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Assessment of Snow, Glacier and Water Resources in Asia

IHP – International Hydrological Programme of UNESCO
HWRP – Hydrology and Water Resources Programme of WMO

Assessment of Snow, Glacier and Water Resources in Asia

Selected papers from the Workshop in Almaty, Kazakhstan, 2006

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Foreword

The topic of water availability and the possible effects of climate change on water resources are of paramount importance to the Central Asian countries. In the last decades, water supply security has turned out to be one of the major challenges for these countries. The supply initially ensured by snow and glaciers is increasingly being threatened by climate change. As yet, a comprehensive understanding and evaluation of the current knowledge on glaciers in Central Asia has been lacking. The present publication aims at filling this knowledge gap in the Central Asian region while contributing to transboundary cooperation in the field of research on snow and glacier hydrology.

The individual contributions of this publication are based on lectures given at the Workshop on “Snow, Glacier and Water Resources in Asia”, held in November 2006 in Almaty, Kazakhstan. The workshop was jointly organized by UNESCO Almaty Cluster Office, the Regional Environmental Centre for Central Asia (CAREC), and the Institute of Geography, Republic of Kazakhstan.

All contributions underwent a peer review, and we believe that they significantly enhance the current understanding of hydrology in Central Asia in a changing climate.

The publication will serve as a contribution to the 7th Phase of the International Hydrological Programme (IHP 2008–2013) of UNESCO, which has endeavored to address demands arising from a rapidly changing world. Several focal areas have been identified by the IHP to address the impacts of global changes. UNESCO IHP undertakes considerable efforts to improve scientific understanding of snow and glacial changes and impacts on water resources in various parts of the world.

The set of recommendations proposed by the participants calls for a better exchange of data relevant to glacier and snow cover changes. Managing the water resources in the region in a sustainable way will be one of the major future challenges.

In this context we trust that this publication will be helpful in tackling future problems associated with water scarcity in Central Asia.

The careful editing of most of the papers by Dr. Stefan Pohl is gratefully acknowledged.

Our sincere thanks are extended to the German IHP/HWRP Secretariat for the layout and printing of this publication.

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Executive Summary

The high mountain ranges of Asia are covered by approximately 100,000 km^2 of glacier ice. They feed the great rivers of South Asia, South-east Asia, China, and the Central Asian States of the former Soviet Union. In the head watersheds of many of these major river systems the proportion of water produced by snow and ice melt is highly significant, especially for the arid lowland areas surrounding the mountain ranges, and during the summer months. The various contributions of this publication address the following questions:

1) to what extent are the river flows and regimes affected by the melting of snow, glaciers and ground ice (permafrost and buried glacier ice)?
2) What is the contribution of ice melt in particular basins?
3) Will the relative importance of snow and ice melt compared to rainfall change with global warming?
4) How long will it take for glaciers to melt out, and how different will the flow regimes of the rivers be once the ice has disappeared?

The answers to these questions vary from region to region, as the climatic and physiographic conditions are highly diverse. Generally it can be stated that the seasonal regime of the rivers originating in the mountain ranges of Central Asia show low flows in winter and relatively high flows in summer. On almost all of the rivers spring snowmelt contributes significantly to streamflow in April and May. This is economically very important as many crops are planted in this period. In the summer months of June to September liquid precipitation dominates runoff in the Tien Shan, the Qilian Shan and in the monsoon areas of the South-east. In the western Himalaya, the Karakoram and in the Pamirs the glacier melt contribution tends to be much larger as summer rainfall is considerably smaller.

Glaciers have a regulatory effect on streamflow: when annual snowfall is well below average, glaciers tend to melt more strongly and therefore partially compensate for lower precipitation. When annual snowfall is above average, glacier ice is protected by the excess snow, and water yield is high due to above-average snowmelt. Should the glaciers continue to shrink markedly in size as was the case during recent decades, this regulatory effect will diminish and the runoff regime will move towards a nival and pluvial one with a larger year-to-year variability in water yield, and as a result water delivery from the high mountain areas will be less dependable.

The volumes of water captured as permafrost and buried ice are very difficult to assess; with continued global warming permafrost and debris-covered parts of glaciers will degrade rather slowly, and it will take centuries until much of the water stored this way is released.

As a result of water being released from glacier and permafrost melt total annual flows in river systems supplying water to arid lowlands may increase by some 4 to 6 %, which is a small but significant percentage, as it will persist over decades. However, this possible increase in yield needs to be seen in relation to probable increased evaporation losses due to global warming, a question that requires further attention.

During the phase of glacier degradation glacial lakes in the tongue areas of glaciers are likely to form, and these bear the danger of rapid drainage, producing glacier-lake outburst floods which may cause severe damage downstream.

Among the recommendations formulated at the workshop is the resumption of glacier and snow monitoring at high elevations, with exchange of data via a Glaciological Data Center to be located in Almaty. This data base is a prerequisite for a wise and sustainable water management.

For the editorial committee
Ludwig Braun and Gordon Young

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Review of hydrometeorological observations in Tajikistan for the period of 1990 – 2005

A. Finaev

The present study describes the hydrometeorological processes monitoring system in Tajikistan and its changes from 1990 to 2005. Until the early 1990s the processing of data supplied by the hydrometeorological stations was done at the Central Asian Regional Scientific and Research Hydrometeorological Institute (SARNIGMI), but with the end of the Soviet Union this service was terminated. As a result, gaps in the course of monitoring were not interpolated, and the processing of data proved to be very difficult. This study tries to explain what measures were taken to gain as much scientific value as possible from the data series.

