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Statistical picture of climate changes in Central Asia: Temperature, precipitation, and river flow

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Abstract: The research presented in this paper is dedicated to the temperature, precipitation and rivers runoff observations in Central Asia. Conclusions about the current situation and the impact of future climate change in the region based on observations from more than 600 meteorological stations during the last hundred years. Special interest was paid to the climatic changes that occurred in the region during the first seven years of the 21 century. The changes in runoff of major Central Asian rivers, such as Naryn, Karadarya, Zerafshan, Amu Darya and its tributary Vakhsh, since the beginning of the last century were studied. Trends in the climatologic and hydrologic data were analysed. The research results provide important insight into climate change and its impacts in Central Asia. The rules of water use and resource-management in the region were developed before the appearance of significant climatic changes in the region. These rules cause growing tension in the relations between countries using water from the same rivers. Adaptive actions based on the research results will be required to reduce water problems and conflicts between neighbouring countries of the Central Asian region.

***Keywords**:* climate change; temperature; precipitation; river runoff;

Introduction

Quite often, from the mass media and from scientific articles, we hear about signs of climate change that occurred on Earth [Boyle, 2001]. But always, only a part of the many processes that take place in the climate changes is demonstrated. Most often average air temperature data are demonstrated. It is difficult to find references about the total amount of precipitation. So, the demonstration of issues related to the yearly distribution of temperature and precipitation is a rare accession. However, this aspect is most important. The study of the intra-annual variability in connection with a change in the average annual temperature, runoff and precipitation is the subject of this article. Only precipitation occurring during the growing season can affect crop production. Average annual temperature precipitation increases have a less important impact for humans than climate change within the year. Conclusions presented in this article, represent the results of numerous statistical calculations using series of historical observations at meteorological and hydrological stations. As expected, there is no direct correlation between the observations of temperature, precipitation and river runoff. The absence of such relationships is caused by multi-year water storage in glaciers at the present time in the region. For example, in a year with low temperatures the precipitation may not cause an increase in river flow because the main amount of precipitation will be accumulated in glaciers. In the next period, if high temperatures occur, this water may appear in the rivers, even if the amount of precipitation is not too great. Finally, for countries in Central Asia the main importance is the water factor and that is why much attention will be payed to the description of existing and possible future changes in water quantity in rivers in correlation to the time of year.

Recently, satellite photos were used for climate change evaluation. For example, photos made by the MODIS satellite have been used for short-term predictions of water flow in rivers. But, there is not enough observation time to evaluate long-term changes in climate. For example, MODIS satellite photos are available only since 2000. There are no doubts that future satellites photos will play a main role in predicting future climate changes. But currently the main source of information about climate change is the series of observations collected at the meteorological and hydrological stations by the usual way.

Observations database

In order to evaluate climatic changes taking place in Central Asia, information about average temperature and precipitation measurements were collected and recorded in an ARCMAP database for more than 1000 meteorological stations during a total period of more than 130 years. Figure 1 shows the GIS project dedicated to mapping the location of the meteorological stations with measurements included in the database.

