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DEVELOPMENT OF MONGOLIAN SEISMIC NETWORK AND INTERNATIONAL MONITORING SYSTEM STATIONS

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First seismic station of Mongolia installed in 1957 with assistance from the Soviet Union and it was using photo paper for recording seismic data. Since the first station installation time, Mongolian seismic network expanded with a number of the seismic stations and developed the technological improvement. Institute of Astronomy and Geophysics (IAG) operates four types of IMS stations including seismic, infrasound, radionuclide and noble gas stations (PS25, IS34, MNP45, and MNX45) now. Mongolian National Data Centre (MNDC) receives seismic and infrasound data including IMS data using different communication technologies in real and near real-time from stations all around Mongolia including IMS stations. Current status of the CTBTO IMS stations in Mongolia and some radionuclide analysis results of the Mongolian IMS noble gas station (MNX45) will be presented.

HISTORICAL BACKGROUND OF THE SEISMIC STATIONS

Mongolia is situated in a seismically-active region due to its situation between the Indian sub-continent and Eurasia. Several strong earthquakes have been registered in Mongolia over the last century. It is showing that earthquake activity is much in Mongolia. First seismic station installed on 6 July 1957 at Ulaanbaatar city with assistance from the Soviet Union equipped with 3 components short period SKM-3 (2 sec) and 3 components long period SK (12 sec) seismometers. This station records ground motion on the photo paper using light and data analysis was performed by using photo image method. From 1959 until 1988 eight photo paper stations installed in the countryside area of Mongolia (Table 1). These stations equipped with 3 components short period SKM-3 seismometers.

Table 1. Installation of the 3 component short period Photo paper stations in Mongolia (1957–1988)

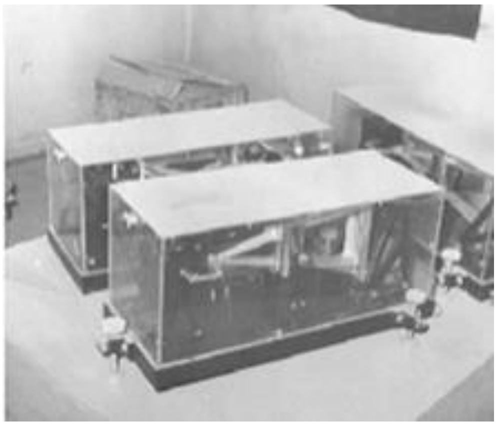
Installation date	Station code	Province/	City or Town
June 1959	altai	Gobi-Altai	Altai
May 1964	Ccg	Arkhangai	Tsetserleg
October 1964	Tsc	Zavkhan	Tosontsengel
July 1965	Hbd	Khovd	Khovd
June 1969	dzd	Umnu-Gobi	Dalanzadgad
November 1973	blg	Bulgan	Bulgan
November 1975	htg	Khuvsgul	Khatgal
August 1987	ulg	Uvs	Ulaangom
August 1988	ban	Bayan-Ulgii	Ulgii

Seismometer and recorder of these stations were located dark room (without light). Every 8 hours operators change photo paper and make time notes using line radio broadcast (Picture 1).

