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DISTRIBUTION OF SNOW COVER BY CLIMATIC ZONES OF THE TRANSBOUNDARY PYANJ RIVER BASIN

Abstract. The results of monitoring the processes of the snow cover accumulation on upstream of the Transboundary Pyanj river of the Central Asia are presented. It is found that the snow cover formation and the spatial distribution of atmospheric precipitation in the Pamir mountain is mainly determined by the orography of the terrain.

Key words: Mountain Pamir, Pyanj river basin,, snow cover, climatic zone, precipitation.

Introduction. Climate change has become the greatest danger of the 21st century. Climate change manifests itself in the form of irregularities and disturbances in the climate cycle because of an increase in the temperature of the Earth due to global warming. Meteorological observations confirm that between two 30-year control periods of 1942-1972 and 1973-2003, surface temperatures in Central Asia increased by 0,65 °C. The serious effects of climate change have already begun to manifest, and the latest example of this is that 2016 has overtaken 2015. It was the warmest year in history. According to the analysis of the World Meteorological Organization (WMO) of the United Nations Climate Agency, the average global temperature in 2016 was 1.1 oC above the previous period [1]. As global temperatures rise, the world's snow resources are predicted to change in significant ways [2]. Long-term changes in global, regional, and local snow depth, snow water equivalent (SWE), and extent will ultimately have major ramifications for ecosystem function, human utilization of snow resources, and the climate itself through feedback mechanisms like snow albedo [3]. Unfortunately, only extent snow cover area (SCA) of the three snow metrics listed above is easily monitored using satellites. This monitoring, under way for several decades [4,5] has shown that global SCA has been decreasing for the past 30 years [6].

Snow accumulation generally increases with elevation because of the combined effect of the prevailing lower temperatures and the increased frequency of precipitation events caused by orographic effects.

Distributed data on snow depth, density and snow water equivalent (SWE) with a high spatial and temporal resolution are essential for validation of and/or as input to snow drift models [7] and snow melt runoff models [8]. Thus, there is a great need for distributed snow data, mainly for SWE data (i.e. snow depth and density). Spatially distributed SWE data is important for many stakeholders, for example, it can be used as an input to the new generation of hydrological models predicting snowmelt runoff [9,10].

By examine glaciers and glacier discharge in Nepal zooming on nine subcatchments of Ganges left tributaries with a total glaciated area of 3,644 km2 it was concluded that glaciers contribute 2-3% to the

discharge of all rivers, flowing from Nepal, i.e., 5.38 km3 in total, which indicates that specific glacier runoff from this area is about 1,500 mm/year [11]. In another research, conducted recently in Nepal Himalaya, the summary of glacier and seasonal snow contribution to MAF is estimated as 14 km3, i.e., about 10% of MAF from Nepal [12].

The results of studies on the establishment of the climate-forming role of Pamir, as well as significant differences in its climatic zones, are widely presented in the work [13] on the example of snow cover formation and atmospheric precipitation on the upper parts of the Transboundary River Pyanj of Central Asia. It has been found that the formation of snow cover and the spatial distribution of atmospheric precipitation in mountain Pamir is mainly determined by the orography of the terrain. It was found that the precipitation ratio to the depth of snow cover is determined by the height of the terrain and the temperature regime. There is a process of shifting the precipitation periods of the snow cover maximum amount to different climatic zones, which is facilitated by the predominance of the orography effect on the promotion of air masses in mountainous areas [13].

On the border of the Southern and Central Pamir zones, the vertical gradient is about 40 mm for every 100 m of height, which indicates more humid foothills and the existence of wide basins that have an open exit to the West, towards the wet air flow. As the air flow moves deeper into the mountain area and passes through the ridges, the moist air converts moisture and becomes dry [13]. The lack of precipitation in the Eastern Pamir is due to the fact that in the Western Pamir which is characterized by high mountain ranges (5000-6000 m a. s. l.) the moist air is discharged with heavy precipitation, and the air passes through the ridges of the Western Pamir becomes dry [14].

