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სერია ბ. ატმოსფეროს, ოკეანისა და კოსმოსური პლაზმის ფიზიკა

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Forecast of Dynamic Fields and Impurity Dispersion in the Easternmost Part of the Black Sea

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Abstract

An advanced version of the regional short-term forecasting system for the easternmost Black Sea, is presented. The forecasting system consists of hydrodynamic and ecological blocks. The hydrodynamic block includes a high-resolution 3D regional model of the Black Sea dynamics of M. Nodia Institute of Geophysics, but the ecological block consists of 2D and 3D models of spreading of oil and other admixtures in the sea environment. The regional forecasting system, which is one of the parts of the basin-scale Black Sea nowcasting/forecasting system, is functioning in the near real time and provides 3 days' forecast of sea dynamic fields – the current, temperature and salinity with 1 km resolution, but in special situations the system will also provide to calculate impurity's concentrations and pollution areas.

Key words**:** numerical simulation, forecasting system, pollution of Black Sea.

Introduction

Coastal and shelf zones of seas and oceans are undergoing great human pressure because of the economic and domestic activities of man, which creates a serious danger to the ecosystem of these areas. The Georgian Black Sea coastal zone is not exception. A significant increase in tourists in recent years, the construction and planning of appropriate infrastructures, hydraulic structures and ports (e. g., Anaklya port) dramatically increases the danger of contamination of Georgian coastal waters by oil and other toxic ingredients. In such conditions, development of the forecasting system of the state of the coastal waters is considerably urgent, which should become the basic component of the coastal monitoring and management system.

Development of in-situ and remote sensing methods, computing and communication tools and high-accuracy numerical modeling of sea dynamic processes in the last decade have led to the creation of the basin-scale Black Sea nowcasting/forecasting system, which allows short-range forecasts of the basic hydrophysical fields [1-3]. Such an achievement of the Black Sea operational oceanography was made possible by close cooperation of oceanographer-experts of the Black Sea riparian countries in the framework of NATO and EC international scientific projects under the coordination of the Marine Hydrophysical Institute of the National Academy of Sciences of Ukraine (MHI, Sevastopol). The regional forecasting system for the easternmost part of the Black Sea developed at the Institute of Geophysics of I.

Javakhishvili Tbilisi State University is one of the components of this basin-scale Black Sea nowcasting/forecasting system. In [4-8] description of the regional forecasting system and the results of the verification, simulation and prediction of dynamic fields are given.

In the present study, an advanced version of the Black Sea regional forecasting system extended by inclusion of 2D and 3D impurity's dispersion models is shortly described and some results of modeling and 3 days' forecast of circulation and spreading of polluting substances are also presented. This study may be consider as continuation of researches presented in [9,10], where some results of forecast of dynamic fields and distribution of contamination in the easternmost Black Sea water area are given.

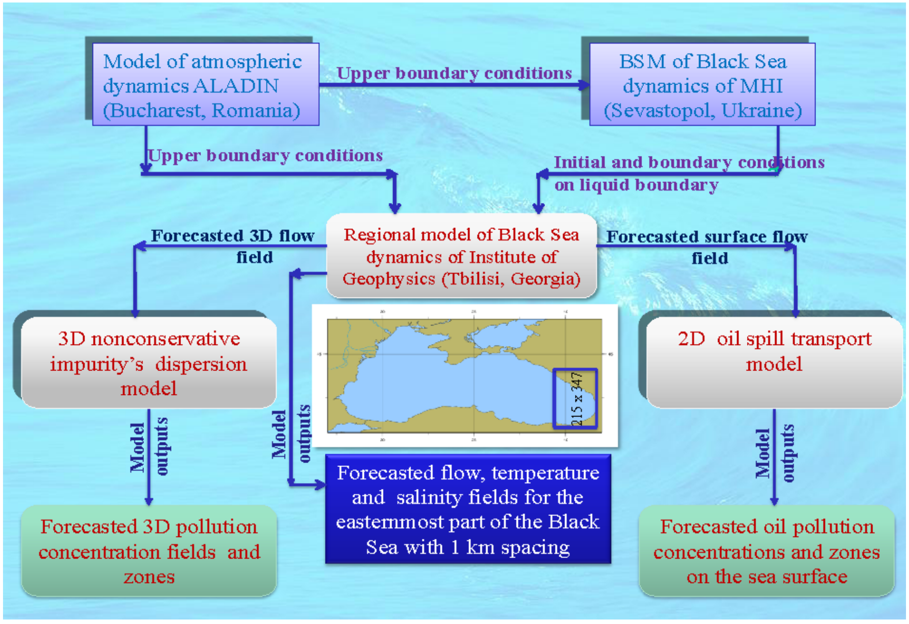

Fig.1. The forecast area, structure and scheme of functioning of the extended version of the regional forecasting system.

Advanced version of the regional forecasting system

In fig.1 the forecast area, the structure and the scheme of functioning of the regional forecasting system are shown. The regional water area is limited to the Caucasus and Turkish coastal lines and the western liquid boundary coinciding with the meridian 39.08^0 E. The new advanced version of the regional forecasting system consists of hydrodynamic and ecological blocks. The hydrodynamic block is based on the Institute of Geophysics of I. Javakhishvili Tbilisi State University's high-resolution regional model of the Black Sea dynamics (RM-IG), which is based on a primitive equation system of ocean hydro and thermodynamics in hydrostatic approximation. This model is nested in the basin-scale model (BSM) of Marine Hydrophysical Institute (MHI, Sevastopol). The input data - the initial and prognostic hydrophysical fields on the open boundary, also 2D prognostic meteorological fields at the sea surface –wind stress, heat fluxes, evaporation and precipitation rates needed for the regional forecasts of dynamic fields are provided from MHI everyday in the near-real time mode via Internet. Prognostic hydrophysical fields are results of forecast by the BSM of MHI [11] and 2D meteorological boundary fields represent the results of forecast by regional atmospheric model ALADIN [12]. All these fields are given on the grid of BSM with 5 km spacing and with one-hour time step frequency for the integrated period. During the regional model implementation these fields are transferred to the grid of the regional model at every time step with 1 km spacing by interpolation.

The ecological block is based on 2D and 3D diffusion models describing spreading of oil and other nonconservative substances in the water area and using nonstationary flow field calculated from the hydrodynamic block. The 3D diffusion model is based on the nonstationary advection-diffusion equation for nonconservative substance:

$$\frac{\partial \varphi}{\partial t}+\frac{\partial \mathrm{u}\varphi}{\partial \mathrm{x}}+\frac{\partial \mathrm{v}\varphi}{\partial \mathrm{y}}+\frac{\partial w\varphi}{\partial z}+\sigma\varphi=\frac{\partial}{\partial x}\mu\frac{\partial \varphi}{\partial x}+\frac{\partial}{\partial y}\mu\frac{\partial \varphi}{\partial y}+\frac{\partial}{\partial z}\nu\frac{\partial \varphi}{\partial \mathrm{z}}+f, \qquad (1)$$

where φ is the volume concentration of a substance; u, v, and w are the sea current velocity components along x, y and z axes, respectively; μ and ν are the coefficients of horizontal and vertical turbulent diffusion, respectively; $\sigma = ln2/T_0$ is the parameter describing changeability of concentration because of physical and biochemical factors; T_0 represents the time interval, during which the initial pollution concentrations decrease two times; in general, f describes the space-temporal distribution of a specific source power, which in case of the point source may be represented by the delta function

$$f = \mathrm{Q}\,\delta(\mathrm{x}-\mathrm{x}_0)\,\delta(y-y_0)\,\delta(z-z_0),$$

where x_0, y_0 and z_0 are coordinates of the source location. Q is power of oil emission from the point source. 2D version of the equation (1) was applied for simulation and forecast of oil spill transport. In both 2D and 3D versions Neumann boundary conditions are applied, at initial time pollution of the sea is absent.

The diffusion coefficient was variable calculated by the formula suggested in [13]

$$\mu = \gamma\,\Delta x.\Delta y\,\sqrt{2\left(\frac{\partial u}{\partial x}\right)^2+\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)^2+2\left(\frac{\partial v}{\partial y}\right)^2}\;,$$

where Δx and Δy are horizontal grid steps along x and y axes, respectively; γ is some constant.

To solve the problems in both blocks splitting methods are used, which enable the solution of complex nonstationary problems to reduce solutions to relatively simple two-dimensional and one-dimensional problems [14,15].

The transport models of oil (2D task) and other substances (3D task) are included in the forecasting system as a separate modules and enables to calculate pollution zones and concentrations in special cases. With this purpose it is required to input in the calculated program written on the algorithmic language “Fortran” the following parameters: coordinates of source location, amount of emission, duration of emission and the parameter σ describing the change of pollution concentrations due to physical and biochemical factors depending on the type of polluting substance.

Thus, the regional forecasting system provides 3 days’ forecast of 3D dynamic fields – flow, temperature and salinity with 1 km spacing, and in case of accidental situations – the forecast of spreading the oil and other pollutants in the Georgian Black Sea coastal zone and adjoining water area.

Implementation of the regional forecasting system

All numerical models included in the regional forecasting system use a grid having 215 x 347 points with horizontal resolution 1 km. On the vertical, the nonuniform grid with 30 calculated levels on depths 2, 4, 6, 8, 12, 16, 26, 36, 56, 86, 136, 206, 306 to 2006 m are considered. The time step is equal to 0.5 h. the parameter of σ depends on the type of chemical ingredient. At simulation of oil spill transport we took into account that reduction of oil concentrations due to evaporation is very intensive during first day after oil flood [16]. Therefore, we accepted $\sigma = 1{,}6.10^{-5}$ if $t \le 24$ h and $\sigma = 8{,}2.10^{-7}$ if t >24 h. The first value of σ corresponds to double reduction of oil concentrations for 12 hours, and the second one - to double reduction of concentrations during 10 days.

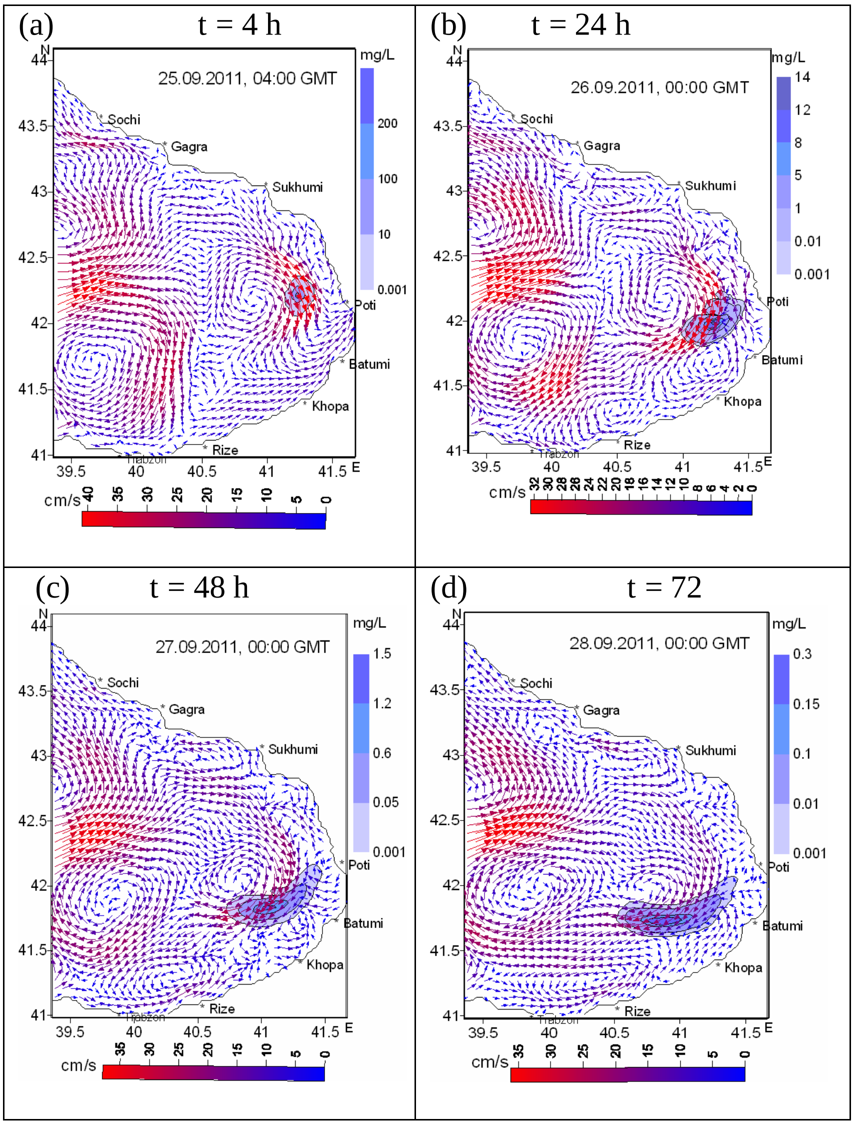

Fig.2. Simulated surface current field and oil spill transport corresponded to the following time moments after oil flood: (a) - 4h, (b) - 24 h, (c) - (48), (d) - (72). The forecasting interval is 00:00 GMT,25-28 September 2011. The source coordinates: 142Δx and 132Δy.

Regular calculations of the regional forecasts started since 2010 show that the easternmost part of the Black Sea, including the Georgian water area, is dynamically very active zone, where continuous generation, deformation, and disappearance of the mesoscale and submesoscale cyclonic and anticyclonic eddies occur throughout the year [8].

Fig. 2 illustrates forecasted regional circulation in the easternmost part of the Black Sea and drifting of oil slick in case, when 50 t was occurred on distance about 50 km from Poti shoreline in the point with coordinates 142Δx and 132Δy (the forecasting period is 00:00 GMT, 25-28 September 2011). Taking into account that the maximum allowable concentration of oil pollution is usually taken to be 0.05 mg/L in all the numerical experiments we have taken to be zero concentration of less than 0.001 mg/L.

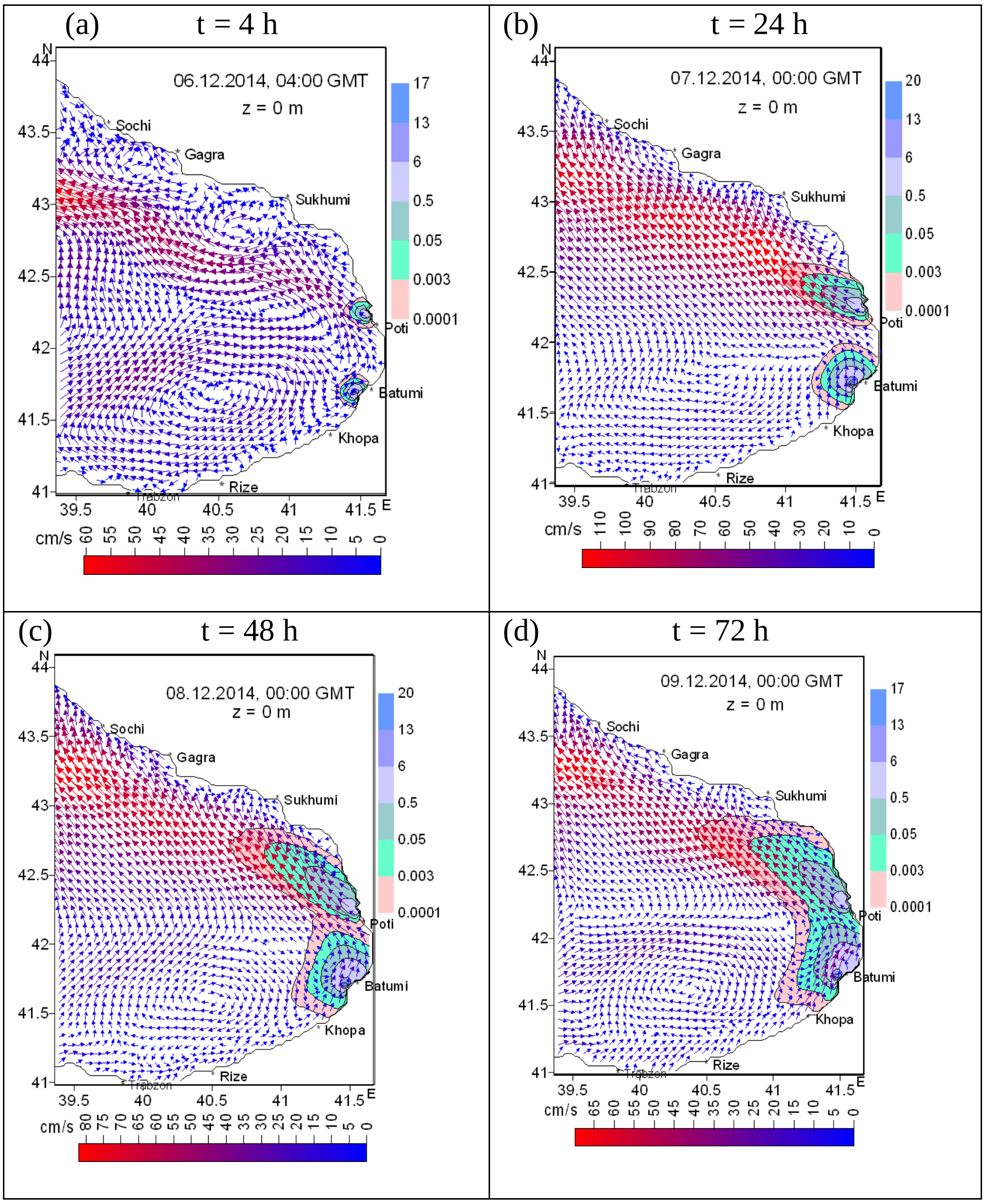

Fig. 3. Simulated surface current field and distribution of impurity at t = 4, 24, 48 and 72 h after start of getting impurity to the sea from rivers Chorokhi and Rioni. The forecasting period is 00:00 GMT, 6-9 December, 2014.

From fig. 2 is well visible that during the considered forecasting interval 25-28 September 2011 the regional circulation in the Black Sea easternmost part is characterized by significant variability with intensive mesoscale and submesoscale vortex formations. Such circulating reorganization is essentially reflected on moving of the oil spill. In the course of migration the oil slick extends gradually and deforms. Simultaneously there is a reduction of oil pollution concentrations, that is caused by diffusion expansion, evaporation and other physical and chemical factors, which are taken into account in the model indirectly.

The numerical experiments carried out in case of different location of hypothetical sources and real circulating modes show a significant role of circulating processes in formation of spatial-temporary distribution of pollution. The numerical experiments also showed that oil spill transport is significantly sensitive to the turbulent diffusion coefficient and the type of oil.

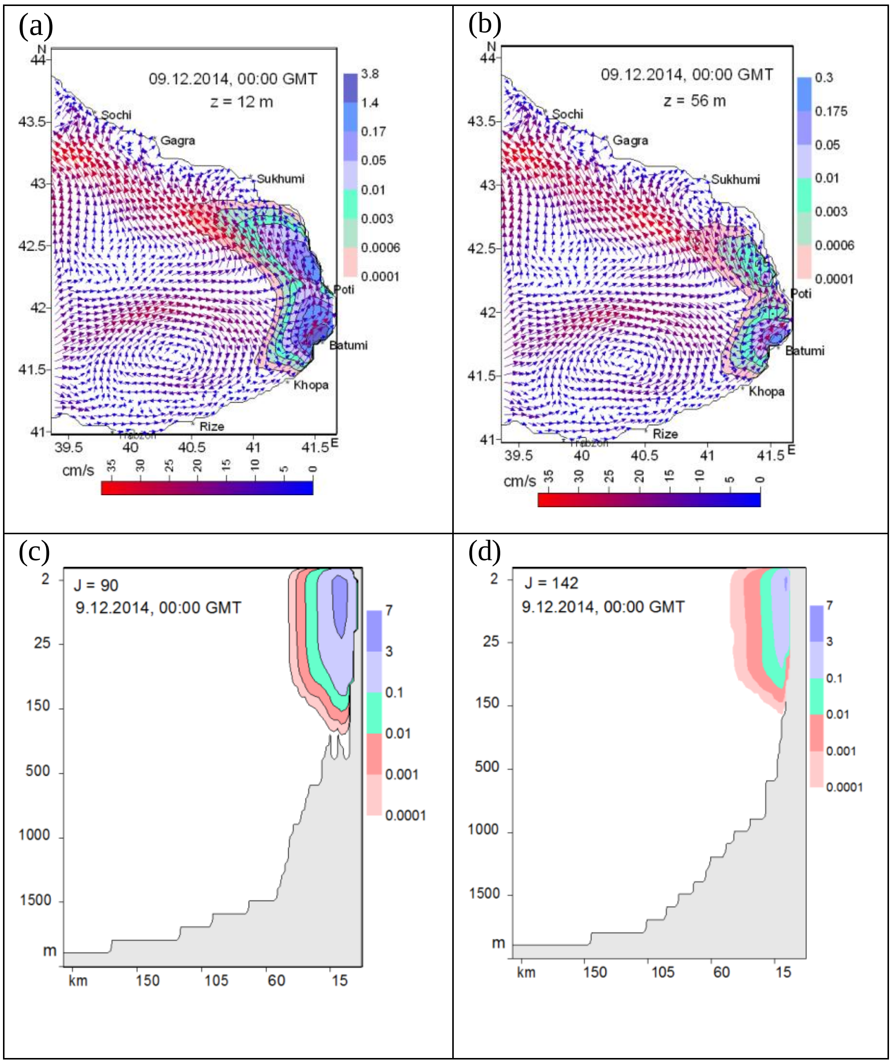

Fig. 4. Simulated surface current field and distribution of impurity on depths of 12 and 56 m (a, b) and in some vertical sections (c, d) at t = 72 h after start of getting impurity to the sea from rivers Chorokhi and Rioni. The forecasting period is 00:00 GMT, 6-9 December, 2014.

Figs. 3 and 4 illustrate results of simulation and forecast of circulation and the distribution of the nonconservative impurity which has been discharged into the sea from rivers Rioni and Chorokhi in the following amount per 1 s: from river Chorokhi - 100000 reference units, from southern and northern Rioni branches - 5000 and 10000 reference units, respectively. The time of disintegration T_0 was taken equal to 30 days. The factor of vertical turbulent diffusion was 15 cm^2/s. The forecasting period corresponded to 00:00 GMT, 6 – 9 December 2014. In Fig.3 the distribution of the impurity on the sea surface at time moments 4, 24, 48 and 72 h after start of getting the impurity to the sea from rivers is shown, but Fig.4 illustrates the distribution of the impurity on depths of 12 and 56 m (Fig.4a and 4b) and in some vertical sections (Fig.4c and 4d) at t = 72 h.

The main feature of the circulation for this forecasting period is very high speeds of sea current, which are caused by strong winds for the considered period. Strong winds and therefore strong wind stress considerably influence sea surface current and renders smoothing action weakening vortex formation in the sea upper layer [17]. From Figs. 3 and 4 it is clearly visible, that the character of circulation considerably predetermines the basic features of impurity's distribution processes. The analysis of the pollution concentration fields showed that the impurity is distributed not only in a horizontal direction, but also on a vertical due to vertical diffusion and vertical flow. pollution concentrations reached up to depth approximately 150 m during 3 days.

Conclusion

The paper presents a new version of the regional forecasting system for the easternmost Black Sea allowing to forecast with 3-days forward not only 3-D dynamical fields – the current, temperature and salinity with 1 km spacing, but also spreading of pollution zones and concentrations of the oil and other pollutants in the case of accidental situations. The regional forecasting system is a part of the basin-scale nowcasting/forecasting system and all required input data are provided from MHI (Sevastopol) in the near-real time mode via Internet. The numerical experiments carried out in different locations of hypothetical sources and real circulating modes, show a significant role of circulating processes in the formation of spatial-temporary distribution of pollution.

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ა. კორძაძე, დ. დემეტრაშვილი, ვ. კუხალაშვილი

რეზიუმე

წარმოდგენილია შავი ზღვის აღმოსავლეთ ნაწილისათვის მოკლევადიანი რეგიონული პროგნოზის სისტემის გაუმჯობესებული ვერსია. პროგნოზის სისტემა შედგება ჰიდროდინამიკური და ეკოლოგიური ბლოკებისაგან. ჰიდროდინამიკური ბლოკი შეიცავს მ. ნოდიას გეოფიზიკის ინსტიტუტის მაღალი გარჩევისუნარიან სამგანზომილებიან შავი ზღვის დინამიკის რეგიონულ მოდელს, ხოლო ეკოლოგიური ბლოკი შედგება ნავთობისა და სხვა მინარევების გავრცელების ორი და სამგანზომილებიანი მოდელებისაგან. რეგიონული პროგნოზის სისტემა, რომელიც ერთ-ერთი შემადგენელი ნაწილია

მთლიანად შავი ზღვის დიაგნოზისა და პროგნოზის სისტემისა, ფუნქციონირებს რეალურთან მიახლოებულ რეჟიმში და უზრუნველყოფს შავი ზღვის დინამიკური ველების – დინების, ტემპერატურისა და მარილიანობის სამდღიან პროგნოზს 1 კმ გარჩევისუნარიანობით, ხოლო საგანგებო სიტუაციებში შესაძლებლობას იძლევა გამოვთვალოთ მინარევის კონცენტრაციებისა და დაჭუჭყიანების ზონების პროგნოზიც.