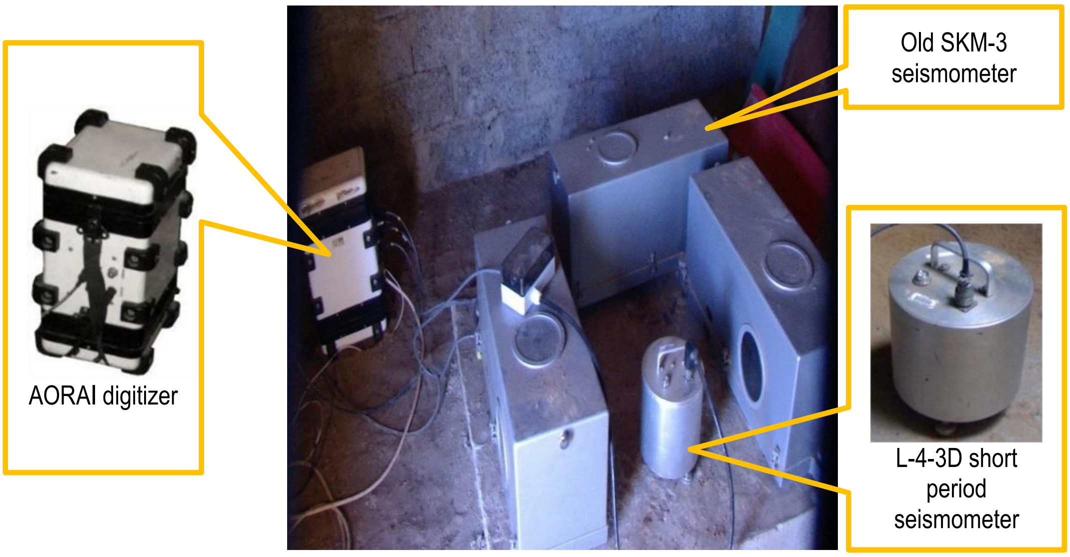
All photo station’s seismogram transported to Research Centre of Astronomy and Geophysics (old name of the current institute) from regional stations after 14 days and starts to analysis.

IMPROVEMENT OF THE REGIONAL STATIONS

IAG needs to develop countryside photo paper stations to digital seismic stations because photo paper resource was decreased. Therefore since 2005 to 2007 technical research work performed on the countryside stations and installed 3 short period component digital stations in 8 provinces. All countryside stations equipped with L-4-3D short period seismometers and AORAI digitizers (Picture 2).



Picture 1. General view of the photo-paper electric magnetic ground motion recorder



Picture 2. Seismometer and digitizer of the first digital regional stations

a) seismometer inside the vault

b) solar panel and 3G modem for the station

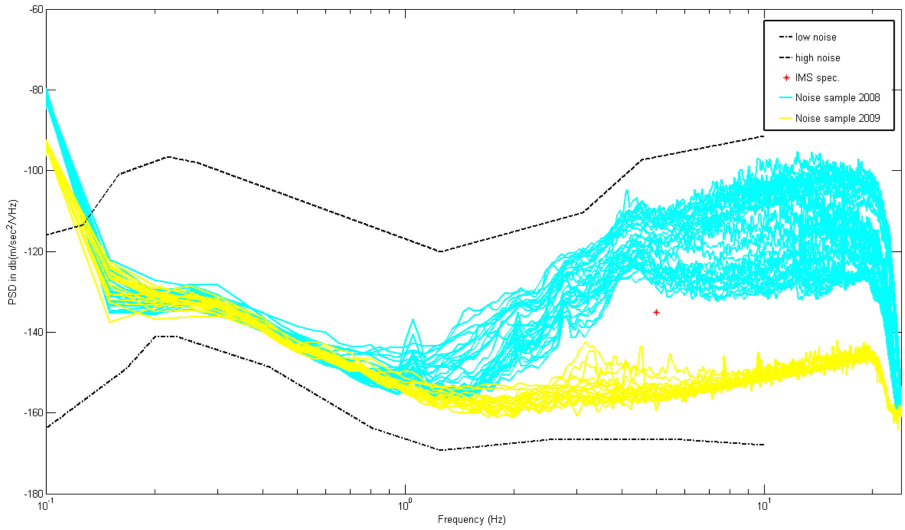
Picture 3. General view of the Automatic seismic stations installed in Mongolia

Then countryside operators started to analyze own digital station data using ONYX software. From 2010 to 2011 all regional station's instruments were swapped with BroadBand Guralp-3ESPC with Guralp digitizer. In 2014 countryside seismic network expands with 3 stations in Selenge, Dundgobi and Bayankhongor province.