Objects and Methodology. The diversity of climatic conditions in Central Asia, the finding of the changes patterns in meteorological processes, depending on the geographic and geoecological features of the region led to the need for climatic zoning. Pamir is considered as an area where there is a change of moist, cold Mediterranean precipitation to dry Central Asian.

The territory of the Republic of Tajikistan is characterized by four climatic zones. In turn, the Gorno-Badakhshan Autonomous Region (GBAO) that covers almost the entire mountain Pamir and is a formation zone of the Transboundary Pyanj river is characterized by three climatic conditions: (figure 1a). The object of research is the climatic zones of the Southern and Western, Central and Eastern Pamir. The data of the snow cover from meteorological stations in the relevant climatic zones of the Pamir presented by the Agency for Hydrometeorology of Tajikistan was used. Location of meteostations in the studied climatic zones are present on the figure 1b.

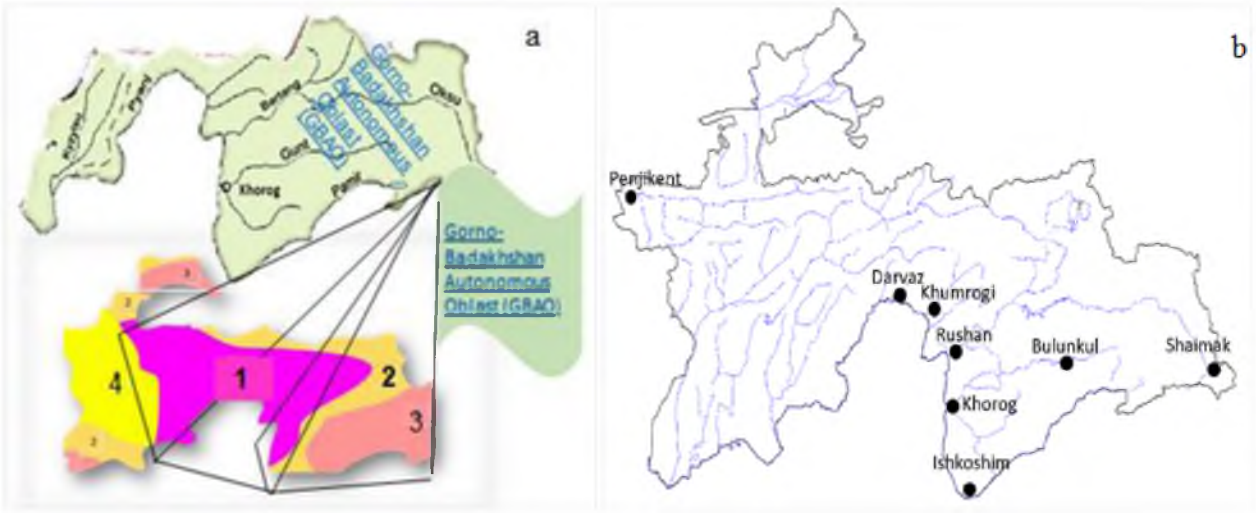

Figure 1 – Climatic zones of the Republic of Tajikistan and Gorno Badakhshan Autonomous Oblast:
1 - warm continental climate; 2 - cold semi-arid climate; 3 - dry cold climate;
4 - warm Mediterranean climate [13] (a) and location of meteostation of the studied climatic zones (b)

Results and discussion. Snow accumulation usually increases with increasing altitude due to the combined effect of prevailing low temperatures and increased frequency of precipitation caused by orographic effects [15]. Data on the distribution of snow depth, density, and water equivalent with high spatial and temporal resolution are needed to verify and / or enter data in the snow drift model [16]. Thus, there is a great need for data on snow distribution, mainly for determining the water equivalent of snow. Values of the spatial distribution of water equivalent are important for many stakeholders, for example, they can be used as a contribution to a new generation of hydrological models that predict snowmelt runoff [18-20].

In the Amu Darya and Syr Darya basins, meltwater resources are 69% and 79%, respectively, i.e. the share of seasonal snowmelt in water runoff is much higher than that of glacial ones.