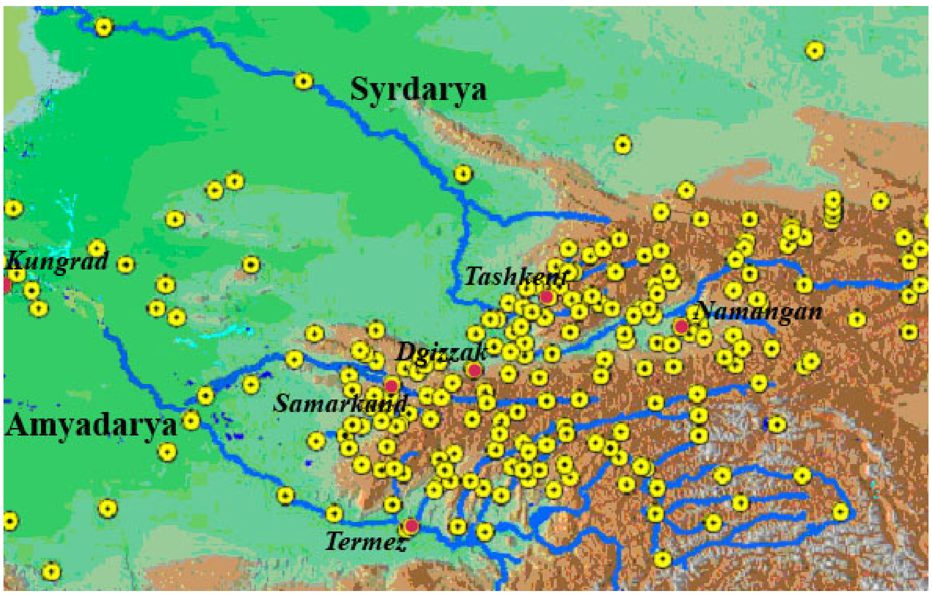

Figure 1. GIS project mapping the meteorological stations location with considered measurements of monthly air temperature and monthly precipitation.

Despite the abundance of observation stations, consistent time series datasets are limited as many observation stations were only operated for a limited amount of time. However, there were also stations that continued to work for more than 100 years. From such stations with long records we collected measurements used in statistical calculations.

In addition, changes in air temperature and precipitation over many years and the yearly distribution of air temperature and precipitation caused some changes in river discharges in Central Asia. Such changes are of great importance, as millions of people in the five Central Asian countries rely on the water supply for irrigation and developments. In this paper the information about intra-annual runoff changes in the two major rivers in Central Asia has been investigated on the basis of series of hydrological observations for water content in the rivers at two constantly and continuously operating observation posts:

· Naryn River (the most studied and the main tributary of the Syr Darya) - a tributary for the Toktogul reservoir.

· Vakhsh River (a well-studied and main tributary of the Amu Darya) - a tributary for the Nurek reservoir.

Spatial relationship between measurements of temperature, precipitation and river discharge at stations in Central Asia are analyzed. This is done to identify representative stations that could be used to derive conclusions on regional trends of climate change in Central Asia.

Precipitation

More than one hundred stations measure precipitation in Central Asia for many decades. Selection of the representative station for the whole region seems to be an impossible task. Precipitation has a high degree of fluctuation. Maximum precipitation occurs in one region in Central Asia, then in another region. Sometimes even the precipitation at two locations separated by a short distance differs greatly from each other. Fluctuations in the air currents over Central Asia interact with the thermal situation and with another unique atmosphere feature creating a variable precipitation distribution in the region.

Figure 2 shows the typical level of the relationship between the stations located for than 150 km apart.

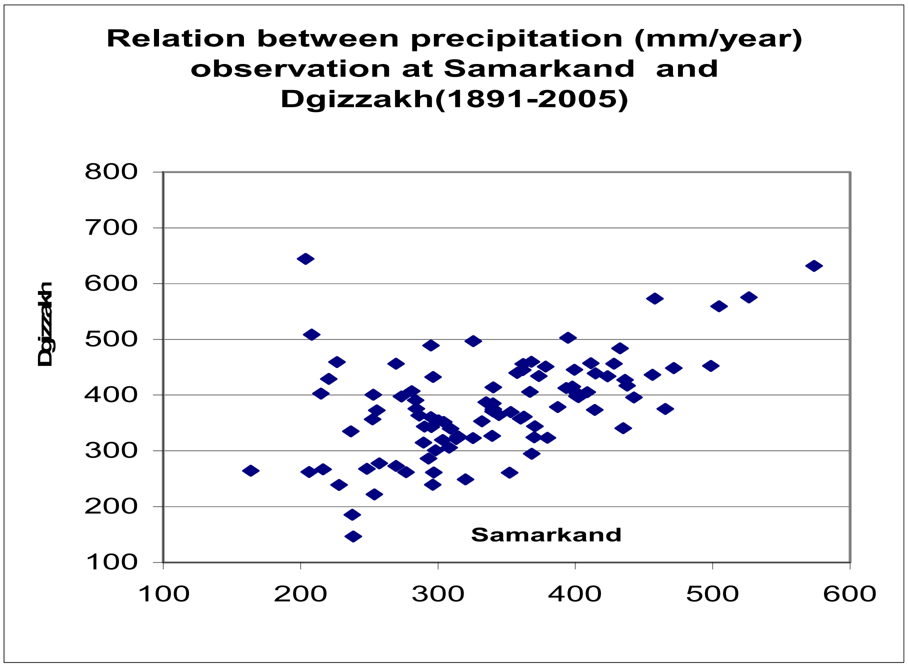

Figure 2. Relationship of the annual precipitation quantity at the stations in Samarkand and Jizzakh for the period of 1981-2005 years (R = 0.48).