Introduction

Since the early 1990s meteorological stations throughout the country carried out atmospheric observations. These observations were conducted at elevations from 300 m a.s.l. to 4169 m a.s.l. High-mountain stations are notorious for their complicated supply and expensive material provision due to their location and difficult access during winter. Therefore, food and other materials required to ensure continuous observations over the winter have to be supplied in summer by road and air transport. After the collapse of the Soviet Union and the decline of the economic situation, the Hydrometeorological Service of Tajikistan was unable to meet the needs of a number of high-mountain stations and to ensure their smooth activity. Many specialists left Tajikistan. A civil war that broke out has also negatively affected the situation. Thus, many stations stopped functioning by the mid-90s. The highest Gorbunov station located at the Fedchenko glacier had been operating since 1928 but ceased its activity in December of 1995, because its staff had to leave. In 1996, the amount of active stations dropped to 29 compared to 57 in 1991.

Upon the end of military actions and some improvement in the economic situation, combined with assistance provided by several international organizations, observations were being resumed in some locations. By the end of 2005 observations were carried out at 45 stations (Figure 1). Seven automatic meteorological stations and several hydrological posts monitoring river streamflow have been established since 2003.

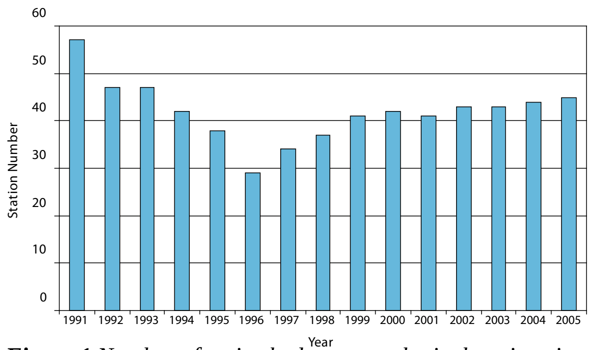

Figure 1 *Number of active hydrometeorological stations in Tajikistan from 1991 to 2005.*

The numbers of hydrological posts has also diminished. Of the 124 posts that operated in 1990, only 97 are still currently functioning. There were even fewer posts in the mid-90s.

From these statistics it becomes obvious that observations at many stations and posts are discontinuous for the last 15 years.

Another problem concerns the data processing. Before the early 90s of the past century, data supplied by stations and posts on paper were forwarded to the Central Asian Regional Scientific and Research Hydrometeorological Institute (SARNIGMI), where it was revised, processed, recorded on magnetic (digital) medium, issued as monthly bulletins, and sent back to Tajikistan. There is no such procedure at the moment. Information received from observation stations is kept in the archives of the National Hydrometeorological Service of Tajikistan (NGMS). However, the NGMS has no financial or human resources to process this data. Its employees only run the regular operations and meet the requests of other organizations. Therefore, we currently cannot expect to obtain comprehensive information from this region.

To analyze the hydrometeorological situation, we have selected a number of stations with available primary information. The records of stations located in valleys generally are more complete, while the records from mountain stations are more discontinuous. Furthermore, it should be noted that a user of this information cannot expect the data to be checked or corrected as evidenced by some obvious errors found in this study. However based on the information available, we are able to analyze the climatic and hydrological changes in the region over the last 15 years. Climate Reference Books were regarded as the norm (Climates of the USSR 1966, Vol. II. and Vol. IV).

Climate

Climate changes can be studied based on two parameters: temperature and precipitation. These parameters are not only major indicators of a change in climate but, generally, also represent the most continuous observational data sets.

Temperature

The observation results obtained from the climatological stations that were chosen for this study reflect the air temperature comprehensively as they were located in different regions and at different elevations. In the following Figures these stations have been sorted according to their elevation above sea level (ascending).

Long-term annual air temperature analysis shows a slightly positive trend within the study period (1990 – 2005) (Figure 2). All the stations show an almost synchronous fluctuations with small amplitude proving that there are temperature changes within the entire range of elevations covered by the selected stations. The maximum values were observed in 2001, with temperatures subsequently gradually decreasing up to 2005.

The temperature trends decrease with elevation above sea level (Figure 3). The highest temperature increase can be observed in the Southern valleys of Tajikistan, as indicated by the data from the Kurgan-Tube station