Recent decades' data indicate an increase in reduction of the glaciation and snow cover area in the mountains as the South and North hemisphere of the Earth [21]. It is expected that geographic areas where the hydrology of melting glaciers and snow predominates in water cycles will be more sensitive to climate change, i.e., seasonal flow in river systems [22]. These climatic responses of mountain river hydrology combined with potential changes at the surface of the Earth, population growth and existing water shortages can create serious problems for the mountain regions. The snow accumulation generally increases with altitude due to the combined effect of the prevailing low temperatures and increased frequency of precipitation caused by orographic effects [23].

Snow and ice resources in mountain areas play an important role in providing water to river systems and thus largely determine the dynamics of agricultural development, hydropower and ecosystem components. These aspects become particularly relevant when a river formed high in the mountains is transboundary and its resources are distributed according to relevant agreements between several countries. This places a special requirement on the countries of the upper reaches of Transboundary rivers to assess the actual water resources in the river formation zone. In this aspect, it is important to consistently monitor the state of water, snow and ice resources in Transboundary river basins.

The paper is devoted to the study of the snow cover distribution in the Pamir climatic zones – the formation zone of the transboundary Pyanj river. From figure 2 where the months with the maximum height of the snow cover are presented it can be seen that in different climatic zones of the Pamir they correspond to different seasons. However, at the same time, a certain dependence can be found between periods with a maximum height of snow cover and climatic conditions.

According to the meteorological stations Rushan, Khorog and Irkht in the warm continental climate zone of the Pamir (figure 2) the maximum height of the snow cover is 32%, 44% and 32% respectively and is formed in the month of February.

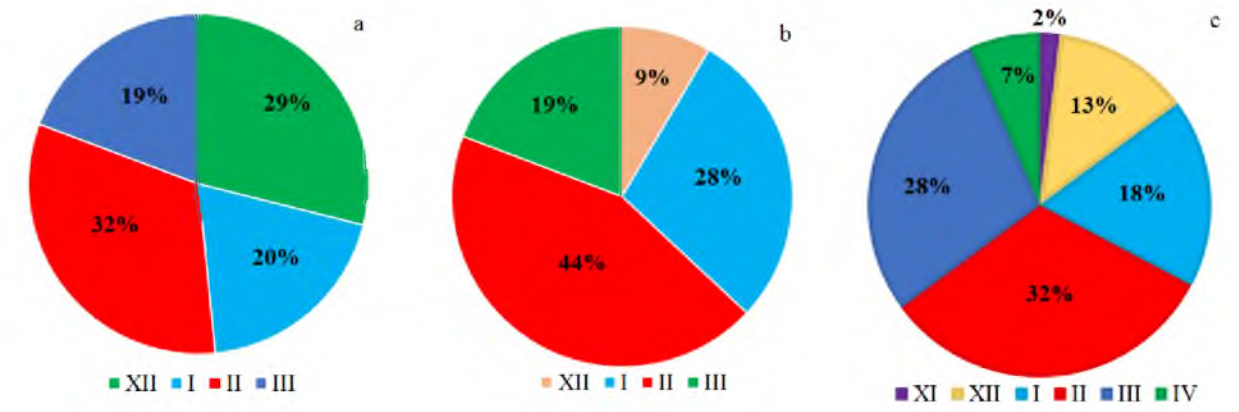

Figure 2 – Long-term average annual value of snow cover by meteostations: Rushan (a), Khorog (b) and Irkht (c)

In the cold semi-arid climate zone (Ishkoshim) 30% of the snow cover is formed in December (figure 3a). Bulunkul and Shaimak are located in a dry cold climate zone and the maximum altitude is formed only in March (figure 3b,c) The observed pattern of snow cover distribution across climate zones is primarily due to the influence of mountain orography on the distribution of air masses.