Also, the relationship between the values of the annual precipitation at more faraway stations doesn't have a higher correlation coefficient.

Samarkand -Termez	(R = 0.47) for the last 100 years
Samarkand - Namangan	(R = 0.38) for the last 100 years
Jizzakh - Namangan	(R = 0.62) for the last 100 years

Observations at 20 longtime working stations (with data for more than 80 years continuously) in Central Asia were statistically analyzed, and the highest correlation coefficient identified was 0.65 (Tashkent-Dgizak stations).

As precipitation patterns are so diverse, the greatest possible number of operating stations for the last 30-50 years is required to examine the rainfall trends over such a large area as Central Asia. This period is taken as the period in which the features of a changing climate are visible and definable statistical characteristics.

Temperatures

The calculations show that the relationship between measurements of average annual temperature at different positions is considerably closer than precipitation. The most common is the relationship with a correlation coefficient around 0.8-0.9. As an example, consider the relationship between annual temperature values measured at the Tashkent station and the Kungrad station (the distance over a thousand kilometers) where the correlation coefficient is 0.82.

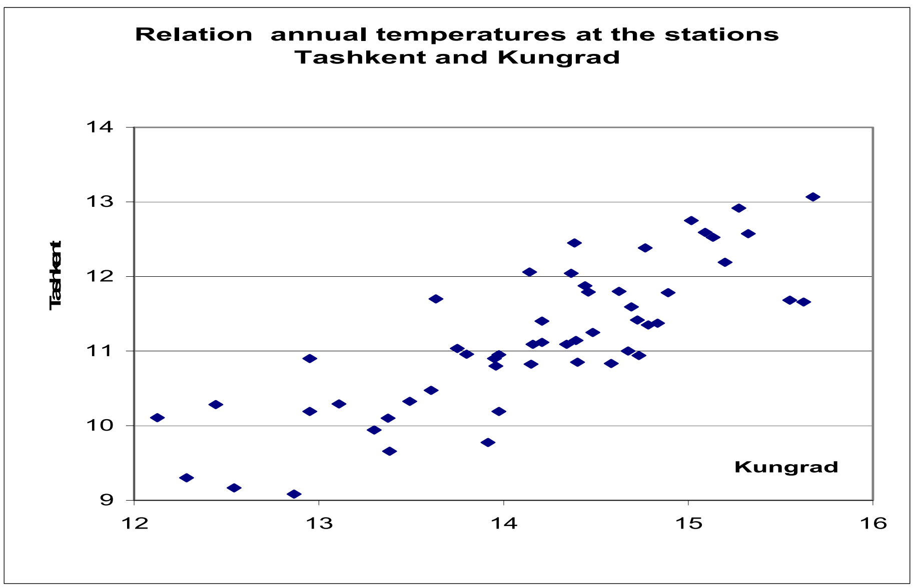

Figure 3. Relationship between annual temperature values at the Tashkent station and the Kungrad station (R = 0.82) for the last 50 years.

The closeness of the relationship between temperatures at different stations allows us to use the historical data series at the most reliable station to determine the general trend of temperature change throughout the region. Tashkent station was selected as such an appropriate station. This station has the longest number of observations, in which there are no gaps in observations.

River flow

Two river basins were considered - the two major Central Asian rivers - the Syr Darya and Amu Darya. In order to evaluate the relationship of flow in both basins, we define representative observation points. These points must have the following properties:

· Water above them should not be diverted for irrigation;

· A long series of observations should be available;
· Points are located at the main tributaries of major rivers of Central Asia;

We cannot take points on the rivers themselves because their natural discharge flow is distorted with reservoirs work and intakes. So, our choice was the following:

- Syr Darya: We chose a point of observation on its Naryn tributary in the inflow zone above the Toktogul reservoir.
- Amu Darya: We chose a point of observation on the Vaksh tributary in the inflow zone above the Nurek reservoir.