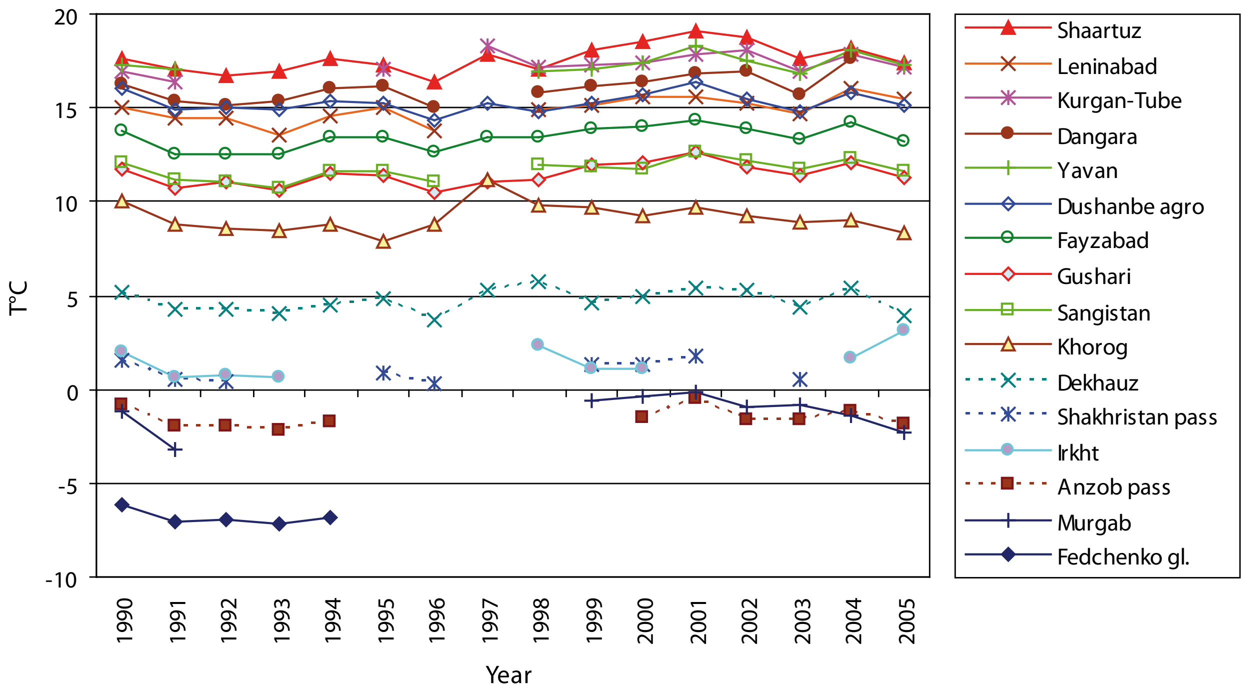

***Figure 2** Annual average air temperature [°C] at meteorological stations of Tajikistan.*

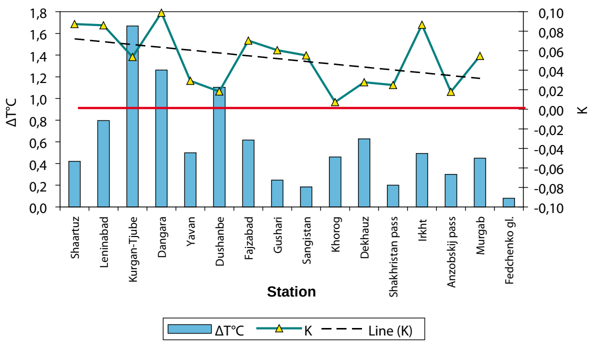

Figure 3 *Air temperature trend (ΔT), trend coefficient (K) and its linear function for the time period 1990 – 2005. Stations are placed according to their elevation ascending above sea level.*

(+ 1.7 °C). At high-mountain stations, the temperature increase is 0.7 °C – 0.2 °C. However, it has to be mentioned that the trend in Kurgan-Tube is likely overstated, since there is a gap in observations from 1992 to 1996. There are gaps in the data series of many other stations as well. Therefore, the obtained general temperature trend should be regarded as a reference point only and specific values of individual stations should not be taken too seriously.

If the long-term annual air temperature is approximated with a linear function, then a trend coefficient (K) can be calculated and used to show the temperature change rate. Figure 3 illustrates that the temperature change rate is decreasing with increasing elevations and that the Fedchenko Glacier actually has a negative value (K= –0,015, this station is not shown in the figure). However, the analysis for this location is somewhat unreliable as it has data during five years only (1990 – 1995). However, this five-year cycle can be analyzed based on data obtained from other stations. This analysis indicates that the period during which the Fedchenko Glacier station operated can generally be characterized as a descending branch of the temperature cycle.

Only six out of 16 stations have a complete data series. Furthermore, even the available data should be considered critically. For example, the abrupt increase of the average annual temperature in 1997 at the Khorog station is quite doubtful (Figure 2). Overall, an average temperature increase rate of 0,039 °C per year was calculated using all stations during the researched period.

An analysis of the seasonal temperature changes shows that the temperature trends are dissimilar for different seasons (Figure 4). The highest temperature increase is obtained for the winter period, especially in valleys. Values of up to 2.5 °C in Dangara and 2.4 °C in Kurgan-Tube, slightly more than 1 °C at the Gissar range and Pamir stations, and up to 0.5 °C in the East Pamir can be observed.

Precipitation

Precipitation is not evenly distributed over the researched area, since its intensity is strongly affected by the topography. Maximum precipitation amounts are observed at the Gissar range and in the Western foothills of Pamir. An analysis of the annual precipitation amounts shows that periodical fluctuations with an interval of about 5 years can be observed from 1990 to 2005 (Figure 5). These cycles are more evident and obvious, than those exhibited by the temperature data. Maximum amounts were recorded in 1991 – 1993, 1998, and 2003 – 2004. The highest fluctuations are observed at stations that also record the highest

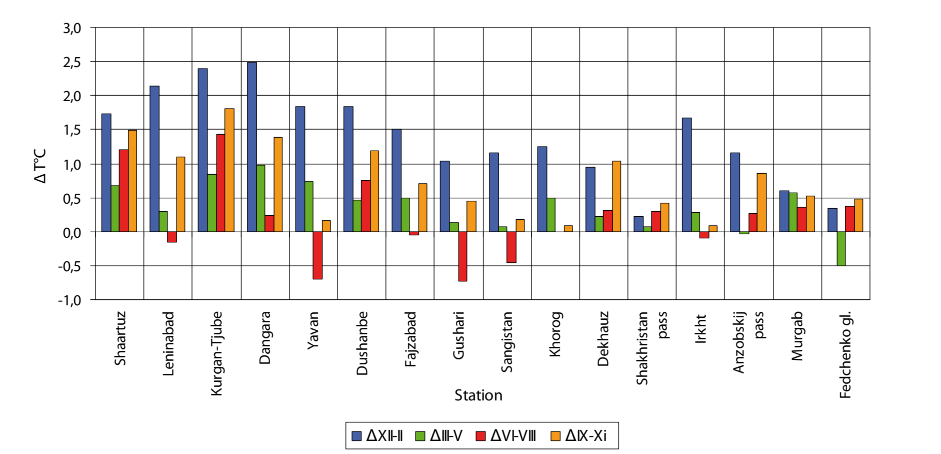

Figure 4
Seasonal air temperature trends. Winter (Dec-Feb); spring (March-May); summer (June-Aug); autumn (Sept-Nov).