Прогноз динамических полей и распространрения примеси в восточной части Черного моря

А.А. Кордзадзе, Д.И. Деметрашвили, В.Г. Кухалашвили

Резюме

Представлена улучшенная версия региональной системы краткосрочного прогноза для восточной части Черного моря. Система прогноза состоит из гидродинамического и экологического блоков. Гидродинамический блок включает в себя высоко разрешающую пространственную региональную модель динамики моря Института геофизики им. М. Нодиа, а экологический блок состиот из двумерных и пространственных моделей распространени нефти и других примесей в морской среде. Региональная система прогноза, которая является одной из частей системы диагноза и прогноза Черного моря в масштабах всего бассейна, функционирует в режиме близком к реальному и обеспечивает прогноз на трое суток динамических полей с разрешением 1 км – течения температуры и солености, но в чрезвычайных ситуациях прогностическая ситема обеспечит также расчет прогноза концентраций примеси и зон загрязнения.

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Numerical Experiments of Prediction of Contaminant Diffusion in Kura River

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Abstract

Numerical simulation of distribution of contaminants discharged to Kura River is elaborated using nonstationary linear three-dimensional equation of transition-diffusion of substances in continuous medium. Model is meant for study of distribution of polluting agents in Kura River in the first approximation. Kura River is divided in 10 conventionally uniform linear sections and annual average values of hydrological parameters specific for the river are used for each section.

Ammonium ions (NH_4^+) *distribution discharged from cities situated at Kura River is modeled. Distribution pattern for ammonium ions concentration in Kura River is received using numerical experiment. It is shown that values of concentration received via mathematical modeling with permissible accuracy are coincided with data of field observations.*

Distribution of passive polluting agents thrown to Kura River near Georgian-Turkish state border is modeled using numerical experiment in case of stationary source. Using the modeling there is determined the time, which is necessary for polluting agent to reach points placed along the river, to pass various sections of river, to reach Georgian-Azerbaijan border and Mingachevir reservoirs. Distribution pattern of polluting agent concentration in the river bed, as well as concentration change when passing from one section to another are determined, and relative change of concentration in 10 conventional river sections is estimated.

Distribution of passive contaminant thrown to Kura river by salvo during 6 hours near Georgian-Turkish state border is studied. Pattern of gradual shift of the contamination plume in Georgian section of Kura River and gradual concentration change are shown.

A possibility of using the model for prediction aims is considered.The correspoding tasks are determined.

Key words**:** numerical simulation, equation of mass transfer, pollution of Kura, ammonium, passive contaminant.

Introduction

The Kura River has an important role in the economy of the Georgian and Azerbaijan Republics. It is one of main sources of the drinking water in the South Caucasus and is intensively used for agricultural and industrial purposes. Georgian part of the Silk Road – main traffic artery of Georgia, the oil and gas pipelines, railways and highways are passing along it. Therefore, it is the water object of high ecological risk factor.

Annually rising turnover between the Europe and China and Middle Asia causes a threat of the ecological disasters in this transport corridor and therefore ecological protection of Kura River is one of main topical problem of the Georgian government.

Scientific and nongovernmental organizations of Georgia [1, 2] are carrying out the natural observations and experimental measurements of the water quality of the River Kura. These investigations are very important and give us the static picture of the river pollution. But there are some other ecological tasks, the solution of which can't be made only on the basis of observation data. In particular, the complications of distribution of contaminant in the river, forecast of the river pollution, and optimal management of the surface waters, e. t. are related to such problems.

The developed countries are widely used the software packages of water pollution forecast, investigation of surface water pollution and the optimal control systems [3-8]. These packages are mainly elaborated for large waters, require a special personnel training and are difficult for use in case of mountains rivers.

According to [7, 8], we elaborated a simple numerical method for calculation of diffusion of passive admixtures to Kura River and we investigated a kinematics of propagation of contaminants. This work is considered as first stage of elaboration a method of prediction of pollution of Georgian mountain river in case of disasters

Formulation of the Problem

For numerical modeling of the pollution distribution the Georgian section of Kura River 513 km length from Georgian-Turkish border to the Mingachevir Reservoir is divided into ten conventionally uniform sections [9] (Fig. 1). It is assumed that each of the river's section is a linear canal and river's hydrologic parameters are constant along it. Therefore, the distribution of pollution may be described by transfer-diffusion equation [10]

$$\frac{\partial C_1}{\partial t} + u_1 \frac{\partial C}{\partial x} + w_o \frac{\partial C_1}{\partial z} = \mu_x \frac{\partial^2 C_1}{\partial x^2} + \mu_y \frac{\partial^2 C_1}{\partial y^2} + \mu_z \frac{\partial^2 C_1}{\partial z^2} \qquad (1)$$

where t is time; x, y, and z are the Cartesian coordinates; x axis is horizontally directed along the river flow; y is the horizontal axis directed perpendicularly to the canal; z axis is directed upward vertically from river bottom; u_i is the river's flow velocity at i section along x axis; river flow velocity is equal to zero along y axis; w_o is the velocity of sedimentation of polluting agent; μ_x, μ_y and μ_z are kinematic coefficients of turbulent viscosity along the x, y and z axes, respectively; C_i is the concentration of the contaminant in the i section of river; α is a velocity of chemical transformation of polluting agent.

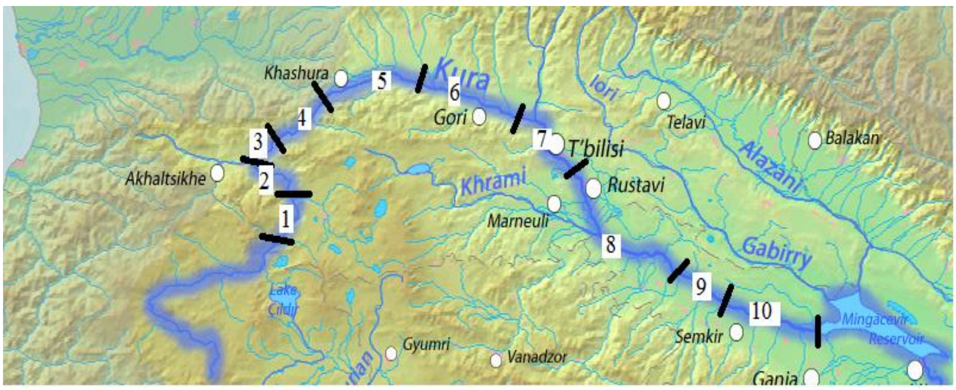

Fig. 1. The scheme of Kura River division into conventional sections.

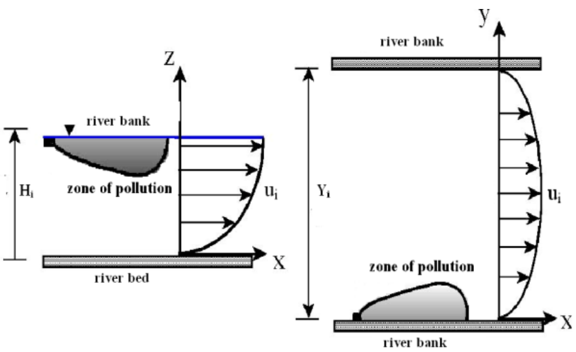

Fig. 2. The scheme of the river flow, velocity and contaminant in vicinity of discharge source.

The river water velocity u_i in each river section is a known and constant value along the axis x, and changes along the y and z axes as follows: $u_i\,(x, y, z) = 1.5U_{i,0} * \sin(\pi y/Y_i)\sin(0.5\pi z/H_i)$ (Fig. 2). $U_{i,0}$=const is the known value of the river water velocity in the i section. Y_i and H_i are the width and depth of the section i. $U_{i,0}$, Yi, Hi are taken from [9]. Since the values of coefficient of turbulent diffusion for Kura River were not determined on the basis of observation data, we used the values given in [11] as follows: $\mu_x = 5\times 6.4\times 10^4$ m^2/s and $\mu_y = \mu_z = 5\times 5{,}57\times 10^{-3}$ m^2/s for territory with complex mountain relief (sect. 1-4) and $\mu_x = 6.4\times 10^{\,4}$ m^2/s and $\mu_y = \mu_z = 5.57\times 10^3$ m^2/s for sections placed at plain territory (sect. 5-10).

Table 1

The hydrological parameters of sections.

Section No.	Section name	Length (km)	Width Y_i(m)	Depth H_i(m)	Velocity of flow Uo (m/s)
1	The Georgian-Turkish state border – R. Faravani	27	40	1.0	1.1
2	R. Faravani –V. Minadze-	42	45	1.2	0.9
3	V. Minadze- V. Atskuri	20	35	1.2	1.2
4	V. Atskuri –V. Qvishkheti	47	40	1.3	1.2
5	V. Qqvishkyeti-T. Gori	61	75	1.2	1.2
6	T. Gori-V. Dzegvi	51	85	1.0	1.5
7	V. Dzegvi-V. Soganlughvi	39	80	1.5	1.5
8	V. Soganlughvi – V. Poili	94	90	1.6	1.4
9	V. Poili – R. Dzegmachai	70	95	1.8	1.3
10	R. Dzegmachai – Mingechavir Reservoir	62	100	2.0	1.2

For integrating of equation (1) the corresponding initial and boundary conditions are used: the concentrations of the contaminant in the points of discharge source, in the beginning of section and at the initial time are known values. The gradient of concentration in the end points of sections $x_i = K_i$, in the river bank and bed points $y_i = 0, 10$ and $z_i = 0,10$ are equal to zero, respectively. The concentrations of the contaminant during the whole interval of time of spilling at the source points are known values. An inflow of tributaries into Kura River is taken into account using change in the parameters $U_{i,0}$, Y_I and H_i. In the table 1 the values of the hydrological parameters of the River Kura for the sections 1-10 are given.

The numerical integration and solution of equation (1) is made using the split method and balance numerical scheme [10] on the rectangle numerical grid. The grid step along the x axis depending on goals of concrete numerical experiment varies within interval of 20 m – 1000 m; the grid steps along y and z axes are equal to Yi /11 and Hi /11, respectively.

Results of simulation

Accidentally, full real data of natural measurements of the distribution of contaminants discharged in Kura are absent. Therefore, the accuracy of simulation we determine by using the standard observation data is.

The quantitative accuracy of calculation will made by means of numerical simulation of ammonium diffusion, for which modeling of h the values of river discharge and concentrations obtained by natural observation are known. In Tab. 2 the mass of ammonium discharged per second to Kura River from Georgian towns is shown. These data are calculated by means of formula $Q = (7 \times N)/(24 \times 3600)$ (g/s) ,where N is a number of city residents. This formula implies that one citizen discharges about 7 g NH_4^+ per day [12]. On the basis of experimental measurement the value of background concentration near the Georgian-Turkish state border is taken equal to $C_{1,0}$ = 0.4 mg/lit.

Table 2

Mass of NH_4^+ discharge per second to Kura River from Georgian towns.

№	1	2	3	4	5	6
Towns	Borjomi	Khashuri	Gori	Mtskheta	Tbilisi	Rustavi
Civilians (thou.)	14.4	28.5	46.7	7.7	1 200.0	122.0
NH_4^+ (g/s)	1.17	2.31	3.78	0.62	97.20	9.88

In Fig. 3 the distribution of ammonium along the Kura River obtained using numerical modeling is given. When comparing these results with data of Tab. 3 we can conclude that results of numerical simulation are in good correspondence with observation data.

Table 3

Concentration (mg/lit.) of ammoniun obtained via natural measurement.

Point of observation	Borjomi	Gori	Mtskheta	Tbilisi	Rustavi
Average Multiyear value of 2007-2010	0.49	0.52	0.53	0.95	0.88
September of 2013	0.48	0.51	0.47	1.02	0.72

The analysis of the distribution of the contaminant along the river shows the ammonium concentration gradually increases from t. Borjomi to Rustavi (Fig. 3). The rapid growth of concentration takes place in vicinity of the points of discharge. The maximum growth of concentration is obtained in vicinity of Tbilisi in the areas of sewage network attaching to the river. The area of rapidly increased concentration is about 5 km near small towns and 25 km for Tbilisi. With increase of distance from the discharge points due to diffusion and dilution caused by waters of influent rivers the concentration gradually decreases. As the calculations show, the concentration of ammonium in Georgian part of Kura River gradually increases along the river and exceeds twice the maximum permissible concentration (MPC) near Mingechavir Reservoir.

The series of numerical experiment are conducted for investigation of kinematics of contaminants propagation in Kura River and possibility of pollution forecast. First, is considered the case when the contaminant is discharged into Kura River in the points located near Georgian-Turkish state border (sect. 1).The concentration of polluting agent is equal to 100 conventional units

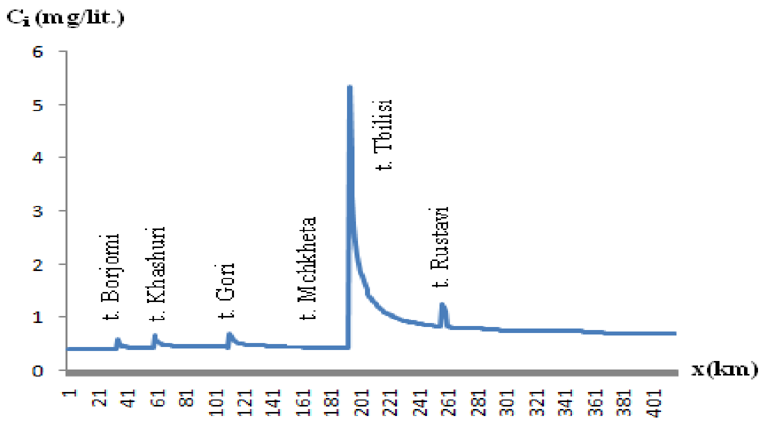

Fig. 3. Distribution of ammonium concentration in the Kura River. City names show discharge points.

(c.u.) in the area of the pollution source during all modeling time. Fig. 4 shows a qualitative picture of distribution of contaminants during the first 6 minutes of the pollution process. As we can see the polluted area is of elliptic form and it is distributed at the distance of about 300 m in the direction of flow and takes the whole width of the river. But the main part of polluting agents is located along the bank where takes place the discharge and is spread approximately at $0.6H_i - 0.7H_i$ distance in width.

Fig. 4. The pattern of distribution of the polluting agents in section 1 within first 6 min. The step $\Delta x = 20$ m.

In Fig. 5 the distribution of the contaminant during first 25 hours of discharge is shown. By means of this figure and Tab. 4 we can see that a pollution is distributed in sections 1, 2 and is reached the section 3. The contaminant passes the first rivers section in 6 hours, the section 2 in 17 hours etc. The average velocity of passing the section 1 is equal to 0.8–1 m/s and is in correspondence with the average river flow velocity in first section. The similar results are obtained for the other sections of the river. The times of reaching the river section beginning by contaminants and establishment of their constant concentration in these sections are given in the Tab. 4.

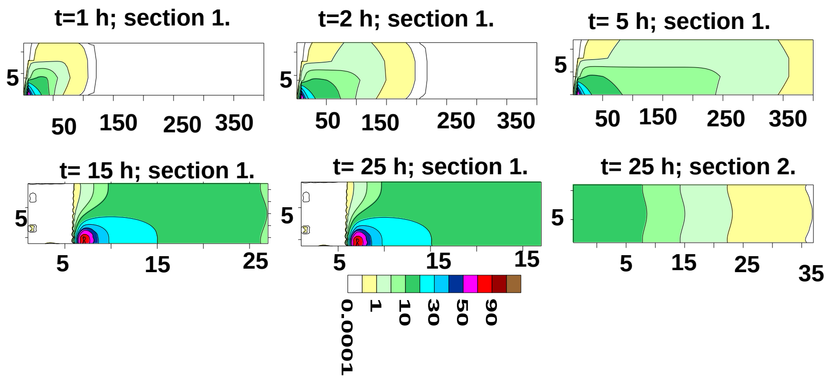

Fig. 5. The distribution of the concentration (in c.u.) on river surface in the sections 1 and 2,when t = 1, 2, 5, 15 and 25 h. The step $\Delta x = 20$m when $t \le 5$h, and $\Delta x = 1$ km when $t \ge 15$ h.

Table 4

Time of reaching the section beginning by pollution substance (t_{min}) and time of establishment ofconstant concentration (t_{max}).

Section №	1	2	3	4	5	6	7	8	9	10
t_{min} (h)	0	6.2	17.8	23.4	37.1	53.7	65.8	74.7	98.1	117
t_{max} (h)	83.3	91.0	103.3	122.1	178.6	196.8	210.7	247.7	277.6	307

Simulation of propagation of the passive pollutant accidentally discharged during a short interval of time (6 h) is conducted. On Fig. 6 the results of numerical modeling are shown. We see that contamination plume that is formed in discharge place, is getting wider due to transfer and diffusion processes and after 75 hours its length reaches 80km. Calculations shown the it is necessary roughly 190 hours for contamination plume to pass the Georgian part of Kura River.

The numerical modeling of diffusion of the petroleum product spilled in River Kura in vicinity of Tbilisi is prepared (Fig. 7). The modeling shows that about 30 minutes are required for pollution diffusion on all width of the river and 1.5 km along the river. The concentration is maximum on the upper surface of river water and its value gradually decrease in the depth – by 50% on the half depth and 75% near of the river bottom.

Discussion

On the basis of nonstationary three-dimensional equation of mass transfer the numerical model of transfer of contaminant through Kura River is elaborated. The model is created for the area of Kura River from Georgian-Turkish state border to Mingechavir Reservoir that is divided into ten parts. For each part the river flow velocity is taken as well-known value and is taken from the materials of hydrological observation. The study of river pollution by ammonium ions is carried out. Comparison of simulation results with observation data shows that model quantitatively correctly describes the average pattern of pollution.

The numerical experiments that investigate the kinematic features of distribution of pollution are carried out. Some parameters characterizing the process of pollutants' diffusion are obtained by means of these experiments, namely: times necessary for passing Georgian section and its separate areas by contaminants etc.

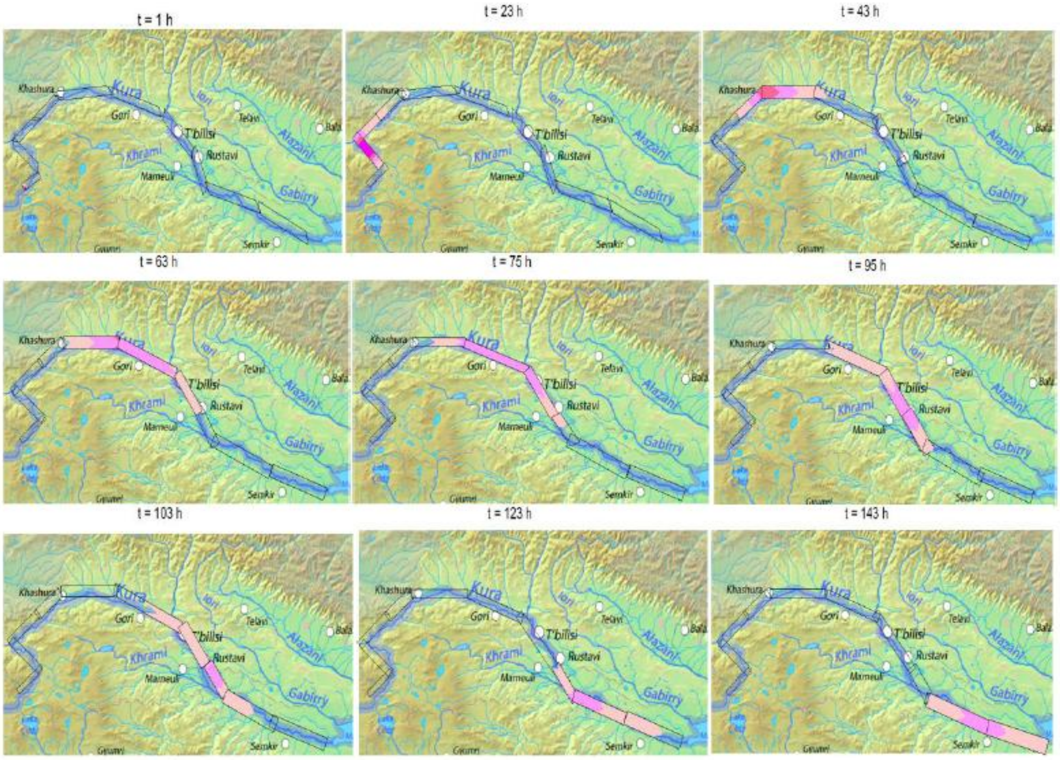

Fig. 6. Displacement of contamination plume in Kura River during 143 hours.

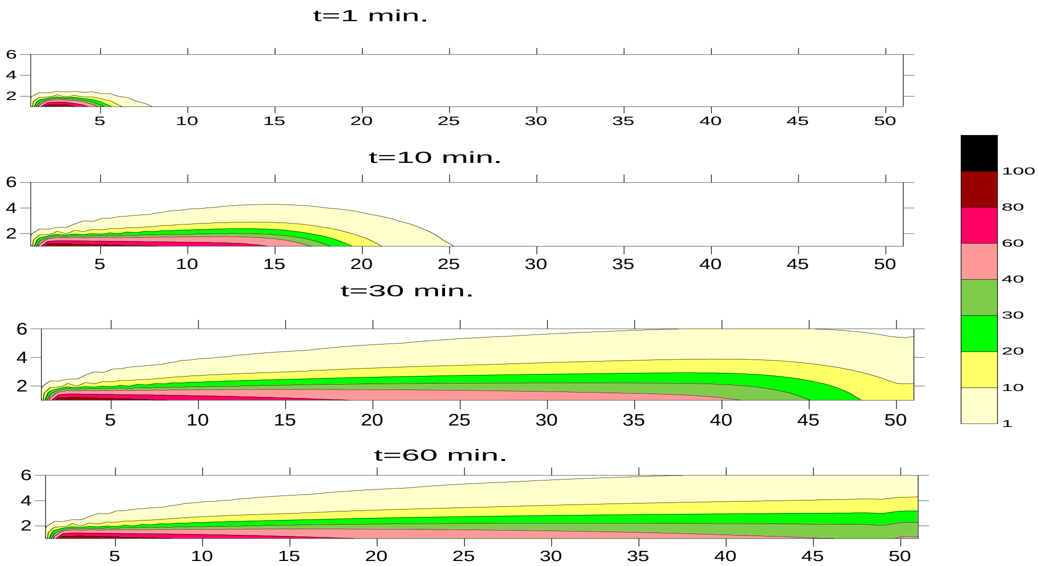

Fig. 7. Concentration of oil products C (mg/lt.) on the surface level at t = 1, 10 , 30 and 60 min. Horisontal grid steps are equal to Δx=20m; Δy=10m.

It should be noted that calculations are carried out for average annual river flow velocity. This fact limits the area of application of this model because the velocity of water flow for mountain rivers may change in wide area in relation with the precipitations taking place in the basin of the separate tributaries. Such limitation can be overcame by two ways: first, for each section the velocity of flow can be calculated using the equation of river water momentum, or second – by database for velocities of flow observed in different situations must be created by means of hydrological observation and these data must be used in equation (1). It is necessary also to obtain semi-empirical formulas for kinematic coefficients of vertical and horizontal turbulence of Kura River and to conduct numerical simulation with the use of them.

The used numerical model can be considered as first experiment of prediction of pollution diffusion in River Kura. After taking into account the comments made above and comparison of the data of the real observations with results of numerical simulation final conclusion can be made about the possibility of using the proposed model for the forecasting aims.

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მდ. მტკვარში ჩაღვრილი დამაბინძურებელი ნივთიერების გავრცელების პროგნოზირების რიცხვითი ექსპერიმენტი

ა. სურმავა

რეზიუმე

უწყვეტ გარემოში ნივთიერების გადატანა-დიფუზიის არასტაციონალური წრფივი სამგანზომილებიანი განტოლების გამოყენებით დამუშავებულია მდ. მტკვარში მოხვედრილი დამაბინძურებელი ნივთიერების გავრცელების რიცხვითი მოდელი. მოდელი გათვალისწინებულია პირველ მიახლოებაში მდ. მტკვარში დამაბინძურებელი ნივთიერების გავრცელების შესწავლისათვის. მდ. მტკვარი დაყოფილია 10 პირობითად ერთგვაროვან წრფივ უბნად და თითოეული უბისათვის გამოყენებულია მდინარის მახასიათებელი ჰიდროლოგიური პარამეტრების საშუალო წლიური მნიშვნელობები.

