# Contemporary fluctuations of climate and natural resources in the basin of the Little Almatinka River (Kazakhstan)

Ludmila Eriskovskaya, Nina Pimankina

*Institute of geography,Pushkin Str., 99, Almaty 050010, Kazakhstan*
*E-mail: pimankina@mail.ru*

**ABSTRACT**. The Little Almatinka River valley (Zailiiskiy Alatau Range, Tien Shan mountains) is important source for the formation of climatic conditions and water supply of 1,5 mln Almaty City. Climate change impacts natural systems of the area, and alters diversity and functions of ecosystems. This paper analyzes data on climate, glaciers, river discharge for the last 40 years. The work briefly describes current trends in climate and shows how its fluctuations affect glacial mass-balance, glacial lakes, river flow, plant settling. Connection between net balance and atmospheric circulation is considered. In general, glaciers located in the valley, retreat in spite of the fact that for the period of meteorological observations the amount of precipitation, depth of snow cover, relative humidity, and total cloudiness have increased, and duration of sunshine decreased, while the average annual, summer and winter temperatures show the trend toward the increase. Some of glacial lakes in the valley increase now, another were drained by special measures. Plant expansion are described briefly.

## INTRODUCTION

Recent observational studies show significant temperature and precipitation fluctuations in Kazakhstan over the last few decades. The all-Kazakhstan average annual temperature increased by 1,5°C during 1954-2003, but the precipitation trend is not so evident (Bultekov and others, 2006). The changing trends of the snow-water equivalent and number of days with snow cover demonstrate big interannual variations exceeding found trends (Pimankina, 2007, 2009). Recent studies (Eriskovskaya, 2003, 2004) show increasing trends in the mean annual and winter temperatures and precipitation in high mountains. Fluctuations of the Tuyuksu Glacier mass-balance were estimated by Makarevich and Kasatkin, 2008b. They found that for the period of observations ( since1958) the net balance of the glacier was mainly negative. The rates of the glaciers retreat in the Zailiiskiy Alatau Range were assessed by Kokarev (2009). As it was revealed, the shrinkage of the total area of glaciers in the range is about 40%. Field monitoring of the glacial lakes is conducted by the departments of Kazselezasita (mudflow prevention) and by the staff of Tuyuksu glaciological station (TGS).

Different meteorological, snow and ice data were collected from the Mynzhilki meteorological station (MMS, H= 3017 m a.s.l.) and TGS (H=3450 m a.s.l.), located in the Little Almatinka River valley. In this paper, the integrated assessment of the current changes in climate, glacial mass-balance, glacial lakes area, river flows, plant settling is presented in brief.

## STUDY SITE

In the basin of the Little Almatinka River (Tien Shan mountains) there are located now 11 glaciers at the different stage of retreat (Fig. 1). The biggest one is the Tuyuksu Glacier ( 43.05 N / 77.08 E) has the surface area 2,4 $km^2$, the length is 2,8 km, the volume is about 100 mln $m^3$ (Makarevich and Kasatkin, 2008b). Maximum altitude is 4219 m a.s.l., the average elevation of surrounding ranges is 4200 m, and the terminus of the glacier is located now at the 3440 m altitude.

Field works at the Tuyuksu glaciological station include meteorological observations, calculation of the value of accumulation using snow cover measurements at 120 stakes and snow pits; precipitation measured at 13 summary precipitation gauges, established between 3200–3760 m a.s.l. The flow of the Little Almatinka River in the

upstreams is being formed mainly from the snow and ice melt, and at the Mynzhilki Station the river freeze in winter, so a major part of discharge (98-99%) runs in summer months.

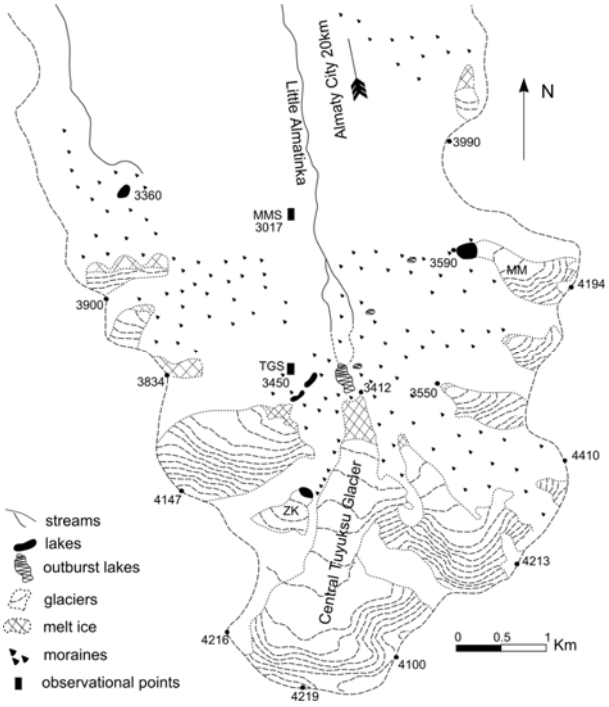


**Fig. 1.** Schematic map showing the glacierized basin of the Little Almatinka River and observational points Mynzhilki Meteorological Station (MMS) and Tuyuksu Glaciological Station (TGS)