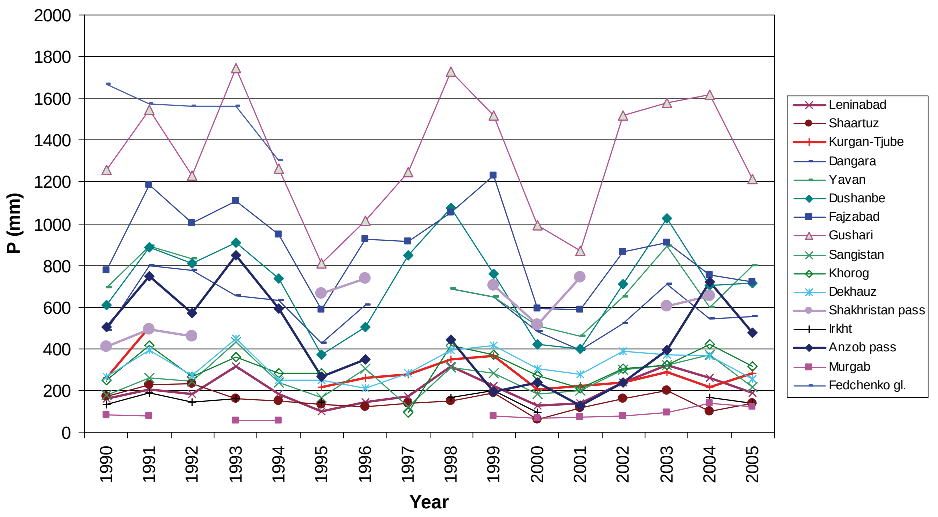

Figure 5 *Annual precipitation in mm.*

absolute amount of precipitation (Gissar-Alay). The intra-annual changes are much weaker in Pamir, especially East Pamir, and in the southern valleys.

Similar to temperature, continuous precipitation data series are available at six stations only. An analysis of annual precipitation shows that the recorded precipitation amounts were above the normal at almost all stations. Below normal precipitation amounts were only observed at the Shaartuz and Anzob pass stations. Further analysis reveals that stations at higher elevations experienced especially pronounced above normal precipitation amounts. Overall, the annual precipitation using all stations was 18 % above the normal during the study period.
The lowest temperature increases are observed for spring and summer. Some stations (Khudjant, Gushari, Sangiston, Yavan) even show a decrease of up to 0.5 °C for the average seasonal temperature in summer.

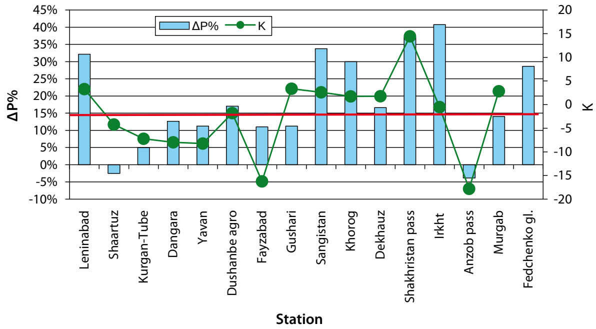

Figure 6 *Annual precipitation deviation from the long term normal (%) and trend coefficient (K), for the time period 1990 – 2005.*

Precipitation trends over the past 15 years were calculated for each station. The obtained trend coefficients are negative for valley stations and positive for mountain stations, with an overall average of +2.27 (Figure 6).

