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Modern studies of the cryosphere of the Zeravshan and Gissar Ranges (Tien Shan)

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Abstract. The paper presents brief results of the modern studies of the cryosphere of the Zeravshan and Gissar ranges. Also the rate of decrease in the area of glaciers over the last almost a hundred years and the presence and degradation of permafrost during that time were considered. The actual description of the methodic for estimation of the depth of the ground freezing based on air temperature and snow thickness data were also given. An experience of application of this method for estimating the depth of ground freezing on the mountain slopes in order to compile the maps of the permafrost zone of the Zeravshan and Gissar ranges was described.

1 Introduction

The World Meteorological Organization (WMO) has recognized the last eight years as the hottest since the start of meteorological observations. The global average temperature in 2022 will be about 1.15 degrees Celsius higher than in the pre-industrial period (1850-1900). This means that every year since 2016 has been a record hot. WMO experts state that greenhouse gas emissions into the atmosphere have led to an increase in the level of the world ocean and the melting of ice, as a result of which extreme weather was recorded in various parts of the world. In Greenland, at an altitude of 3.2 thousand meters above sea level, it rained for the first time. Thus, since the main elements of the cryosphere in high-mountain regions are frozen soils, underground ice and glaciers, it is precisely their state that is most sensitive to the current global and regional climatic fluctuations. According to Gorbunov and Ermolin (1981), the volume of ground ice in the Tien Shan is 320 km^3. Over the past sixty years, the volume of ground ice in relation to the volume of glaciers has decreased significantly. This trend continues in all mountainous regions of Central Asia. Such rates of thawing of mountain permafrost, in turn, can provoke the development of dangerous permafrost geological processes, the role of which is great in shaping the ecological situation in mountainous areas. The development of dangerous and often catastrophic cryogenic geological processes is promoted by the increased seismo-dynamic activity of the areas of high mountain permafrost. These factors must be taken into account both when drawing up projects for the economic development of these areas, and when carrying out measures to protect objects already built in the mountains.

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2 Materials and methods

The climate in the Tien Shan mountains varies according to the altitude zonality from the climate of the sultry deserts at the foot of the mountains to the cold climate of the snowy-icy highlands. The average July temperature in the valleys of the lower mountain tier is 20-25°C, and on the tops of mountain ranges it drops to 0°C and below (Figure 1).

The main part of the Tien Shan Mountains lies in the temperate zone, but the Fergan ridges (Southwestern Tien Shan) are on the difference with the subtropical, experiencing the influence of dry subtropics, especially in the lower altitude zones. In general, the climate is characterized by a sharp aridity, a significant duration of sunshine (2500 – 3000 hours / year). In most of the Tien Shan (especially in the highlands), the western transport of air masses prevails, which is overlaid by the local mountain-valley circulation. Great heights, complexity and dissection of the relief cause sharp contrasts in the distribution of heat and moisture. In the valleys of the lower belt of the mountains, the average temperature in July is 20-20°C, near the foothills

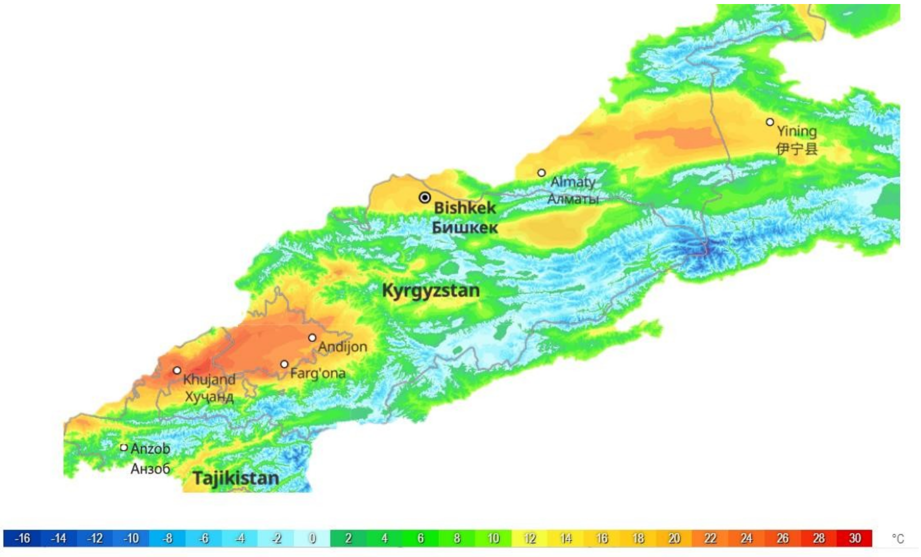

Fig. 1. Air temperature map of Tien Shan.