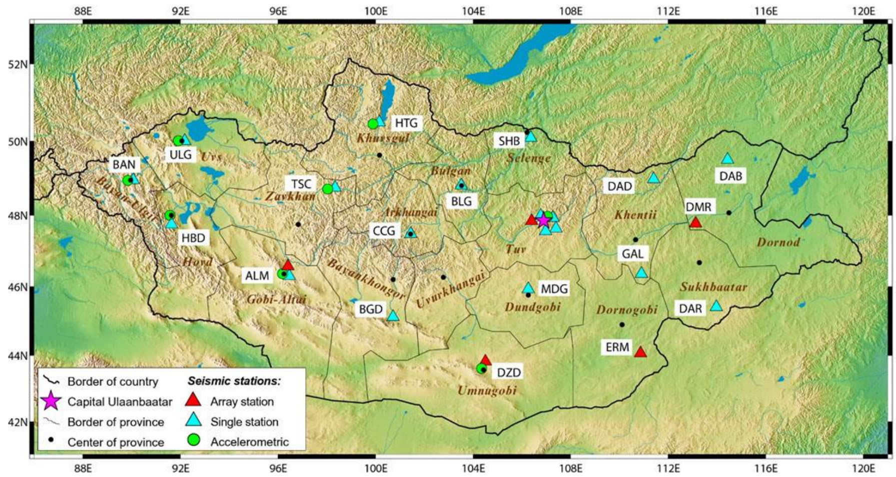
From 2016 to 2017 we installed four automatic seismic stations that equipped with Guralp 6TD instrument. Automatic stations transmit data using 3G internet modem (Picture 3).

Regional seismic stations installed far (2–3 km) from town in last century. But a population of the town increased and the seismic station became one part of the town. Then background noise increased since first installation and seismic stations need to move far from the town. Then we moved seismic stations 15–20 km distance from 2008 to 2018 to decrease seismic noise (Picture 4).

Now countryside station network [1] consists of 12 stations and all stations equipped with Guralp seismometers (CMG-3ESP or Guralp 6TD). In 2013 8 strong motion seismic stations were built in regional stations. 5 seismic mini area are working in Mongolia. 8 strong motion stations are working with regional stations. In 2015 all regional stations were connected by fiber optic cable with 1MB/s data rate (Picture 5).



Picture 4. Seismic noise figures before and after sensor location changes of the BANM station



Picture 5. Location of the Mongolian seismic stations

In 2004 AFTAC installed ALMAR seismic network in Taishir of the Gobi-Altai province and ERMAR seismic network in Erdene of the DornoGobi province. Then AFTAC installed DOMAR network in 2008 at Khulenbuir of the Dornod province. These 3 seismic network consists of 10 elements and seismometer of these stations installed deep position between 30 to 60 meters deep. These stations are with very low noise and IAG receives data after 7 to 11 seconds from stations using satellite communication.