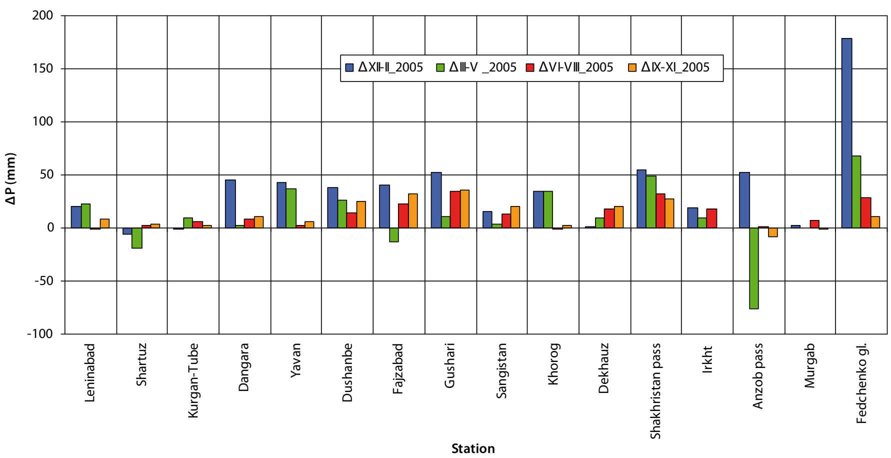

Figure 7 *Seasonal precipitation deviation in mm.*

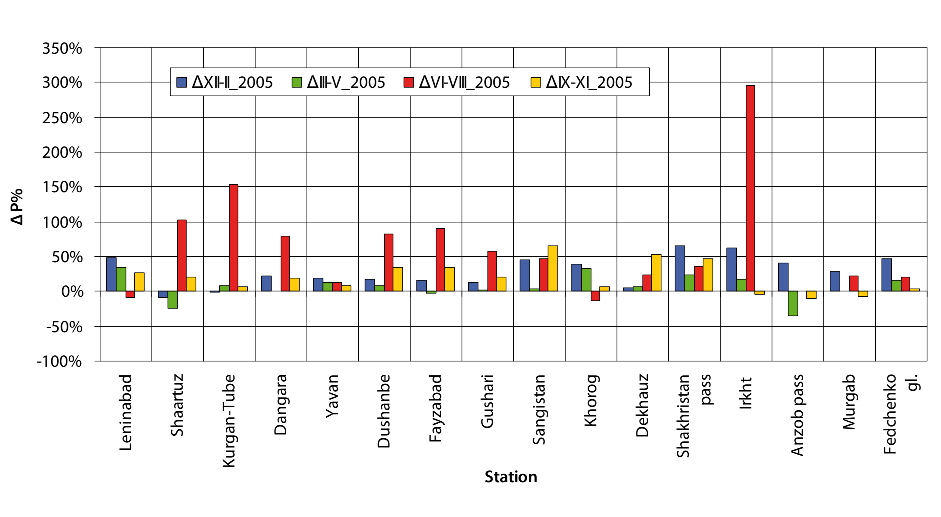

Figure 8
Seasonal precipitation trends in %.

Overall, no obvious trend could be identified. Precipitation decreased in the flat valleys of Southern Tajikistan but increased in the mountain regions of Gissar and Pamir-Alay. It is not possible to estimate a precipitation trend at Fedchenko Glacier because, as mentioned before, data is available for the first five years only.

The analysis of seasonal changes in precipitation amounts shows an increase of up to 50 % in valleys and high mountains and by 6 – 9 % in the mid-elevation locations for winter, spring, and autumn (Figures 7, 8). The most pronounced changes were obtained for summer with precipitation increases from 20 % to 100 % in all areas, except for the high mountains. However, as there is little precipitation during that season, such increases do not exceed 30 – 50 mm by absolute value.

The abrupt decrease in precipitation at Anzob pass can be explained by a lack of data. The observed strongly positive summer precipitation trend at the Irht station can be attributed to the same reason (Figure 8).

In general, it has to be noted that a conclusive trend could not be determined over the past 15 years, especially in view of the discontinuous data series, which show considerable deviation.

Snow cover
The depth of the snow cover was measured at some stations with the help of a stable snowstake during routine observations. Snowstake measurement data obtained from nine stations for the period of 1990 – 2002 were used for a snow cover analysis. The remainder of the information has not been processed yet.

The average decade maximum, annual maximal, and minimal depth of the snow cover were calculated for a comparison with climate normals and for trend estimation (Figure 9). The average decade snow depth varies from a few centimetres in the Southern valleys of Tajikistan to 100 cm in the mountain areas. Maximum annual snow depth values vary from 20 cm in the South to more than 300 cm in the mountain passes of the Gissar range.

Snow cover thickness changes were analyzed in comparison to the average long-term value for six stations. There are no data for three other stations, because they were not functioning when reference books were being developed (before 1960).

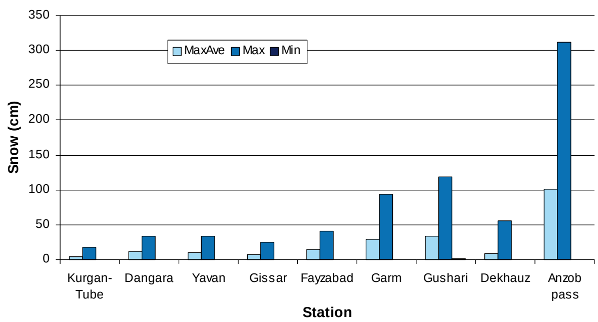

Figure 9 *Snow cover depth (average decade maximum, maximal and minimal depth for the period of observations (1990 – 2002).*
Stations are placed according to their elevation ascending above sea level.

Differences between the observed snow cover depth parameters for the study period compared to the long term normals were calculated to estimate the deviation (Figure 10). The analysis shows that the differences from the normals for average decade maximum snow depth were positive as well as negative. Therefore, no clear trend could be observed. It became evident however, that the range between absolute maximum and minimum values has expanded. No trends could be determined for Southern areas (Kurgan-Tube), however, snow depth are generally low in these locations anyway.

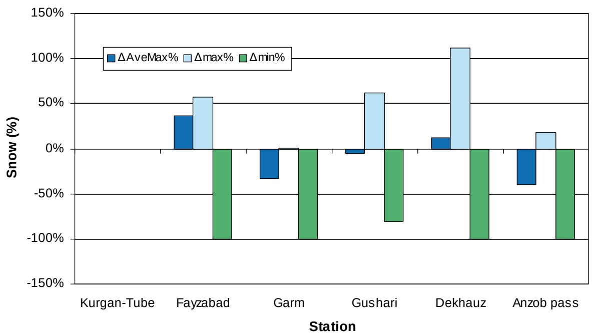

Figure 10 *Difference in snow depth between study period and long term normals in %.*

It should be noted that more data is needed to see the real picture. Such data, however, is currently unavailable due to abovementioned reasons.

