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ATMOSPHERE PROCESSES AND CLIMATE PARAMETERS VARIATION IN RIVER MTKVARI BASIN

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Summary: *The River Mtkvari is a main artery of the Trans-Caucasus. The aim of presented research is to investigate atmosphere processes and climatic parameter variability in Mtkvari River basin. Mathematical modeling is used to assess wind velocity value in river basin, namely in Tbilisi, as the main city of the country. In order to investigate climatic state of territory the following climatic parameters (temperature, precipitation, wind velocity and direction, snow cover) meteorological station observation 1960-2015 data located along River Mtkvari gorge were used. The location of Georgia, its physical and geographical conditions, allow for a wide variety of meteorological processes with appropriate thermal-barrier fields to reflect and develop this area. Thus, any physical-mathematical model capable of describing microprocessors developed in individual regions is of theoretical and practical value. The results may be used in river water management issues.*

Key words: *Mtkvari River, atmosphere processes, climate change.*

Introduction

The River Mtkvari is a main artery of the Trans-Caucasus. The river starts on the territory of Turkey on the Karsi mountain and crosses the Georgian border in Akhaltsikhe region where it starts to run northeast in a gorge for about 75 km. spilling out of the mountains near Khashuri. It then arcs east and starts to flow east-southeast for about 120 km., past Gori, then near Mtskheta, flows south through a short canyon and along the west side of T'bilisi. The river flows steeply southeast past Rustavi and turns eastward at the confluence with the Khrami River, crossing the Georgia-Azerbaijan line and where it receives the Aras as a right tributary and enters the Caspian Sea.

The river is now moderately polluted by major industrial centers like Tbilisi and Rustavi and it is now much slower and shallower, as its power has been harnessed by hydroelectric power stations in Georgia.

Fig.1. River Mtkvari basin.

The complex mountainous relief and influence of Black Sea have conditioned the diversity of climate zones across the region, from everlasting snow caps and glaciers to warm humid subtropical forests and humid semi-desert steppes. The river basin covers areas with unequal climatic conditions, threatened by both floods and droughts.

Research aim and methodology

The aim of presented research is to investigate atmosphere processes and climatic parameter variability in River Mtkvari basin.

Atmospheric processes are highly heterogeneous and anisotropic in space and time. The main reason for this is Solar energy uneven distribution to the Earth's surface. In the lower layers of atmosphere, the heat regime is provided by the long-wave radiation reflected from the Earth's surface. The heterogeneous surface causes the rays to be reflected at different angles, which in turn causes an uneven distribution of the heat field. Uneven heat field causes unsmooth distribution of atmospheric pressure and formation of permanent "barrier centers". These centers provide air masses motion mainly from west to east ("leading" flow) with approximately 8-12 m/sec velocity and other zonal flows. These processes are irregular everywhere, especially in such difficult physical terrain as Trans Caucasus and Georgia in particular [1].

Wind velocity is a three-dimensional vector. Vertical component is small compared to horizontal motion and can only be (10-20) cm/sec. or more in intense convective motion. Such convective motions, however, often occur on bumpy, mountainous terrain. Therefore, in the mountainous terrain it is not acceptable to have wind zero divergence as allowed for a smooth surface. Experimental measurements of wind vertical velocity are associated with principal difficulties and therefore their evaluation using theoretical methods is necessary.

It is assumed that origin of wind velocity is conditioned only by surface friction and relief; in particular it is defined from integration of continuity equation:

$$W = -\int_0^H \left(\frac{du}{dx} + \frac{dv}{dy}\right) dz \tag{1}$$

The air flows are affected by upwind –downwind currents rising from relief considering of which is essential on any selected local polygon. Those currents define local circulations and peculiarities. After transformations the equation (1) obtains the following type:

$$W = \frac{1}{lp}\left[rot_z\tau + \frac{1}{\eta}(pln\eta)H\right] \tag{2}$$

The obtained equation is differing from already existing ones by the last member that reflects orographic loading [2].

$$W_0 = \frac{1}{l\rho\eta}(p, \ln\eta)H \tag{3}$$

where H is atmosphere layer altitude and W_0 reflects upwind flow velocity rising from orographic factor. After calculations W_0 amounts 8,7sm/sec. that indicates that orographic factor is important. Namely, Surami Ridge affects air masses dynamic on west and east sides. This fact is revealed on the formation local wind nature in Mtkvari River gorge. In Mtkvari River gorge wind transfers in gradient wind and their directions coincide. Thus we got one wind flow in the gorge that is much stronger than in other river ones (Rioni River). Such event is observed everyday and is of orographic nature. We can use this factor to explain so called “Tbilisi concave” phenomena.