EARTHQUAKE EARLY WARNING SYSTEM

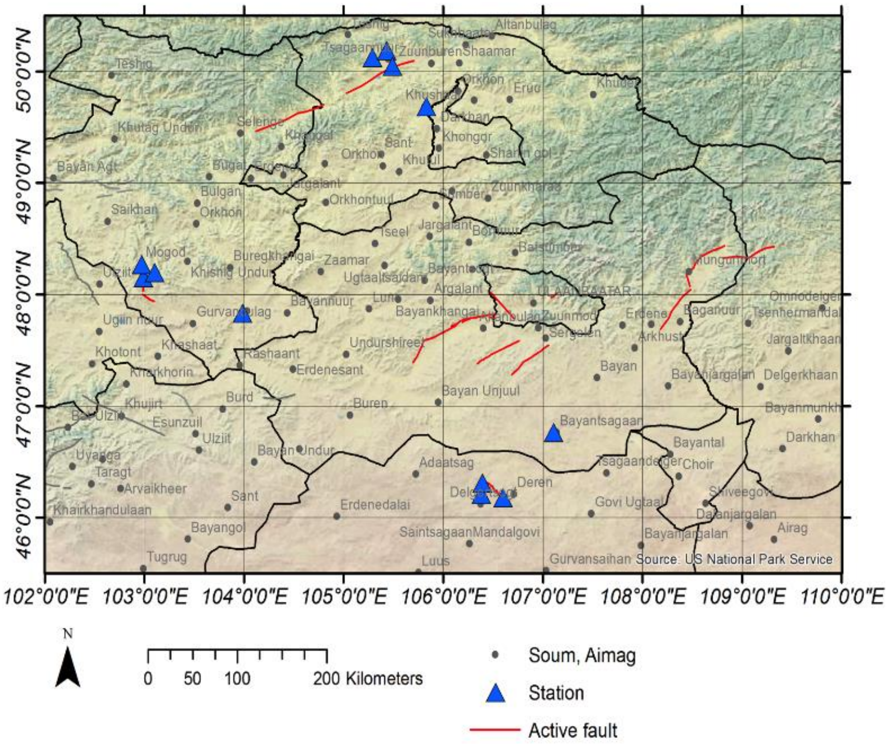
3 seismic crack area located from 170 to 300 km far from Ulaanbaatar. In 2012–2014 request of the Mongolian Government, built Earthquake Early Warning (EEW) system equipped with 12 accelerometers installed in 3 seismic crack area Mogod, Tsagaannuur, and Deren (Picture 6). EEW system started operational in January 2015.

Earthquake Early warning system stations send data to IAG using satellite communication. If the magnitude is high than seven earthquake occurs in those places, EEW system sends alarms to Ulaanbaatar before an earthquake hits the city:84 seconds for Mogod, 46 seconds for Deren and 80 seconds for Tsagaannuur.

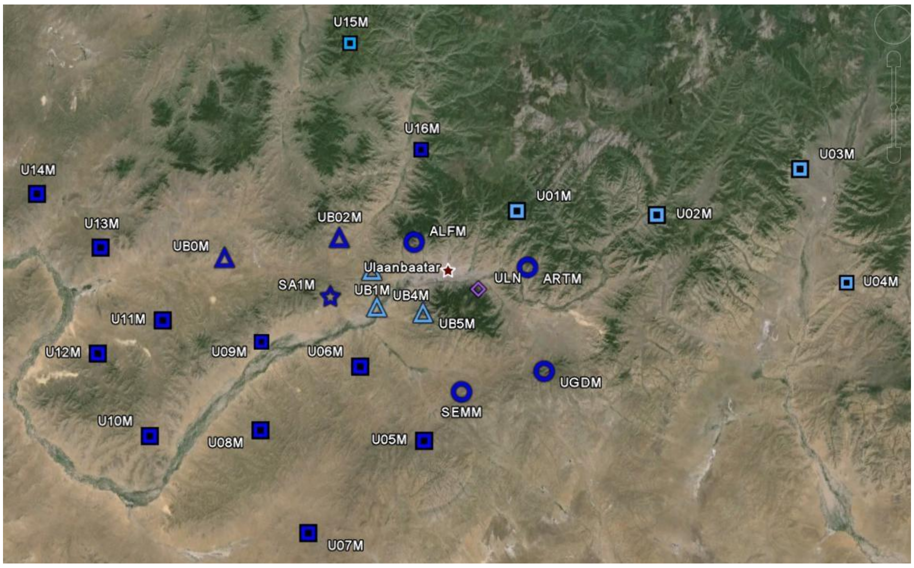
ULAANBAATAR GEOPHYSICAL STATIONS

Brief history:

- On 6 July 1957, the first seismic station “Ulaanbaatar” was installed.
- First digital seismic station ULN installed in Mongolia 1994 by USGS of the United States. It was equipped with the capability to amplify 0.1-360 s period seismometer STS1, high-frequency seismometer GS-13, and accelerometer FBA-23. Installation location was Observatory at Khureltogoot.
- From 1994 to 1997 Department Analyse Surveillance Environment (DASE) of France installed 6 stations in Tuv province. These stations transmit data using radio transmission. 5 station was equipped with vertical component short period ZM500 (1 sec) seismometer and one station equipped with 3 component short and long period LPZ&H12 (12 sec) seismometers.