Glaciation

Fresh water stored in the glaciers of mountain regions represents a crucial share of the available water resources. Glaciers are amongst the least studied fields of the geographical environment because of problems with access and other factors of high mountain areas. Before 1990, various departments and institutions had occasionally run extended research programs and expeditions. We know of several professional studies of glaciation in Tajikistan over the period of 1990 – 2005 consisting of surveys and reconnaissance field works. For example, in 2002, Dr. L. Braun headed an expedition to the lower reaches of the Grum-Grzhimailo glacier, and in the summer of 2006, a team from the National Hydrometeorological Service and International Foundation for Aral Saving conducted a two week expeditions along the Gissar range and to the Fedchenko glacier. It is doubtful whether such short-term expeditions are able to provide sufficient glaciological information to estimate glaciation change.

According to Krenke (Krenke 1982), for 20 years of intensive glaciological studies comprehensive measurements cover only 1/200 (0,5 %) of the glaciated area, partial measurements are available for about 1/25 (4 %), while fragmentary observations were conducted for 1/6 (17 %) of the glaciated area. Nowadays, studies of glacial systems should be based on indirect and distant methods using remote sensing techniques. Direct measurements should only be used to calibrate the calculations and to verify results.

The insufficiency of glacial studies is further illustrated by the fact that neither quantity of glaciers, nor the area of glaciations has been determined conclusively yet. One available source, the official glaciological publication, “Catalogue of Glaciers”, states that there currently are 8492 glaciers in Tajikistan with a total area of 8476 km², or about 6 % of the entire territory of Tajikistan (Catalogue of Glaciers of USSR, 1969 – 1980).

The atlas “Natural Resources of Tajik SSR” was published in 1983 based on satellite images. A map of current glaciation is included in this publication. The accompanying preamble states: “The map of ‘Current glaciation’ specifies all glaciers of Tajikistan with an area over 0.5 km². It was identified that the total number of glaciers with an area over 0.5 km² is not 8745 as assumed previously but 9009. The amount of surging glaciers increased from 18 to 78. The total glaciated area is 7979.2 km²”. This map had been developed by the Tajik branch of the State Centre “Nature” and glaciologists from the Department of Natural Resources Preservation and Rational Use of the Academy of Sciences of Tajik SSR.

Thus, just these two official publications provide three different pieces of information on the amount of glaciers and their areas. Furthermore, the provided values on glaciation differ substantially from each other.

The world atlas of snow and ice resources (1997), based on information available before 1980, was published in 1997. This Atlas refers to the Fedchenko glacier and many other glaciers as surging type glaciers. The majority of the data for all mentioned publications was obtained from space images and air photos.

Nowadays, new technologies including remote-sensing become more and more important. This minimizes the access problems and expands the area that can be covered. However, air photographs and satellite images should be deciphered and interpreted with due care, attention, and professionalism since considerable errors can occur in the process both through the fault of researchers.

The latest generalization and analysis of glaciological data from Pamir-Alay was done by A. Schetinnikov (Schetinnikov 1998). He estimated glaciation changes from 1957 to 1980 (23 years), and gave detailed description of this glacial region. It is, however, not clear how glaciers have changed as a result of climate change in the 25 years since then as there were no regular studies conducted since the early 90-s.

According to Schetinnikov (Schetinnikov 1998, p.p. 184 – 185), the initial period of research, the years from 1957 – 1959 (Kotlyakov 1968), were quite snowy . The studies were based on air photo images (API) and, towards the end of the study period, on satellite photo images (SPI). There were photo interpretation errors which made it difficult to identify glacier mar-gins covered by snow especially in the snow rich initial phase. In the following years, the snow cover disappeared from the upper parts of the mountain ridges due to precipitation de-crease and the rock margins of glaciers were exposed. Thus, the upper glaciation border re-ceded. The same phenomenon could be observed in the lower reaches of the glaciers. As a re-sult, a reduction in glaciation area was observed. This is one of the obvious factors.

There are other reasons influencing the accuracy of glaciation assessment. In the course of the research expedition conducted in 1957 – 1958 under the Programme of the International Geophysical Year (IGY), the borders of Fedchenko Glacier were studied. Based on results of these studies, S. Chertanov wrote: "… Rapid advance of the glacier in 1910 – 1913 was caused not by meteorological processes but by shifts of ice and snow masses in firn area from steep slopes as a result of an earthquake in the Sarez locality on the night of 19 February in 1911, which accelerated the glacial movement speed. This might be true for other glaciers in the region as well. Glacial masses, which advanced to the wide part of the valley by 800 – 1000 m, started fading because in the following years movement speed dropped significantly, i.e. showed values adequate to sustainable (permanent) meteorological processes, taking place in the glacial equilibrium line …". He also notes: "The glacier margin should retreat to the narrow part of the valley (behind the crossbar) at an elevation of 3150 – 3200 m a.s.l., where it becomes more stable as its losses are replenished annually by melting glacial masses". It is known, that at present the glacial margin has not reached this level yet.

There is no doubt that the same event affected other large Pamir glaciers, including the second largest glacier, Grum-Grzhimailo. The strong earthquake which happened on February 19, 1911 influenced the entire Pamir and has doubtless triggered the advance of many glaciers. The event was also the reason for the formation of the Usoy dam and Sarez Lake. But as the region had not been studied at that time, researchers identified the position of glaciers that had already advanced, and took their margins as the norm in the following years.

M. Hauser (Braun & Hagg 2003) selected several sources to compare the changes of the lower margin of Grum-Grzhimailo glacier. First maps of this region, developed by R. Finsterwalder, and space images obtained in different years were used for a reconstruction of glacier position (Figure 11). A comparison of data shows that the glacier has retreated more than one kilometre from 1928 to 1990. However, this cannot conclusively prove glacier degradation since, in all likelihood, the Grum-Grzhimailo glacier had also experienced the same shift of ice in 1911 as the Fedchenko glacier, and it could be argued that, at present, the advanced mass is melting. This, however, is only an assumption as the Grum-Grzhimailo glacier has not been studied in detail yet. Only one reconnaissance expedition to the region (headed by Dr. L. Braun in 2002, as was mentioned before) has been conducted so far.