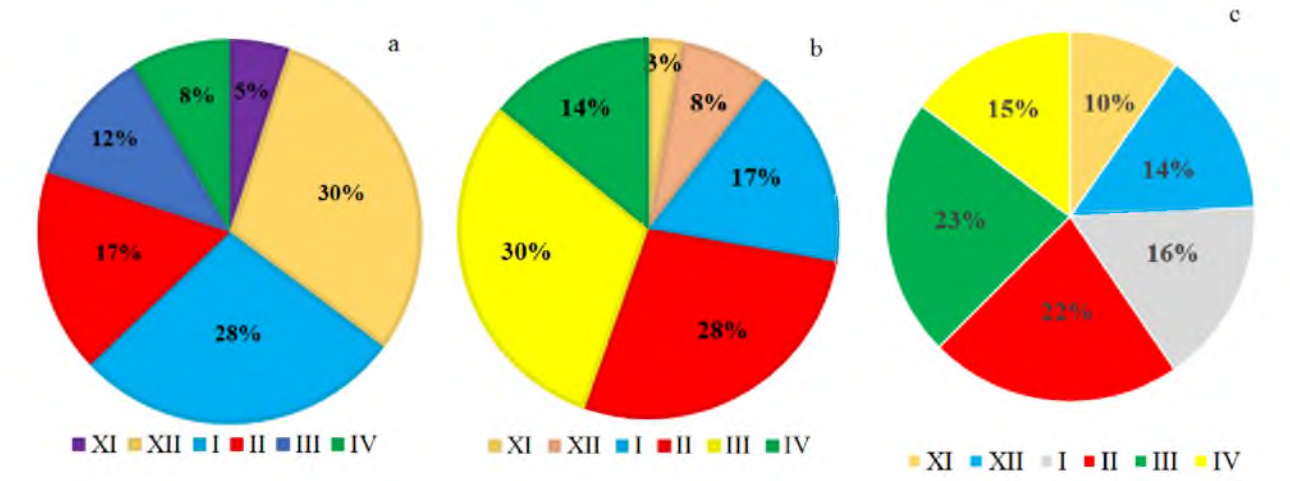

Figure 3 – Long-term average annual value of snow cover by cold semi-arid (a) and dry cold (b, c) climatic zones

The results obtained suggest that the Mediterranean moist air mass penetrates the territory of the Pamir Mountain from the Southwestern part of the Gorno-Badakhshan region, i.e. the warm continental climate zone (Khorog, Rushan). As it can be seen in figure 4, precipitation is also highest in the warm continental climate zone.

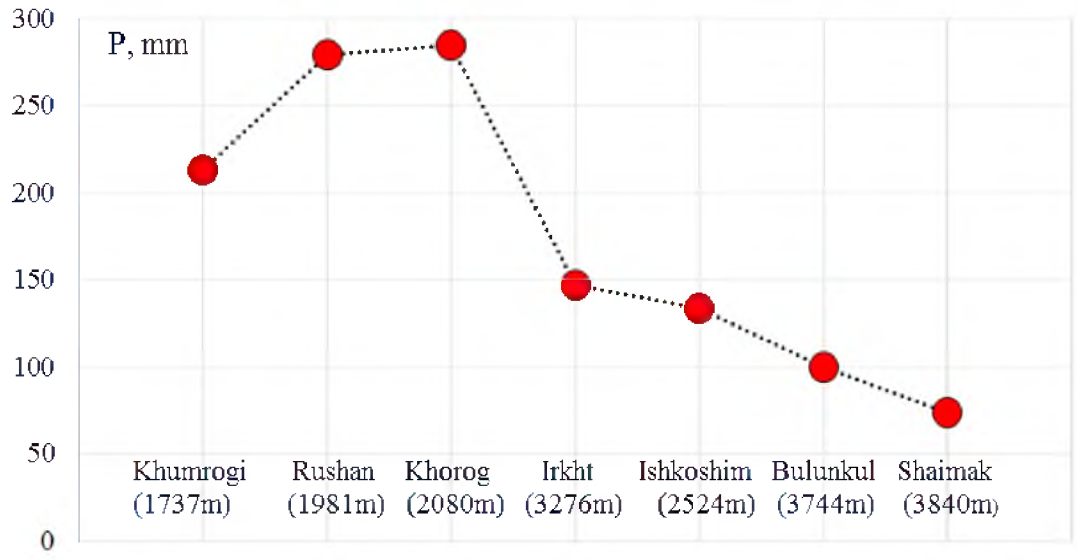

Figure 4 – Average long-term annual precipitation by the climatic zones of the Pyanj River Basin

The maximum value of the snow cover at the Ishkoshim weather station in the month of December, according to [13,24] is associated with the penetration of air masses from Iran and Afghanistan.