The southern slope of the sublatitudinal-elongated Hissar ridge is practically the first major obstacle in the way of southern and southwestern moisture-bearing air masses. With increasing altitude, the average annual temperature decreases. Temperature gradients for different altitude zones are not the same. For the interval from the weather station "Gushary" to the weather station "Mayhura" it is equal to 1 degree. per 100 m of ascent, for the intervals "Mayhura" – "Haramkul", "Haramkul" – "Anzob pass", respectively 0.31 and 0.83 degrees at 100 m . The estimated height of the average annual zero temperature for the starboard side of the Ziddin Valley is 3130 m. On the left side, due to its northern exposure, it drops below, to the marks of 2500-2800 m.

Precipitation is determined by cyclonic activity and a wide variety of terrain. The complexity of the orographic structure of the Southwestern Tien Shan causes great contrasts in the distribution of precipitation over the territory and high-altitude zones. Maximum precipitation is observed on the southern slope.

According to the 1982 Glacier Catalogue, in the basin of the Zeravshan glacier, as of 1957, there were 72 glaciers with a total area of 162.02 km^2, of which 12 had an area of less than 0.1 km^2. According to the Glacier Catalog of 1980, according to the state of glaciation for 1980, 63 glaciers with a total area of 141.62 km^2 are represented in the basin of the Zeravshan glacier. Under conditions of glaciation degradation in the Zeravshan glacier basin, the number of small glaciers with an area of less than 0.1 km^2 was 17 in 2021. According to the catalogs of the USSR in 1957 and 1980, their number was 12 glaciers.

Table 1. Glacier analysis.

Basin	Glacier area, km²			Number of glaciers		
	1957	1980	2021	1957	1980	2021
Zeravshan Glacier Basin	162.02	141.62	126.06	72	63	57

The average annual temperatures of the rocks of the Pamir-Alai cryolithozone are exceptionally diverse due to the mosaic nature of the mountainous country and vary from 0 to -15°C and below. In accordance with the geocryological high–altitude lean, the lowest stage of the cryolithozone - the zone of sporadically permafrost distribution - is characterized by the predominant development of thawed rocks with a temperature of up to 4 °C, decreasing in the upper boundary of the belt to 2 °C and below. Rare permafrost islands have an average annual temperature close to 0 °C and mostly not lower than -0.5 °C. Such temperatures are characteristic of permafrost massifs in the Alai Valley at an absolute mark of about 3500 m, within the altitudes of 3000 – 3400 m on the slopes of the Alai and Zaalai ridges (in the latter on the slope of the northern exposure), as well as in the Turkestan, Zeravshan and Pamir ridges proper in the altitude range from 3000 to 3600 m.

The cryolithozone of the crest part of the Turkestan and Zeravshan ridges is characterized by a wide development of frozen rocks of intermittent distribution with average annual temperatures ranging from +0.5 to -2 °C. The same temperatures are characteristic of a significant part of the Alaya cryolithozone, the spurs of the Sarykol and Muzkolsky ridge.

The temperature field in the area of the surface layers of the soil is unstable and largely depends on the temperature gradient on the surface. The fluctuation in the temperature of the soil column mainly depends on diurnal changes, but the amplitude of the seasonally frozen layer is influenced by annual temperature changes.

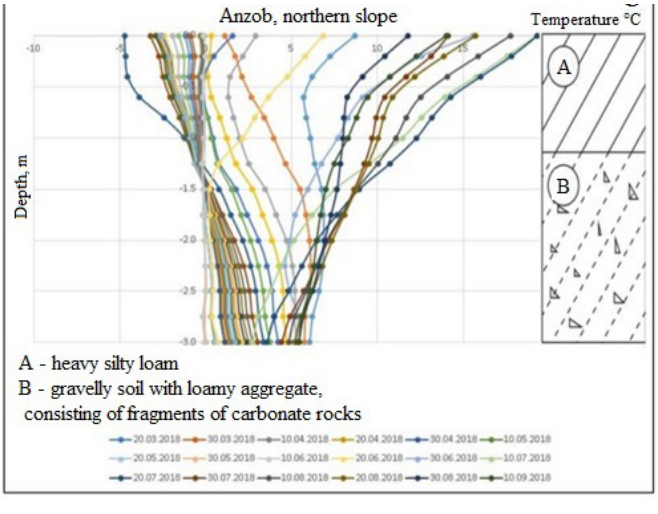

Fig. 2. Results of soil temperature observations for the Anzob Pass weather station for the winter period 2017/18.