მოდელირებულია მდ. მტკვარზე განლაგებული ქალაქებიდან ჩაშვებული ამონიუმის (NH_4^+) იონის გავრცელება. რიცხვითი ექსპერიმეტით მიღებულია მდ. მტკვრში ამონიუმის იონის კონცენტრაციის განაწილების სურათი. ნაჩვენებია, რომ მათემატიკური მოდელირებით მიღებული კონცენტრაციების მნიშვნელობები დასაშვები სიზუსტით ემთხვევა ნატურული დაკვირვებების მონაცემებს.

მოდელირებულია საქართველო-თურქეთის სახელმწიფო საზღვართან მდ. მტკვარში ჩაღვრილი პასიური დამაბინძურებელი ნივთიერების გავრცელება სტაციონალური წყაროს შემთხვევაში. მოდელირებით განსაზღვრულია დრო, რომელიც საჭიროა იმითვის, რომ დამაბინძურებელმა ნივთიერებამ მიაღწიოს მდინარეზე განლაგებულ პუნქტებს, განვლოს მდინარის სხვადასხვა უბანი, მიაღწიოს საქართველო-აზერბაიჯანის საზღვარს და მინგეჩაურის წყალსაცავს. განსაზღვრულია დამაბინძურებელი ნივთიერების კონცენტრაციის მდინარის კალაპოტში განაწილების სურათი, კონცენ¬ტრაციის ცვლილება მდინარის ერთი უბნიდან მეორეში გადასვლისას, შეფასებულია კონცენტრაციის ფარდობითი ცვლილება მდინარის 10 პირობით უბანში.

შესწავლილია საქართველო-თურქეთის სახელმწიფო საზღვართან მდ. მტკვარში 6 სთ განმავლობაში ზალპურად ჩაღვრილი პასიური დამაბინძურებელი ნივთიერების გავრცელება. ნაჩვენებია დაბინძურების ლაქის თანდათანობითი გადაადგილების სურათი მდინარის საქართველოს მონაკვეთში და კონცენტრაციის თანდათანობითი ცვლილება.

განხილულია მოდელის პრიოგნოსტიკული მიზნით გამოყენების შესაძლებლობა. დასახულია შესაბამისი სამუშაოები.

Численный эксперимент прогноза распространения сброшенного загрязняющего вещества в р. Кура

А. А. Сурмава

Резюме

С помощью линейного нестационарного уравнения переноса вещества в сплошной среде разработана модель распространения загрязнения в р. Кура. Модель предназначена для исследования загрязнения и оценки возможности прогноза распространения загрязняющего вещества, сброшеного аварийно в р. Кура. С этой целью грузинская часть р. Куры разделена на 10 условно однородных линейних участков. Для каждого участка в качестве входных даных используются среднегодовые значения гидрологических параметров.

Смоделирована распространение аммоний (NH_4^+), сброшеной в реку из городов расположенных на р. Кура. Путем численного моделирования получены распределение концентрации аммония в воде р. Кура. Показано, что расчетние значения концентрации с достаточной точностью совпадают с данными натурных наблюдений.

Смоделировано распространение пассивного загрязняющего вещества, поступающего в реку из стационарного источника в окрестностиях Грузинско-Турецкой границы. Определены временные интервалы, за которые вещество достигает отдельных пунктов, расположенных на реке и вливается в Мингечаурское водохранилище. Рассмотрена возможность использования модели в прогностических целях и намечены соответсвующие мероприятия.

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Using Isotope Application for Assessment Water Origin in the Kakheti Region

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Abstract

In order to assessment water origin and pathway, was organized monitoring network in East Georgia's lowland - Alazani and Shiraki catchments. Observation set up with the aim to study the evolution of water isotopic composition from precipitation to groundwater and stream, what allowed determining the residence time of groundwater flow. The network estimated groundwater flow directions and velocities between recharge and discharge areas, as well as groundwater age for East Georgia catchments. Snow cover measurement was organized, also.

Key words: groundwater origin and pathway, isotopic analysis.

Introduction

Study area is represented by a valley surrounded by the Greater Caucasus Mountains (altitudes up to 3500 m a.s.l.) in the north and lower Gombori Range (altitudes up to 2000 m a.s.l.) in the south (Fig 1). The valley is drained by the Alazani river. Another important source of water is the groundwater from numerous boreholes and wells. The origin of the groundwater remains unknown.

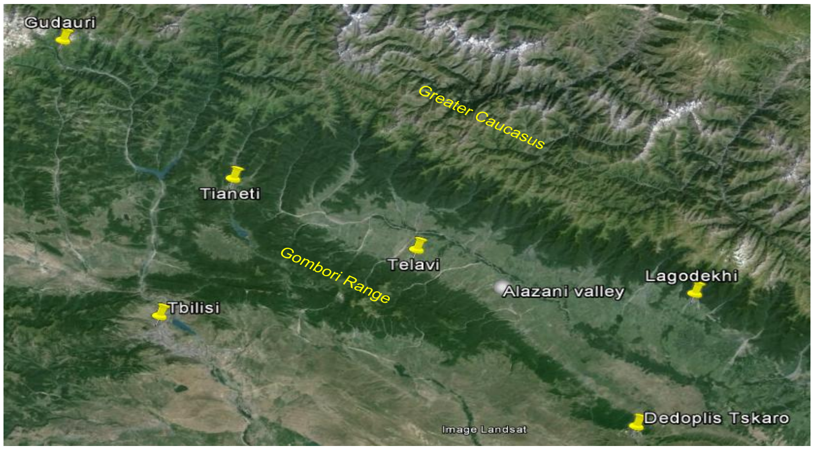

Fig. 1. Study area - the Alazani river valley (Google Earth) and location of stations collecting monthly composite precipitation samples; GNIP station Tbilisi which is relatively close to the study area is shown as well; the distance between Tianeti and Telavi is about 47 km.

Previous investigations carried out within the project [1-3] revealed three types of geochemically different groundwaters:

- old groundwaters which recharged before the 1950
- younger groundwaters containing higher amounts of total dissolved solides.
- groundwater of the Alazani series, Kvareli aquifer and springs which are of modern origin

Perceptual model of the study area built by the counterpart on the basis of hydrogeological knowledge assumes that the last group of groundwater originates by infiltration of precipitation falling on southern slopes of the Greater Caucasus. The water percolates into the Alazani valley which is filled by Quarternary sediments and is used in the boreholes and also becomes source of water for the river during the dry periods [4-5].

Monitoring network was set up with the aim to study the evolution of water isotopic composition from precipitation to groundwater. The database of isotopic data contained over 600 samples. Isotopic analyses were made using the Picarro laser analyser obtained within projects. Overview and interpretation of available data are summarised below.

Evaluation of available data

Isotopic composition of precipitation was studied on the basis of monthly composite samples from stations located at altitudes 400-1100 m a.s.l. (Tianeti, Telavi, Lagodekhi, Dedoplis Tskaro; Fig. 1). The highest altitudes of the Greater Caucasus are sparsely inhabited which prevented monitoring of isotopic composition of precipitation. Data on precipitation depths for each station need be completed in cooperation with the national hydrometeorological service.

Available data on isotopic composition of precipitation is presented in Figs. 2-4. Several samples, especially from the most arid conditions at Dedoplitskaro were affected by evapotranspiration (Fig. 2). Evaporated samples mostly did not occur in the hottest months which indicates that evaporation probably occurred either in the gauge or after sampling. Such samples should be excluded from further processing. Isotopic composition of precipitation at Dedoplis Tskaro between August and October 2013 and then November to February 2014 (Fig. 3) did not show any variability which is unusual and does not resemble to data from other stations.

Isotopically the lightest precipitation was measured at stations Lagodekhi and Tianeti. That would agree with expectations. However, according to the coordinates of stations provided the elevation of station Legodekhi is only about 400 m a.s.l. This should be checked when newer samples are analysed and an attempt to estimate possible altitude gradient of isotopic composition of precipitation is made. Additional data from Gudauri, if available should be used as well to evaluate the gradients at least for the limited period of December 2014 to April 2015. In months where rainfall and snowfall were measured separately, the weighted averages should be calculated.

River water was systematically monitored at GNIR station Shakriani near Telavi, about 40 km from the place where the Alazani River leaves the Greater Caucasus Mountains and enters the Alazani valley. Shorter data series were available from Dedoplis Tskaro. The isotopic composition of the Alazani river near Telavi presented in Fig. 4 shows that the river is contributed mainly by isotopically light water from higher altitudes. Deuterium excess has higher values which are typical for mountain precipitation and snow in other mountain ranges, e.g. in the Carpathians. Seasonal variability of $\delta^{18}O$ and $\delta^{2}H$ indicates an influence of snowmelt in spring 2013 (Fig. 5). Minimum values occurred in May 2013. Isotopically light (probably snowmelt) water in 2014 was observed already in January. It indicates snow-poor and warm winter. Amplitudes of $\delta^{18}O$ and $\delta^{2}H$ in precipitation (Lagodekhi) and in the river suggest the mean transit time of river water at Shakriani of about of about 15 months according to exponential model (the sine curves method).

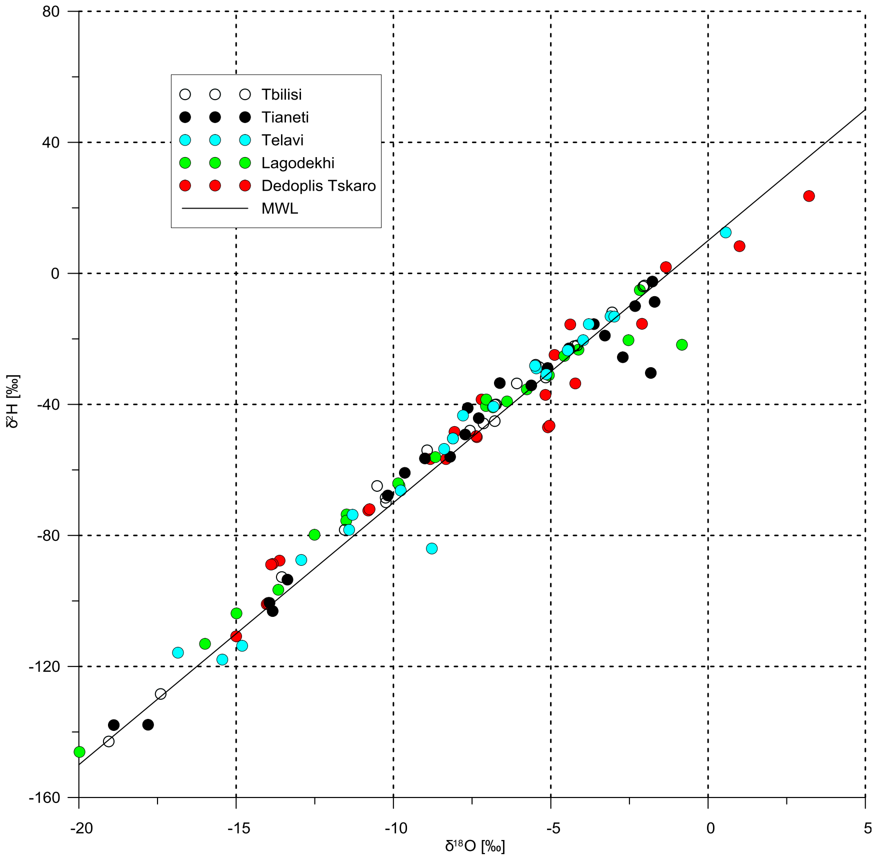

Fig. 2. Position of precipitation samples along the global meteoric water line.

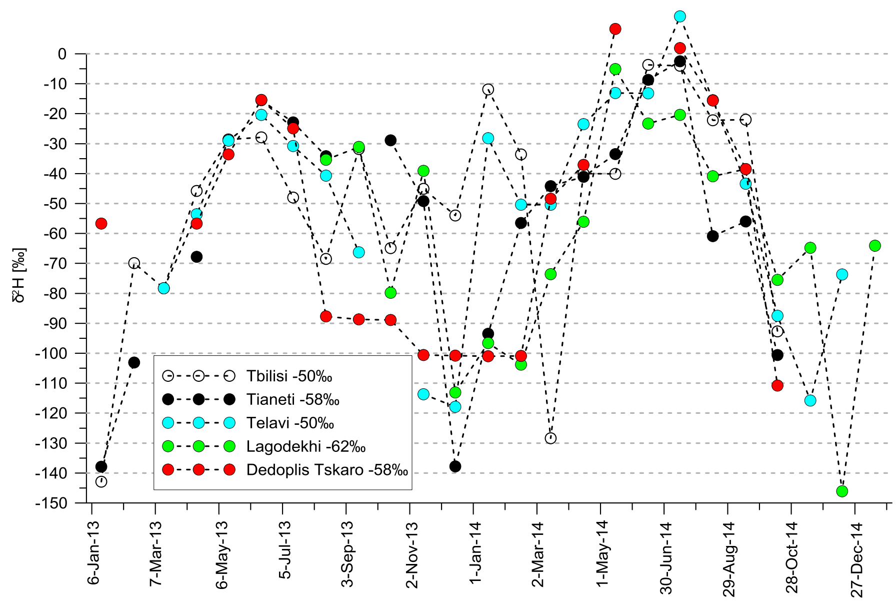

Fig. 3. Seasonal variability of δ^2H in precipitation; evaporated samples are excluded.

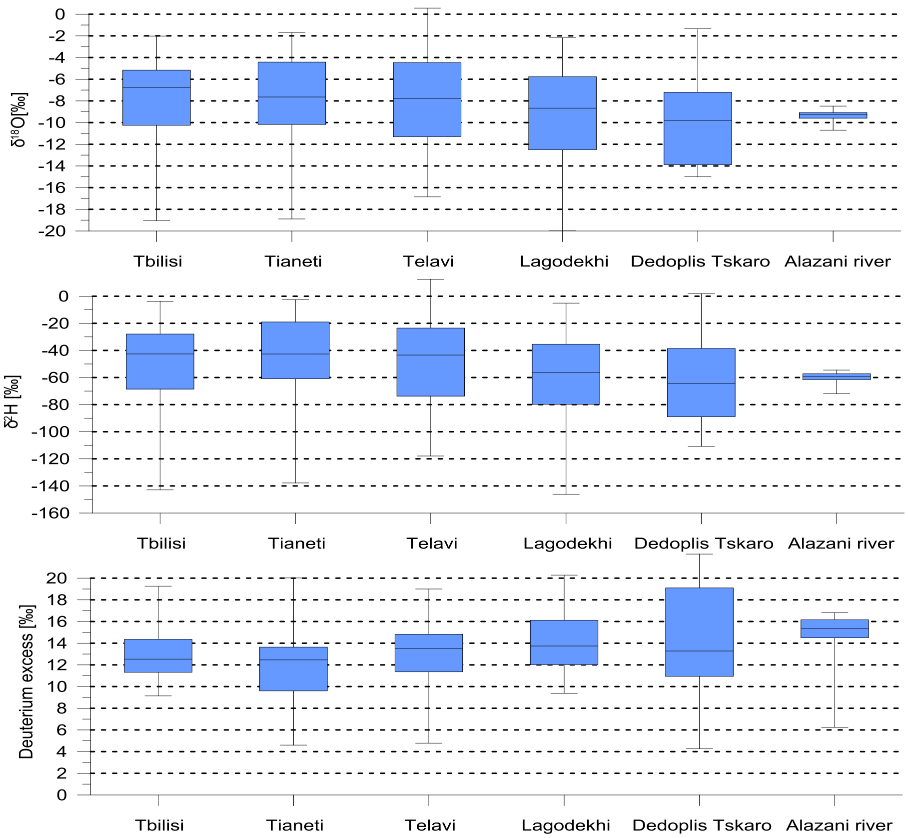

Fig. 4. Box-whisker plots of monthly precipitation (samples approximately between January 2013 and October 2014) and Alazani river water from January 2013 until February 2015.

Evaporated samples are excluded; the whiskers represent minimum and maximum; stations are plotted approximately from the west to the east (see Fig. 1); statistics from the Dedoplis Tskaro station are affected by suspicious samples from August 2013 to February 2014 (see Fig. 3); the data series from Lagodekhi is shorter.

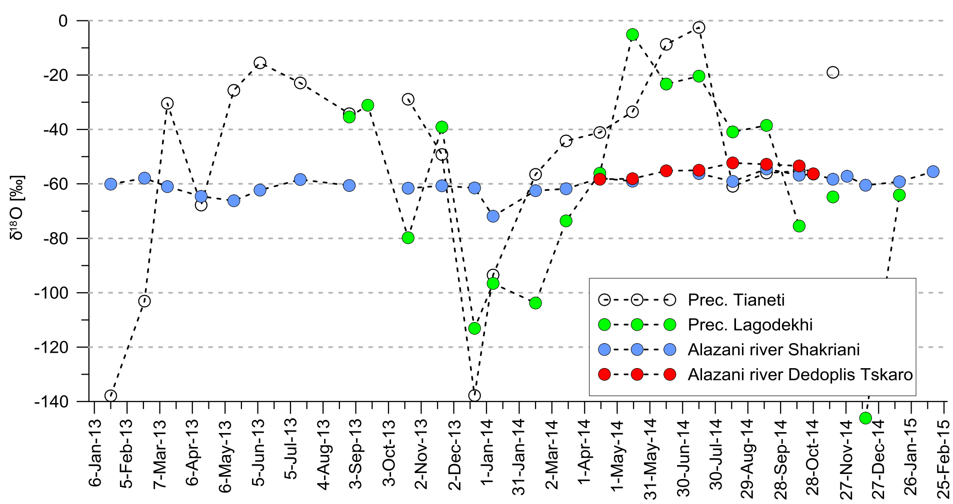

Fig. 5. Temporal variability of δ^2H in precipitation and in the Alazani river at Shakriani (near Telavi) and at Dedoplis-Tskaro.

Limited data from the downstream part of the river at Dedoplis Tskaro (Fig. 5) show an increase of heavier isotopes by about 0.3-0.5‰ for δ^{18}O and about 1-3‰ for δ^{2}H. Snapshot sampling along the Alazani river on 28 October 2014 (Fig. 6) indicates that isotopic composition of river water in the Alazani valley evolves according to a line parallel with the global meteoric water line. Isotopic composition of the river near the outlet of the headwater part of the catchment (Omalo) changes as the river enters the Alazani valley. δ^{18}O in Omalo and Shakriani differ while the δ^{2}H are similar.

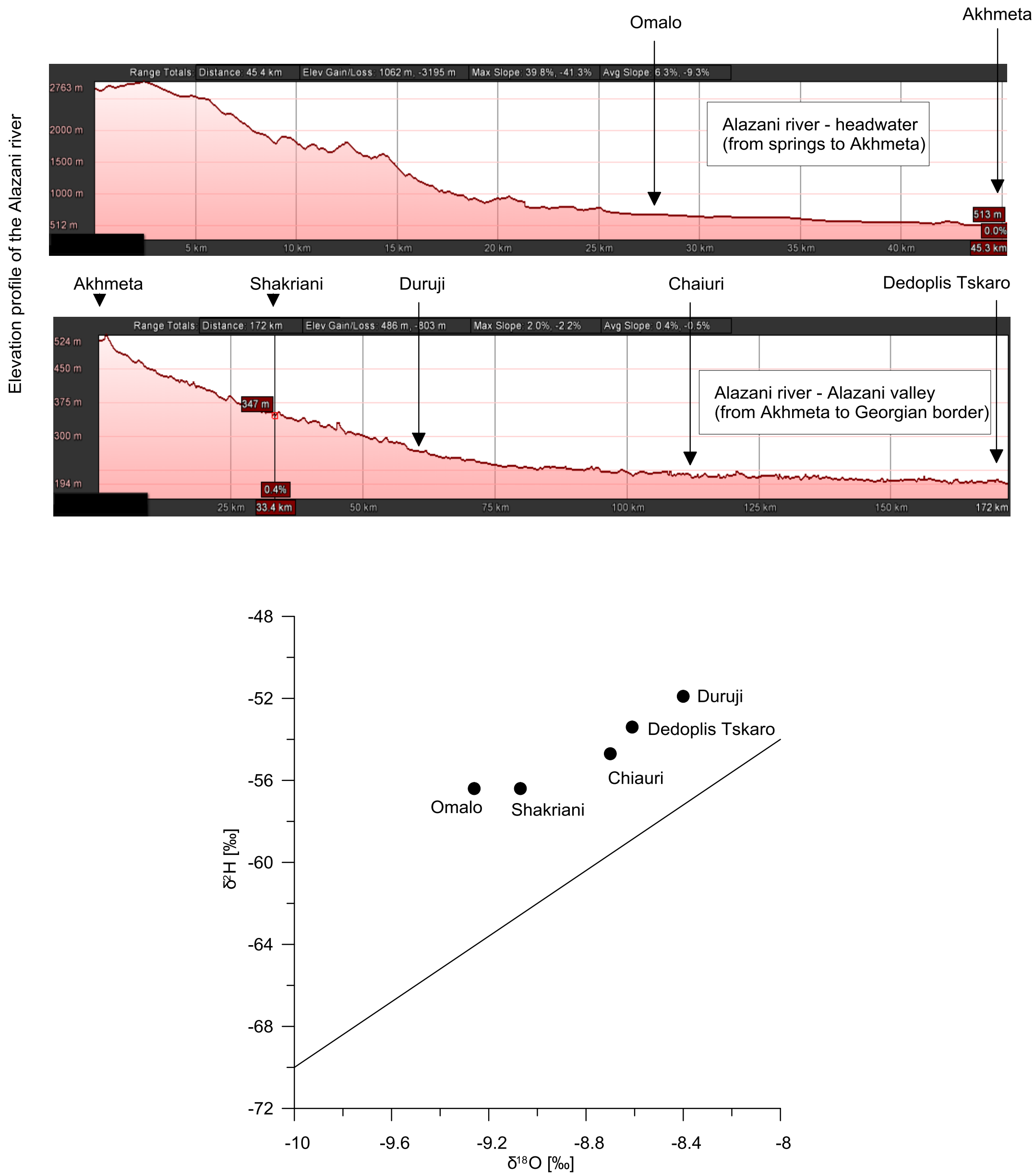

Fig. 6. Elevation profile of the Alazani river (modified from Google Earth) and position of samples from the snapshot sampling along the river on 28 October 2014 with regard to global meteoric water line.

Groundwater sampling was generally conducted in the NE-SW transects, i.e. from the southern slopes of the Greater Caucasus across the Alazani valley (Fig. 7). The sampling sites comprise springs, boreholes and structures of the local water supply systems. Most samples were collected during snapshot sampling campaigns. Available isotopic data indicate several groups of groundwaters (Fig. 8). Samples from Akhmeta, Telavi and Gurjani are isotopically similar. Groundwaters in Kvareli and Lagodekhi are isotopically disctincylt lighter, but they plot along similar meteoric water line as the above group. Groundwaters from the Sighnaghi area probably contain evaporated water.

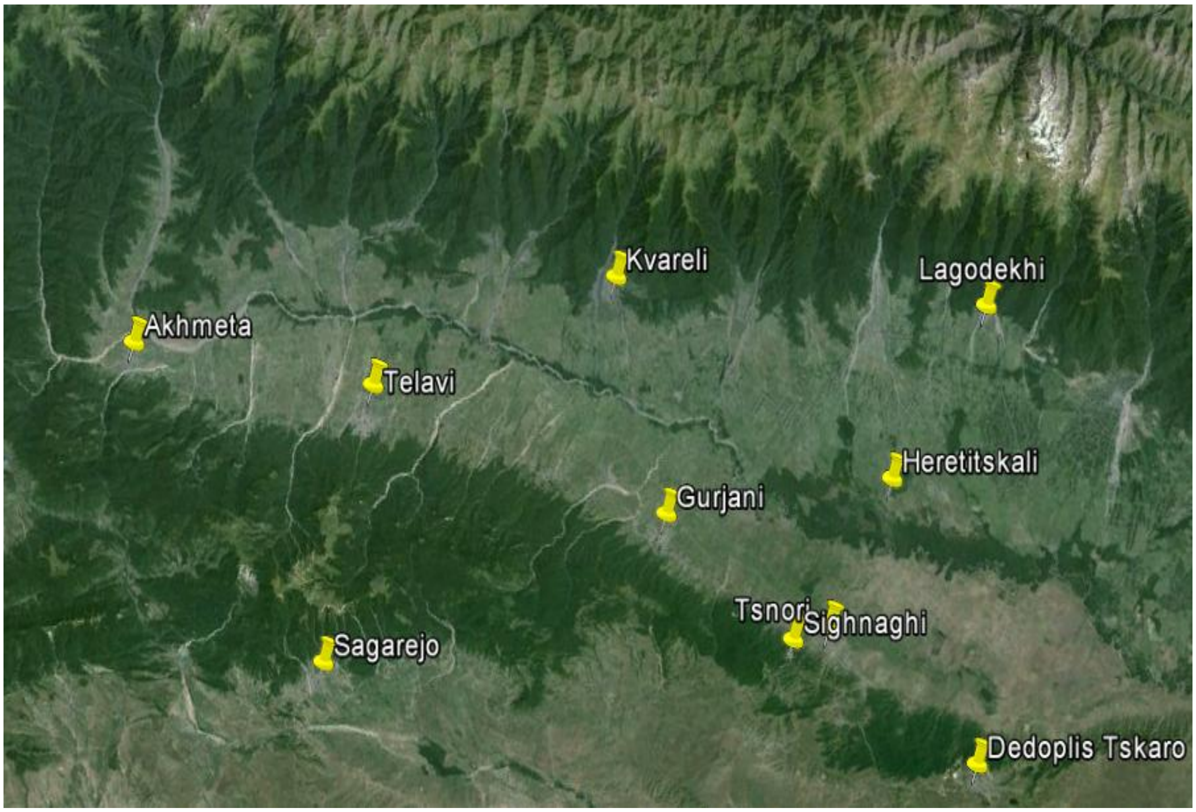

Fig. 7. The main groundwater sampling sites (Google Earth); the Sagarejo site is located in the neigbouring catchment (the Iori river) at the foot of the Gombori range; the distance between Akhmeta and Dedoplis Tskaro is about 97 km.

