Analysis of seismic noise level at high-mountain stations of the KNET network

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Abstract. In this work we estimate level of seismic noise at Kyrgyz Network’s (KNET) high-mountain stations for 19 years of the time this network operated in real-time mode (1999-2017). To do that for each channel (E–west-east, N–south-north and Z–vertical, all with 100 Hz sample rate) of each station we made fifteen-minute (900 seconds) segments of seismic noise. We took such segments for different seasons (March, June, September, December) and for various times of day (00, 06, 12 and 18 hours UTC) for the whole 19 years. We analyzed probabilistic power spectral density heatmaps and found out some features of KNET’s high-mountain station’s operation. These features depend on season-wise weather changes. The worth month for all stations is September. In general, when weather is favorable these stations can be characterized as low-noise ones and their data may be used in various researches.

1. Introduction
Kyrgyz seismologic network KNET includes 10 digital broadband stations; it was set up in August-September 1991. Location of stations is shown in Figure 1 and described in Table 1. Three stations are located along sides of Chu valley and seven other ones – in foothills and mountains of North Tien-Shan. More detailed description of KNET may be found in [1-3].

At each KNET station main equipment (Figure 2) is placed into certain container. At ULHL and TKM2 stations it is inside underground metal box of volume about 2 m³; At EKS2, KBK, and USP stations it is inside basements of small buildings; at AML, UCH – KZA it is inside a box of dimensions 3x4x2 m; at CHM station it is inside a small building. At AAK station the seismosensor is inside of 75-meter-length gallery, also in the same place at 10 m distance there is another seismic station belonging to the worldwide IRIS (Incorporated Research Institutions for Seismology) network [4].

Because of extreme weather conditions in mountain areas of Kyrgyzstan temperature inside high mountain containers may lower down to -30°; that may influence operation of seismic sensors. It the current research we consider only high-mountain stations of KNET: AML (3400 m), KZA (3520 m) and UCH (3850 m).

In North Tien-Shan there are three types of relief: mountains, foothills and intermountain basins. This relief influences climatic features of the region. As in any mountain area, climate here is defined by vertical zoning, latitude and distance from lakes and seas. With increasing altitude local climate changes from warm and humid to cold and wet. In general by global air circulation North Tien-Shan belongs to the temperate climate zone; foothills have temperate warm climate and high mountains have temperate cold and cold climate. Wind variations are defined by mountains as they work as obstacles for air streams. Also mountains hold moisture and cause local winds blowing from peaks to valleys in
night time and from valleys to peaks in daytime. Sometimes these winds reach speed of 20-30 m/s. Most of the time during summer weather at North Tien-Shan is calm and without strong winds [6].

![Figure 1. Location of Kyrgyz seismologic networks’ (KNET) stations. Triangles – seismic stations, straight lines – telemetry radio links between stations and signal repeaters.](image)

| №  | Code | Full name         | φ, north | λ, east | H, m | Geographical object, country                                      |
|----|------|-------------------|----------|---------|------|------------------------------------------------------------------|
| 1  | AAK  | Ala-Archa         | 42.6333  | 74.4944 | 1680 | Ala-Archa ravine, Kashkasu village, Kyrgyzstan                   |
| 2  | AML  | Almaly-Ashuu      | 42.1311  | 73.6941 | 3400 | Almaly-Ashuu mountain pass, Kyrgyzstan                          |
| 3  | CHM  | Chumysh           | 42.9986  | 74.7513 | 655  | Chumysh village, Chumysh mountains, Kazakhstan                 |
| 4  | EKS2 | Erkin-Sai         | 42.6615  | 73.7772 | 1360 | Erkin-Sai and Kara-Bulak villages, Kyrgyzstan                   |
| 5  | KBK  | Karagai-Bulak     | 42.6564  | 74.9478 | 1760 | Karagai-Bulak village, Kyrgyzstan                                |
| 6  | KZA  | Kyzart            | 42.0778  | 75.2496 | 3520 | Kyzart mountain pass, Kyzart Mountains, Kyrgyzstan             |
| 7  | TKM2 | Tokmak-2          | 42.9208  | 75.5966 | 2020 | North slope of Kastek ridge, Kazakhstan, 30 km from Tokmak city, |
|    |      |                   |          |         |      | Kyrgyzstan                                                      |
| 8  | UCH  | Uch-T’or          | 42.2275  | 74.5134 | 3850 | Uch-T’or mountain pass, Tuz-Ashuu mountain pass, Kyrgyzstan     |
| 9  | ULHL | Ulakhol           | 42.2456  | 76.2417 | 2040 | Ulakhol village, Dondustuk place, Kyrgyzstan                    |
| 10 | USP  | Uspenovka         | 43.2669  | 74.4997 | 740  | Betkainar village (former Uspenovka), Kazakhstan               |
Figure 2. Scheme of field station and data acquisition subsystem refraction REF TEK [5].

Figure 3 shows climatic characteristics for three areas of North Tien-Shan: Suusamyr valley (AML station), Kyzart Mountains (KZA station) and Uch-T’or mountain pass (UCH station). For all three these areas we can emphasize common features: in cold seasons wind speed is greater and can reach 20 km/h, air temperature may lower to -30 °C, predominant wind direction is southwards.

Figure 3. 30-year average climatic characteristics of the Suusamyr valley (AML), Kyzart Mountains (KZA) and Uchtor pass (UCH): precipitation, temperature, wind speed and directions [7].

Weather conditions (temperature, pressure, wind speed) and also glacier melting can influence on the seismic sensor operation and seismic noise levels.