Figure 4 displays the relationship between annual discharges at these points of the observation.

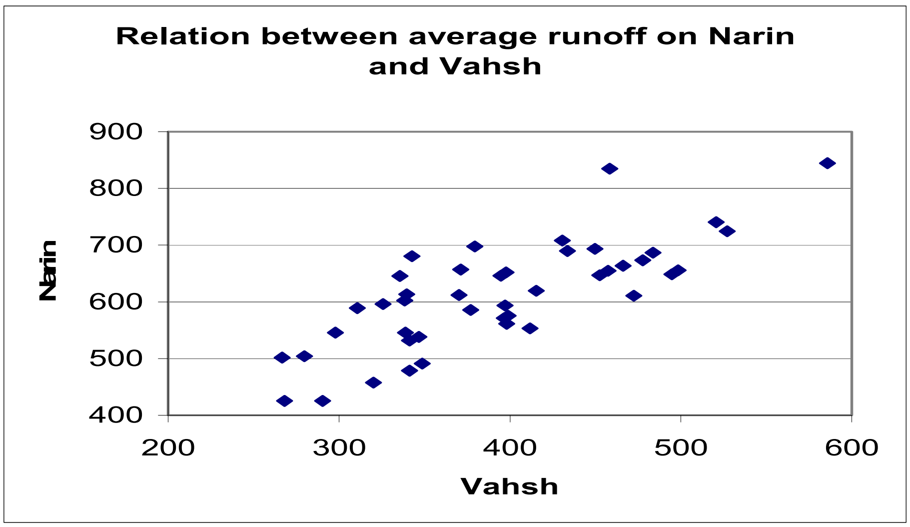

Figure 4. Relationship between annual water discharge at the cross-sections of the inflow to the Nurek reservoirs and Tohtogul reservoirs (R = 0.72) for the last 50 years.

The high correlation between river discharges at Naryn and Vahsh shows that both of these basins have a similar response to climate conditions (i.e., precipitation as a source of snow accumulation and temperature as a factor determining snow melting).

Trends in precipitation and temperatures, water content in the rivers of Central Asia.

To evaluate the trends in precipitation changes in Central Asia we selected observation posts operating continuously for the last 50 years. Statistical analysis showed that the precipitation varies from year to year. For example in Namangan (East Ferghana Valley) rainfall varied from 450 mm to 75mm during two years. Such a strong ripple does not allow us to identify any statistical trends in precipitation in the region. Correlations between precipitation at different locations are very low, which indicates a high variability in processes determining the precipitation pattern in Central Asia [Agaltseva, 2007].

The relationship between air temperatures measured at the various observation posts in Central Asia is quite high. For example the relationship between annual temperature values measured at Tashkent and Samarkand stations (distance is more than 300km) has a correlation coefficient 0.82.

In order to evaluate changes in the amount of precipitation linear trends were counted for stations with records longer than 50 years. Average value of the slope corresponding to the linear trend in the precipitation in Central Asia is 5mm per year (this is correct for the previous 50 years). This amount does not include the increasing evaporation caused by increasing air temperatures. It is possible to conclude that increasing precipitation in Central Asia does not affect the increase of water content in rivers.

The annual average air temperature in the region for the last 30 years has increased from 1.5 (Ferghana Valley) to 2.2 degrees C (Tashkent and Khorezm). These numbers are high and coincide with the values found for the Central Asian region in other researches [Ososkova, 2000]. In the intra-annual context, the situation with air temperature changes looks much worse. Figure 5 shows the course of the average temperature for the winter half of the year and it's averaging by Tashkent Station.