Samples from Dedoplis Tskaro form two groups. Part of the water (from the Samtatskaro borehole) probably represents older waters. The rest of samples are modern water which partially underwent evaporation. The Sagarejo waters do not form one group. The most variable are samples from Tsnori. The data presented in Fig. 9 and generalised in Fig.10 indicate the evolution of groundwater isotopic composition from the recharge area in the mountains through river valley to exfiltration areas. The concept which is in agreement with hydrogeological knowledge of the area is presented also in Table 1.

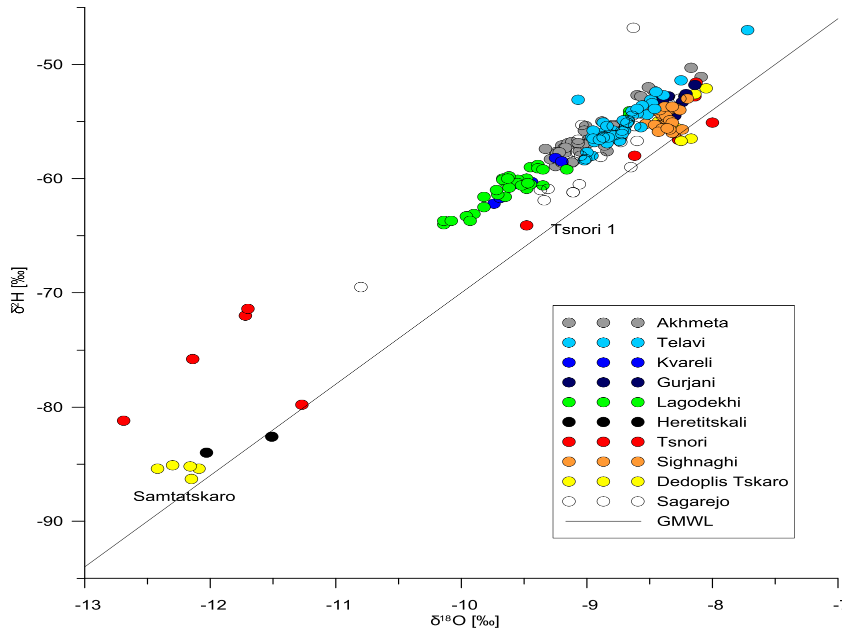

Fig. 8. Isotopic composition of groundwater samples.

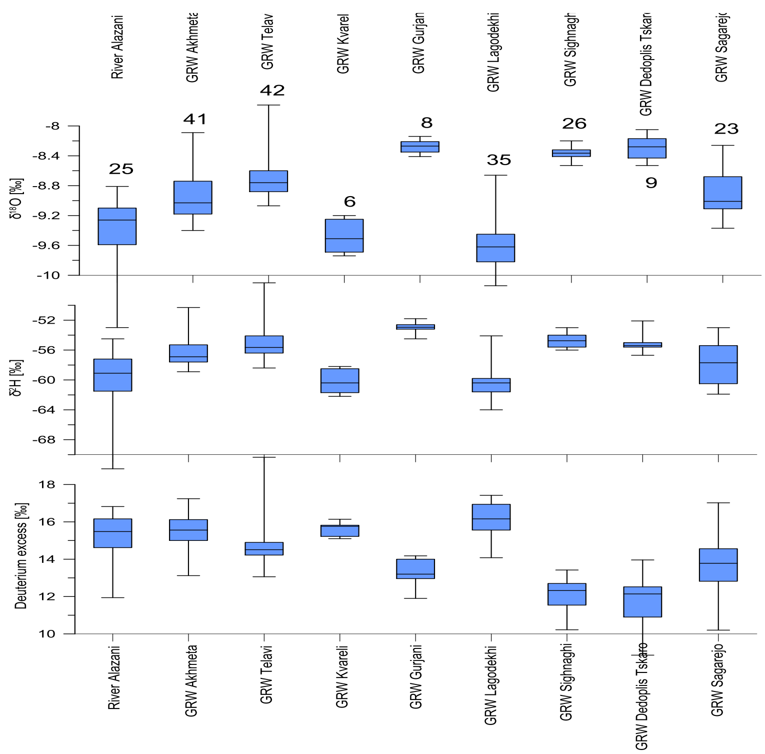

Fig. 9. Box-whiskers plots of the isotopic composition of Alazani river at Shakriani and groundwaters (old groundwaters are excluded); whiskers represent minimum and maximum; the number of samples for each boxplots is given in the graph for $\delta^{18}O$.

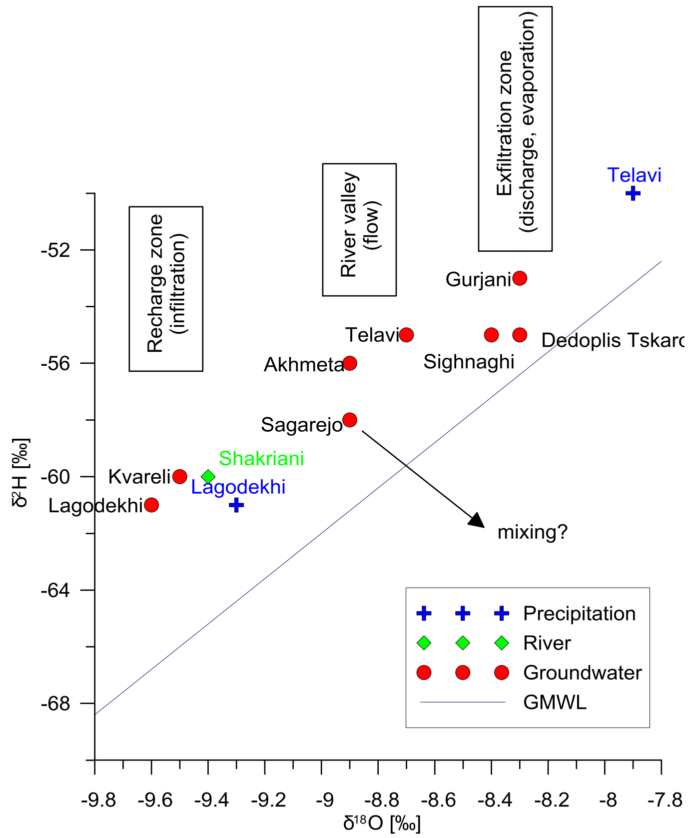

Fig. 10. Evolution of isotopic composition of groundwater in the study area (average values).

Table 1

Average values of isotopic composition of precipitation, river and groundwater samples and perceptual model of groundwater movement (column groundwater zone).

Groundwater zone	Site	^{18}O average [‰]	^{2}H average [‰]	Deuterium excess average [‰]
	Precipitation Telavi	-7.9	-50	12.9
	Precipitation Lagodekhi	-9.3	-61	14.1
	River Alazani (Shakriani)	-9.4	-60	15.3
Recharge area	GRW Kvareli	-9.5	-60	15.6
	GRW Lagodekhi	-9.6	-61	16.1
River valley	GRW Akhmeta	-8.9	-56	15.4
	GRW Telavi	-8.7	-55	14.6
Exfiltration	GRW Gurjani	-8.3	-53	13.3
	GRW Sighnaghi	-8.4	-55	12.1
	GRW Dedoplis Tskaro	-8.3	-55	11.7
Mixed water (Iori river basin)	GRW Sagarejo	-8.9	-58	13.6

Perceptual model suggested by current data on water isotopic composition should be validated when all samples are analysed and water chemistry data is available. Validated perceptual model will be useful in groundwater modelling.

Climatic data presented in Fig. 11 indicate that favourable conditions for snow cover formation probably occur only at higher elevations. Winter precipitation is small and maximum daily air temperature rarely drops below the freezing point even at Tianeti (elevation 1112 m a.s.l.).

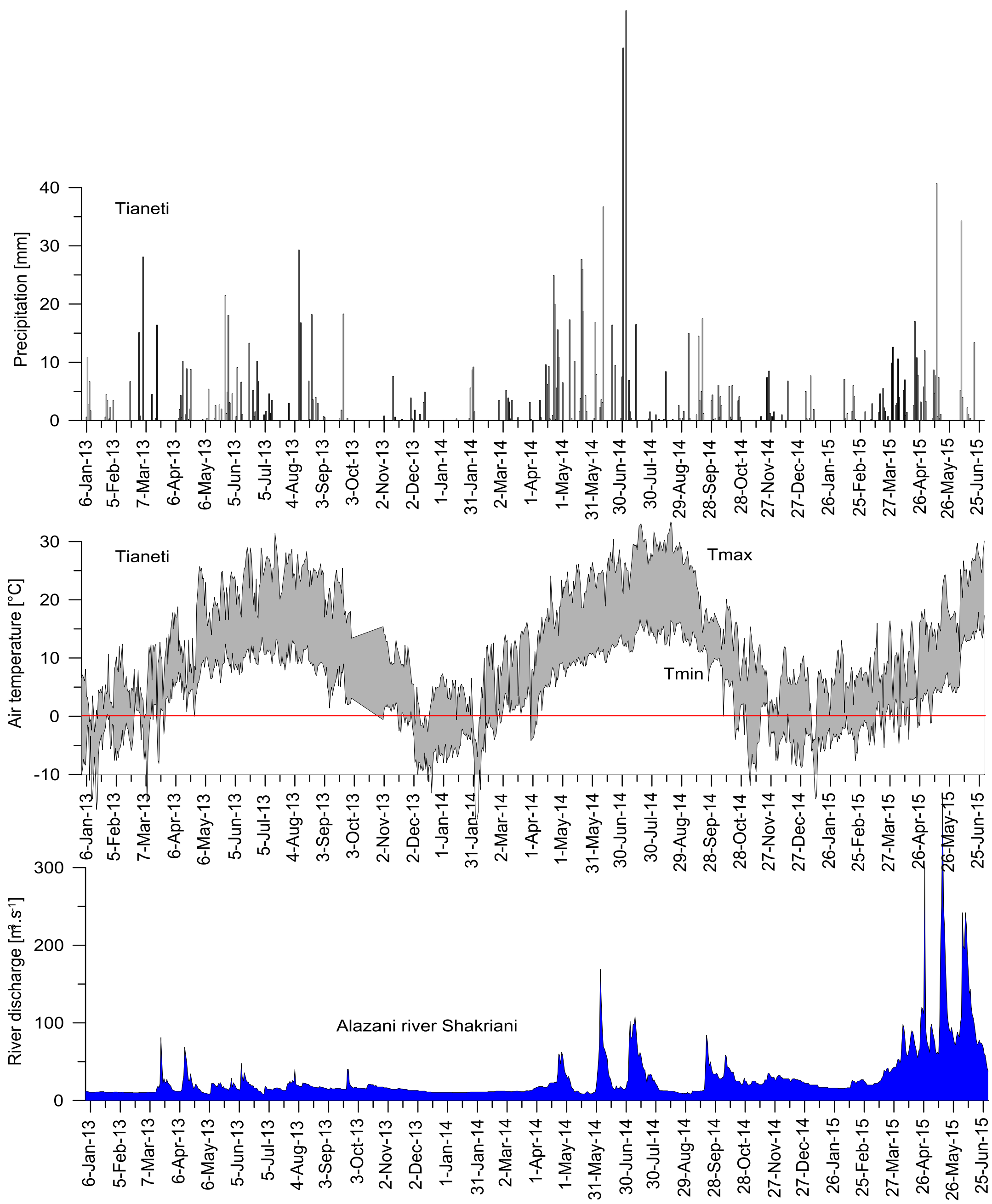

Fig. 11. Daily precipitation and air temperature (minimum, maximum) at Tianeti, daily discharge of Alazani river at Shakriani between 1 January 2013 and 30 June 2015.

Snow cover measurement at 12 snow profiles (281 to 1648 m a.s.l.) was organized by the counterpart on 11th January 2015. The depth of snow cover was only 6 to 17 cm. Comparison of precipitation and discharge data in Fig. 11 and isotopic composition of groundwater and early spring precipitation suggests that replenishment of groundwater storage could also take place in spring months from precipitation. If the seasonal snow cover at the foothills of the Greater Caucasus does not last for a longer period, spring rainfalls might be crucial for groundwater replenishment.

Conclusions

Isotopic composition of river water in the Alazani valley evolves according to a line parallel with the global meteoric water line. Available isotopic data indicate several groups of groundwaters . Some of them probably represents older waters. The most variable indicate the evolution of groundwater isotopic composition from the recharge area in the mountains through river valley to exfiltration areas. The isotopic composition river Alazani near Telavi presented that the river is contributed mainly by isotopically light water from higher altitudes. Deuterium excess has higher values which are typical for mountain precipitation and snow in other mountain ranges. If the seasonal snow cover at the foothills of the Greater Caucasus does not last for a longer period, spring rainfalls might be crucial for groundwater replenishment.

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კახეთის რეგიონში სტაბილური იზოტოპების მეთოდიკის გამოყენება წყლის გენეზისის დადგენის მიზნით

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ნ. კაპანაძე, თ. ჭიქაძე, გ. ქაჯაია

რეზიუმე

მიწისქვეშა წყლების გენეზისის და მოძრაობის გზის შესწავლის მიზნით ორგანიზება გაუკეთდა მათ მონიტორინგს აღმოსავლეთ საქართველოს დაბლობ რაიონებში ალაზანი-შირაქის წყალშემკრებებში. მონიტორინგის მიზანი იყო შესწავლილიყო სტაბილური იზოტოპების ევოლუცია ნალექქებიდან, მიწისქვეშა წყლებსა და მდინარის ნაკადამდე, რაც საშუალებას იძლევა დადგინდეს მიწისქვეშა წყლის გადაადგილების დრო, და წყლის ასაკი ალაზანი-შირაქის წყალშემკრებებში. ასევე ორგანიზება გაუკეთდა თოვლის საფარის სიმძლავრის გაზომვებს.

Использование стабильных изотопов для изучения происхождения водных ресурсов в Кахетинском регионе

Г.И Меликадзе, Л. А Голко, Н. О. Жукова, М. Ш.Тодадзе, С. Г. Вепхвадзе, Н. А. Капанадзе, Т. А. Чикадзе, Г.Т. Каджаия

Резюме

С целью выяснения движения и генезиса подземных вод в Восточной Грузии в Алазани-Ширакской низменности был организован их мониторинг. Мониторинговая сеть была создана с целью изучения эвалюции водных изотопов от осадков, поступающих к подземним водам и речным стокам, что позволяет оценить время движения подземного потока, а также возраст воды Алазани-Ширакской водозборов. Также было организовано измерение высоты снежных покровов.

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Zonal Flow and Stremaer Generation by Small – Scale Drift-Alfven Waves in Ionosphere Plasma

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Abstract

In the present work, the generation of large-scale zonal flows and streamers by modulationally unstable short-scale drift-Alfven waves in the ionosphere is investigated. Positive feedback in the system is achieved via modulation of the skin size drift-Alfven waves by the large-scale zonal flow. The conditions for the instability development and possibility of the generation of large-scale structures are determined. The instability pumps the energy of primarily small-scale Alfven waves into that of the large-scale zonal structures which is typical for an inverse turbulent cascade. Energy pumping into the large-scale region noticeably depends also on the width of the pumping wave spectrum and with an increase of the width of the initial wave spectrum the instability can be suppressed. It is assumed that the investigated mechanism can refer directly to the generation of mean flow in the atmosphere of the rotating planets and the magnetized plasma.

***Key words*:** Skin-size perturbations; Small and large scale turbulence; inverse cascade; Zonal flow; large scale magnetic field; pumping of energy with respect to scales. Reynolds and Maxwell stresses.

Introduction

Large scale coherent structures such as zonal flows and streamers can play important roles in transport behavior of magnetized plasmas. They present the integral parts of the collective activity of the majority of the planetary atmospheres and are manifested in the form of the large-scale low-frequency modes, propagating along the parallels (Busse, 1994; Aubert, et al., 2002). In toroidally enhanced plasmas, radially localized and poloidally elongated zonal flows can suppress (Lin et al, 1998; Li and Kashimoto, 2004), but poloidally localized and radially elongated streamers can enhance (Diamond et al, 2001; Yamada et al, 2010), the radial particle transport. There is evidence that these coherent structures are excited by drift and/or Alfv´en type of waves and the corresponding turbulence at time scales below the ion cyclotron frequency (Smolyakov et al, 2000; Kaladze et al, 2005). Earlier studies have focused mainly on waves with spatial scales larger than the ion gyroradius.

On the other hand, oscillations with spatial scales smaller than the ion gyroradius, such as the small-scale drift-Alfv´en waves (SSDAWs), can also efficiently drive coherent structures (Kaladze et al, 2007). In particular, it is found that pump SSDAWs propagating in the poloidal direction can excite zonal flows most efficiently (Kaladze et al, 2007), and the SSDAWs can be in either the electron or ion diamagnetic drift directions. However, up to now there is little investigation on the generation of streamers by SSDAWs.

The previous authors made the trials of investigations of the special features of the zonal flow generation by means of drift-Alfven type fluctuation on the basis of three sufficiently simplified models, describing nonlinear interaction between these modes: the first, a class of the models in which the effect of the ion temperature is negligible and only the effect of the so-called finite Larmor radius of ions according to the electron temperature (Guzdar, et al., 2001; Lakhin, 2003) is taken into account; the second model, where both disturbances, the primary small-scale as well as the large-scale zonal disturbances, have characteristic scale less than a Larmor radius of ions ρ_i (Smolyakov, et al., 2002); and the third class of the models, where finite Larmour radius of ions are considered neglecting the skin size inertial effects (Lakhin, 2004; Mikhailovskii, et al, 2006 b; Shukla, 2005; Kaladze et al, 2013). Although in the work (Pokhotelov, et al., 2003), generation of the zonal flow was studied by inertial Alfven fluctuations. But, it was made in uniform plasma neglecting finiteness of a Larmor radius of electrons, ions (T_e, $T_i \to 0$). One of the important wave modes in non-uniform magnetized space (Stasiewicz, et al., 2000; Sahraoui, et al., 2006; Narita, et al., 2007) as well as in laboratory (Gekelman, 1999) plasma media are electromagnetic small-scale drift-Alfven (SSDA) modes with the transverse wavelengths, small in comparison with a Larmor radius of ions (Aburjania et al, 2009) These small scale fluctuations can generate large-scale zonal modes and streamers in the space and as well as in the laboratory plasma. Moreover, the contemporary theory of anomalous transfers (Kadomtsev, Pogutse, 1984; Aburjania, 2006; Aburjania, 1990) predicts, that the anomalous thermal conductivity and diffusion in the plasma medium may be stipulated, in essence, by the processes with the characteristic wavelength $\lambda_\perp$ of the order of collision-less skin length λ_s, $\lambda_\perp = 2\pi / k_\perp \sim \lambda_s = c/\omega_{Pe}$, where $k_\perp$ is transversal (according to external equilibrium magnetic field) wave number of perturbations, $\omega_{Pe} = \left(4\pi e^2 n_0 / m_e\right)^{1/2}$ is a plasma frequency. In this connection, description of the nonlinear wave processes on the scales $\lambda_s \sim \lambda_\perp < \rho_i$ appears necessary.

In this paper we consider excitation of streamers from modulational instability of SSDAWs. A nonlinear equation describing the coupling of coherent structures and SSDAWs propagating in arbitrary directions is obtained.

1. Initial dynamic equations

The nonlinear equations describing the coupling of the SSDAWs with coherent structures in terms of the scalar potential ϕ and the parallel component A of the vector potential are (Aburjania et al, 2009)

$$\frac{\partial A}{\partial t} + V_{*e}\frac{\partial A}{\partial y} + c(1+\tau)\nabla_{||}\phi - \lambda_s^2 \frac{d}{dt}\Delta_\perp A = 0, \tag{1}$$

$$\frac{d}{dt}\phi + V_{*i}\frac{\partial \phi}{\partial y} - \frac{V_{Te}^2}{c\tau}\lambda_s^2 \nabla_{||}\Delta_\perp A = 0. \tag{2}$$

Here $V_{*e,i} = \mp c T_{e,i}\kappa_n/(eB_0)$ are electron and ion drift velocities respectively, where subscript "e" means electrons and "i" means ions; $V_{Te} = (T_e/m_e)^{1/2}$ – electrons' thermal velocity; $\tau = T_e/T_i$, $\nabla_{||} = \partial/\partial z - B_0^{-1}(\nabla A \times \nabla)_z$. Getting (1), (2) ion longitudinal motion is neglected and it is supposed that longitudinal current $J_{||}$ are caused by plasma electrons, $J_{||} = -c\Delta_\perp A/4\pi$.

For threee-wave interaction involving a pump SSDAW and their satellites (secondary SS modes) we can write:

$$X = \tilde{X} + \hat{X} + \bar{X}, \tag{3}$$

where

$$\tilde{X} = \sum_k \left[\tilde{X}_+(k)\exp(i\mathbf{k}\cdot\mathbf{r} - i\omega_{\mathbf{k}}t) + \tilde{X}_-(k)\exp(-i\mathbf{k}\cdot\mathbf{r} + i\omega_{\mathbf{k}}t)\right], \tag{4}$$

describes a spectrum of SSDA initial pumping modes, $\mathbf{k} = (k_x, k_y, k_z)$, ω-wave vector and frequency of the initial modes, amplitude satisfies the condition $\tilde{X}_- = \tilde{X}_+^*$, where asterisk indicates a complex conjugation,

$$\hat{X} = \sum_k \left[\hat{X}_+(k)\exp(i\mathbf{k}_+\cdot\mathbf{r} - i\omega_+ t) + \hat{X}_-(k)\exp(i\mathbf{k}_-\cdot\mathbf{r} + i\omega_- t) + \text{c.c.}\right], \tag{5}$$

describes the small scale satellite (secondary) modes and

$$\bar{X} = \bar{X}_0 \exp(-i\Omega t + i\mathbf{q}\cdot\mathbf{r}) + \text{c.c.}, \tag{6}$$

describes zonal flows. Laws of energy and impulse conservation is written in the next form: $\omega_\pm = \Omega \pm \omega_k$ and $\mathbf{k}_\pm = \boldsymbol{q}\cdot\mathbf{r} \pm \mathbf{k}$, respectively. Thus, the pairs $(\omega_{\mathbf{k}}, \mathbf{k})$ and $(\Omega, \mathbf{q}\cdot\mathbf{r})$ represent frequency and wave vector of SSDA pumping modes and zonal flows, respectively. Amplitude of the zonal modes $\bar{X}_0 \equiv (\bar{A}_0, \bar{\phi}_0)$ is considered to be constant in local approach. Since the coherent structures are perpendicular to the external magnetic field we have $q = q_\perp$. Further analyze will be carried out in the frames of the standard approximation $q_\perp / k_\perp << 1, \Omega/\omega << 1$.