Picture 6. Locations of the Earthquake Early warning system stations



Picture 7. Geophysical stations near Ulaanbaatar

- 2000 – CTBTO IMS PS25 mini seismic area installed. /9 elements have vertical SP ZM500 (1 sec) seismometer and 1 element has 3 component short and long period LPZ&H12 (12 sec) seismometers.
- 2006 – Built-up Mongolian National Data Center (MNDC).
- 2013 – Ulaanbaatar Monitoring Geophysical stations were installed around UB /Guralp CMG-3ESPC CMG-DM24S3EAM, Upgraded ULN station.

The Institute of Astronomy and Geophysics (IAG) has been built a real-time and seismic and geophysical observation network (The Network of capital Ulaanbaatar area) in 2012 and keep improving its performance. From 2012 to 2014 near Ulaanbaatar city installed seismic broadband 16 stations, 5 GPS stations for measuring plate motion, 5 tiltmeter stations, and 3 magnetometer stations for research seismic activity of the Ulaanbaatar area (Picture 7).

Since the installation of this network, we have been monitoring persistently their characteristics and noise level and data availability. The purpose of this station network is to monitor seismic activity near Ulaanbaatar region, its vicinity area and establish an earthquake forecasting system on the preliminary basis. We installed 8 radon stations with assistance from the DASE. We have 14 mobile seismic stations for deep research for interesting area. These mobile stations equipped with REFTEK-130B/S digitizer and Guralp CMG-3ESPC seismometer.

In 2006, RCAG & DASE teams built Mongolian National Data Centre (MNDC). It was received data from 8 infrasound, 11 seismic stations and 4 mini array seismic stations all around Mongolia including IMS stations. Then the MNDC started to produce routinely seismic bulletins on a monthly and yearly basis.

Today, the Mongolian seismic networks are widespread over 15 sites (Ulaanbaatar region is considered here as one site) that have, all together, 87 high sensibility digital seismic stations. All station data are transmitted in near real-time to the MNDC. At the MNDC integrates waveforms into a database and the waveform data analysis performs. We monitor the station's data quality using PQLX.

CTBTO IMS Stations in Mongolia

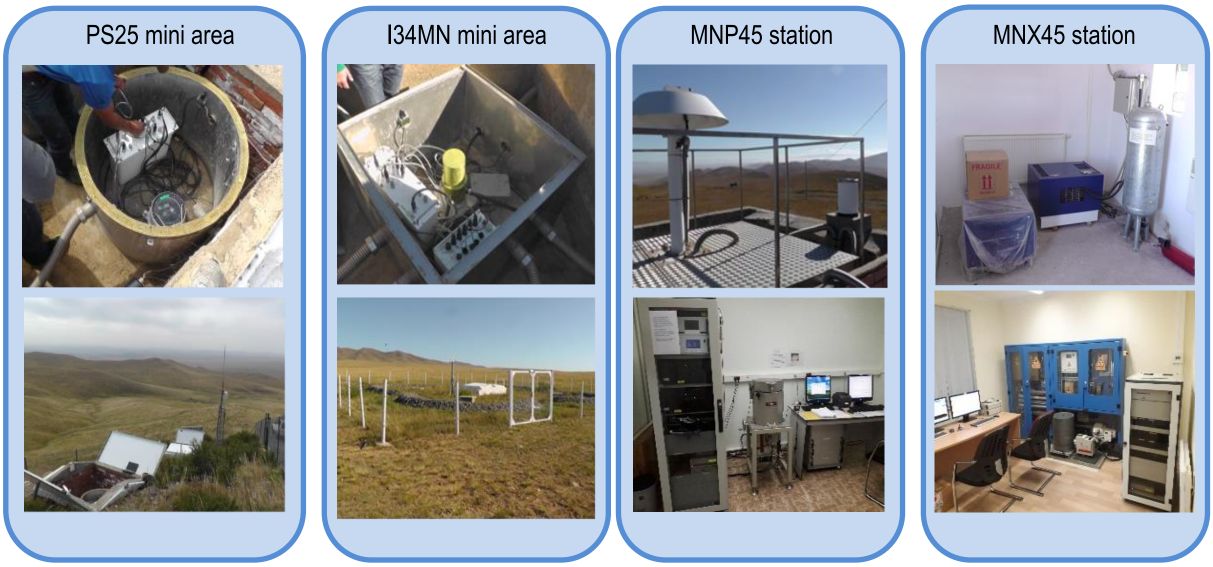
IAG operates 4 kinds of IMS stations: Primary seismic (PS25), Infrasound (I34MN), Radionuclide (MNP45) and Noble gas (MNX45) stations. IMS stations in Mongolia is a very important part for the Mongolian NDC. The IS34 network consists of 8 infrasound stations equipped with MB2000 micro barometers (acoustic pressure sensors) – Table 2.