The scheme was compiled on the basis of topographic maps of 1971, and glacier retreat are shown out of scale with corrections taken from the ALOS 2006-16-08 image. Present-day configurations and detailed calculation of the open ice and moraines area are presented in: Severskiy and others, 2006*;* Makarevich and Kasatkin, 2008a.

**DATA**

Zailiiskiy Alatau mountains experience effect of four dominant cyclone trajectories: The major part of atmospheric precipitation in summer (June-August) falls at the invasions of the Iran cyclones of Polar front. The main direction of their tracks is from south-west toward north-east. Prevalence of meridional circulation with coming southern cyclones is favorable for the glaciers, and number of days with circulation of those type (so-called 13 s) has increased since 1980s (Eriskovskaya, 2009). Days with precipitation at that type of circulation is observed almost by 3 times often than at another synoptic process.

Initial information for the statistical assessment of the changes in the time series of meteorological parameters was obtained from the TGS data (measurements for 1973-2007 period). As it was found, in high mountains the average annual air temperature has increased by 0,9° (calculation from the linear trend), while the rise in the temperature for the cold period (September-May) is 1,1°, and for the summer (June-August) is 0,4°. Time series of the sums of precipitation show positive trends, and yearly sums have increased by 114 mm, sums for the cold period by 60 mm, and for summer – by 46 mm. It makes around 10-12% from the normal value. Yearly fluctuations in the sums of precipitation depend mainly on the changes in the atmospheric circulation patterns and vary significantly: the extreme values are 736 (1984) and 1232 mm (2003). Time series of the total cloudiness and relative humidity demonstrate positive trends, while duration of sunshine slightly decreased (Eriskovskaya, 2009).

Peak accumulation is observed usually at the end of May – beginning of June, though in separate years the maximum values of snow-water equivalent can be measured in the first 10-days of May (for example, in 2008 – on May, 9), that prolonges period of ablation. The maxima of the snow depth, measured at permanent stake at the TGS site, has also show tendency toward the increase (almost by 50%).

The features of the glacier mass-balance formation and dynamics were established during long-term studies conducted since 1958. Dynamics of morphometrical characteristics of the Tuyuksu Glacier and fluctuations of the summer, winter, and annual mass-balance, data on the ELA, etc., are sent to the Glacier Mass Balance Bulletin (published in Switzerland), and are summarized in the recent publications (Makarevich and Kasatkin, 2008a, b). According to the authors, the average multiyear value of the winter balance (for 1957-2006 period) is +73 cm w.e., average summer balance is –112, and annual is –38 cm w.e. Despite of the difficulties with the definitions of the geometrical parameters of the glacier, the changes in its area and length were assessed. The researchers evaluated the glacial front retreat as 687 m, and the mean annual retreat is 13,6 m. The average value of ELA is 3820 m.

On the basis of repeated photogrammetrical surveys of 1958 and 1998 the map of the changes in the elevation of ice surface was compiled (Severskiy and others, 2006). At the most part of the glaciers the elevation of the ice surface decreased by 5 – 25 meters. In the zone of accumalation of glaciers the changes vary from +5 to –5 m. The researchers defined at the upper zones of the glaciers the areas with the increase in the elevation of the ice surface amounted from 5 to 25 m. The biggest losses of ice thickness were found at the glacier tongues – up to 50 m. As it was calculated, buried ice of the moraine complexes melts at the approximate rate 1% per year.

At present, intensive melt of the glaciers promotes an increase in the area and volume of glacial-moraine lakes. The most hazardous for the city lake is located on the frontal moraine of the Manshuk Mametova Glacier (on the schematic map – MM) at the altitude 3590 m a.s.l. Its size in summer, 2010, is approximately assessed as 200 ×150 m, depth reaches 30 m, and volume is more than 230 thousand cub. m. On the images there can be found new lakes which were not drawn on the topographic maps compiled earlier, i.e., they appear during the last 15-20 years or less. In 2000, a new lake at the Zoya Kosmodemianskaya Glacier (on the schematic map – ZK) was formed at the altitude 3570 m a.s.l. as a result of glaciers retreat. During the last 5 years its area and water volume have increased by 2,5 times (Kasatkin and Kapitsa, 2009).