According to our observations, since 2016, the Anzob Pass belongs to the area of seasonal freezing. According to thermometric observations, soil freezing in this area on the slopes of the northern exposure begins in mid-October and continues until the end of April. So in the winter period of 2018, on the slopes of the northern exposure, the depth of seasonal soil freezing was 1.5 meters (Figure 2). In the winter period of 2020, on the slopes of the northern exposure, the depth of seasonal soil freezing was 1.2 meters at an average annual soil temperature of 2.42 °C (Figure 3).

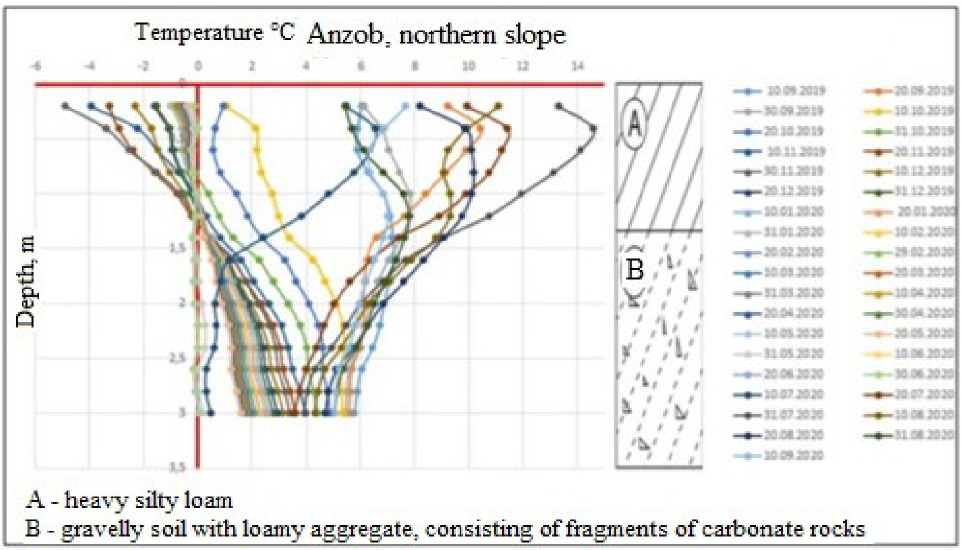

Fig. 3. Results of soil temperature observations for the Anzob Pass weather station for the winter period 2019/20.

3 Results and Discussion

The geophysical studies carried out at the Anzob pass made it possible to correct the geoelectric section, where, according to the difference in electrical resistance, loams up to 3 m thick, a zone of coarse clastic rocks with sandy aggregate, a zone of rocks and a fault zone are well distinguished. As a result of a year of research, maps-schemes of the distribution of frozen rocks of the Gissar Range were built (Figures 4 and 5). To compile maps, an approach was used that takes into account differences in the altitude position of the permafrost distribution boundaries for macroslopes with the most pronounced differences in the geothermal regime. These are macroslopes of northern and southern exposure. The soil samples taken at the Anzob pass during artificial freezing under laboratory conditions are characterized by a massive cryogenic texture. The distribution of ice over the entire volume of the soil is observed in the form of cement. The formation of ice schlieren is observed only with an increase in humidity up to 30%.

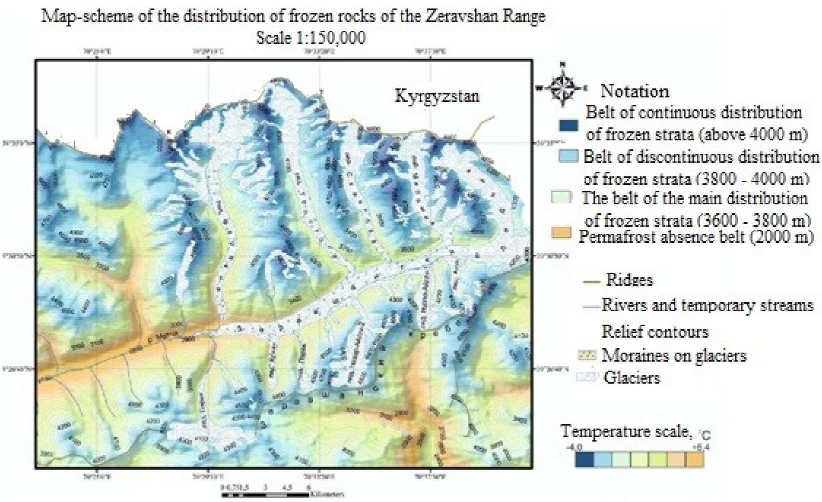

Fig. 4. Map of the permafrost zone in the headwaters of the Zeravshan River (Matcha River).