1.1 Generation of the zonal flows by SSDAWs

If we consider a case when $q_y = 0$, e.i. $q_\perp = q_x$, following the standard quasi nonlinear procedure, substituting the expressions (3)-(6) in the equations (1), (2) and neglect small nonlinear terms with high frequency modes we obtain the coherent structures – the zonal flows:

$$(\omega_k - \omega_{*i})\tilde{\phi}_\pm(\mathbf{k}) - \frac{cT_i k_z k_\perp^2}{4\pi e^2 n_0}\tilde{A}_\pm(\mathbf{k}) = 0, \tag{7}$$

$$k_z c(1+\tau)\tilde{\phi}_\pm(\mathbf{k}) - \left[\omega_{\mathbf{k}}(1 + \mathbf{k}_\perp^2\lambda_{\mathbf{s}}^2)\right]\tilde{\mathbf{A}}_\pm(\mathbf{k}) = 0. \tag{8}$$

$$(\omega_\pm \mp \omega_{*i})\hat{\phi}_\pm \mp \frac{cT_i k_z k_{\perp\pm}^2}{4\pi e^2 n_0}\hat{A}_\pm = \mp\alpha_2^\pm \frac{cT_i k_z (k_\perp^2 - q_x^2)}{4\pi e^2 n_0[(1 + k_\perp^2\lambda_s^2)\omega_\pm - \omega_{*e}]}, \tag{9}$$

$$\mp k_z c(1+\tau)\hat{\phi}_\pm + [(1 + k_\perp^2\lambda_s^2)\omega_\pm \mp \omega_{*e}]\hat{A}_\pm = \mp\alpha_1^\pm\left[1 - \alpha_0\frac{\bar{\phi}_0}{\bar{A}_0}\frac{ck_z(1+\tau)}{(1 + k_\perp^2\lambda_s^2)\omega_k - \omega_{*e}}\right]. \tag{10}$$

$$i\Omega\bar{\phi}_0 = \frac{cT_i q_x^2}{4\pi e^2 n_0 B_0}\sum_{\mathbf{k}} k_y R_1(\mathbf{k}), \tag{11}$$

$$-i\Omega\left(1 + q_x^2\lambda_s^2\right)\bar{A}_0 = \frac{cq_x(1+\tau)}{B_0}\sum_{\mathbf{k}} k_y R_2(\mathbf{k}) + \frac{c}{B_0}q_x\lambda_s^2\sum_k k_y R_3(\mathbf{k}). \tag{12}$$

Here

$$\alpha_0 = \frac{1+\tau+k_\perp^2\lambda_s^2}{1+\tau+q_x^2\lambda_s^2}\ , \quad \alpha_2^\pm = \frac{ic}{B_0} k_y q_x (1+\tau)\overline{A}_0 \tilde{\phi}_\pm , \quad \alpha_1^\pm = \frac{ic}{B_0} k_y q_x \left(1+\tau+q_x^2\lambda_s^2\right)\overline{A}_0 \tilde{\phi}_\pm \ .$$

$$R_1(\mathbf{k}) = q_x\left(\tilde{A}_-\hat{A}_+ - \tilde{A}_+\hat{A}_-\right) + 2k_x\left(\tilde{A}_-\hat{A}_+ + \tilde{A}_+\hat{A}_-\right), R_2 = \tilde{\varphi}_-\hat{\delta}_+ - \tilde{\varphi}_+\hat{\delta}_-,$$

$$\hat{\delta}_\pm = \hat{A}_\pm - \frac{ck_z(1+\tau)}{\left(1+k_\perp^2\lambda_s^2\right)\omega_k - \omega_{*e}}\hat{\varphi}_\pm ,$$

$$R_3 = k_\perp^2\left(\tilde{A}_+\hat{\phi}_- + \tilde{\phi}_-\hat{A}_+ - \tilde{A}_-\hat{\phi}_+ - \tilde{\phi}_+\hat{A}_-\right) + q_x^2\left(\tilde{\phi}_-\hat{A}_+ - \tilde{\phi}_+\hat{A}_-\right) + 2q_x k_x\left(\tilde{\phi}_-\hat{A}_+ + \tilde{\phi}_+\hat{A}_-\right).$$

1.2 Dispersion equation of the large scale zonal flows and magnetic fields

Using the above expression general dispersion relation can be obtained:

$$\overline{\phi}_0 = L_1^\phi \overline{\phi}_0 + L_1^A \overline{A}_0 \ , \tag{13}$$

$$\overline{A}_0 = L_2^\phi \overline{\phi}_0 + L_2^A \overline{A}_0 \ . \tag{14}$$

where

$$\left(L_1^\phi,\ \ L_1^a,\ L_2^\phi,\ L_2^A\right) = \sum_k \frac{\left(l_1^\phi,\ l_1^A,\ l_2^\phi,\ l_2^A\right)}{\left(\Omega - q_x V_g\right)^2}\ \ . \tag{15}$$

Here $\mathbf{V_g} = \mathbf{V_g}(\mathbf{k})$ - zonal group velocity, defined by equality bellow:

$$V_g = \frac{2k_x}{k_\perp^2}\frac{(\omega_k - \omega_{*i})\left[\left(1+k_\perp^2\lambda_s^2\right)\omega_k - \omega_{*e}\right]}{2\left(1+k_\perp^2\lambda_s^2\right)\omega_k - \left(1+k_\perp^2\lambda_s^2\right)\omega_{*i} - \omega_{*e}}, \tag{16}$$

And the functions $\left(l_1^\phi,\ l_1^A,\ l_2^\phi,\ l_2^A\right)$ denote

$$l_1^\phi = (1+\tau)\frac{q_x k_x}{k_\perp^2}\frac{(\omega_k - \omega_{*i})\Gamma_0^2}{\left[\left(1+k_\perp^2\lambda_s^2\right)\omega_k - \omega_{*e}\right]\cdot\left[2\left(1+k_\perp^2\lambda_s^2\right)\omega_k - \left(1+k_\perp^2\lambda_s^2\right)\omega_{*i} - \omega_{*e}\right]^2} R_1^\phi , \tag{17}$$

$$l_1^A = \frac{1}{c}\frac{q_x k_x}{k_z k_\perp^2}\frac{(\omega_k - \omega_{*i})\Gamma_0^2}{\left[2\left(1+k_\perp^2\lambda_s^2\right)\omega_k - \left(1+k_\perp^2\lambda_s^2\right)\omega_{*i} - \omega_{*e}\right]^2} R_1^A \tag{18}$$

$$l_2^\phi = c(1+\tau)\frac{k_z\Gamma_0^2\left[(1+\tau)R_2^\phi + \frac{q_x\lambda_s^2}{\Omega}\left(1+\tau+k_\perp^2\lambda_s^2\right)R_3^\phi\right]}{\left[\left(1+k_\perp^2\lambda_s^2\right)\omega_k - \omega_{*e}\right]\cdot\left[2\left(1+k_\perp^2\lambda_s^2\right)\omega_k - \left(1+k_\perp^2\lambda_s^2\right)\omega_{*i} - \omega_{*e}\right]^2}, \tag{19}$$

$$l_2^A = -(1+\tau)\frac{\Gamma_0^2\left(R_2^A + \frac{q_x\lambda_s^2}{\Omega}R_3^A\right)}{\left[2\left(1+k_\perp^2\lambda_s^2\right)\omega_k - \left(1+k_\perp^2\lambda_s^2\right)\omega_{*i} - \omega_{*e}\right]^2}, \tag{20}$$

where

$$\Gamma_0^2 = \frac{c^2 q_x^2 k_y^2}{B_0^2} I_k \ . \tag{21}$$

From the closed system of equations (13) and (14), we simply get the dispersion equation for large scale zonal flows and the magnetic fields:

$$1 - \left(L_1^\phi + L_2^A\right) + L_1^\phi L_2^A - L_2^\phi L_1^A = 0 , \tag{22}$$

The dispersion relation of the zonal modes (22) allows an investigation of their generation via continuous spectrum of the initial modes with skin scale, which is the main subject of the traditional theory of such generation, which uses a kinetic equation for the waves, summarized in (Diamond, et al., 2005). Thus, the approach developed in section 3.4, based on dynamic equations of magnetic hydrodynamics of the ionosphere, is an alternative to the approach in (Diamond, et al., 2005) and in our opinion, is more convenient in to realize, also in the interpretation of results obtained based on them. It's obvious that the dispersion relation (22) represents bisquared equation according to $\Omega - q_x V_g$. However, as it will be shown bellow, this equation can be reduced to a squared one for a very interesting range of frequencies Ω of the zonal perturbation.

1.3 Generation of the streamers by SSDAWs

Let us consider the case of coherent structures $q_\perp \neq 0$. We define an angle between the direction of pump wave SSDAW $k_\perp$ and **x** radial direction θ_p, angle between $k_\perp$ and direction of the coherent structure $q_\perp$ - θ_c. Therefore, zonal flows and streamers correspond to $\theta_c = 0^\circ$ and $\theta_c = 90^\circ$, respectively. For $\theta_c \neq 0^\circ$ and $\theta_c \neq 90^\circ$, it corresponds to oblique coherent structure.

$$\begin{aligned}\left(\Omega - \omega_{*i}^{q}\right)\overline{\Phi}_0 = -\frac{iV_A^2\rho_i^2}{cB_0}[&\left(k_x k_{+y} - k_{+x}k_y\right)\left(k_\perp^2 - k_{+\perp}^2\right)A_k^* A_{k+} \\ &-\left(k_x k_{-y} - k_{-x}k_y\right)\left(k_\perp^2 - k_{-\perp}^2\right)A_k^* A_{k-}];\end{aligned} \tag{23}$$

$$\begin{aligned}\left(\Omega - \omega_{*i}^{q}\right)\overline{A}_0 = -\frac{ic}{B_0}\left(1+\frac{1}{\tau}\right)[&\left(k_x k_{+y} - k_{+x}k_y\right)\left(A_k^*\Phi_{k+} - A_{k+}\Phi_k^*\right) \\ &-\left(k_x k_{-y} - k_{-x}k_y\right)\left(A_k^*\Phi_{k-} - A_{k-}\Phi_k^*\right)];\end{aligned} \tag{24}$$

Where

$$\omega_{*i,e} = V_{*i,e}k_y, \quad \omega_{*i,e}^{q} = V_{*i,e}q_y, \quad \omega_{*i,e}^{\pm} = V_{*i,e}k_{\pm y},$$

$$\alpha = -\frac{ic}{B_0}\left(1+\frac{1}{\tau}\right)\left(k_y q_x - k_x q_y\right)\overline{\Phi}_k,$$

$$D_\pm = \left(\omega_\pm - \omega_{*i}^{\pm}\right)\left(\omega_\pm - \omega_{*e}^{\pm}\right) - \frac{k_{\pm\perp}^2}{k_\perp^2}\left(\omega_k - \omega_{*i}\right)\left(\omega_k - \omega_{*e}\right).$$

We can obtain the coupling equations for the coherent structures:

$$\begin{pmatrix} \frac{1}{\omega_{ci}^2}\left(\Omega - \omega_{*i}\right)D_+D_- - a_1 I_{11} & a_2 I_{12} \\ b_1 I_{21} & \frac{1}{\omega_{ci}^2}\left(\Omega - \omega_{*e}\right)D_+D_- - b_2 I_{22} \end{pmatrix}\begin{pmatrix}\overline{\Phi}_0 \\ \overline{A}_0\end{pmatrix} = 0, \tag{25}$$

Eq. (25) gives the general dispersion relation of the coherent structures

$$\left[\frac{1}{\omega_{ci}^2}\left(\Omega - \omega_{*i}\right)D_+D_- - a_1 I_{11}\right]\left[\frac{1}{\omega_{ci}^2}\left(\Omega - \omega_{*e}\right)D_+D_- - b_2 I_{22}\right] + a_2 b_1 I_{12} I_{21} = 0. \tag{26}$$

If the nonlinear term $|B_\perp/B_0|_2$ is small and can be neglected, Eq. (26) is reduced to

$$D_+^2 D_-^2 \left(\Omega - \omega_{*i}^0\right)\left(\Omega - \omega_{*e}^0\right) = 0, \tag{27}$$

whose solutions are

$$\begin{aligned}
\Omega_{1\pm} &= \frac{1}{2}\left(-b_+ \pm \sqrt{b_+^2 - 4c_+}\right), \\
\Omega_{2\pm} &= \frac{1}{2}\left(-b_- \pm \sqrt{b_-^2 - 4c_-}\right), \\
\Omega_3 &= \omega_{*i}^0, \\
\Omega_4 &= \omega_{*e}^0,
\end{aligned} \tag{28}$$

Where

$$\begin{aligned}
b_\pm &= \pm\left(2\omega_k - \omega_{*i} - \omega_{*e}\right) - \omega_{*i}^0 - \omega_{*e}^0, \\
c_\pm &= \pm\omega_{*i}^0\left(\omega_k - \omega_{*e}\right) \pm \omega_{*e}^0\left(\omega_k - \omega_{*e}\right) + \omega_{*i}^0\omega_{*e}^0 \\
&\quad - \frac{1}{k_\perp^2}\left(q_\perp^2 \pm 2k_\perp \cdot q_\perp\right)\left(\omega_k - \omega_{*i}\right)\left(\omega_k - \omega_{*e}\right),
\end{aligned}$$

where $\Omega_{1\pm}$ and $\Omega_{2\pm}$ are the solutions of $D_+ = 0$ and $D_- = 0$, respectively.

Discussion of the results and conclusion

In this work, the features of the generation of large scale zonal flows and the streamers due to small scale drift Alfven (SSDA) turbulence in the ionospheric plasma medium are investigated. Two self-consistent interconnected nonlinear equations (5) and (6), determining electrostatic and vector potentials describing the dynamics of the wave structures with finite ion Larmour radius. They are valid for the structures till the skin scale ($k_\perp^2 c^2 / \omega_{pe}^2 \sim 1$). Analysis of these structures was carried out in the frames of nonlinear parametric formalism, analogous to the theory of convective cells generation due to monochromatic pumping waves, but generalized in the sense that instead of separate monochromatic packet we investigated the initial waves arbitrary according to spectrum width. Such modification of the parametric approach reveals a new feature of the interaction of the small scale and the large scale modes . As in the majority of preceding works, we suppose the existence of some linear or nonlinear mechanisms of initial mode excitation responsible for growth of their amplitudes above the fluctuation level. Due to competition between linear and nonlinear effects, some stationary state of the initial waves will form. Herewith, we consider that zonal mode generation treated by us takes place at the end of the corresponding initial modes' stationary level formation. These initial modes have real frequencies.

It must be mentioned that zonal mode generation by SSDA pumping waves is possible (see eq. (26), only at drift effects ($\omega_{*e,i} \neq 0$), but the initial nonlinear equations of these modes (5) and (6) are valid also neglecting these effects, i.e., for uniform plasma.

It is established, that SSDA of the skin size as well as comparably long wavelength one, effectively generate the large scale zonal flows and the streamers. These modes will be excited due to joint nonlinear action of the Reynolds and Maxwell stresses. Physical reason of the zonal flow generation due to electron drift modes represents Reynolds stress. As it comes to quasi electromagnetic ion-drift waves, they as well as kinetic Alfven pumping in uniform plasma, can not excite the large scale zonal modes as a result of whole compensation of moderate Reynolds stresses with Maxwell's ones.

We suppose, the mechanism discussed in this work is applicable for theoretical foundation experimentally observed mean flow generation in the atmospheres of the rotating planets and in magnetized plasma. On the one side, it can play a definite role in boundary layer Alfven turbulence formation (Pokhotelov, et al., 2003). On the other side, parametric instability can cause shear flow generation in laboratory plasma where it can sufficiently impact the drift plasma turbulence and suppress the transfer processes (Smolyakov, et al., 2000; Manfredi, et al., 2001). Thus, this instability can be one of the main nonlinear saturation mechanisms of amplitudes of the wave perturbations in space and laboratory plasma.

This study developed a general nonlinear dispersion equation to describe the generation of coherent structures by SSDA modes. For the meso-scale streamer structure ($\theta_{\mathrm{coh}} = 90°$), it is found that its excitation comes from either the nonlinear coupling between two branches $\mathbf{\Omega}_{1+}$ and $\mathbf{\Omega}_{2-}$ for the ion diamagnetic-drift pump wave, or two branches $\mathbf{\Omega}_{1-}$ and $\mathbf{\Omega}_{2+}$ for the electron diamagnetic-drift pump wave. The excitation is most effective when the pump SSDA mode propagates at $\theta_{\mathrm{pump}} \sim 30$

The study compared the streamer excitation to the zonal flow excitation. It is shown that like the streamer case both ion and electron diamagnetic-drift pump modes can drive zonal flows. However, the strongest excitation of zonal flows happens at the angle different from that for streamer excitation. Therefore, it proposed that the generation of coherent structures depends strongly on θ_{pump}.

The theory which is developed in this work is applicable for nonlinear dynamics of the ionospheric Alfven resonator (IAR). Ground-based observations of mid-latitudes (Belyaev, et al., 1990; Bosinger, et al., 2002), high-latitudes (Belyaev et al., 1999; Demekhov, et al., 2000) and satellite observations (Grzesiak, 2000; Chaston, et al., 2002) convincingly verify the existence of IAR in the upper ionosphere. Results of ionospheric measurements indicate also (Stasiewicz, et al., 2000), that Alfven waves excited in the IAR actually are not seen as small amplitude linear waves. They always have comparably large amplitudes and represent eigen modes of IAR in a strongly nonlinear state. Let's estimate effectiveness of the mechanism considered for IAR regions (Pokhotelov, et al., 2003). For characteristic parameters of IAR (Pokhotelov, et al., 2003): $E \sim 10^{-2}$ v/m, $B_0 \sim 3\times10^{-5}$ T, $\lambda_s \sim 100$ m, $k_\perp\lambda_s \sim 1$, $q_x \sim 0.01k_x$, we get $\gamma_{opt} \sim 10^5\ s^{-1}$. Thus, the considered parametric instability pumps energy of SSDA pumping waves into the energies of the large scale zonal flow or streamers in $\sim 10^{-5}$ seconds. A more detailed qualitative comparison of the theoretical results obtained through the observed and experimental data is outside the scope of this work and is a subject for a separate publication.

Thus, our analysis shows that the parametric instability in the ionosphere is developed simply, and can become a sufficient nonlinear mechanism of energy pumping from small-scale drift Alfven turbulence into large-scale (or meso-scale) zonal flows and the streamers. Such energy distribution leads to a small-scale turbulence level decreasing and to noticeable weakening of anomalous transfer processes in the medium. So, parametrically excited meso-scale flows can present sufficient parts of elements of the structural plasma turbulence in the ionosphere and lower magnetosphere of the Earth.

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ზონალური დინებებისა და სტრიმერების გენერაცია მცირე-მასშტაბიანი დრეიფული ალფენის ტალღებით იონოსფერულ პლაზმაში

ხ. ჩარგაზია

რეზიუმე

ნაშრომში შესწავლილია დიდმასშტაბიანი ზონალური დინებებისა და სტრიმერების გენერაცია მოდულაციურად არამდგრადი მცირე მასშტაბიანი დრეიფული ალფენიოს ტალღებით იონოსფეროში.გამოვლენილია დადებითი უკუკავშირი სკინ-სისქის დრეიფულ ალფენის ტალღასა და დიდმასშტაბიან ზონალურ დინებებს შორის. განსაზღვრულია არამდგრადობის განვითარებისა და დიდმაშტაბიანი სტრუქტურების გენერაციის პირობა. არამდგრადობა განაპირობებს ენერგიის გადაქაჩვას მნიშვნელოვნად მცირე მასშტაბიანი ალფენის ტალღიდან დიდმასშტაბიან ზონალურ დინებებში, რაც დამახასიათებელია ტურბულენტური უკუკასკადისათვის. ენერგიის გადატანა შედარებით დიდმასშტაბიან არეში დამოკიდებულია საწყისი ტალღის სპექტრის სიგანეზე, რომლის ზრდასთან ერთად, არამდგრადობა ითრგუნება. აღნიშნული ენერგიის გადატანის მექანიზმი შეიძლება გამოყენებულ იქნას ფონური დინების გენერაციის შემთხვევისათვის მბრუნავი პლანეტების ატმოსფეროებში და ასევე მაგნიტური ველებისათვის.

Генерация зональных течений и стримеров мелко масштабными дрейфого Альвеновскими волнами в ионосферной плазме

Х. Чаргазия

Резюме

В работе изучена генерация крупномасштабных зональных течений и стримеров с модуляционной неустойчивостью мелкомасштабных дрейфовых Альвеоновских волн в ионосферной плазме. Выявлена позитивная обратная связь между дрейфовыми Альвеоновскими волнами скиновой толщины и зональными течениями. Определены условия развития неустойчивости и генерации крупномасштабных структур. Неустойчивость определяет перекачку энергии с мелкомасштабных дрейфовых Альвеоновских волн в зональных течений, что свойственно турбулентному обратному каскаду. Перекачка энергии в относительно крупномасштабной области зависит от ширины спектра начальных волн, с ростом каторого неустойчивость убывает. Рассмотренный механизм перекачки энергии может быть использован для случая генерации фонового течения в атмосферах вращающихся планет, а также для магнитных полей.

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Environmental Risks of Man-Made Air Pollution in Grand Algiers

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Abstract

The rapid economic growth and development in Algeria especially in Algiers which is the main metropolis in the country take place last decades. Uncontrolled urbanization and industrialization are contributing to deteriorate the environment. All these activities lead to an increase in the number of vehicles in the Grand Algiers, which adversely affect the air quality. Air quality in urban areas constitutes a major concern, taking in consideration the impact of pollution on environment and inhabitant's health. The main important urban air contaminants in terms of emissions and effect on environment and human health which could be taken into account are: carbon monoxide, nitrogen dioxide and particulate matter PM. The aim of our research is to assess the risks of man-made emissions into the atmosphere of Grand Algiers as a result of impact from stationary and mobile sources of pollution. GIS maps of air pollution with PM 1.0; 2.5; 10 microns in Grand Algiers were carried out. Based on the obtained results, it was revealed a tendency of increased content with nitrogen dioxide in the atmosphere of Algiers which demonstrates the existence of the risk of falling out of nitric acid rain not only within the city limits but also in the scale of grand Algiers. According to the GIS mapping revealed features of the propagation of man-made dust particles size 1.0; 2.5 and 10 microns. Further investigations should be focused on the establishment of a sufficient number of monitoring stations and planning ways to reduce the negative impact on the environment.

***Key words*:** Air pollution, particulate matter PM 1.0; 2.5; 10 microns.

Introduction

Industrial objects growth in the cities of Algeria are followed by a series of negative phenomena and, first of all, extra accumulation of different contaminating gases and vaporized pollutants. Mainly, emissions take place in the cities of Algiers, Annaba, Oran and Skikda because of the high concentration of harmful industries located in these cities.

The development of urbanization, the increase in the number of industrial facilities, the constant improvement of the density of urban transport in the Grand Algiers accompanied by a number of negative phenomena, and, above all, excessive accumulation in the atmosphere of various gas and vapor contaminants. The main components of harmful substances into the atmosphere are emissions from high-temperature fuel combustion products (exhaust gases of vehicles, aircraft, industrial emissions) [1-6]. Industrial activities in Algiers associated with engineering, chemical and petrochemical industry. Significant impact on the state of atmosphere of the metropolis due to the heavy vehicular traffic. Aerotechnogenic pollution of the environment is the cause of most problems related to the presence of atmospheric dust particles of various sizes, which differ in size into three types (1; 2.5 and 10 μm). The potential adverse effects associated with these particles by their sizes (they are easily and deeply penetrate into the alveoli of the lungs) and the presence of toxic heavy metals (iron, lead, cadmium). The fine particles and, particularly diesel emissions are nowadays in all cities around the world, the problem for the public health. Moreover, national report on the state of environment demonstrated that 30% of consultations are for respiratory diseases, 40% of infant mortality (children under 1 year) is caused by respiratory diseases and 600 000 asthmatics suffer permanently [7-9].

The purpose of our research is to assess the risks of man-made emissions into the atmosphere of Grand Algiers as a result of stationary and mobile sources of pollution.

Material and method.

Regular grid satellite measurements were interpolated into ground observation points and regression is built on these relationships. The satellite measurements are recalculated for the whole study area by regression equations obtained. The monthly-averaged concentrations of the atmospheric contaminants are processed under time series analysis algorithm, interpreted and mapped. The data of CO remote atmospheric sensing in 4 cities of Algeria have been obtained within the different periods for the last decade.

Specialized optical or microwave sensors, mounted on the remote sensing satellites were used to analyze the Earth's atmosphere. Now the atmospheric remote sensing satellites Envisat (equipped with GOMOS, MIPAS and SCIAMACHY spectrometers), MetOp (equipped with IASI, GOME-2 and HIRS/4 spectrometers), EOS (equipped with MOPITT, AIRS, OMI and TES infrared spectrometers as well as HIRDLS and MLS microwave radiometers) and NPOESS (equipped with OMPS ultraviolet/visible spectrometer) are operated. Assessment of the atmospheric pollution with inorganic gases is carried out by satellite measurements using ground truth data. As the source the level 3 data products from NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) are used. Spatial segment of interest and required data layers selection and monthly averaging produced by Giovanni web-service (http://disc.sci.gsfc.nasa.gov/giovanni/).