The formation of the maximum snow cover in the cold semi-arid climate zone as well as in the warm continental climate zone according to meteostation Penjikent occurs in January although this climate zone is not characterized by heavy precipitation. It is appropriate to note that the cold mass from the North of the Republic of Kazakhstan penetrates into territory of the Republic of Tajikistan from the Northwestern part. The period of penetration of this air mass occurs mainly for the period December - January. Therefore, it can be assumed that the air mass from the Republic of Kazakhstan is the reason for the formation of a sufficient layer of snow cover on the cold semiarid climate zone (figure 5).

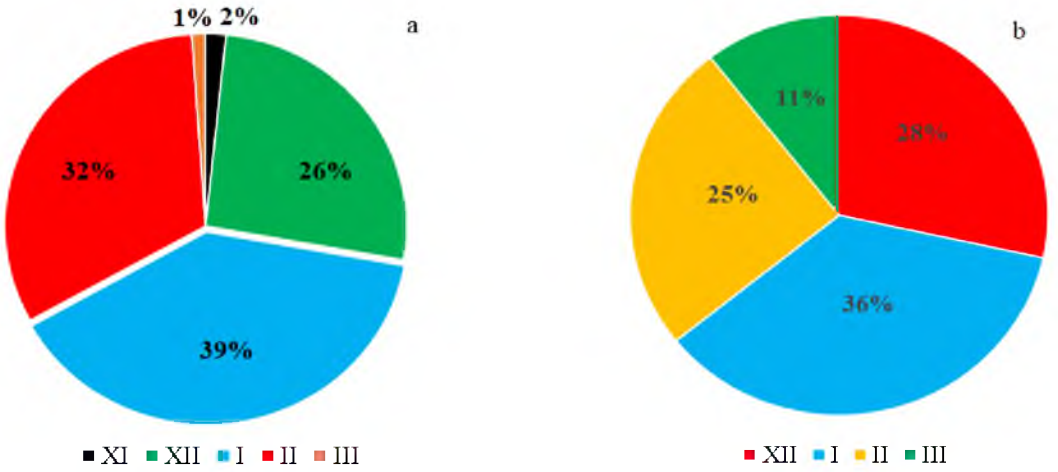

Figure 5 – Long-term average annual value of snow cover by meteostations: Khumrogi (a) and Penjikent (b)

The snow cover formation by climatic zones is more clearly illustrated by the example of cold semi-arid (Penjikent), warm continental (Khorog) and dry cold climatic zones (Shaimak) is shown in figure 6. From a comparison of the histograms in Fig. 6, the functional dependence of the snow cover height on the degree of penetration of air masses and the orography of climatic zones becomes apparent.