The Tuyuksu group of glaciers give origin to the Little Almatinka River which then takes tributaries –small rivers of mixed snow-rainfall feed. Rivers flow is regulated, and often used for irrigation. It can be said in brief, that there is a slight trend to the increase in the river discharge despite the glaciers shrinkage.

Moraines of the glaciers of the Tuyuksu group (considered as Fernau stage) located at the altitudes 3100-3500 m a.s.l. in nival belt, are covered with moss, lichens, cryophyl plants *Driadanthe tetrandra* and *Thylacospermum caespermum*, and others.

**RESULTS AND INTERPRETATION**

Observational data from TGS can be grouped into several periods. From 1956 to 1972 big accumulation, low ice and total ablation, and small negative balance were typical. Snow line was at the average at the altitude 3750 m.

Period from 1973 to 1990 was characterized by opposite tendencies in the glacier regime, that was manifested in the big negative annual mass-balance, strong summary ablation, snow line rose to the altitude 3870 m a.s.l. (by 120 m higher than in the first period). Next period was defined as 1991– 2009. Comparison of the average multiyear values of the mass-balance and its components, and also meteorological characteristics for the periods 1973 – 1990 and 1991– 2009 has made it possible to make a conclusion, that the last time span is rather favorable

for the glacier. As criteria of favourable conditions we consider the average annual sum of precipitation exceeding normal by 2–3%; the average temperature of July by 2-3% lower than normal; the depth of snow cover (at the permanent stake) by 10-15% higher than normal.

Fig. 2 shows fluctuations of the annual mass-balance (bn) and ELA (m), integrated with the summer (June-August) air temperature (TºC) at the TGS. High summer air temperature and intensive melt lead to the big values of the negative annual mass-balance and high snow line.

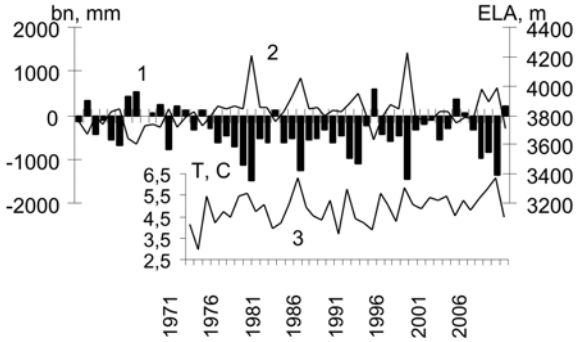


**Fig. 2.** Multiyear course of the glaciological parameters of the Tuyuksu Glacier and summer air temperature during 1971-2009 period. 1– annual mass-balance of the Tuyuksu Glacier, 2– ELA, m, 3– mean summer temperature (June-August)

Fluctuations of the mass-balance take place on the background of increasing air temperatures, especially in autumn-winter period (Table 1), but the mean air temperature in July – central month of the period of ablation – was by 0,2°C lower, and intensity of ablation, therefore, was less.

**Table 1**. Glacioclimatic characteristics of the Tuyuksu Glacier

| Parameter | Period of observations | |
|---|---|---|
| | 1973-1990 | 1991-2007 |
| Winter balance, cm | 58,0 | 55,6 |
| Summer balance, cm | –122,6 | –96,5 |
| Annual balance, cm | –64,6 | –40,9 |
| Equilibrium line altitude, m a.s.l. | 3870 | 3840 |
| Annual sum of precipitation at TGS, mm | 960 | 1005 |
| Sum of precipitation for September-May, mm | 565 | 570 |
| Average air temperature for June-August, T°C | 4,9 | 5,0 |
| Average air temperature in July, T°C | 5,9 | 5,7 |
| Average air temperature for October-May, T°C | –8,1 | –7,6 |
| Average snow depth in May, cm | 64 | 84 |

In the year 1993 (favorable for glaciers) in summer period there were observed 32 days with the type of circulation 13s, when 259 mm of precipitation fall, from which 232 mm was solid or mixed. The average summer temperature was by 1° lower than usual. ELA was by 200 m lower, and the yearly mass-balance of the glacier was positive making + 60 cm w.e. Despite of this, the glacier retreated by 7 m. Discharge of the Little Almatinka River, measured at the Mynzhilki Station (H=3000 m a.s.l.) near the glacier, was about 30% less than normal. However, the discharges of the small rivers of non-glacial origin were not reduced because the sums of precipitation brought by coming southern cyclones, exceeded norms significantly: in the different altitudinal belts there fell by 30-70% precipitation more than usual.