Automatic selection of air samples in Algiers held since 2002 [7]. Monitoring posts have been set up in four areas: 1er Mai, Ben Aknoun, Bab El Oued and El Hamma. Additional studies were conducted during the first decade of the 21st century, and in other parts of the Grand Algiers [10].Among them, three urban areas with high population density: U1- district of Bab-Ezzouar; U2-center of Algiers; The U3-region Bach-djerrah, S - National Polytechnic University, and two suburbs (PU1- Dely-Brahim and PU2- Bouzaréah). The resulting average daily, monthly and annual averages data of background monitoring of test substances in the air compared to the maximum permissible concentration (MPC). According to WHO standards, the MPC for NO_2 is 0.03 mg / m^3 [11]. SAMASAFIA [1, 15, 17] Networks analyzers are equipped with size of 10 microns. In a further series of investigations was assessed not only by the size of 10 microns, but also other dangerous for breathing (2.5 microns), as well as emitted by diesel engines (less than 1 micron). The two classes of PM10 and PM2.5-particles are strictly regulated by the WHO in developed countries [10]. In accordance with WHO and EU limit values for PM10 standards of technological dust are 0.02 and 0.04 mg / m^3, but in Algeria, they were raised to 0.08 mg / m^3. MPC according to the WHO standards for man-made dust particles PM 2.5 is 0.02 mg / m^3 [10].

Results and discussion.

The data on remote sensing of CO concentration in the troposphere during last decade and its distribution in the north of Algeria are shown in the fig. 1.

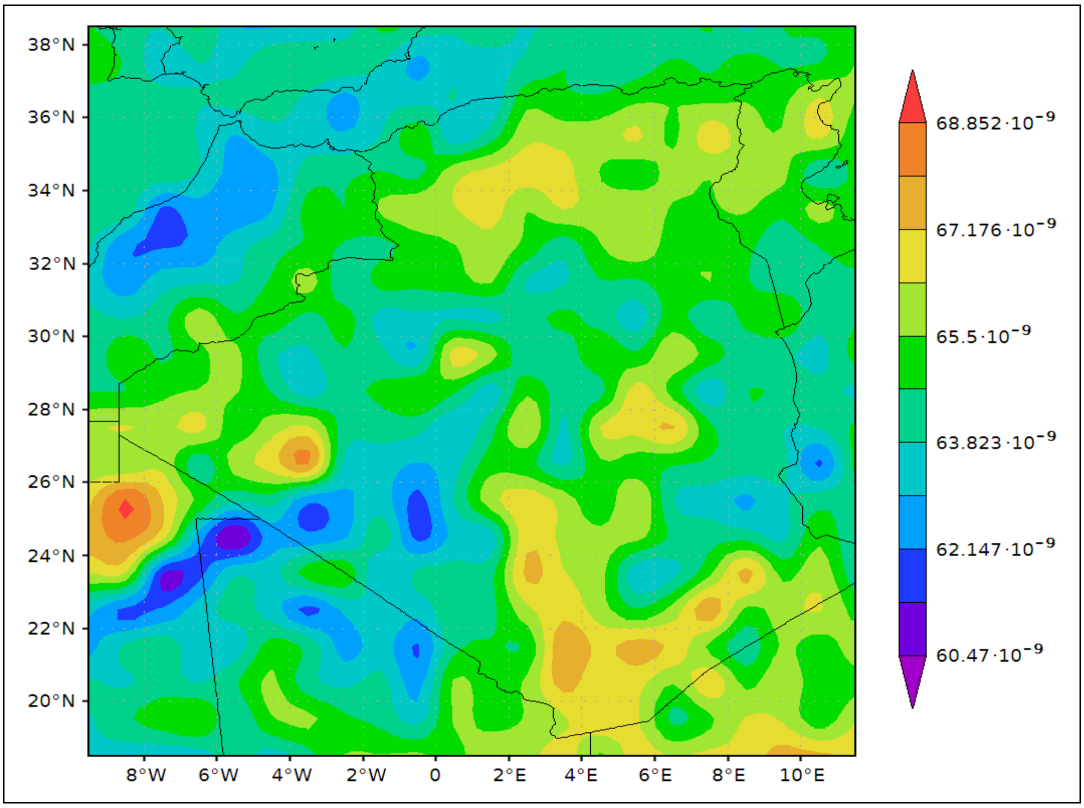

Fig.1. Giovanni web-service processing results: Aura/AIRS CO monthly volume mixing ratio AIRX3STM.005 data product, Algeria, September 2006

The data on annual monitoring of CO concentration in the urban agglomerations of Algiers are shown in the fig. 2.

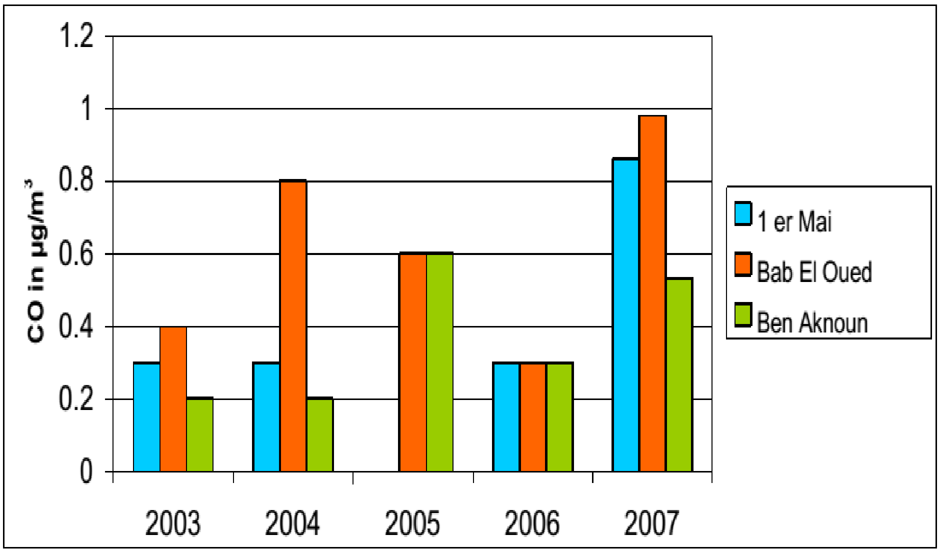

Fig. 2. Annual evolution of carbon monoxide concentration in Grand Algiers [7].

Carbon monoxide results from incomplete combustion of fuels and fuels. In the ambient air, it occurs mainly in the vicinity of the tract of traffic. A decrease of the annual values in 2007 from 0.98 mg/m^3 at Bab El Oued to 0.53 mg/m^3 at Ben Aknoun because of the traffic more disturbed and less rapid. At the level of the urban agglomeration of Algiers, the carbon monoxide is essentially the automotive traffic. Gasoline vehicles are the main sources of emission of the pollutant.

The dynamics of air pollution nitrogen dioxide in Algiers from 2003 to 2009 is shown in fig. 3.

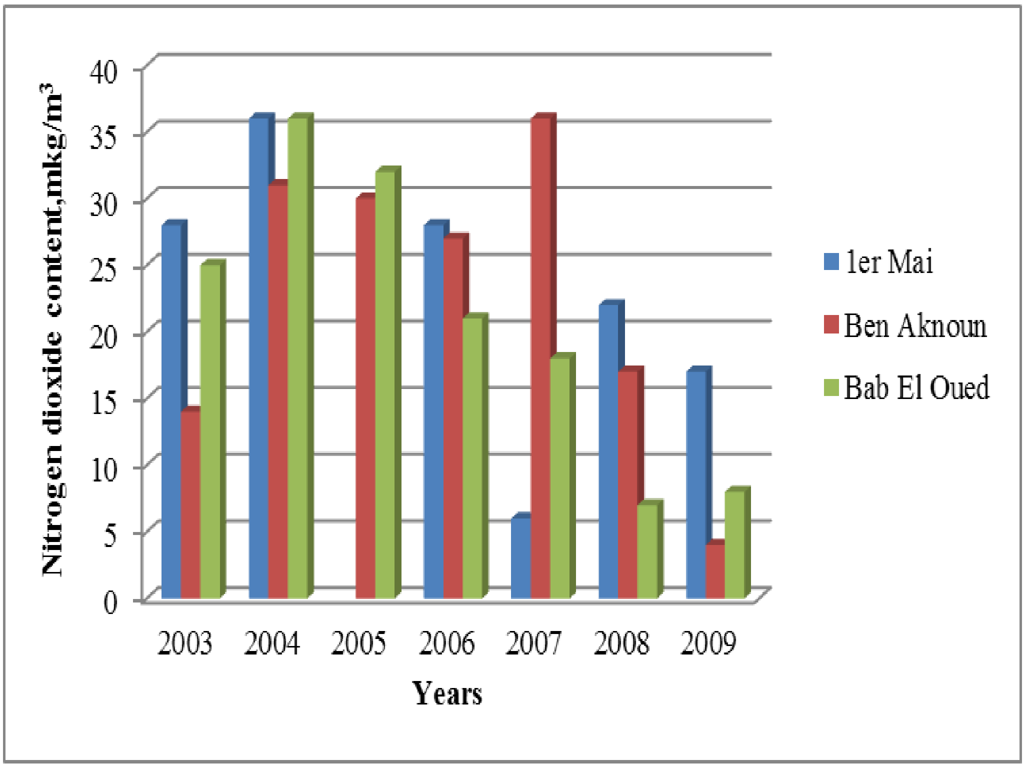

Fig. 3. The dynamics of air pollution with nitrogen dioxide in Grand Algiers

It could be argued that the average concentration of nitrogen dioxide from 2003 to 2007 in the city territory was close to 1 MPC. The annual average levels in NO_2 at the stations of Ben Aknoun and Bab El Oued are very contrasting depending on the environments considered.

The highest contents are recorded on sites in the vicinity of the axes busy in the case of Ben Aknoun (37 μg/m^3), followed by the urban site of Bab El Oued (17 μg/m^3). All sites do not exceed the quality objective, annual (40 μg/m^3).

It is known that nitrogen dioxide entering into a chemical reaction with water vapors converted to nitric acid [11]. In this regard, there is a risk of precipitation of nitric acid rains over Algiers. Necessary to consider that continuous acidification of soils due to the precipitation leads to increased migration of heavy metals in the links: soil - plant, soil - groundwater. Significant environmental risks are also associated with the increase in frequencies of respiratory human disease [12] anthropogenic degradation of soil biocoenosis, reduced crop yield in areas of acid rain [13]. Results of air pollution with dust particles during the years 2003 and 2004 in megapolis are shown in fig. 4.

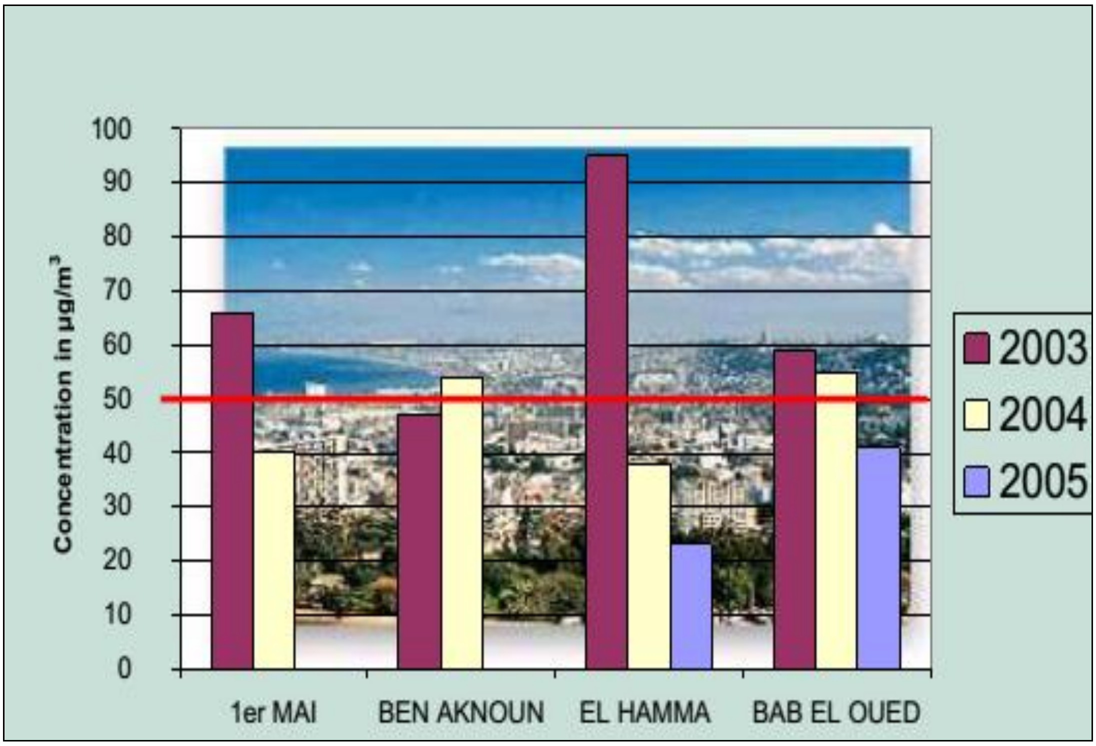

Fig. 4. Annual evolution of dust concentrations in the urban area of Algiers [15]

Comparing the obtained data demonstrates that the content of PM10 dust particles in Algiers is 1.5-4 times higher than the WHO standards. Atmospheric pollution with technogenic dust is associated with fallout of lead and other heavy metals. Data on the content of heavy metals of man-made dusts, selected in two posts of SAMASAFIA are shown in Table 1.

Table 1

Content of heavy metals in the atmosphere of two districts of Grand Algiers, $\mu g / m^3$

Element	Station of Bab El Oued		Station of Ben Aknoun	
	14.08.05	12.09.05	14.08.05	12.09.05
Lead	0.38	0.80	0.05	0.08
Cadmium	0.001	n.d	n.d	n.d
Nickel	1.56	1.67	0.37	0.38

Been recorded a greater pollution with lead, nickel and cadmium in the district of Bab El Oued compared to Ben Aknoun district. Exceeding the European standard (0.2 mg / m^3) reaches up to 4 times. Unfortunately, until now the preferential refueling of vehicles in Algeria used gasoline as an antiknock additive of tetraethyl lead (0.4-0.8 g / l) [16]. However, the presence of such additives leads to the fact that more than half of lead pollution of soil and plants accounted for the share of road transport.

Additional monitoring of technogenic pollution with PM10 was organized in the large settlements of Algiers, where the population is exposed to particles of about 60-70 $\mu g / m^3$. GIS maps of air pollution with PM 1.0; 2.5; 10 microns in Grand Algiers are shown in fig. 5-7.

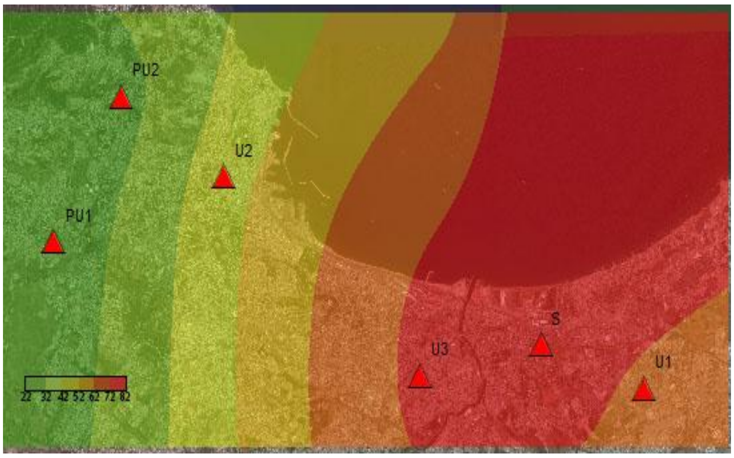

Fig. 5. Air pollution with PM10 in Grand Algiers

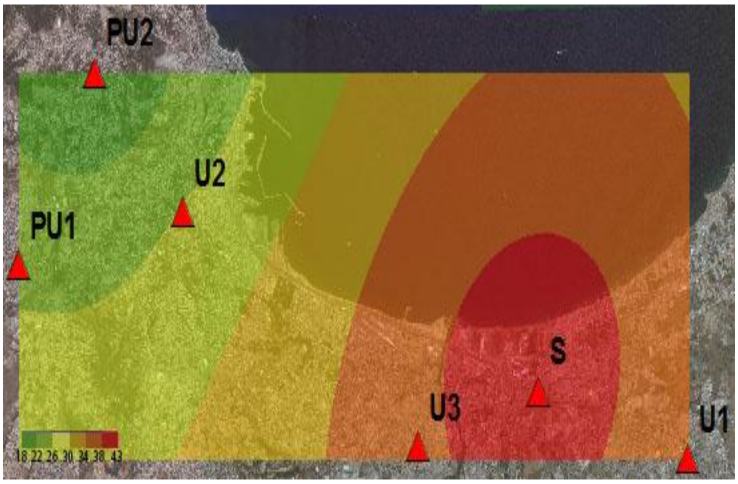

Fig. 6. Air pollution with PM2.5 in Grand Algiers

Pollution levels of ground layer air in the area of Bab-Ezzouar, in the center of Algiers, district Bach-djerrah (point U1, U2 and U3); near the Polytechnic University (S) concentrations of PM-10 and PM-2.5 exceed the international standards. In suburban areas pollution levels was twice less.

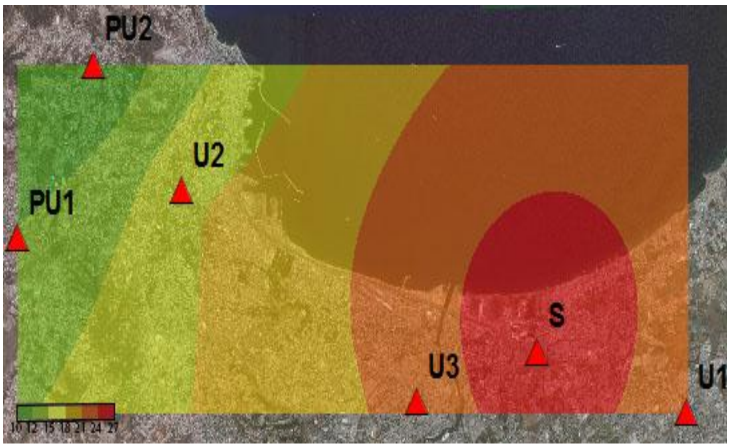

Fig. 7. Air pollution with PM1.0 in Grand Algiers

The highest level of air pollution in the area S is associated with an enormous cluster of cars around the Polytechnic University.

The weak or total absence of vegetation along the streets and in residential areas contributes to a high level of air pollution with dust particles.

Decrease in pollution growth compared to the current level can be expected in the nearest future after the introduction of ecological management measures Cement works companies Meftah and Rais-Hamidou, displacement and disposing of some animal waste repositories in the locality of Oued-Smar. It is possible to wait for better, if develop the measures to reduce the emissions from road transport. One of alternatives is the application of environmentally friendly anti-knock additives. It is known that effective additives based on metal complex compounds for diesel engines [14]. A further measure is to increase the efficiency of automobile engines.

Conclusions.

The obtained results allowed us to draw the following conclusions:

1. At the level of the urban agglomeration of Algiers, the carbon monoxide is essentially the automotive traffic.
2. Revealed the tendency of increased content of nitrogen dioxide in the atmosphere of Algiers which demonstrates the existence of the risk of falling out of nitric acid rain not only within the city limits but also in the scale of grand Algiers.
3. According to GIS mapping, it was found a features of man-made propagation of dust particles size 1.0; 2.5 and 10 microns.
4. Further investigations should be focused on the establishment of a sufficient number of monitoring stations and planning ways to reduce the negative impact on the environment.

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ჰაერის ტექნოლოგიური დაბინძურების ეკოლოგიური რისკი დიდ ალჟირში

ა. ბენსელჰოუბ, მ. ხარიტონოვი, ა. ზაიჩენკო, ს. სტანკევიჩი

რეზიუმე

ბოლო ათწლეულებში დაიმზირება ალჟირის განვითარებისა და ეკონომიკის სწრაფი ზრდა, განსაკუთრებით მისი დედაქალაქის – დიდი ალჟირის, რომელიც წარმოადგენს მთავარ მეგაპოლისს ქვეყანაში. უკონტროლო ურბანიზაცია და ინდუსტრიალიზაცია ხელს უწყობს გარემო პირობების გაუარესებას. სატრანსპორტო საშუალებების რაოდენობის ზრდა დიდ ალჟირში უარყოფითად

ზემოქმედებს ჰაერის ხარისხზე. ჰაერის ხარისხი ქალაქის სხვადასხვა რაიონში დიდ შეშფოთებას იწვევს, რადგანაც დაბინძურება გავლენას ახდენს არამარტო გარემოზე, არამედ მოსახლეობის ჯანმრთელობაზე. ქალაქის ჰაერის ძირითადი გამაჭუჭყიანებელი გამონაბოლქვისა და გარემოსა და ადამიანის ჯანმრთელობაზე ზემოქმედების თვალსაზრისით არის: ნახშირბადის ოქსიდი, აზოტის დიოქსიდი და მტვრის ნაწილაკები. ჩვენი კვლევის მიზანი მდგომარეობს რისკების შეფასებაში, რომლებიც დაკავშირებულია დიდი ალჟირის ატმოსფეროში ტექნოლოგიურ გამონადენებთან დაბინძურების სტაციონარული და მოძრავი წყაროებიდან. აგებულია მტვრის ნაწილაკებით დაბინძურების გის-რუქები 1.0; 2.5 და 10 მკმ დიდ ალჟირში. მიღებული შედეგების საფუძველზე გამოვლენილ იქნა ალჟირის ატმოსფეროში აზოტის დიოქსიდის შემცველობის ზრდის ტენდენცია, რომელმაც შესაძლოა ხელი შეუწყოს აზოტოვან წვიმას არამარტო ქალაქში, არამედ დიდი ალჟირის მასშტაბით. გის – კარტოგრაფიის მიხედვით გამოვლენილია მტვრის ტექნოგენური ნაწილაკების ზომით 1.0; 2.5 და 10 მკმ გავრცელების თავისებურებები. შემდგომი კვლევები მიმართული უნდა იქნას საკმარისი რაოდენობის მონიტორინგის სადგურების შექმნისკენ და გარემოსა და ადამიანის ჯანმრთელობაზე ნეგატიური გავლენის შემცირების გზების დაგეგმარებისკენ.

Экологические риски техногенного загрязнения воздуха в Большом Алжире

А. Бензелхоуб, М.М. Харитонов, А.О. Зайченко, С.А. Станкевич

Резюме

В последние десятилетия наблюдается быстрый экономический рост и развитие Алжира, и особенно его столицы – Большого Алжира, который является главным мегаполисом страны. Неконтролируемая урбанизация и индустриализация способствуют ухудшению окружающей среды. Увеличение количества транспортных средств в Большом Алжире негативно влияет на качество воздуха. Качество воздуха в городских районах представляет собой серьезную озабоченность, принимая во внимание влияние загрязнения на не только на окружающую среду, но и на здоровье жителей. Основными загрязнителями городского воздуха с точки зрения выбросов и воздействия на окружающую среду и здоровье человека являются: окись углерода, двуокись азота и пылевые частицы (ПЧ). Цель нашего исследования заключалась в оценке рисков, связанных с техногенными выбросами в атмосферу Большого Алжира от стационарных и передвижных источников загрязнения. Построены ГИС-карты загрязнения воздуха ПЧ 1.0; 2.5 и 10 микрон в Большом Алжире. На основании полученных результатов была установлена тенденция увеличения содержания диоксида азота в атмосфере Алжира, который может способствовать повышению риска выпадения азотнокислых дождей не только в пределах города, но и в масштабе Большого Алжира. Согласно ГИС-картографирования выявлены особенности распространения техногенных частиц пыли размером 1.0; 2.5 и 10 мкм. Дальнейшие исследования должны быть направлены на обоснование создания достаточного количества станций мониторинга и планирования путей снижения негативного влияния на окружающую среду и здоровье человека.