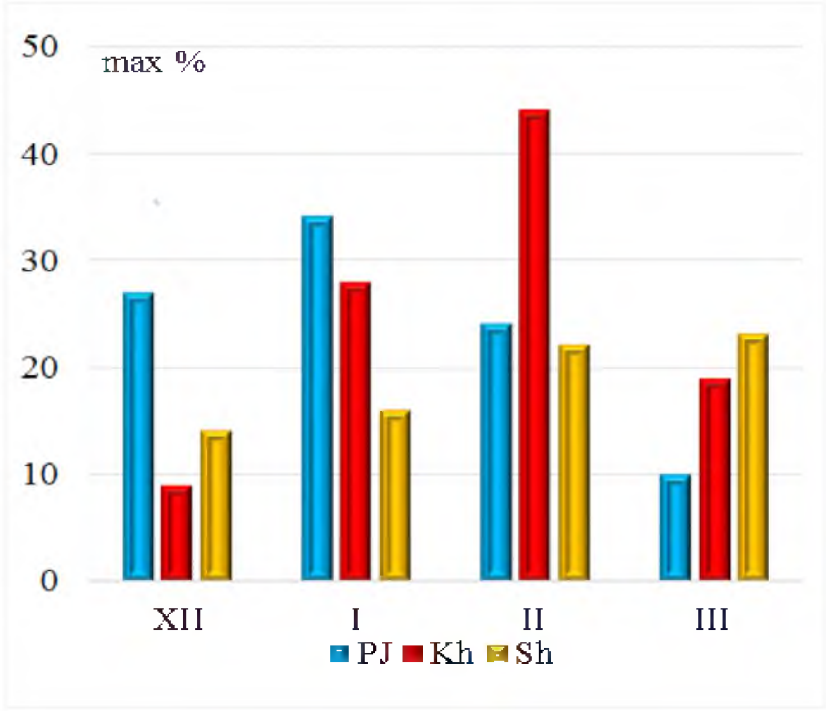

Figure 6 – Long-term average annual value of snow cover by climatic zones Penjikent (PJ), Khorog (Kh) and Shaimak (Sh)

Thus, it can be assumed that the penetration of the predominant part of air masses into the climate zones of the Republic of Tajikistan occurs in the area between 38°07' N 70°07'E and 37°49'N 71°54'E. The Gissar ridge will act as a barrier due to which air masses losing a fair share of moisture reach the cold semi-arid climate zone weakened. This pattern is observed also at air masses move to the Eastern part of the Pamir (figure 7).

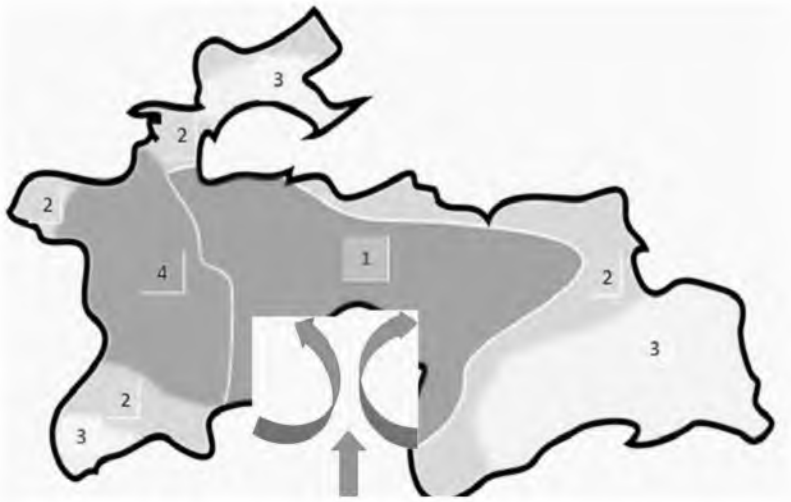

Figure 7 – The air mass penetration scheme to the territory of the Republic of Tajikistan

Conclusion. The heterogeneity spatial distribution of atmospheric precipitation and snow cover on the Pamir climatic zones - due to the orography of the mountainous terrain and the peculiarity of air masses promotion was observed. The Southwestern climate zone is characterized by more abundant precipitation than the Eastern climate zone. It is assumed that the duration of snow cover preservation is determined by the temperature regime of the area.

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ПЯНДЖ ТРАНСШЕКАРАЛЫҚ ӨЗЕНІ БАССЕЙНІНІҢ КЛИМАТТЫҚ АЙМАҚТАРЫ БОЙЫНША ҚАР ЖАМЫЛҒЫСЫН БӨЛУ

Аннотация. Климаттың өзгеруі мен жаһандық температуралардың артуына қарай, экожүйенің басқа компоненттерімен қатар, қар-мұз ресурстарының қорлары елеулі өзгерістерге және тозуға ұшырайды. Соңғы онжылдықтардың мониторингі қар жамылғысының алаңы айтарлықтай азайғанын көрсетеді. Қардың жиналуы, әдетте орографиялық әсерден туындаған төмен температуралардың аралас әсерінен және жауын-шашынның жоғары түсу жиілігіне байланысты биіктіктің жоғарылауымен артады. Жүйелі мониторинг жүргізу және қардың тереңдігі туралы деректерді жинау, ең алдымен, қар туралы таратылған деректердің үлкен қажеттілігімен байланысты. Ең бастысы, қардың су баламасы туралы деректермен байланысты, олар көптеген мүдделі тараптар үшін маңызды болғандықтан, еріген сулардың ағынын болжайтын ғидрологиялық үлгілердің жаңа буыны үшін кіру деректері ретінде пайдаланылуы мүмкін.