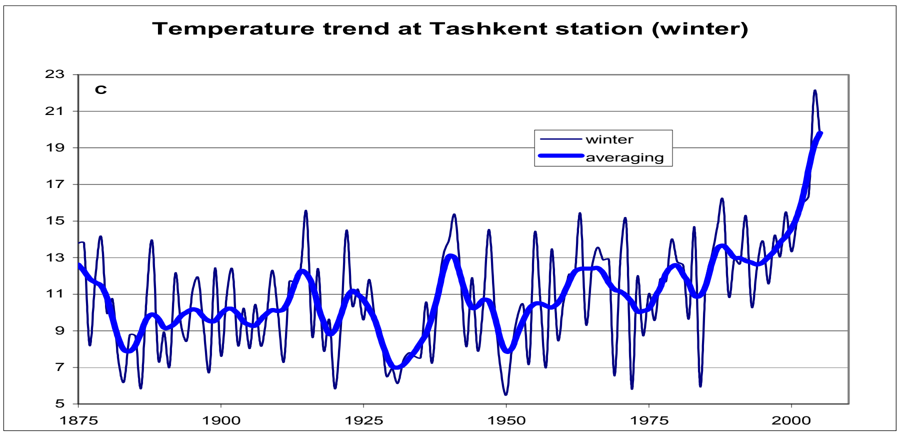

Figure 5. An average temperature values for the winter half of the year and their averaging by Tashkent Station.

In figure 5 the temperature increased is clearly visible and almost exponential since 1975, and summer in Central Asia has become a bit cooler. This is the only way to explain the 2.2 degree C annual increase, taking into account results on the figure 5.

Winter is a period of precipitation in Central Asia with snowfield and glacier accumulation in the mountains. In summer, during snowmelt, water flows down from the mountains and appears in the rivers providing irrigation needs. Tashkent is a rapidly growing city and it is quite possible that rapid growth of the winter temperatures is associated with this. However, the growth of winter temperatures is significant for other cities too. For example, the temperature growth in winter at Djizzak city for the last 50 years was more than 3 degrees C. In Termez the average winter temperature increased 17 degrees from 40 years ago. Since 2000, the temperature in the same winter period was 22 degrees C. In Termez the anthropogenic factor in relation to Tashkent is insignificant. These values of increasing winter temperatures are higher than the average increase of temperature in the region and suggest that in most of the region warmer winter seasons have appeared.

We will consider two graphs. Figure 6 shows the chronology of the inflow to the Tohtogul reservoir for the last 60 years. Representative position situated at the largest tributary of the Syr Darya River above, which no water abstraction for irrigation occurs [Shults, 1965]. Figure 7 shows the chronology of the inflow to the Nurek reservoir. This is a representative position at one of the main tributaries of the Amu Darya River. There are no water abstractions discharges for irrigation above this position also [Shults, 1965]. Both locations are consistent in the trend representation of the water content in rivers of Central Asia.

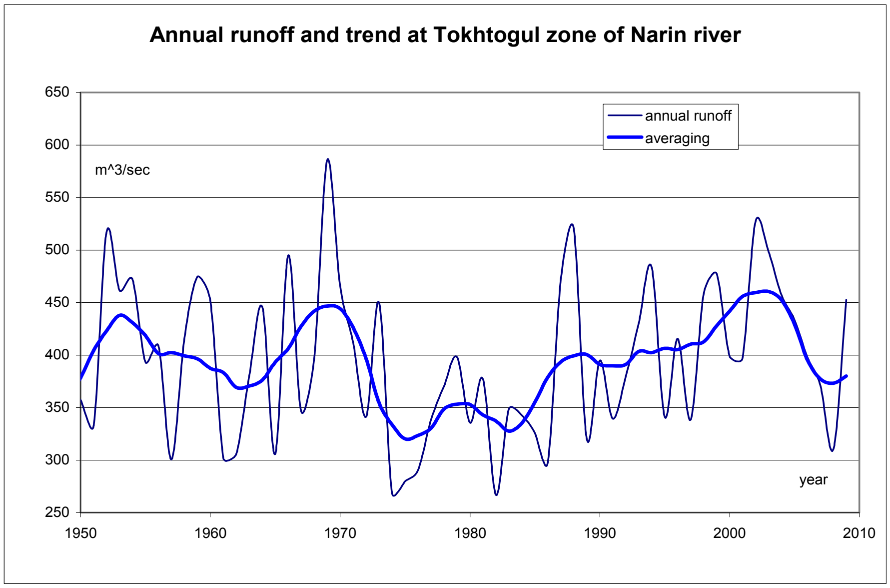

Figure 6. Historical data of the inflow in the Tohktogul reservoir and the trend for the last 60 years (moving averaging).