In 1980, during the expedition to the East Pamir glacier No 266 – Gurumdi (South-Alichur range), several panoramic photos were taken. The glacier, which has an area of 0.4 km² according to API for 1947, or 0.5 km² according to API for 1948 (it is not known whether the different values are due to a difference in actual glacier size or just an inaccurate interpretation) is not strongly affected by solar radiation as it is located on a North facing slope. Rather the glacier balance depends mostly on air temperature and precipitation. Photographs were taken from the opposite slope at an elevation of 4850 m a.s.l. In August 2001, the glacier was visited again and new photographs almost from the same point were taken (Figure 12).

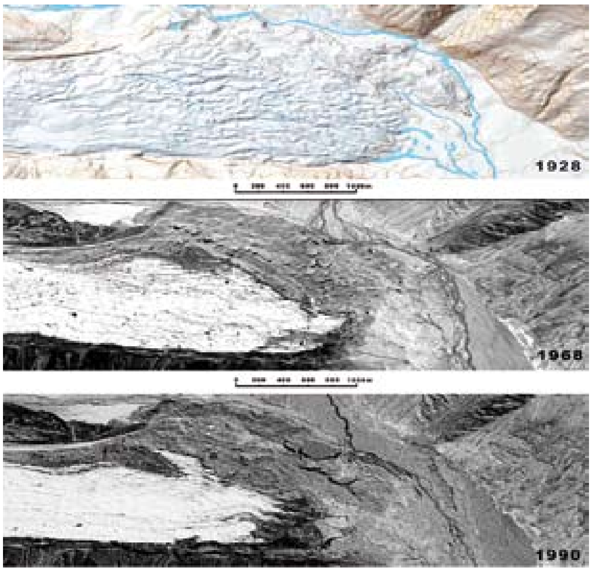

Figure 11 *Comparison of the lower margin of the Grum-Grzhimailo glacier in different years. Data of 1928 (R. Finsterwalder), 1968 (satellite image Corona), and 1990 (satellite image TFA 1000). Figure produced by M. Hauser, personal communication.*

A preliminary comparison of the photos indicated that the glacier had degraded significantly. But when dates and images were carefully compared and studied, this finding proved to be wrong.

The first photo was taken on July 26, 1980, and the second one on August 16, 2001. The large photos of 1980 show that the glacier tongue was rutted by cavities and had snow on it. As Mid-August is the final ablation period in this area and considering the low snowfall amounts of the previous winter, it can be concluded that in August of 2001, when the photo was taken, the snow had completely melted and the glacier showed its real dimensions. Visual observations made in the 1980-s and data from the Catalogue of Glaciers10 based on air photography of 1947 show that "the glacier's lower margin has two branches with the right one reaching the border of glacier No 265". The photos of 2001 confirm this statement. In the right bottom part of the photo the margin of glacier No 265 can be seen.

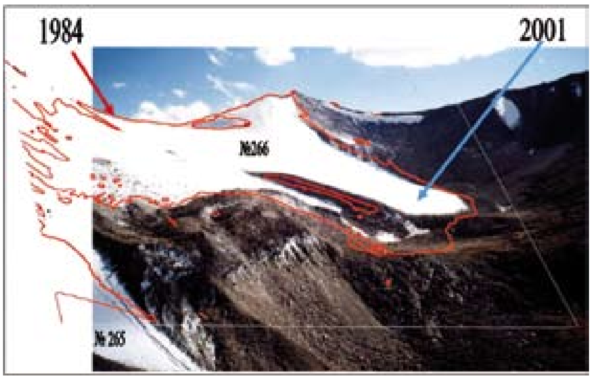

Figure 12 *Comparison of margins of Glacier No 266 (Gurumdi) based on photograph of 1980 (red outline) and 2001 (photo). Photo taken by A. Finaev.*

This proves the ambiguous assessment of glaciation changes based on air photos. It is obvious, that in addition to climate changes, there are other reasons influencing glacier margin positions. Thus, it would be, at least, incorrect to talk about glacial degradation in Tajikistan due to global warming without carrying out further fundamental studies and regular observations in this field. The emphasis should be put on remote-sensing methods, confirmed by field work research of some typical glaciers.

River runoff

The data from 5 hydrological posts (h/p) measuring streamflow and representing different regions were selected to study the hydrological situation. It should be noted that these posts also had observation gaps within the researched period. Despite this fact, we may assess water discharge trends and changes with regard to average climate values (State Water Cadastres 1987) based on the information available.

The Kzylkishlak post on the Syrdarya river represents the typical hydrological regime of Northern Tajikistan. For the past 15 years, the post showed a constant increase of average annual water discharge from 500 to 800 m^3/s (Figure 13).

It should be noted, that after 1999 there are data available for 2003 only at Kzylkishlak post. The lowest growth trend was observed at the Zeravshan river (Dupli h/p, data till 1997 with interruption in 1995 – 1996) with water discharge increasing from 170 to 220 m^3/s.

In the Gissar range and in the Pamir mountain areas, water discharge trends could not be observed (Dagana and Khorog h/p respectively). Data for these posts are most complete, though there still are some gaps – one year in Dagana and three years in Khorog.