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Study of Georgian Natural Waters Thermodynamic Parameters Behavior by Means of Original Fluids Bubble Boiling Method

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Abstract

Some years ago the authors suggested new fluids bubble boiling method (BBM) for modeling vertical convection processes having place in the geospheres. Then they were developed in our recent articles for artificial solutions and analyzed by means of T (t), ΔS (T), and T (ρ) experimental curves for definition of admixture of the mass content density of any solution or natural waters. In suggested article, luckily, were obtained optimal values of the liquid volume, the heating intensity, and temperature measurement frequency at any solution concentration allowed us, without waste of time and any trouble, to work out the original method BBM for modeling of above mentioned geophysical convective motions in the laboratory conditions and provide at that stage the planned experiments. Thus, it was investigated: the regimes of heating, the first smallest air-vapour micro-bubbles ($d \approx 10^{-2}$ cm), then macro-bubbles ($d \approx 2 \cdot 10^{-1}$ cm) boiling before the end of experiments ($T = T_{max} = T \geq 100\ ^0C$). The experimental curves showed clearly the succession of the regimes: (1) thermal ($T_0 = 10\ ^0C < T < T_1 = 40\ ^0C$); (2) microscale bubbles ($T \leq T_1 = 40\ ^0C$); (3) macroscale bubbles ($T \leq T_2 = 80\ ^0C$); (4) intensive, in the form of some winding vertical bubble-chains ($80\ ^0C < T \leq T_3 = 100\ ^0C$); (5) bubble-projectile ($T \geq T_3 = 100\ ^0C$). To the end of experiments, mean value of loss of liquid mass was equal to about 10 % of the whole mass. At last, it was constructed universal experimental curves, connecting the values of parameters of the liquids at the points of the boiling regimes, changed and obtained three linear curves T (t), ΔS (T), and T (ρ), and sinusoidal ΔT (Δt) one for natural waters of Georgia and artificial chemical matter solutions of any density at the points of the regime break.
Unlike the Nu-Ra case, our BBM allows to experimenter for short time to determine main thermodynamic parameters, avoid technical difficulties of preparation, and carry out measuring, especially near the breaking points of the regimes, and recommend it to corresponding physical-chemical laboratories.

Keywords: vertical convection, incipience, one-dimensional, two-phase flow, temperature, entropy, points of discontinuity, Archimedes force, bubble boiling, vapour, beaker.

> Thermodynamic laws are empirical, therefore they may be considered with different ways, which are equivalent… It would be great mistake to be carried away mathematics and forget about physics. Ryogo Kubo.

Introduction

It is well known lots of scientific works devoted to the investigation of convective motions in different geospheres such as thermals and convective clouds, thermal waters, gazers, volcanos, many technical applications, sufficiently small scale geophysical phenomena, etc. [1-28]. Our laboratory experiments provided earlier on the water solutions of NaCl, $C_6H_{12}O_6$, other matters of different concentrations, and some natural waters of Georgia showed some new results [25-28]. The liquids bubble boiling method (BBM) have presented in the more complete form. New results analyzed in the context of the entropy change regimes allowed us to confirm their reliability. A work, as a priest gravity and Archimedes forces. The last part of the article is dwelled on the **optimal** characteristics of the modelled system – natural waters and artificial waters solutions – significant peculiarities of these simple models. One may say, that even this simplest case of one-dimension vertical motion reveals a **rich wealth** of considered phenomena.

II. Laboratory experiments

(a) Here are obtained and analyzed results of systematic laboratory experiments on the modeling of the vertical convection process and independent investigations of the thermodynamic parameters of the Georgian thermal waters by means of suggested original method BBM. The experiments, carried out on a samples of natural waters, are following: the spring of the Berebis Church (t. Tsalka); the Black Sea water (t. Anacklia); sulphuric waters (lake Lisi, Tbilisi); sulphuric waters (Bath-Houses, old Tbilisi); mineral waters (m/c Kazbegi); spring waters of m. Mtatsminda Pantheon (over Cap.Tbilisi) (according to the annals data, sacred waters sprang in the Mtatsminda Pantheon, thanks to the urgent prayers of the Pantheons priest, David Garejeli (VI a.Chr.))

Results of these experiments are illustrated in Figs. 1-5.

Fig. 1 shows thermodynamic picture of the Berebis Church drinking waters sample (t. Tsalka) on the basis of our bubble boiling method.

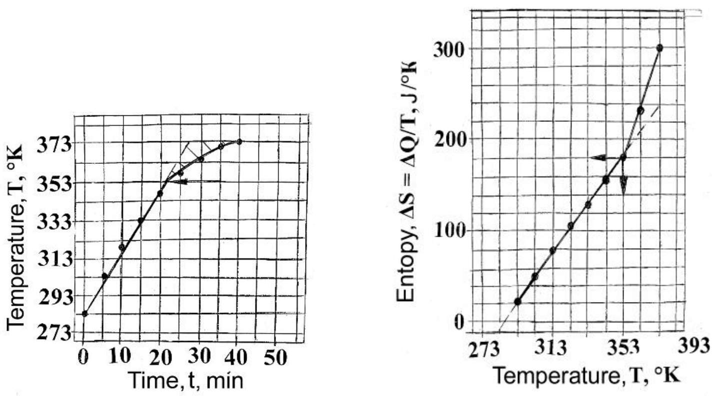


Fig. 1. A sample of the spring at the Berebis Church (t. Tsalka).

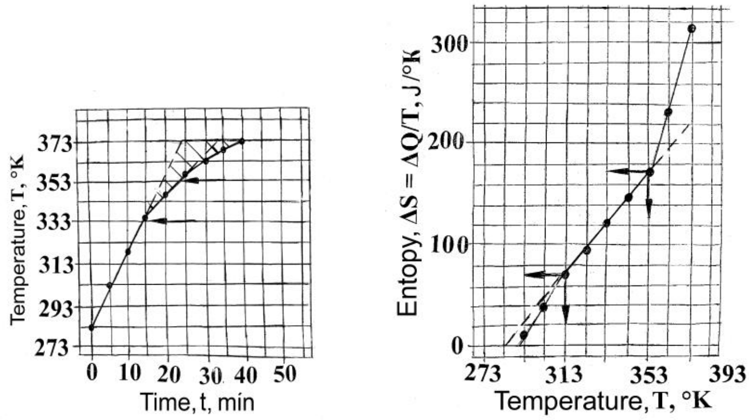
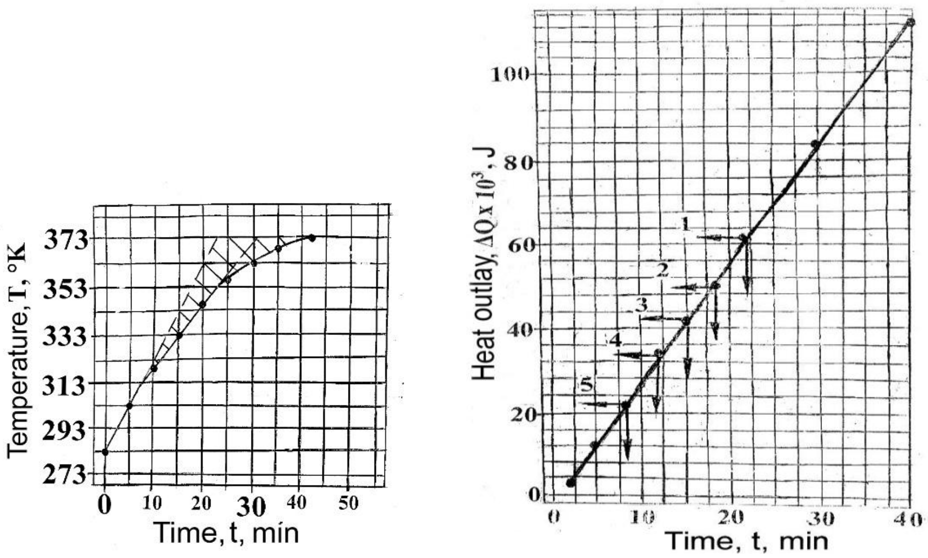


Fig. 2. The Lake Lisi sulphuric waters sample (Tbilisi)

Analogical result was obtained for the sulphuric waters sample of the old Tbilisi range (Abanoebis Ubani) by means of our bubble boiling method.
Results of constructions of dependence between the characteristics of studied natural waters at the breaking (changes of boiling regimes, kink when takes place large-scale vertical convection) points – the second kind discontinuities during the bubble boiling process (Figs. 1-5).

b. Special sample of well-known in Kakheti Region of Georgia, r/c Velistsikhe, a grapes juice – badaghi – natural glucose of different values of density.



(a) (b)

Fig. 3. Kakheti, t. Velistsikhe, (badaghi – $C_6H_{12}O_6$ solution): (a) – max density of glucose; (b) – outlayed heat against the time of heating of badaghi solutions.

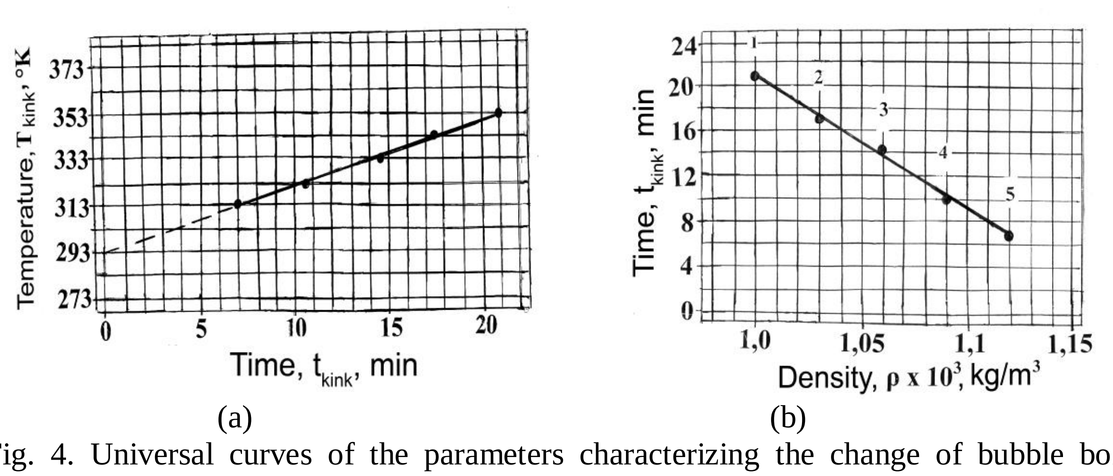
Fig. 3b shows the ΔQ(t) function for glucose water solutions of different densities. The points of change of bubble boiling regime are indicated by the **pair of pointers** (1, 2, 3, 4, 5). Experiments carried out by the bubble boiling method on artificial solutions and natural water samples showed that measuring of some parameter change gives us sufficiently full and precise information about the **changes of heating and bubble boiling regimes** values of respective bubble boiling temperature, density and other thermodynamic parameters of investigated object.

For example, the water solutions of NaCl and a honey of the same density (ρ = 1.03 g/cm^3) have equal values both of all three measured values of parameters (T, ρ, t) and calculated values of the entropy $\Delta S(T)$. Thus, the investigated fluid, having volume equal 300 ml, is heated from below; the temperature is measured in time, T(t), beginning from initial value, T(0), through all studies of formation of bubble boiling regime having fix the two by two points of the second kind of discontinuities (“kink”, “break”), T_1 and T_2, before achievement of the last, most intensive bubble boiling, T_3 = 100 ^{0}C. After detail analysis of the results of these experiments we constructed two groups of the experimental curves, T(t), $\Delta S(T)$, and T(ρ): (a) – concrete values, and (b) – for the points of the discontinuity. These experimental curves have universal character. It is evident, that using suggested method, these universal experimental curves, one can determine unknown values of the density, characteristics of each stage of investigated liquids for modelling of vertical convection in nature: in the atmosphere, oceans, volcanoes, etc. It is necessary to note that investigation of this process, having great scientific interest, may be qualified as independent significant problem. In this light, suggested original simple and cheap method may recommend to physical and chemical laboratories.

III. Construction of universal curves at discontinuities thermodynamic main parameters.

The (T, t), (ΔS, T), and (t, ρ) experimental curves of (for any samples of liquids) investigated liquids helped us to obtain following results. (a) the temperature-time curves fix all points of bubble boiling regime change (break / kink) which are between **T = 40 ^{0}C** (solution with density $\rho \geq$ 1.2 g/cm^3) and **T = 80 ^{0}C** (clear water, ρ = 1 g/cm^3) (see Figs. 1-5); (b) the entropy-temperature curves show only the latter point **T = 80 ^{0}C**; these curves, having make the others round, grow **linearly** before the point T = 80 ^{0}C and then, bending to the right, continue their grow to the **T = 100 ^{0}C**, but with diminishing rate (Figs. 1, 2, 5a).

Below, Fig. 4 represents the universal experimental curves connecting with each other the main thermodynamic parameters points of the second kind of discontinuity (kink, break)



(a) (b)

Fig. 4. Universal curves of the parameters characterizing the change of bubble boiling regimes:

(a) – $(T, t)_{kink}$; **(b)** – $(t, \rho)_{kink}$; **1**– spring of r/c Tsalka(21.5 min); **2**– Black Sea’s water, t. Anaklia (17 min); **3** – sulphuric water of the Lisi Lake (14.5 min); **4** – sulphuric water of Tbilisi old region’s bath-houses (11 min); **5** – honey solution (7 min).

The data of parameters of investigated liquids, presented above in Fig. 4, illustrate linear character of the functions (T, t) and (ρ, t) at the points of change of the bubble-boiling regime (usually noted by terms: “kink” or ”break”, or “discontinuity of the second kind”) for any natural liquids or artificial solutions. Their corresponding empirical formulas have following :

$$T_{изл} = T_0 + \alpha t, \qquad T_0 = 19^0C, \qquad \alpha = 2.8^0C/min;$$

$$(\rho_{изл} - 1)/a + t_{изл}/b = 1, \quad a = 0.18\ g/cm^3, \quad b = 21.5^0C. \qquad (1)$$

Repeated boiling experiments with artificial water solutions or natural waters shoe that measured value of their any parameter (for example, $T_{kink}(t_{kink})$) gives us sufficiently right an d precise information about bubble-boiling regime and unknown parameter (for example, density, ρ) of studied liquids (natural/thermal/mineral waters).
For example, the water solutions of an edible salt (NaCl) and a honey ($C_6H_{12}O_6$) of the same volumetric density (ρ = 1.03 g/cm^3) on the curves $T_{kink}(\rho_{kink})$ and $T_{kink}(t_{kink})$ have the same reading of experimentally measured values of three parameters (T, ρ, t) and calculated values of entropy, $\Delta S_{kink}(T_{kink})$. Full picture give the control experiments on the specially prepared samples of water solutions of a honey with following proportion ((1:2:3:4:5) g) / (300 g of water) confirmed once more obtained earlier (Fig. 3 in [26]) conformity to natural laws (T_{kink} /ρ_{kink}):
80^0C/1.0 g/cm^3; 70^0C /1.02 g/cm^3; 60^0C /1.07 g/cm^3; 50^0C /1.08 g/cm^3; 40^0C /1.27 g/cm^3. (2)
Thus, suggested bubble boiling method allows us during ~ 50 min obtain a density, temperature, entropy, intensity of heating any solution at the points of change of the thermal-bubble-boiling regimes, respectively by means of the system experimental curves.

IV. Heating of fluids from below – fast straight absorption process.
Using equality of the heating flux through the bottom of the vessel

$$dQ = \lambda\,(T_k - T)/\delta\ Sdt, \qquad (3)$$

to the quantity of the heat $dQ = mc\ dT$, spent on the heating of the m mass of liquid, we obtain the simple differential equation

$$\lambda\,(T_k - T)/\delta\ Sdt = mc\ dT, \qquad (4)$$

at the conditions:

$$t = 0,\ T = T_0;\ t = \tau,\ \ T = T_{k,} \qquad (5)$$

where T_k is a temperature of the bottom of the chemical vessel, λ – is the vessel's material thermal conductivity, δ and S are the thickness and the square of the vessel's bottom, respectively; the temperature homogeneity at the whole bottom surface was achieved by means of thin metallic plate between the vessel's bottom and an electric stove. Analytical solution of differential equation (4) is

$$T(t) = T_k + (T_0 - T_k)\, e^{-(\lambda S/\delta mc)t}\,. \qquad (6)$$

Formula (6) describes initial stage of heating of fluid as a solid body, where a heat conductivity prevails over convection and, of course, latter is absent, a circumstance expressed by means of an exponential multiplier of formula (6); the first and third addendums of equation (4) consider as most important ones. Using numerical values of parameters given in (11), one obtains for exponent:

$$\lambda S/\delta\ mc = 0.007 \cdot 11.9/0.3 \cdot 300 \cdot 4.19\ s^{-1} = 7 \cdot 10^{-7}\ s^{-1} \approx 0. \qquad (6')$$

Temperature of liquid achieves the point $T = T_k = 100^0C$. This is a process **of heating of liquid** modelled by means of criterions of similarity **Fo** and **Pe,** and in case of its **boiling** – with **Nu** and **Ra,** [9, 15-18]. Here we note, that construction of experimental curves $(T, t)_{kink}$, $(\Delta S, T)_{kink}$, and $(T, \rho)_{kink}$ allowed us to obtain some new results on the physical properties of the investigated fluids (natural waters, sea water, artificial solutions etc.). They are following: changing of regimes (at the surface of beaker's bottom T ~ 108 ^0C) – over the bottom of beaker thermals (20 ^0C), microscale bubble boiling (40 ^0C), macroscale bubble boiling (80 ^0C), intensive heavy turbulent in form of vertical bubbles pillars (100 ^0C), saturated vaporization (100, 8 ^0C).

V. Loss of heat by fluid – slow reverse process. Let us consider heat conduction, Q, through lateral cylindrical wall of a beaker

$$Q = \lambda \frac{T - T_a}{d} D, \qquad (7)$$

where λ is coefficient of heat conduction of beaker's lateral wall; d – thickness of beaker's lateral wall; D – square of beaker's lateral wall; T – temperature of beaker-liquid system); T_a – temperature of laboratory air (constant during experiment at open window).
In more concrete, Fourier law, form, of beaker's

$$Q = -\lambda \frac{dT}{dr} 2\pi Rh, \qquad (8)$$

where dT/dr is temperature gradient in cylindrical wall of the beaker; R is a radius of the beaker's circle bottom; h is thickness of liquid's layer in a beaker.
Consider two cases of boundary conditions:

(a) $dT / dr < 0$, $(T < T_a)$

$$Q_1 = mc\,\Delta T + \Delta m\,L + \lambda \frac{dT}{dr} 2\pi Rh + Mc'\Delta T; \qquad (9)$$

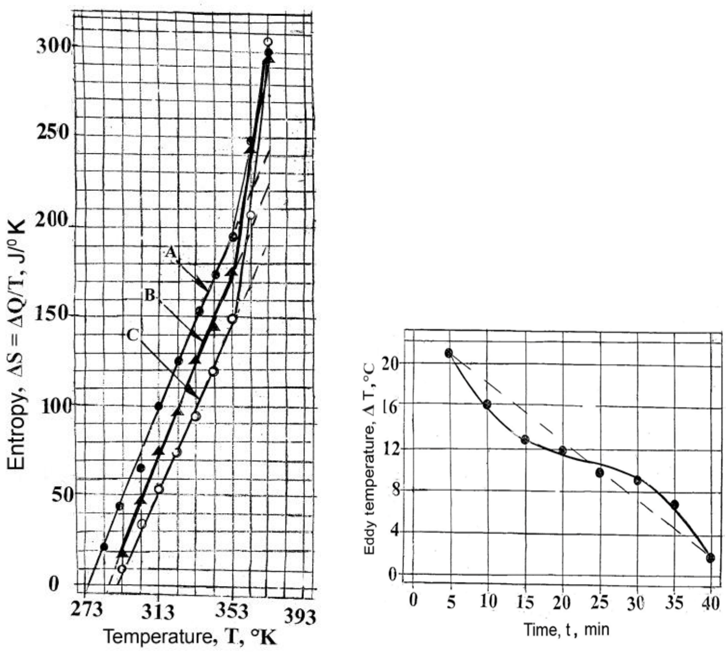
(b) $dT / dr = 0$ (cylindrical wall is isolated),

$$Q_2 = mc\,\Delta T + \Delta m\,L + Mc'\Delta T, \qquad (10)$$

where M is the mass of the glass; $c' = 0.779$ J / (g · K) is the glass heat capacity; usual glass $\lambda_1 = 0.7$ J / (m · s·K) = 0.007 J / (cm · s · K); quartz glass $\lambda_2 = 1.36$ J / (m · s·K) = 0.0136 J / (cm · s · K); $\Delta T = 90^0C$; d = 0.3 cm; $S = \pi R^2 = 37.37$ cm^2, h = 8 cm, m = 300 g; $\Delta m = 30$ g; $R_{bot} = 3.45$ cm; $\rho = 1$ g / cm^3; c = 1 cal / g · K = 4.19 J / (g · K); $L = 2.25 \cdot 10^3$ J / g; $W_0 = 103$ J / s, $W_{bot} = 47$ J / s. (11)

VI a. **Peculiarity of behavior of the liquid temperature under their heating at different intensity.**

Changing rates of liquids heating process we determined relation between scales of parameters of studied liquids – time intervals (Δt); temperature interval (ΔT); mass of liquid (Δm); form and size of beaker (cylinder, ΔV); interval of solution density ($\Delta \rho$); intensity of heating (q). Obtained values are following: $\Delta t = 5$ min; $\Delta T = 5\ ^0C$; $\Delta m = 300$ g; $\Delta V = 10^3$ cm^3; $\Delta \rho = (1 \div 1.2)$ g cm^{-3}; q = 47 J s^{-1}.



(a) (b)

Fig. 5. **(a)** – entropy-temperature dependence, ΔS (T); (b) – temperature-time, ΔT (t), dependence at the heating intensity, respectively: q = 35 J/s (low branch), q = 47 J/s (intermediate branch), and q = 75 J/s (upper branch); **(b)** – the sinusoidal temperature-time dependence ΔT (t), obtained for every successive time interval Δt = 5 min, at the intensity of heating q = 47 J/s).

The empirical formula of the temperature-time dependence**,** T (t), for the r/c Tsalka natural thermal waters sample has following sinusoidal form:

$$T(t)_{emp} = T_0 + (T_b - T_0)\ (t/\tau)\ \bar{A}\ \sin 2\pi(t/\tau)\,, \qquad (12)$$

where $\bar{A} \approx 2\ ^0K$ and τ = 35 min are the mean value of the amplitude and the period of sinusoidal change of temperature, respectively; T_0 and T_b are the initial temperature and the point of boiling of liquid, respectively.

It was possible to measure the average temperature during providing of experiment with an accuracy to ± 1 ^{0}C by using of both optimal quantity mass of solution and time interval of measuring. The latter was in following: the mass of a liquid was approximated to the m = 300 g = 300 ml which boiled between 40 min with intensity, water and time interval about nine points between laboratory temperature T_0 = 10 ^{0}C and then as initial constant one before beginning of every experiment (by using refrigerator). As it is was shown in this work, whole process of thermodynamic state of liquids, heating from below, is characterized, quantitatively, and, as well as qualitatively, by temperatures T_0 = 10 ^{0}C, $T_{1,\,kink}$ = 40 ^{0}C, $T_{2,\,kink}$ = 80 ^{0}C, T_b = 100 ^{0}C, T_{bot}, and T_{up} – overheating of fluid at the rigid bottom of the vessel and free upper surface of liquid, respectively.

Fig. IA shows that the curves: **(a)** ΔS (T), and sinus **(b)** ΔT (Δt), reveal only one point of the second kind of discontinuity (at 80 ^{0}C = 353 ^{0}K). Only the entropy displays effective growth with temperature $\Delta S(T)$ (at different intensities of heating of liquid, q),

VI b. Energetic characteristics of liquids bubble-boiling process obtained in laboratory.

The Table 1 shows data obtained on the base of optimal values of parameters of the thermodynamic system (samples of studied waters): q = 47 J – the intensity of an electrical source; m = 300 g – the mass of a liquid; V =10^3 cm^3 – the volume of a beaker; ΔT = 5 ^{0}C; Δt = 5 min.

Table 1. Energetic characteristics of heating of clear thermal water from r/c Tsalka
(q = 47 J/s, m = 300 g, V = 10^3 cm^3, ΔT = 5 ^{0}C, Δt = 5 min)

T, ^{0}C	t, min	Heat quality, Q_n, J	Share of Q_n/Q,	Q_n/Q, %
10	0	–	–	–
40	9	25320	25320/112800	22.5
80	21.5	35310	35310/112800	31.3
100	40	52170	52170/112800	46.2

VII. Fragments from discussion of known numerical modeling of large-scale convective motions in atmosphere and ocean [22].