Орталық Азияның климаттық жағдайларының алуан түрлілігі, аймақтың ғеографиялық және ғеоэкологиялық ерекшеліктеріне байланысты метеорологиялық процестердің өзгеру заңдылықтарын табу климаттық аудандастыру қажеттігінен туындады. Памир ылғалды, суық Жерорта теңізіндегі жауын-шашын құрғақ ортаазиялық аймаққа ауысатын аймақ ретінде қарастырылады.

Тәжікстан Республикасының аумағы төрт климаттық зонамен сипатталады. Өз кезегінде, тау-Бадахшан автономды облысы (ГБАО), барлық дерлік тау-кен Памирін алып, Орталық Азия аймағындағы трансшекаралық өзеннің негізгі ағынының бірі – Пяндж трансшекаралық өзенін қалыптастыру аймағы.

Таулы жерлердің климаттың өзгеруіне ерекше сезімталдығын ескере отырып, трансшекаралық өзендердің жоғарғы сағаларында қар-мұз және су ресурстарының жай-күйін және олардың өзгеру сернінін анықтау бойынша кешенді зерттеулер жүргізу перспективасы болашақта өзендердің төменгі сағаларында сумен қамтамасыз ету дәрежесін болжау тұрғысынан өзекті болып табылады.

Осы жұмыстың зерттеу объектісі – Онтүстік және Батыс, Орталық және Шығыс Памирдің климаттық аймақтары.

Жұмыстың мақсаты – Пяндж өзені бассейнінің климаттық аймақтары бойынша қар жамылғысының қалыптасу процестерін зерттеу және Памир өзен жүйелерінің қалыптасу аймағында ауа массаларыныц ену аймагын анықтау.

Памирдің түрлі климаттық аймақтарында қар жамылгысының жогары қабатының пайда болуы жылдың әртүрлі кезеңдеріне сәйкес келеді. Алайда қар жамылгысының ең жогары биіктігі мен климаттық жағдайлар арасындағы өзара белгілі бір байланыс анықталады. Памирдің жылы континенталды климаттық аймагында қар жамылгысының жеткілікті биіктігінің қалыптасуы ақпан айында, суық жартылай ауарайы аймағында желтоқсан айында орын алады. Құргақ суық климаттық аймақта орналасқан Бұлункул мен Шаймакада қардың жеткілікті қабаты наурыз айында пайда болады. Памир биік тауының климаттық аймақтарында қар жамылгысының қалыптасуындағы алуан түрлілік, ең алдымен, ауа массаларының таралуына жергілікті жердің орографиясының әсерімен байланысты.

Суық жартылай құрғақ (Пенджикент), құргақ суық (Шаймақ) және жылы континенталды (Хорог) климаттық аймақтарда қар жамылғысының максималды мәиі тиісінше қаңтарда, наурызда және ақпанда қалыптасатыны анықталды.

Жылы континенталды климат – Ирхт аймагында орналасқан метеостанцияда қар жамылғысының ең жогары биіктігі ақпан айында, ал желтоқсан айында Пенджикентпен салыстырганда, құргақ суық климат аймагындагы Пенджикент сияқты орналасқан Ишкошим метеостанциясында қалыптасатыны анықталды.

Ауа массаларының басым бөлігінің Тәжікстан Республикасының климаттық аймақтарына енуі 38°07'N 70°07'E және 37°49'N 71°54'E арасындағы ауданда болып отыр. Бұл заңдылық Памирдің шыгыс бөлігіне ауа массаларының қозгалысы кезінде де байқалады

Түйін сөздер: Таулы Памир, Пяндж өзенінің бассейні, қар жамылғысы, климаттық аймақ, жауын-шашын.