The peculiarities of “Tbilisi hollow” may be explained using above given theory. To do this, let's evaluate the impact of the terrain parameter. The relief characterizing parameters $a=5,52*10^{-6}m^{-1}$ and $b=23*10^{-6}m^{-1}$, W0=12,64sm/sec. Significant results will be obtained considering those values [3]. As the terrain impact parameter b in the north-south direction is four times greater than that in the west-east direction, therefore, the air masses generally move only in one direction – across the Mtkvari gorge (h = 4.12m). In the cavern there rises congested circulation that is enhanced by the deficiency of vertical velocity (max. 20sm/sec). Such flow dynamic justifies all the climate "phenomenal" peculiarities.

In order to investigate climatic state of territory the following climatic parameters (temperature, precipitation, wind velocity and direction, snow cover) meteorological station observation 1960-2015 data located along River Mtkvari gorge were used. The only those station data were used that have continuous and homogeneous observation series. These stations are: Tbilisi, Borjomi, Gori, Khashuri, Paravani, Akhalkhalaki, Akhaltsikhe, Skra, and Rustavi. The observation period is sufficient to reveal climate change effect on River Mtkvari basin [4]. The climatic parameters data are given in Tab. 1-5. On Fig.1 annual sum of daily precipitation is presented for Tbilisi.

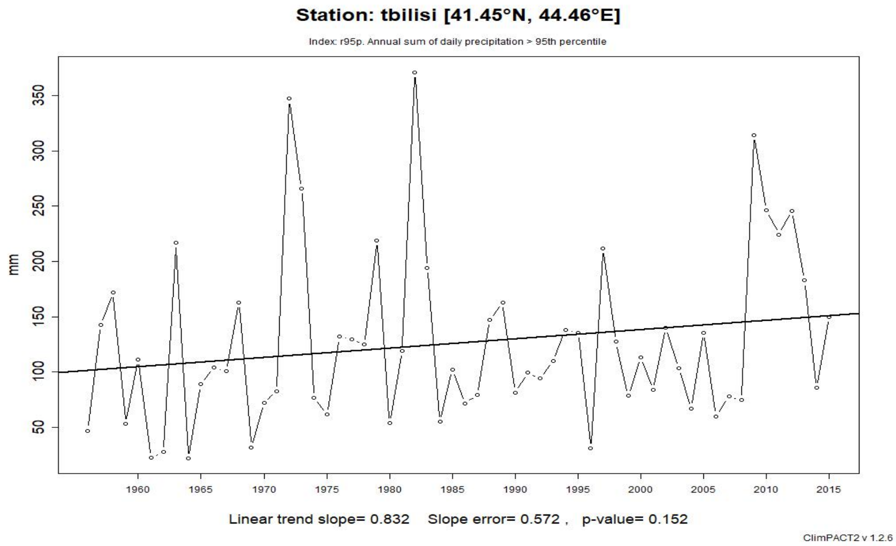

Fig.2. Annual sum of daily precipitation (1960-2015)

As it is shown in the given Tables, average annual air temperature for all the m/stations is positive and it ranges within 13.0°C (Rustavi) and 9.1°C (Borjomi). Average monthly air temperature of the coldest month – January in five m/stations is negative. The absolute minimum air temperature in all the m/stations in January is negative and it ranges between 31.0°C and -23°C. The absolute maximum of the air temperature is observed in July-August and it ranges within 37.0°C (Borjomi) and 41.0 °C (Rustavi).

Table 1. Air temperature absolute minimum (°C)

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Tbilisi	-16.3	-14.8	-7.4	-4	1.5	6.3	12.1	11.5	4.8	-2	-5.5	-11.4	-16.3
Paravani	-31.3	-32.5	-31.1	-18.6	-9	-6	0.2	0.7	-4.2	-11.7	-21.5	-31.5	-32.5
Khashuri	-23.1	-21.8	-16.4	-8.8	-2.4	2.9	5.9	4.7	0.1	-9	-16	-21.4	-23.1
Akhalkhalaki	-27	-29.5	-27.5	-22.2	-9.6	-4	-1.7	-0.3	-5.8	-15.7	-23.3	-28.8	-29.5
Akhaltsikhe	-27.8	-24.3	-21.4	-10.8	-4.8	0.5	3.3	3.6	-2.9	-13.2	-18.6	-24.4	-27.8
Borjomi	-19.5	-19.9	-15.9	-10.1	-0.8	3.2	7.1	6.2	1.1	-4.6	-10	-15	-19.9
Gori	-26.1	-23.5	-15.1	-8.6	-2.3	3.4	6.7	5.1	-0.8	-4.9	-17.5	-20.1	-26.1

Table 2. Mean maximal air temperature (°C)

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Akhalkhalaki	-1.6	-0.4	3.9	11.3	16.3	19.5	23.2	23.5	20.2	13.9	7.2	0.9	11.5
Akhaltsikhe	2.5	4.6	10.6	17.4	21.7	24.8	28	27.9	24.4	18	10.8	4.5	16.3
Borjomi	4	5.9	10.4	16.6	20.6	23.8	26.6	26.6	23.1	17.3	11.3	5.7	16
Gori	4.1	5.8	11.3	17.8	21.9	25.4	28.1	27.6	23.9	17.8	11.4	6	16.8