The IS34 network (Picture 8) to detect very low-frequency sound waves in the atmosphere produced by natural and man-made events. The PS25 network consists of 9 elements equipped with vertical short period (2 seconds) seismometer and 1 element equipped with short period (2 seconds) 3 component and long period (12 seconds) 3 component LPZ and LPH12 seismometers. PS25 seismic area detects and locates seismic events. PS25 seismic mini array station is one of 50 primary CTBTO stations, which send its data in real-time to the International Data Centre (IDC) in Vienna.

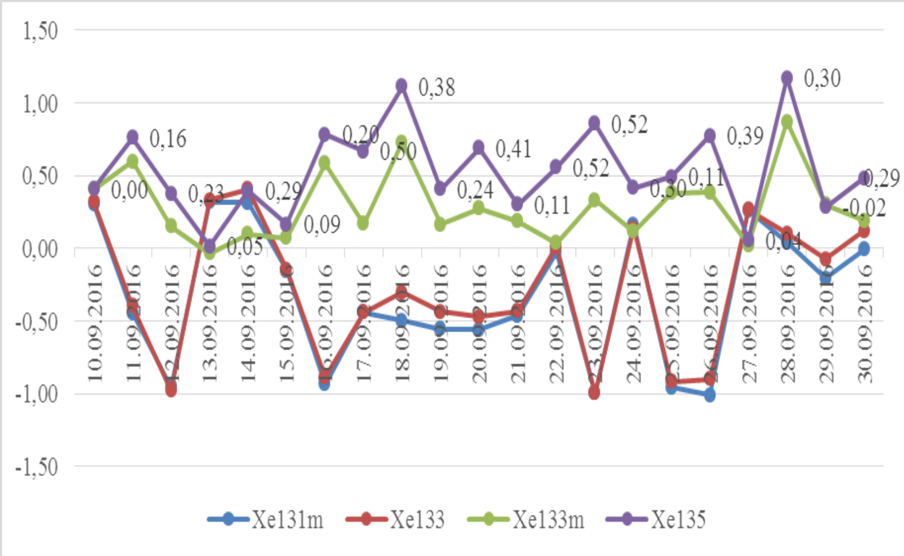
The radionuclide MNP45 station uses air samplers to detect radioactive particles released from atmospheric explosions or vented from underground and underwater explosions. The relative abundance of different radionuclides in air samples can distinguish between materials produced by a nuclear reactor and a nuclear explosion. MNX45 station detects radioactivity of the noble gas released from atmospheric explosions or vented from underground and underwater explosions. MNX45 station samples air 24/7and collects the xenon every day. Everyday MNX45 station performs radioactivity measurement for the collected sample using a gamma spectrometer.