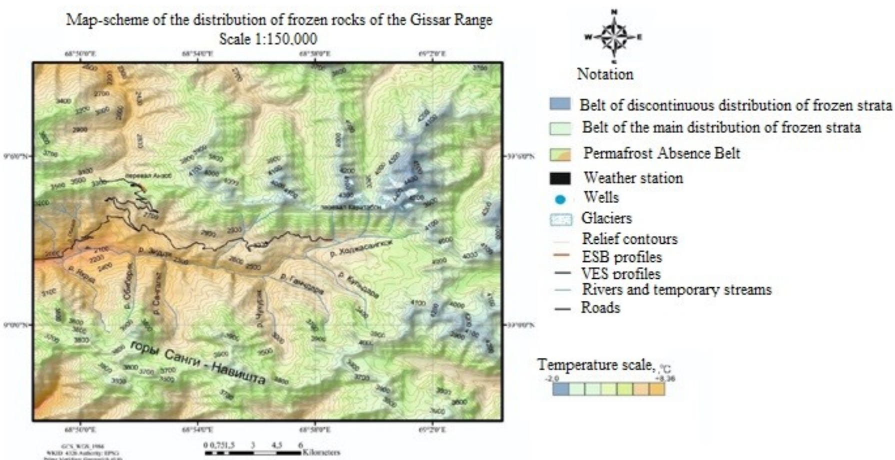

Fig. 5. Map of the permafrost zone in the upper reaches of the Varzob River (Zideh River).

4 Conclusion

The territory of the Anzob pass (height 3372 m) belongs to the area of non-deep seasonal freezing. Depending on the surface temperature, the thickness of the snow cover and the exposure of the slopes, the depth of seasonal freezing varies from 0.5 to 2 m and rarely 2.2 m. According to the results of observations, it was noted that in the annual cycle of the temperature state of soils 2019-2020, (compared to previous years), there have been changes. In the well located on the slope of the southern exposure, a significant decrease in soil temperature in the upper horizons was noted. This led to an increase in the capacity of the seasonally frozen layer by almost 1.5 m, and it amounted to 2.2 m. While on the slope of the northern exposure, the capacity of the seasonally frozen layer did not exceed 1.5 m. Apparently, such a difference in the thickness of the seasonally frozen layer is primarily due to the redistribution of snow cover, which on the Hissar ridge is perhaps the main cryogenic factor (greater than the slope exposure), which determines the thermal condition of soils. In the middle mountains (relief height 1500-2500 m) the thickness of the seasonally frozen layer of the Hissar ridge will vary from 0.4 to 0.6 m.

The criterion for the activation of geocryological processes is the phase transformations of water in the ground column. For this reason, permafrost processes mainly develop in the area of seasonal freezing and seasonal thawing. In the area of Hissar-Zeravshan region in the middle mountains and highlands, all engineering and geological processes take place with the active participation of the cryogenic relief-forming factor. The development of a number of cryogenic processes confined to the upper loamy horizon has been revealed. Monitoring the behavior of these cryogenic objects is extremely important, since they can be considered as hotbeds of dangerous mudflows, and, in addition, a change in their behavior can be an indicator of changes in the environmental situation in the area associated with natural or anthropogenic factors.

The study of mountain glacial systems at the present stage is associated with the use of remote sensing data from space and the use of geographic information technologies. The interpretation of satellite images of different periods allowed the author to assess the current state of glaciation of the Zeravshan glacier basin against the background of an increase in the average annual air temperature at 5 weather stations located at different hypsometric levels. As of the glaciation in 2021, the Zeravshan glacier basin unites 57 glaciers with a total area of 126.06 km^2. The results of measurements from 2009 to 2021 showed that the Zeravshan glacier retreated by an average of 137 m in length and 145 m in width. During this period, one of the main tributaries of the Farakhna glacier (No. 203) separated from the main body of the Zeravshan glacier and became an independent glacier retreating by an average of 390 m.

The geocryological studies described in the work in the areas of the Hissar ridge were the basis for the compilation of a geocryological map-scheme of scale 1:150,000. A thorough study of the composition, structure and temperature regime of soils of the seasonally shallow and seasonally frozen layer, the compilation of maps-schemes of permafrost rocks is an important task for assessing the state of the cryolithozone within the Hissar-Zeravshan region and they will serve as a justification for the development of technical solutions for the development of this territory.

Acknowledgement

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