Tbilisi	6.3	7.8	12.5	18.9	23.6	27.7	30.9	30.1	25.9	19.4	13.3	8.3	18.7
Khashuri	2.8	4.3	9.9	16.8	21	24.2	26.7	26.5	23.1	17	10.5	5	15.7
Paravani	-4.1	-3.4	0.3	7.1	12.3	15.6	18.5	18.1	15.5	10.1	3.9	-1.7	7.7
Pasanauri	2	4	8.4	14.7	19	22.5	25.3	24.9	21.3	15.6	9.7	4	14.3

The east direction winds are prevailed here during the whole year in Borjomi, in Khashuri west, in Skra east and west, in Gori, Tbilisi and Rustavi north-west and south-east winds are prevailed [5].

Table 3. Average monthly and annual wind velocities, (m3 /sec)

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Borjomi	3.0	3.2	2.9	2.4	1.8	1.6	1.5	1.6	1.4	2.0	2.2	2.5	2.2
Khashuri	2.8	2.8	3.5	4.2	3.7	3.4	3.5	3.7	3.5	2.8	2.9	2.4	3.3
Skra	3.9	4.6	5.8	5.8	4.7	4.3	4.7	4.3	4.5	4.0	4.3	3.4	4.5
Gori	3.2	4.0	4.9	5.1	4.6	4.3	4.6	4.3	4.2	3.5	3.4	2.9	4.1
Tbilisi	2.2	2.7	2.8	2.8	2.5	2.5	2.8	2.3	2.1	2.0	1.7	1.8	2.4
Rustavi	4.4	6.0	5.3	4.9	5.2	5.4	6.0	4.9	4.5	4.2	3.1	3.4	4.8

Table 4.Multi-annual monthly and annual precipitation level, (mm)

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Borjomi	40	40	42	56	81	88	55	48	53	59	54	37	653
Khashuri	47	48	47	58	87	70	49	38	48	53	50	49	644
Skra	42	44	44	52	77	62	44	35	42	48	47	44	581
Gori	42	47	45	52	76	62	44	34	43	48	47	45	585
Kaspi	23	33	30	49	95	69	48	37	42	34	34	23	517
Tbilisi	19	27	36	57	93	78	52	39	46	46	40	26	559
Rustavi	19	22	36	44	70	60	29	30	36	37	33	21	437

Total of annual precipitation level ranges between 653 mm (Borjomi) and 437 mm (Rustavi). The month of May is especially prominent for the abundance of precipitations and in January its level is very low. The precipitation level starts to increase from the month of April on each m/station and lasts until the month of July. In July-August the level of precipitation is gradually decreasing, while in September and October it increases again. The precipitation level is especially increased during the warm period (the VI-X months) and it ranges between 61.3% (Skra) to 73.5% (Tbilisi) and the rest is distributed among the months of the cold period.

The earliest date of snowfall in Borjomi, Khashuri, Skra and Gori is the 26th of October and in Tbilisi in the 6th of November. The number of snow cover days to the direction of the Mtkvari River gradually decreases from 67 (Borjomi) to 14 (Tbilisi).

Table 5. The max. decadal snow covers height in Winter period (cm).

Post	Mean height from decade	max. from decade	Min. from decade	Max. of period	Date
Akhalkhalaki	21.3	91	2	95	21-Feb-1990
Akhaltsikhe	13.6	71	1	89	2-Feb-1988
Borjomi	20.5	63	1	85	28-Nov-1964
Gori	11.3	45	1	63	3-Feb-1988
Tbilisi	4.9	29	0	44	3-Feb-1988
Pasanauri	35.3	115	2	147	19-Jan-1976
Tsalka	20.9	70	1	85	11-Feb-1976
Khashuri	24.7	90	1	101	5-Feb-1988

The climatic parameters variation conditions River Mtkvari hydrological regime. The water regime of the River Mtkvari is characterized by high waters in spring as a result of the seasonal snow melting, by the stable summer and low water in winter. The high water period downstream start in the middle of March and its peak level is observed at the end of April and beginning of May and it ends in the beginning of July. After the stable low water period in summer, the autumn stability is often violated by the peak levels as a result of rainfall. The low water period in winter is characterized by long, low, stable levels and the minimum level is observed in January-February. The river structure is mainly formed by: snow and ice melting, rainfall and ground waters. 60% of the river water flows in the springtime (III-IV months).

Conclusion

The location of Georgia, its physical and geographical conditions, allow for a wide variety of meteorological processes with appropriate thermal-barrier fields to reflect and develop this area. Thus, any physical-mathematical model capable of describing microprocessors developed in individual regions is of theoretical and practical value. The investigations of precipitation forming processes are important for river flooding prediction that includes not only surface meteorological parameters investigation but also upper atmosphere processes [6], where weather is formed. The climatic parameters evaluation is essential for river water hydrological potential assessment and management for sustainable development.

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