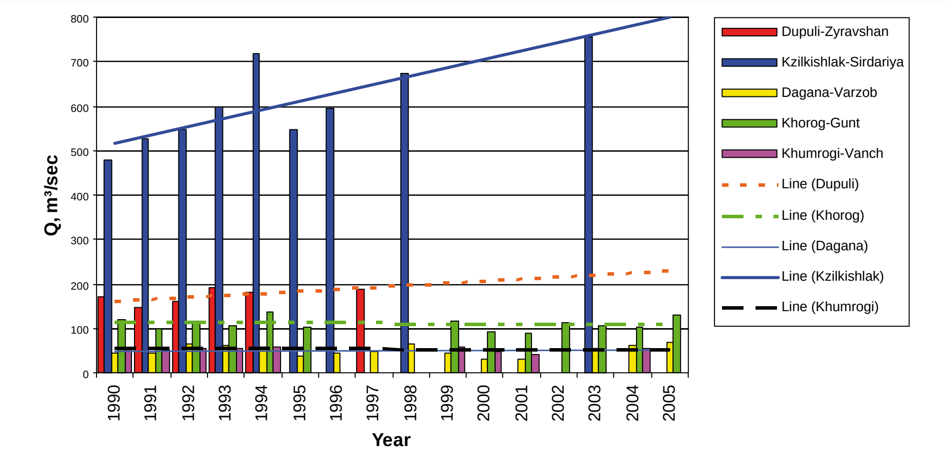

Figure 13
Average annual water runoff in m³/s

To enhance the runoff monitoring, it is necessary to improve the activities of existing posts and to reinstate inactive stations, especially at outlets. For example, it would be important to reactivate the Tigrovaya balka post located on the downstream portion of the Vakhsh river, because its data could be used for an assessment of the water discharge of the entire Vakhsh basin.

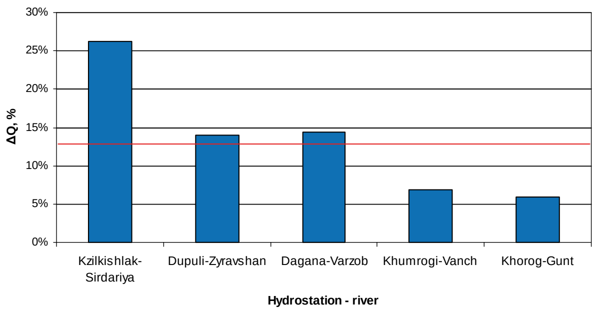

Figure 14 *Average water runoff trend for 1990 – 2005 in %.*

Conclusions

The hydrometeorological situation in Tajikistan is monitored by the National Hydrometeorological Service (NGMS) through a network of stations and posts. Over the period from 1990 – 2005 the amount of operating observation points has changed significantly, resulting in the discontinuity of many data series. Most information is available on paper, as documents and materials have been received from stations for more than 15 years. Presently however, the NGMS is unable to process this extensive information and does not convert them on to magnetic or other database media.

The study of data supplied by 16 stations from various regions showed that air temperature increase continued at the rate of 0,039 °C per year on average. The temperature increase rate decreased with elevation. The highest air temperature increases were observed in winter (0,093 °C/year) and autumn (0,05 °C/year), while the increase in spring and summer was insignificant with values of 0,024 °C and 0.013 °C respectively. Average annual temperature fluctuations were periodical. Three peaks of maximum and two peaks of minimum values can be identified within the study period (1990 – 2005).

For precipitation, a five-year cyclic recurrence becomes obvious especially at the stations that have the highest precipitation amounts. Maximum annual precipitation totals are about twice as high than minimum values. We may note that in winter and spring precipitation exceed the norm by 20 % to 50 % and in summer and autumn by 70 % to 100 %. There was no trend in long-term average annual precipitation change within the researched period (1990 – 2005). The average annual precipitation over the study period using all stations was 18 % higher than the normal. This suggests that the increase of precipitation above the climatic norm must have taken place before 1990.

To study the depth of the snow cover, we used data supplied by nine stations. However, only six of those could be compared to a long term normal. The analysis shows that the average decade snow cover thickness seems to be increasing with elevation from a few centimetres in valleys to one meter in the mountains with absolute maximum values reaching three meters. There was no trend revealed in the analysis of snow cover thickness change.

No regular glaciological studies have been done to estimate glaciation changes for the research period. The most recent publications are based on data obtained before 1980 – 1990. In the last 15 years, there were several short-term reconnaissance and survey field studies but they did not provide reliable glaciological information. There is some evidence of a reduction of the glaciated area, but it is too early to give a conclusive assessment. Factors impacting the assessment of glaciation parameters include air and space image interpretation errors, the date of image recording, the melting of surging glaciers after their large advances, and the temperature increase as a result of global warming.

The analysis of average annual water discharge was based on data supplied by five hydrological posts and showed that, for the selected period, annual water discharge increased in the rivers of Northern Tajikistan: Syrdarya river – 19 m^3/year, Zeravshan river – 4.6 m^3/year and Varzob river – 0.2 m^3/year. In the Pamir rivers – Gunt and Vanch – the average water discharge rate decreased by 0.28 and 0.33 m^3/year respectively. However, average annual water discharge for all rivers exceeds the long term normal of 13.5 % ranging from 5.9 % at Gunt river to 26 % at Syrdarya river (Figure 4). As the precipitation exceeds the normal during the same period by 18 %, it is plausible to assume that the annual water discharge increase occurs basically as a result of precipitation increases.

Thus, in order to get a true assessment of the hydrometeorological changes, it is necessary to process the available archived observations for the last 15 – 20 years and to improve the effectiveness of the entire net of stations and posts. Only then a forecast of the climatic characteristics and glaciation changes in the region becomes feasible.

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