Table 2. IMS stations of Mongolia

Installed year	Treaty Code	Technology info	Certification
1998	I34MN	Infrasound network	Certified on 19 December 2002
2000	PS25	Primary seismic station mini area	Certified on 5 December 2003
2002	MNP45	MNP45 (Radio Nuclide, Particulate Station)	Certified on 26 May 2003
2006	MNX45	MNX45 SPALAX (Noble Gas Analysis Station)	Certified in 2013



Picture 8. General view of the IMS stations of Mongolia



Picture 9. Xenon detection of MNX45 station from 9/10/2016 to 9/30/2016

Radionuclide Analysis Results of the MNX45 Station

We use openspectra software for MNX45 data analysis and ATM calculated by webgrape for the all DPRK events [2] (Picture 9).

In September 2016, the wind direction was from west to east, then Mongolian IMS RN station detection possibility was decreased. During DPRK2016 and DPRK2013 events wind directions were directed from west to east in the ATM, then nuclear explosion radioactivity detection capabilities decreased for the MNX45 and MNP45 stations.

Summary

All stations data collects to Mongolian National Data Centre (MNDC). MNDC receives 1242 MB data every day and MNDC equipped with nonstop electrical power supply using UPS and electrical generator. In order to detect in all station capacity, well data interpretation, analysis of seismic source parameters (time, location, depth, magnitude), necessary to have good seismic stations and as well as to use some related geophysical instruments. In future MNDC will completely perform waveform data analysis on Linux operating system software.

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МОҢҒОЛИЯНЫҢ СЕЙСМИКАЛЫҚ ЖЕЛІСІН ЖӘНЕ ХАЛЫҚАРАЛЫҚ МОНИТОРИНГ ЖҮЙЕСІНІҢ СТАНЦИЯЛАРЫН ДАМЫТУ

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Моңғолияның бірінші сейсмикалық станциясы 1957 жылы Кеңес Одағының көмегімен орнатылған және онда сейсмикалық деректерді тіркеу үшін фотоқағаз пайдаланылған. Сол кезден бастап моңғолияның сейсмикалық желісі бірнеше сейсмикалық станцияларға кеңейді және технологиялық жақсартулар әзірленді. Қазіргі уақытта Астрономия және геофизика институты (АГИ) сейсмикалық, инфрадыбыстық, радионуклидтік және бекзат газдар (PS25, IS34, MNP45, және MNX45) станцияларын қоса алғанда, ХМЖ станцияларының төрт түрін басқарады. Моңғолияның ұлттық деректер орталығы (МҰДО) ХМЖ қоса алғанда, Моңғолияның бүкіл станцияларынан нақты уақыт және нақты уақытқа жуық уақыт режимінде әртүрлі коммуникациялық технологияларды пайдалана отырып ХМС деректерін қоса алғанда, сейсмикалық және инфрадыбыстық деректерді қабылдайды. Мақалада Моңғолиядағы ЯСЖТШҰ ХМЖ станцияларының ағымдағы ахуалы және ХМЖ моңғолияның бекзат газдар станциясының (MNX45) радионуклидті талдауының кейбір нәтижелері көрсетілген.

РАЗВИТИЕ МОНГОЛЬСКОЙ СЕЙСМИЧЕСКОЙ СЕТИ И СТАНЦИЙ МЕЖДУНАРОДНОЙ СИСТЕМЫ МОНИТОРИНГА

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Первая сейсмическая станция Монголии была установлена в 1957 году при помощи Советского Союза, и в ней использовалась фотобумага для регистрации сейсмических данных. С тех пор, монгольская сейсмическая сеть расширилась рядом сейсмических станций и для нее разработаны технологические улучшения. В настоящее время Институт астрономии и геофизики (ИАГ) управляет четырьмя типами станций МСМ, включая станции сейсмические, инфразвуковые, радионуклидные и благородных газов (PS25, IS34, MNP45, и MNX45). Монгольский национальный центр данных (МНЦД) принимает сейсмические и инфразвуковые данные, включая данные МСМ, используя различные коммуникационные технологии в режиме реального и близко к реальному времени со станций по всей Монголии, включая станции МСМ. В статье представлен текущий статус станций МСМ ОДВЗЯИ в Монголии и некоторые результаты радионуклидного анализа с монгольской станции благородных газов МСМ (MNX45).