In the year 1997 (unfavorable for glaciers) there was registered only 14 days with the type of circulation 13s, during which 82 mm of solid and mixed precipitation fell. The average summer air temperature was by 1° higher

than the average multiyear value. The annual glacier mass-balance was –147 cm w.e., that is almost by 3 times less than the average value, and the summer one was –181 cm w.e. The glacier tongue retreated by 20 m. The researchers calculated the rise of the snow line as 400 m; Almost all surface of the glaciers and frozen grounds were involved in melting, that caused the increased water income into the glacial-moraine lakes and rise of water level into them. The water volume in the lake at the MM Glacier reached the critical level, that generated need to drain it using special measures. Discharges of the rivers with glacial feed increased, and the yearly flow of the Little Almatinka River (at Minzhilki) was by 36 % bigger than usual.

The retreat of glaciers and rather favorable climatic conditions of the last years (relatively big amount of precipitation and warm summer, prolonged vegetation period) has made preconditions for colonization of moraines with shallow stony soils by low fur woods (*Picea schrenkiana f. prostrata*) and willows (*Salix alatavica*). Usually low fur woods can be found at the elevation 3100 m a.s.l. Personnel of the Tuyuksu station note settling of the associations of the low fur and willows on rather steep slopes of north or north-east exposure at the altitudes 3200-3300 m a.s.l. The age of woods has not been determined, but apparently varies from several years to 2-3 decades.

## CONCLUSIONS

Summarizing aforesaid, it should be stated that the glaciers remain in the stage of degradation. Vegetation colonizes areas at higher altitudes. The retreat of glaciers causes origination of glacial lakes, which can be hazardous because of rapid melt of glacier or even break off the ice pieces resulted in the slow or catastrophic overfill of the lake. The increase in the summer air temperature by 1° in 1997 was equivalent to the rise of snow line by 400 m, involving vast areas of glaciers and permafrost into melting and increasing share of snow/ice meltwater by 1/3. The extremal rise of snow line (0° isotherm) increase the risk of outburst of glacial-moraine lakes significantly. However, in the last several years the absolute values of negative summer and annual glacier mass-balance have reduced, snow line was observed lower.

## ACKNOLEDGEMENTS

The authors express their gratitude to the staff of the Tuyuksu Glacier Station for the long-term works in severe alpine conditions. We also would like to thank Prof. V. Blagoveshenskiy, Dr N. Kasatkin for their constructive reviews of the paper.

## REFERENCES

Bultekov, N.U., I.B. Esserkepova, P.J. Kozhakhmet, N.V. Pimankina, I.V. Severskiy, 2006. Climate. Medeu, A., ed., Republic of Kazakhstan, vol. 1 – Natural Settings and Natural Resources. Print-S Press, Almaty, Kazakhstan, 2006, 215-235.

Pimankina, N.V., 2007. Some features of the winter season in the mountains of south-east Kazakhstan at the end of XX century. *Vestnik KazNU*, ser. Geogr, **1** (24), 57-61.

Pimankina, N.V., 2009. Current fluctuations of the snow cover over the territory of Kazakhstan, *Data of Glaciological Studies*, **107**, 110-114.

Eriskovskaya, L.A., 2003. Impact of climatic changes on glaciers in the Zailiiskiy Alatau Range: Tuyuksu Glacier case study. *Hydrometeorology and Ecology*, **4**, 31-34.
Eriskovskaya, L.A., 2004. Meteorological conditions influencing the Tuyuksu Glacier behavior for the last years. *Hydrometeorology and Ecology*, **1**, 34-41.

Makarevich, K.G., N.E. Kasatkin, 2008b. The 50-years studies of the mass-balance of the Central Tuyuksu Glacier in the Zailiiskiy Alatau. Medeu, A., ed., Geographical Problems of Sustainable Development: Theory and Practice. Print-S Press, Almaty, Kazakhstan, 99-111.

Kokarev, A.L., 2009. Monitoring of glacial belt of the northern slope of the Ileyskiy Alatau using space images and GIS. *Vestnik KazNU*, ser. Geogr, **2** (29), 17-25.

Severskiy, I.V., A.L. Kokarev, S.I. Severskiy, T.G. Tokmagambetov, L.B. Shagarova, I.N. Shesterova, 2006. Contemporary and prognostic changes of glaciation in Balkhash Lake basin. VAC Press, Almaty, Kazakhstan, 68.

Makarevich, K.G., N.E. Kasatkin, 2008a. Dynamics of morphometrical characteristics of the Tuyuksu Glacier during the last 50 years. Medeu, A., ed., Geographical Problems of Sustainable Development: Theory and Practice. Print-S Press, Almaty, Kazakhstan, 89-98.

Eriskovskaya, L.A., 2009. Meteorological regime of the Tuyuksu Glacier. *Data of Glaciological Studies*, **107**, 130-136.

Kasatkin, N.E., V.P.Kapitsa, 2009. The morainic lakes dynamics in the Ile Alatau. Tuzova,T., ed., Mitigation of Natural Hazards in Mountain Areas. Salam Press, Bishkek, Kyrgyzstan, 58-61.