time period of 1900-2017 (inclusive). In addition to the national data centres and seismic networks of Kazakhstan, Kyrgyzstan, and Tajikistan, Soviet era data covering portions of Uzbekistan, Turkmenistan, and Russia were also included for completeness. Consistent with the requirements of a PSHA, the region under study

for the earthquake bulletin compilation includes all of the Central Asia plus a border extending out about 300 km, in order to include earthquakes that can impact seismic hazard in Central Asia.

The data collection is divided into the analogue era covering 1900 through 1992 and the digital era covering 1993 through 2017. Most of the data from the analogue era was manually typed by project participants from local agencies in Central Asia as part of this project. The earthquake bulletin contains many event parameters such as phase and arrival times, component specific amplitudes, station magnitude and energy-class (K Class) measurements, notes, sources, and other parameters.

Primary analogue-era data sources for this project are the seismological archives in Central Asia. Data from the original seismogram analysis were recovered and merged from different networks. Some original seismograms were reanalyzed. Data were supplemented with bulletins from the International Seismological Centre (ISC) and other Soviet publications. The analogue era data contains over 230,000 event entries and over 1.6 million arrivals from 10 primary and secondary sources.

Digital-era data are comprised of data from the digital seismic networks of each participating country (Kazakhstan, Kyrgyzstan, and Tajikistan). Data available from the ISC for all years, and local digital seismic bulletins since 1993 were also collected and merged with the digitized bulletins. The digital era data contains over 725,000 event entries and over 10 million arrivals from 8 primary and secondary sources.

After merging all available information, the Central Asia unified seismic bulletin was created. This is the first comprehensive bulletin developed for this region. This project fills in a considerable portion of a gap in data for the region, increasing the accuracy of event parameters, preserving unique archival data, and supplementing ISC bulletins with new data for the region.

The entire bulletin data compiled in this project was stored in a database, specifically designed for the data collection needs of this project. The earthquake catalog was then generated from this database.

MAGNITUDE AND LOCATION IMPROVEMENTS

The primary magnitude required in PSHA is the moment magnitude (Mw), which is mainly obtained from global sources and derived from moment tensor solutions, limiting the lower magnitude threshold to about magnitude 5. Using Coda Calibration Technique (CCT), we were able to directly calculate moment magnitude for a wider magnitude range. Employing this method, we calculated Mw for about 450 events ranging from Mw 2.3 to Mw 7.3. These, along with moment magnitudes from moment tensor solutions formed the basis for the region-specific magnitude conversions we generated as part of this project, greatly improving the moment magnitude estimates, especially for magnitudes smaller than 5.

In addition to magnitude improvements, we performed event relocations for more than 100,000 events in the earthquake catalog, taking advantage of the over 10 million arrivals we compiled for the digital era.

PSHA-READY CATALOG

Additional steps were taken as described below to prepare the catalog for use in PSHA after the incorporation of CCT moment magnitudes and event relocations:

1) General quality check was performed on all fields of the earthquake catalog as some values were entered manually. Where errors were found, they were corrected based on feedback from local agencies and checks against other data sources. In some cases this lead to the deletion of the event.

2) Events with no location or no magnitude were removed.

3) Explosions were removed based on identification by local agencies.

4) Depths that were entered as ranges (e.g. 5-10 km) were repopulated with a depth that is the middle of the range, and depth fields that were blank (unknown) were assigned zero depth. This may constitute slight conservatism in PSHA.

5) While duplicates were already identified in the bulletin merge, once the catalog was generated further duplicate identification was carried out. When records were merged at this stage, the record with the higher priority location was kept and the magnitudes from the deleted record were added to the record that was kept in the catalog.

6) Events that are located outside the 300km buffer around the Central Asia study area were removed (Figure 1).

7) Generally, the locations provided by local Central Asia agencies were used in the catalog due to their instruments' proximity to the earthquake. However, where the ISC locations were within 0.2 degrees and had more resolution than locally calculated locations, these were inserted instead.

8) Where events had multiple magnitudes from different agencies, these were prioritized based on input from local agencies.

9) The following magnitude conversions were derived from our catalog and used in the harmonization of the magnitudes to moment magnitude:

   i. $Mw = 0.4811\ (K\ Class) - 0.9137$

   ii. $Mw = 1.1885\ mb - 0.9182$

   iii. $Mw = 0.8919\ ML + 0.7763$

   iv. $Mw = 1.1578\ MPVA - 1.1902$

   v. $Mw = 0.6996\ MLH + 1.8153$

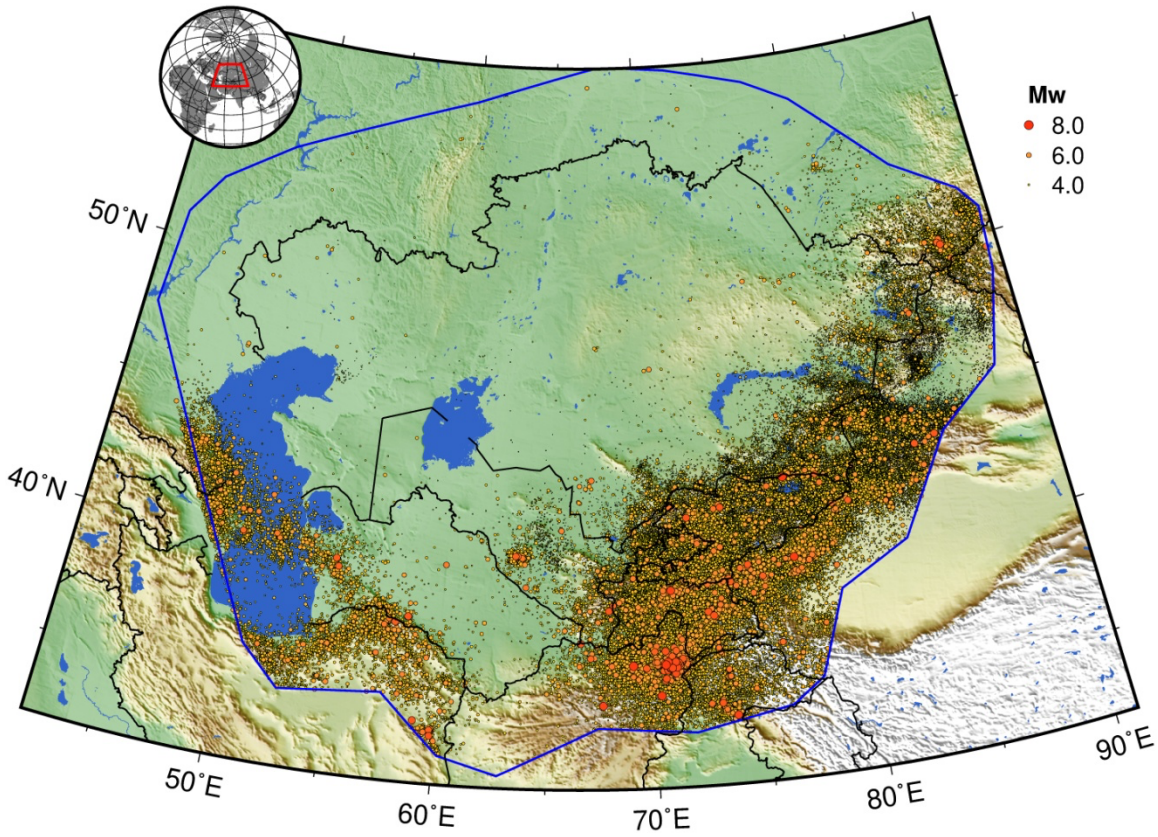

Figure 1. Earthquakes within the Central Asia study area (1900 – 2017 inclusive)

At the end of these processing steps, there were about 442,500 events in the catalog (Figure 1). The last processing step that was applied is described below:

10) Completeness intervals were applied to the catalog, i.e. events with magnitudes lower than the completeness threshold were removed. This analysis was done for two separate regions: i) Northern Kazakhstan where instrumentation has typically been sparse, ii) The rest of the study area where seismic networks have historically had more instrumental coverage. The completeness intervals determined as a result of our completeness analyses are as follows:

    i. Northern Kazakhstan

        a) Mw5.3+ complete between 1900 – 1959

        b) Mw4.4+ complete between 1960 – 2004

        c) Mw3.2+ complete between 2005 – 2017

ii. Rest of the study region

a) Mw5.3+ complete between 1900 – 1950

b) Mw4.4+ complete between 1951 – 1965

c) Mw3.6+ complete between 1966 – 2002

d) Mw3.2+ complete between 2003 – 2017

After the completeness intervals were applied, there were about 83,400 events left in the catalog (Figure 2).

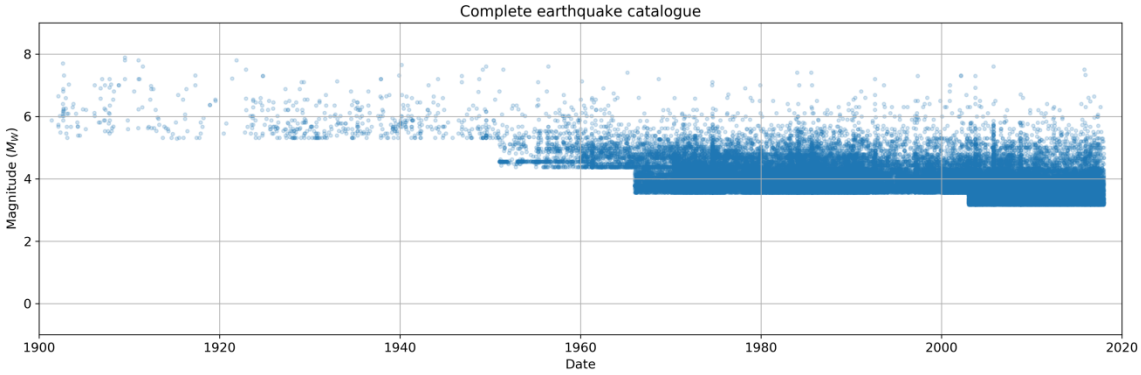

Figure 2. Complete catalog plotted against time for region (ii)

CATALOG FIELDS

The earthquake catalog distributed with this report has the following fields:

CASHA_EVENTID: Event ID for the CASHA earthquake catalog. This event ID was developed for our study and applies both to the bulletin and the catalog.

AUTHOR: Source of the primary data. This field was modified to ILOC where the location was obtained from our own relocations.

DATE: Date of the event in yyyy-mm-dd format.

TIME: Time of the event in hh_mm_ss.oo format.

LAT: Latitude in decimal degrees. Positive values indicate northern latitudes.

LON: Longitude in decimal degrees. Positive values indicate longitudes east of the Prime Meridian.

DEPTH: Depth of the earthquake in km. Events with unknown depths were assigned zero depth.

MW: Moment magnitude, either directly calculated (by moment tensor solutions or coda calibration technique) or converted using the relationships provided in the previous section.