The goal of current research in assessment of seismic noise level at high mountain KNET stations located in areas with complex weather conditions.
2. Data and method
To perform seismic noise research we considered digital records with 100 Hz sampling rate for the period from the beginning of 1999 till middle of 2017. We made segments (cutoffs) of records containing seismic noise with the length of 15 minutes (900 seconds). These segments were made from four different times of the day with 6-hour step: 00:00, 06:00, 12:00 and 18:00 UTC. Each of these times of day was considered for each season (specifically – March, June, September, and December) of each of years (1999-2017).

These months were chosen as the ones containing equinoxes, the longest daylight and the longest night. Segments used for the analysis do not contain any seismic events and artificial impulse noise. We studied frequency composition of seismic noise by plotting probabilistic power spectral density (PPSD) of seismic noise for every signal component (E, N and Z). This method is described in detail in [8]. We compare PPSD distribution to standard noise models presented in [9]. As the data processing result we have plot PPSD of seismic noise for every channel (E, N, Z) for following data sets: for each of four different times of the day (00, 06, 12 and 18 hours UTC) for the entire study period. For each of four seasons (March, June, September, December) for the entire study period.

3. Results
For three channels (E, N, Z) of each station studied we plotted and analyzed PPSD heatmaps of seismic noise for four times of a day and four seasons. After considering typical PPSD distribution of all stations relatively to noise models from [9] we can conclude that the stations have low noise levels at periods 0.02-10 s. Nevertheless each of three stations shows some deviations of noise power from typical PPSD distribution.

AML. Figure 4 shows PPSD of seismic noise at AML station for every season and every time of a day. The best channel for this station is horizontal channel E where the smallest number of deviations from typical distribution is observed. Most deviations are presented at channel N, a bit less – at channel Z. Presence of these deviations at all times of a day (Figure 4) on both N and Z channels means that this phenomena does not depend on time of a day.

In contrast, PPSD for different seasons (Figure 5) show that the best seasons for this station are March having no deviations from typical PPSD and December having very few ones. Also in December there is minimal variations in seismic noise power at periods 10-100 s. The most problematic months for this station are June and September. Since May, all throughout the summer till and including
September there is massive glacier melting in Suusamyr valley; it can lead to flooding the bunker with seismic sensor. In September the season of frequent winds begins that can also influence on seismometer operation.

![Figure 5. PPSD of seismic noise on all channels of the AML station for the four seasons.](image)

KZA. On PPSD heatmaps for KZA station (Figures 6, 7) there are fewer deviations of seismic noise power from typical distributions relatively to AML; while overall variance of power is greater, without any relation to time of a day (Figure 6), but depending on the season (Figure 7).

![Figure 6. PPSD of seismic noise on all channels of the KZA station for the four times of day.](image)

At periods 10-100 s there is large variance in all seasons but December. At periods 0.02-10 s the best seasons for the station are March and June. Similar to the AML station the worst season for KZA is September.
UCH. UCH station has highest altitude among the KNET network (3850 m). PPSD at this station (Figures 8, 9) has greater number of deviations from typical distribution than the ones at AML and KZA for all seasons and all times of the day. The smallest number of deviations is on channel E. The least favorable (according to number of deviations) month for this station is September. For periods 0.02-10 s the best months are March and July while for periods 10-100 s the best one is December.

Figure 7. PPSD of seismic noise on all channels of the KZA station for the four seasons.

Figure 8. PPSD of seismic noise on all channels of the UCH station for the four times of day.
Figure 9. PPSD of seismic noise on all channels of the UCH station for the four seasons.

Presence of deviations from typical PPSD distributions in all times of a day at all three stations means that phenomena causing increase of seismic noise power do not depend on time of a day but are defined by season-wise weather conditions change.

At all three stations variance of noise power on periods 10-100 s (very low frequencies) increases in certain months. Such power increase on very low frequencies can be explained by the influence of strong wind. This was pointed also by academician B.B. Golitsyn. In [10] it is said that wind speed influences mostly horizontal components of seismic signal. According to Figure 3 in the areas of all three stations considered predominant wind direction is southwards. It is quite probable that such wind direction influences operation of North-South component of seismic sensors (N channel) as we see at AML and UCH stations. UCH station may be affected by wind direction and speed especially strongly because it is located on the mountain peak. At neighbor Uch-t’or mountain pass wind speed can sometimes reach 15-20 km/h.

To find the reason of rapid increase of seismic noise power on all periods a much more detailed research of weather condition influence is require. However the three stations considered are located far away from inhabited areas and roads. They can only be reached by helicopter. The only thing we can do now is to notice that September is the most problematic month for all three stations. According to Figure 3 this month has minimal amount of precipitation, dry and still warm season.

4. Conclusion
We have done analysis of seismic noise levels at high-mountain stations of KNET network: AML, KZA and UCH. We found out certain features of noise associated with climatic features of the stations’ locations. One of probable reasons of noise power increase is wind speed changing with seasons. Other reasons of instabilities in operation of stations may be glacier melting, change of temperature, pressure and other weather conditions. To clarify their influence further research is required which is hard to perform in high mountain areas. In general during favorable weather conditions all three stations may be characterized as ones having low noise levels and their data may be used in various researches.

Acknowledgements
The research was performed within the framework of the state assignment for Federal State Budgetary Institution of Science Research Station of Russian Academy of Sciences in Bishkek (topics No. AAAA-A19-119020190064-9 and No. AAAA-A19-119020190066-3).
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