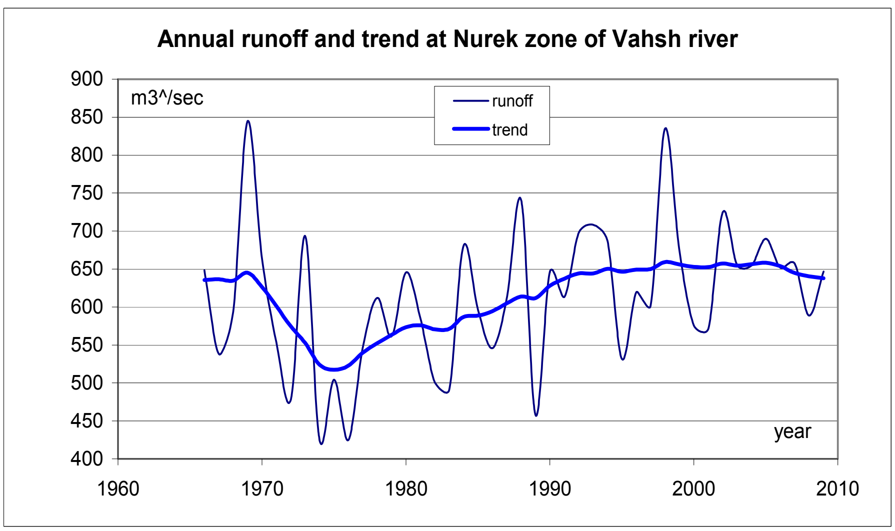

Figure 7. Historical data of the inflow in the Nurek reservoir and the trend for the last 50 years.

Analysis of the figures 6 and 7 shows an increase of the water content in the Syr Darya and Amu Darya rivers since 1975 that perfectly coincides with the explosive growth of the temperature (Figure 5). And for the Narin River it is possible to see a sudden rough drop of the water volume in 2005. There was a smoother decreasing in water content of the Vakhsh River for the same period of time. It is important to remember that Narin River mostly fills in with melted snow and melting of seasonal snow mainly forms the water in it. Water of the Vakhsh River in a significant amount is obtained by melting of the perennial ice.

The recent data displayed in Figures 5, 6 and 7 gives a reason to assume that the glaciers and snowfields in Central Asia decreased from 1975 to 2005 year. And after all they have reduced so much that in the future the Amu Darya and Syr Darya Rivers will have only a continuous drought in vegetation periods and water content in these rivers will decrease with the income reducing from the irrigation land. Precipitation will transform to runoff without stage of freezing and will be lost for irrigation in Summer time. The simple research was done in another river basins [Beven, 1987].

Probably, the temporary increasing of the water level in rivers for period 1965-1970 coinciding with temperature growth represents the consequences of the glaciers degradation. Situation becomes dramatic because the temperature increasing does not cause the water amount increasing in the rivers as result of the temperature rising since 2000 year. The additional water income from melting will become impossible because there are no any significant glaciers for melting. And remain glaciers will not provide additional water. Moreover, there are evidences that Central Asia glaciers are remains from ancient ice ages. Even without any future temperature growth the glaciers will not appear again after melting in the region.

In the very near future, countries located in the basins of the Syr Darya and Amu Darya Rivers will have to change their water management strategies and implement new water-saving technologies. Otherwise, the region has to expect a series of droughts. Based on the presented analysis we can conclude that Central Asia is strongly affected by climate change, which may increase conflicts of water usage in the future [Chub, 2000]. A large population is almost entirely occupied in the agricultural production capacity does not have flexibility yet to adjust to a changing climate. Central Asia is one of the groups of the vulnerable regions that will assume the impact of climate change and therefore it needs the assistance of the entire world community with solving the appeared and growing problems associated with the climate change.

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