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РАСПРЕДЕЛЕНИЕ СНЕЖНОГО ПОКРОВА ПО КЛИМАТИЧЕСКИМ ЗОНАМ БАССЕЙНА ТРАНСГРАНИЧНОЙ РЕКИ ПЯНДЖ

Аннотация. По мере нарастания изменения климата и повышения глобальных температур, наряду с остальными компонентами экосистемы, запасы снежно-ледовых ресурсов подвергаются существенным изменениям и деградациям. Мониторинг последних десятилетий показывает, что площади снежного покрова существенно уменьшаются. Накопление снега, как правило, увеличивается с повышением высоты из-за комбинированного воздействия преобладающих низких температур и повышенной частоты выпадения осадков, вызванных орографическими эффектами. Проведение систематического мониторинга и сбор данных о глубине снега, прежде всего, обусловлено большой потребностью в распределенных данных о снеге, главным образом, для данных о водном эквиваленте снега, так как они важны для многих заинтересованных сторон, например, они могут быть использованы в качестве входных данных для нового поколения гидрологических моделей, предсказывающих сток талых вод.

Разнообразие климатических условий Центральной Азии, нахождение закономерностей изменения метеорологических процессов в зависимости от географических и геоэкологических особенностей региона обусловили необходимость климатического районирования. Памир рассматривается как область, где происходит смена влажных, холодных средиземноморских осадков на сухие среднеазиатские.

Территория Республики Таджикистан характеризуется четырьмя климатическими зонами. В свою очередь, Горно-Бадахшанская автономная область (ГБАО), занимающая почти весь горный Памир и являющаяся зоной формирования трансграничной реки Пяндж – одной из главных притоков трансграничной реки региона Центральной Азии Амударьи.

Учитывая особую чувствительность горных местностей к изменениям климата проведения комплексных исследований по определению состояния снежно-ледовых и водных ресурсов на верховьях трансграничных рек и динамики их изменения является актуальной с точки зрения предсказывания степени водообеспеченности низовий рек в перспективном будущем.

Объектом исследования настоящей работы являются климатические зоны Южного и Западного, Центрального и Восточного Памира.

Целью работы является исследование процессов формирования снежного покрова по климатическим зонам бассейна реки Пяндж и определение зоны проникновения воздушных масс в зоне формирования речных систем Памира.

Установлено, что в разных климатических зонах Памира образование высоких слоев снежного покрова соответствует разным временам года. Однако обнаруживается определенная взаимосвязь между периодами с максимальной высотой снежного покрова и климатическими условиями. Обнаружено, что в теплой континентальной климатической зоне Памира формирование достаточной высоты снежного покрова происходит в феврале, в холодной полуаридной климатической зоне в декабре месяце. На Булункуле и Шаймаке, расположенных в сухой холодной климатической зоне, образование достаточного слоя снега происходит в март месяце. Предположено, что разнообразие в формировании снежного покрова в климатических зонах высокогорья Памира, прежде всего, обусловлено влиянием орографии местности на распространении воздушных масс.

Обнаружено, что максимальное значение снежного покрова в холодных полузасушливых (Пенджикент), сухих холодных (Шаймак) и теплых континентальных (Хорог) климатических зонах формируется в январе, марте и феврале соответственно. На метеостанции, расположенной в зоне теплого континентального климата – Ирхт, максимальная высота снежного покрова формируется в феврале, а на метеостанции Ишкошим, расположенной так же, как и Пенджикент в зоне сухого холодного климата, в отличие от Пенджикента – в декабре. Указано, что проникновение преобладающей части воздушных масс в климатические зоны Республики Таджикистан происходит в районе между 38°07'N 70°07'E и 37°49'N 71°54'E. Гиссарский хребет будет выступать в качестве барьера, за счет которого воздушные массы, теряя изрядную долю влаги, достигают ослабленной холодной полузасушливой климатической зоны. Эта закономерность наблюдается также при движении воздушных масс в восточную часть Памира.

Ключевые слова: Горный Памир, бассейн реки Пяндж, снежный покров, климатическая зона, осадки.

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