During intensive and heavy turbulent boiling part of liquid, the entropy **curve** increase shows slowing-down to the end of experiment; that means that heat energy spends almost completely for evaporation of liquid. The following quotations from article [22] as we think would be very useful and relevant at discussion of results of our experiments: **(1)** Two general expressions are derived for a rate of entropy production due to thermal and viscous dissipation (turbulent dissipation) in a fluid system. It is shown with these expressions, that maximum entropy production in the Earth's climate systems suggested by Paltridge, as well as maximum transport properties of heat or momentum in a turbulent system suggested by Malkus and Busse, correspond to a state in which the rate of entropy production due to the turbulent dissipation is at a maximum…For **thermal convection** of a fluid layer **heated from below** (our case), Malkus (1954) suggested that the observed mean state represents a state of maximum convective heat transport. For **turbulent flow** of a fluid layer **under a simple shear,** Malkus (1956) and Busse (1970) suggested that the realized state corresponds to a state with a maximum rate of momentum transport. **(2)** Two developments should be mentioned here. One is a theoretical investigation of MEP (maximum entropy production) based on statistical interpretation of entropy (Dewar, 2003). Information theory (Jaynes, 1957) showed that the most probable macroscopic steady state is one with MEP among all other possible states, given the boundary conditions and mass and energy conservation laws. This statistical approach will broaden the horizons between MEP and information theory (Lorenz, 2002, 2003). It will also be a theoretical basis for the energetic explanation shown above since the between the heat energy and the kinetic energy is only of statistical significance. That is, spontaneous conversion of the heat energy into the kinetic energy is in principle possible, but is just extremely improbable. **(3**) Another development has been made with numerical model simulations: (a) numerical experiments on Bénard-type experiments of thermal convection in a rotating fluid system – obtaining **a kink in the rate of entropy production between two different convection regimes.** One founded that irreversible changes always occur in the direction of the increase of entropy production (see [22]) (compare with our experimental results, Figs. 1-5, !).

VIII. Heating balance of the liquids' bubble boiling process.

Defined more precisely with additional information, the method allow better understand both the peculiarities of liquids bubble boiling kinetics and their regimes changing high rate:
(1) thermals (at $T_0 = 10\ ^0C < T < T_1 = 40\ ^0C$); (2) microscale bubbles (at $T \le T_1 = 40\ ^0C$); (3) macroscale bubbles (at $T \le T_2 = 80\ ^0C$); (4) intensive, in the form of some winding vertical bubble-chains ($80\ ^0C < T \le T_3 = 100\ ^0C$) – wellknown in literature intermediate structure – "bubbly-slug flow" [13] ; (5) bubble-projectile ($T \ge T_3 = 100\ ^0C$), [13],

It is suggested improved defined more precisely simple laboratory method of definition of admixture density of any fluids or water solutions. We can determine a degree of **purity** of liquids using experimentally obtained universal curve $T_{kink}(\rho_{kink})$ (see Fig. 3, [26, 25]), (lower mark "kink" was used by Ozawa et al. [22]). Results of constructions of dependence between the characteristics of natural waters or artificial solutions at the breaking points (changing of boiling regimes) show a linear character of all experimental curves $(T, t)_{kink}$, $(\Delta S, T)_{kink}$, $(t, \rho)_{kink}$. As a rule, the term "breaking" is used in thermodynamics and special literature (for example, cited here, [5, 7, 10, 13, 19, 30, 31]), the authors of article [22] use term "kink" to the change of large scale thermal convection regimes in atmosphere and in oceanic general circulation, [32].

Latter data are in accordance with our modelling results (Figs. 1-5).

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საქართველოს ბუნებრივი წყლების ძირითადი თერმოდინამიკური პარამეტრების ყოფაქცევის შესწავლა სითხის ბუშტოვანი დუღილის ორიგინალური მეთოდით

ა. გველესიანი, ნ. ჭიაბრიშვილი

რეზიუმე

უკანასკნელ წლებში ავტორების მიერ შემუშავებული ბუშტოვანი დუღილის ორიგინალური მეთოდი საშუალებას იძლევა ლაბორატორიული წყალხსნარების და ბუნებრივი თერმალური (მინერალური) წყლების მახასიათებელი პარამეტრების – სიმკვრივის, ტემპერატურის, ენტროპიის და დროის მომენტების – ურთიერთ კავშირის დადგენა დუღილის რეჟიმის გარდატეხის წერტილებში მოცემული უნივერსალური ექსპერიმენტული მრუდთა სისტემის მეშვეობით.

მიღებულია ოპტიმალური შეფარდებები საკვლევი სითხის მოცულობასა და მიწოდებული სითბოს ნაკადის ინტენსივობის შორის. კონტროლირდება ბუშტების წარმოშობის პროცესი სათანადოდ მიკრო-მასშტაბური რადიუსის $R \leq 10^{-2}$ სმ ზომიდან მაკრო-მასშტაბური რადიუსის $R \geq 0.2$ სმ სმ ზომამდე. დადგენილია ექსპერიმენტული მრუდების გარდატეხა (უწყვეტობის მეორე გვარის წყვეტა) $T = 40 - 80^0$ C ინტერვალში. მიღებული ექსპერიმენტული მრუდები $T(\rho)$, $T(t)$, $\Delta S(T)$ და დეტალური ცხრილები სრულ ინფორმაციას იძლევა თერმოდინამიკური სისტემის სიმკვრივესა და სხვა მახასიათებელი პარამეტრის შესახებ. გაანალიზებულია ენტროპიის მნიშვნელობა სითხის დუღილის რეჟიმების ცვლილების მომენტების დაზუსტებაში, რომლებიც ტემპერატურის დროში $T(t)$ მრუდების მეშვეობითაა დადგენილი, განსაკუთრებით მხურვალე ბუშტოვანი დუღილის პროცესის ტემპერატურის $80 - 100^0$ C ინტერვალში. აქ ადგილი აქვს ბუშტების ჯაჭვისებრი მდგრადი ვერტიკალური კლაკნილი სვეტების სახით მხურვალე ინტენსიური დუღილი.

მიღებული ექსპერიმენტული მრუდები საშუალებას იძლევა თერმოდინამიკური მდგომარეობის რეჟიმების და მათი ცვლილების შემდეგი თანმიმდევრობით განხილვა: **(1)** – თვალით უხილავი, თავისუფალი კონვექციის (თერმიკული) რეჟიმი, ტემპერატურის $T_0 \geq 0^0$ C $< T_1 \leq 40\ ^0$ C ინტერვალში; **(2)** – მცირე ზომის ბუშტოვანი ($R_1 \leq 10^{-2}$ სმ) დუღილის რეჟიმი, $T \leq T_1 = 40\ ^0$ C ინტერვალში; **(3) –** $R_2 \leq 10^{-1}$ სმ რადიუსის მქონე ბუშტოვანი დუღილის რეჟიმი, $T \leq T_2 = 80\ ^0$ C ინტერვალში; **(4) –** $2 \cdot 10^{-1} \approx R_3 > 10^{-1}$ სმ რადიუსის მქონე ინტენსიური ბუშტოვანი დუღილის რეჟიმი, $T_2 = 80^0$ C $< T < T_3 = 100^0$ C ინტერვალში;

(5) –- ბუშტოვან-ჭურვისებრი დუღილის რეჟიმი, სითხის ტემპერატურის $T \geq T_3 = 100\ ^0$C ინტერვალში; ექსპერიმენტის დასასრულს სითხის მასის დანაკლისი, Δm, საშუალოდ შეადგენდა მთელი მასის 10 % -ს ($\Delta m \approx 30$ გ.). შემდგომი: **(6)** – დისპერსიული და **(7)** – ორთქლისებრი დუღილის რეჟიმების შესწავლა არ შეადგენდა პროგრამის საგანს.

მეთოდი საშუალებასიძლევა საკმაოდ სწრაფად და ზუსტად დადგინდეს ნებისმიერი ნივთიერების წყალხსნარის სიმკვრივე, ტემპერატურა, ენტროპია, დრო, სითბოს ინტენსივობა დუღილის რეჟიმების გარდატეხის წერტილებში, შრომატევადი Nu-Ra მრუდების აგების აუცილებლობის გარეშე. და ბოლოს, მეთოდის სიიაფე და სიმარტივე იმედს იძლევა რეკომენდაცია გაეწიოს სხვადასხვა დონის სასწავლო და ფიზიკა-ქიმიურ კვლევით ლაბორატორიებს გასაცნობად.

Исследование основных термодинамических параметровприродных вод Грузии оригинальным методомпузырькового кипения жидкости

А.И. Гвелесиани, Н.Г. Чиабришвили

Резюме

Получены универсальнаые экспериментальные кривые для определения плотности содержания примеси в жидкости любого раствора или естественных термальных вод оригинальным методом пузырькового кипениях. Получены оптимальные соотношения между объёмом исследуемой жидкости и интенсивностью подаваемого теплового потока. Контролируется процесс появления пузырьков от мельчайших (микромасштабных) размеров, диаметром порядка 10^{-2} см, до крупных ~ 0,2 см. Установлено по-парное существование разрывов непрерывности второго рода в интервале (40-80) ^{0}C. Полученные экспериментальные кривые, T (ρ), T (t), and ΔS (T), и детальные таблицы дают полную информацию о плотности термодинамической системы и других её характерных параметрах. После T(t) вступает в роль ΔS (T) в установлении моментов смены режимов кипения жидкости, в особенности во второй половине процесса бурного пузырькового кипения в виде устойчивых извивающихся вертикальных цепей пузырьков пар-воздух (впечатляющих “пузырьковых шлангов”!).
Экспериментальные кривые наглядно обнаруживают смену режимов: (1) – режим свободной конвекции (термиковый, от 0 ^{0}C до 40 ^{0}C (2) – режим мельчайших газовых пузырьков при $T \leq T_1 = 40\ ^0$C; (3) – крупнопузырьковый режим с ярко выраженным изломом T (t) и ΔS (T) кривых при $T \leq T_2 = 80\ ^0$C; (4) – режим бурного крупно-пузырьковогого кипения в виде ряда вертикальных цепей, столбиков в интервале температур 80^{0}C - 100^{0}C; (5) – режим пузырьково-снарядного кипения при $T_3 = 100\ ^0$C; (5) – режим пузырьково-снарядного кипения при $T_3 = 100\ ^0$ C; в среднем к концу экспериментов – с 10 %-й убылью всей массы жидкости (Δm 30 г.). Последующие режимы: (6) – дисперсный и (7) – парообразования, не входили в программу настоящих исследований.
Метод позволяет за короткое время достаточно точно определить плотность, температуру, энтропию, интенсивность нагрева водного раствора любого вещества в переходных точках режимов кипения, обойти трудоёмкие построения Nu-Ra кривых. Наконец, простота и дешевизна разработанного метода позволяет рекомендовать его разного уровня учебным и исследовательским физико-химическим лабораториям для ознакомления.

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Content of Some Heavy Metals in Soils of Kakheti Region

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Abstract

Content of some heavy metals (Cu, Zn, Pb, Cd) in soils and surface waters of Kakheti region is considered in the work. Physical and chemical parameters (pH, electric conductivity, salt content, temperature, amount of water-dissolved oxygen) of river water were determined in field conditions. In particular cases in soil samples were identified high contents of lead and zinc, which several times exceed their appropriate maximum allowable concentrations (MAC).

Key words: soil pollution, natural water, heavy metals, ecosystems, maximum allowable concentration (MAC)

Introduction

Kakheti is the eastern border region of Georgia. It adjoins in the north with Russian Federation, while in the east and south with Azerbaijan republic. Area of Kakheti region is 11,310 thou. sq. km, that is 17,5% of Georgian territory. According to January 1st, 2013 data of GEOSTAT (National Statistics Bureau of Georgia) there are 405 thousand people in Kakheti that equals to 9% of whole population of country. According to this parameter, Kakheti is on the fourth place, after Imereti, Kvemo (Lower) Kartli and Samegrelo – Zemo (Upper) Svaneti. There are 9 cities and 276 villages in the region, and Telavi is the administrative center of Kakheti. Location of Kakheti, in particular, vicinity to Tbilisi and common border with Azerbaijan republic causes the role of this region as of transport corridor and creates good basis for economic cooperation between countries in case of increase of tourist flow.

11-12% of forest area of Georgia falls on Kakheti region. 30% of Kakheti territory is covered by forests and in this regard it is on third place in Georgia compared with other regions. 98% of regional forests belongs to category of mountain forests, which are of great ecological and economic importance.

Kakheti is main agricultural region, and mineral fertilizers and toxic chemicals are intensely used here. Lots of toxic agents are added to soil along with fertilizers. For instance, due to high rates of systematic use of phosphorous fertilizers takes place soil pollution by heavy metals – lead, cadmium, copper, chrome, zinc that created great threat to the health of humans and animals. Most of potassium fertilizers causes environment pollution by chlorine and sodium. Also should be mentioned the fact that there are a lot of uncontrolled dumps in Kakheti region, which usually are located near settlements in village gorges (where rivers flow frequently) or near pasture lands. All this also creates the threat to health of population resident in the region.

Proceeding from abovementioned is obvious that there are a lot of sources of ecosystem pollution (including soil contamination) in the selected region. That's why we decided that assessment of soil contamination degree by heavy metals is one of the priority problems of Kakheti region. Based on this circumstance the goal of carried out research works was a determination of carcinogenic metals content in soils of some districts of Kakheti, such as Cu, Zn, Pb, Cd, as well as determination of physical and chemical parameters of some surface waters.

Study area, method and data description

Physical-chemical and hydrochemical analyses in Kakheti region were conducted in Sagarejo, Gurjaani and Telavi (Ikalto village) districts, on soil and water analysis samples taken from previously selected observation points.

For correct assessment of pollution degree on territories under study we selected object of study, which played the role of background (Gombori, 1800 meters above sea level) that was conditioned by the fact that this observation point is at a distance from all types of pollution sources. In some cases obtained results were compared with maximum allowable concentrations (MAC) of determined components; sometimes, for comparison we turned to such parameters as tentative (estimated) allowable concentrations (TAC) of heavy metals in soils. Physical-chemical parameters (pH, electric conductivity, salt content, temperature, amount of water-dissolved oxygen) of river water were measured in situ (in field conditions), by means of portable equipment.

Following methods and equipment were used in studies for determination of researched components:

1. Ion-selective chromatography (ICS-100) *ISO100304-1:2007*

2. Spectrophotometry SPECORD 205*ISO7150-1:2010*

3. Membrane filtration *ISO9308-1*, *ISO 7899-2*

4. Plasma-emission spectrometry ICP-MS

5. Field portable device.

Heavy metals in soil and water samples were determined by atomic-absorption method that implies transition of metal being in excited state into the solution. Also flame spectrometers are used, where metals' atomization occurs at high temperature, which is created in the device by flame. Thanks to modern equipment (ICP-MS) metals' atomization occurs by means of laser beam that sufficiently increases method sensitivity. We offer exactly this equipment – plasma-emission spectrometer ICP-MS, which is characterized by high determination sensitivity. Given equipment and used methods [1-5] in all cases (soil, water, and air) give us an opportunity to simultaneously test several dozens of samples using the device and respectively to simultaneously determine several dozens of components by its means.

Results and discussion

Results of chemical analysis of all taken water and soil analysis samples are given in Tables 1-3 and Diagrams 1-2.

As we can see, total content of some heavy metals (Pb, Zn) in soil samples is quite high. In particular, lead concentration in soil samples from territory adjacent to Sagarejo is 9-times higher than MAC and 2-times exceeds estimated allowable concentration. Also zinc content in the same sample is 1,6-times higher than its estimated allowable concentration. It should be noted that soil analysis sample section, which was selected at Sagarejo territory is placed near uncontrolled dump, which exists for many years as local residents testify. In our opinion exactly the dump existing at the given territory is the reason of the fact that increased contents of lead and zinc were discovered in analysis samples, since only this type of pollution sources is located at the given territory.

Table 1

The heavy metal (Cu, Zn, Pb, Cd) concentration in the soil samples collected from the adjacent areas of uncontrolled landfill sites in Kakheti Region

Sampling location	**Sampling time**	**Coordinates**	**Altitude (m.a.s.l.)**	**Cu, ppm**	**Zn, ppm**	**Pb, ppm**	**Cd, ppm**
Sagarejo, Tskarostavi village	01.11.2013	524120 4620201	813	65	**350**	**295**	<2.5
Gurjaani, irrigation Channel (3 km from the city)	21.11.2013	568940 4623145	303	70	170	15	<2.5
Telavi, Ikalto village (200 m from the settlement)	06.12.2013	532596 4644794	589	20	75	20	<2.5
Gombori, 1200 m.a.s.l (background)	06.12.2013	513908 4634711	1200	50	200	15	<2.5
Maximum Allowable Concentration (MAC)						32	
Estimated Allowable Concentration (EAC)				132	220	130	2.0

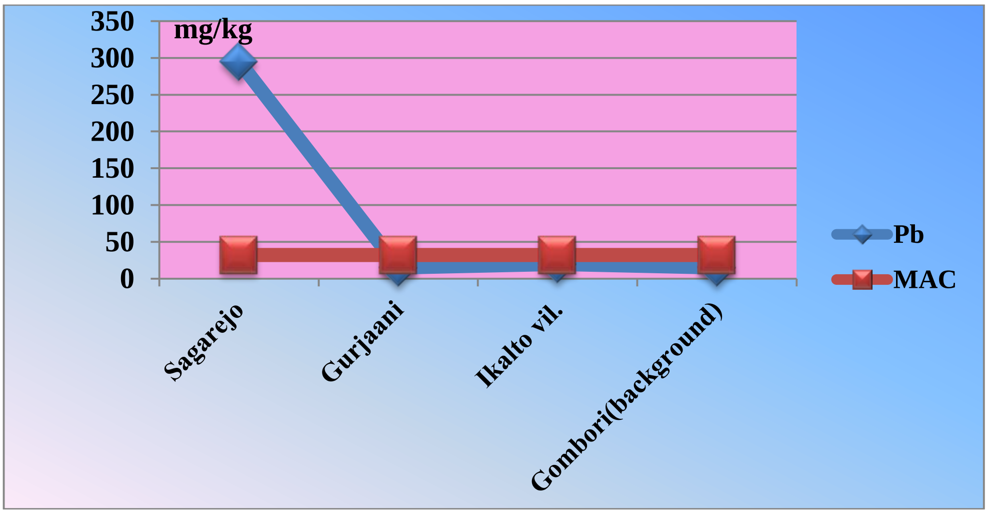

Diagram 1. The lead concentration in soil samples collected in Kakheti Region.

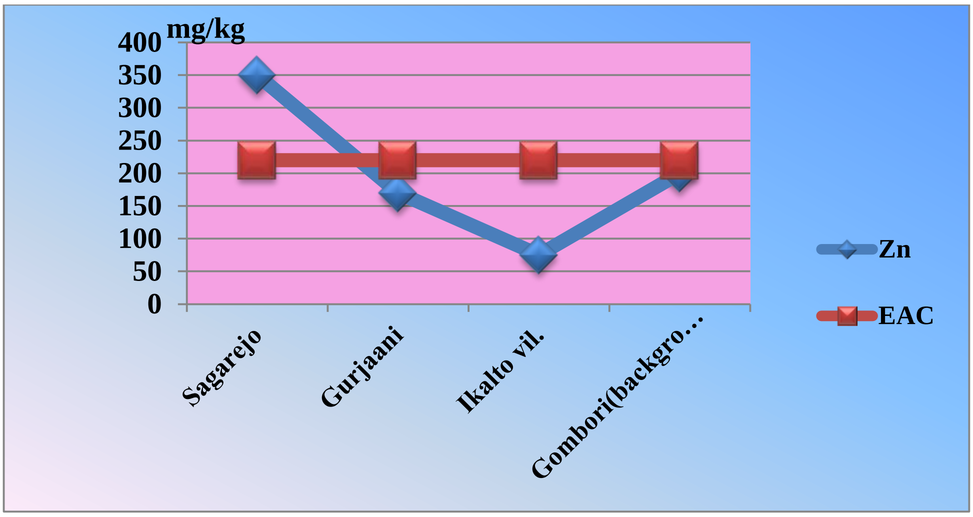

Diagram 2. The zinc concentration in soil samples collected in Kakheti Region.

Water samples from irrigation channel (uncontrolled dump is located nearby) situated near Gurjaani, and water from Ikalto village were taken for analysis in Kakheti region. Physical-chemical parameters and heavy metals contents (Tables 2, 3) were determined in them. Obtained results are given in Tables 2-3.

Table 2

Physical-chemical parameters of Gurjaani irrigation channel and Ikalto water (2014).

Sampling location	Sampling time	Coordinates	pH	Conductivity µS/cm	Salinity	Do	T,°C
The river flowing into Ikalto gully	29.04.2014	532596 4644794	8.2	368	0.04	3.97	21.0
Irrigation channel (3 km from Gurjaani center)	21.11.2013	568940 4623145	8.08	297	0.01	5.31	9.9

Table 3

The heavy metal (Cu, Zn, Pb, Cd) concentration in water samples of Gurjaani irrigation channel and Ikalto water (2014).

Sampling location	Sampling time	Coordinates	pH	Cu, ppm	Zn, ppm	Pb, ppm	Cd, ppm
Irrigation channel (3 km from Gurjaani center)	21.11.2013	568940 4623145	8.08	0.02	0.03	0.003	0.0012
The river flowing into Ikalto gully	29.04.2014	532596 4644794	8.2	0.02	0.02	0.003	0.0012

As we can see, according to physical-chemical parameters both surface waters (Ikalto water and Gurjaani irrigation channel) don't experience any kind of heavy anthropogenic impact, as to heavy metals, their concentrations in water phase are considerably lower than MACs that is caused by high pH index of water (Table 3), at this time major part of heavy metals experiences sedimentation in bottom settings in the form of hydroxides.

Conclusions

Researches and obtained results obviously showed that high contents of some toxic elements (Pb, Zn) were found in soils samples of Kakheti region, particularly at territories adjacent to Sagarejo district. Their concentrations several times exceeded not only MAC values, but even their content in background samples. In our opinion it is caused by the presence of agricultural and domestic waste that are located in large quantities in settlements of Kakheti region. As to surface waters, no signs of anthropogenic load are observed in them.

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კახეთის რეგიონის ნიადაგებში ზოგიერთი მძიმე ლითონის შემცველობა

ლ. ინწკირველი, ნ. ბუაჩიძე, ლ. შავლიაშვილი

რეზიუმე

შესწავლილია კახეთის რეგიონის რამოდენიმე რაიონის (საგარეჯო, გურჯაანი, თელავი, გომბორი) ნიადაგებისა და ზედაპირული წყლის დაბინძურების ხარისხი ზოგიერთი მძიმე ლითონით (Cu, Zn, Pb, Cd) და გამოვლენილია დაბინძურების წყარო. ადგილზე, საველე პირობებში, განსაზღვრულია ზედაპირული წყლების ფიზიკურ-ქიმიური მაჩვენებლები (pH, ელექტროგამტარობა, მარილიანობა, ტემპერატურა, წყალში გახსნილი ჟანგბადის რაოდენობა).

Содержание некоторых тяжелых металлов в почвах региона Кахети

Л.Н. Инцкирвели, Н.С. Буачидзе, Л.У. Шавлиашвили

Резюме

Изучена степень загрязнения почв и поверхностных вод некоторых районов региона Кахети, Грузия (Телави, Гурджаани, Сагареджо, Гомбори) тяжёлыми металлами (Cu, Zn, Pb, Cd). Выявлен источник загрязнения. В полевых условиях, с помощью портативного аппарата, определены физико-химические параметры поверхностных вод (pH, электропроводность, температура, соленость, растворенный в воде кислород).

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Fog Dynamics in Tbilisi

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Abstract

The aim of this paper is to study regimes of fog in urban areas and to determine its variation. It is used 5 years (2012-2016) of meteorological bulletins (SYNOP and METAR) from two meteorological stations (MS): Tbilisi (WMO code 37545) (403 m.s.l.), and Tbilisi airport (ICAO code UGTB) (495 m.s.l.). It is analyzed the following characteristics of fog: quantity of foggy days per months, duration (hours), periodicity of foggy days in different dates, fog gradation, and number of occurrences of fog. For a determination of changes in these characteristics, we compared 2012-2016 data to the mean of 1936-1965.

Key words: Fog dynamics, Meteorological station, SYNOP and METAR, Tbilisi.

Introduction

Fogs represent one of an important climateforming factor. Together with such dangerous geophysical phenomena as earthquakes, eruptions of volcanoes, landslides, mudflows, avalanches, mountain collapses; strong wind (storms, hurricanes, tornadoes, blizzards, etc.), intensive or long precipitation (rain, snow, hail), thunder-storms, high level of ultra-violet radiation, extreme air temperatures, droughts, etc.; floods, sea storms, typhoons, tsunami, intensive drift of ices, etc.; magnetic storms, falling of meteorites, cycles of solar activity, etc. the fogs frequently bring essential harm to the living environment of people [1-4].

Current changes in the global climate, mainly expressed by warming tendency effects on climate systems, is also undergoing significant changes of its cause and effect components. Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased [5-8].

Fogs represent not only an important climateforming factor, but also a sensitive indicator of climate change. Therefore, in Georgia, where almost all kinds of climate are encountered, the investigations of fogs have always carried a particular importance. A detailed analysis of the variability of the number of fog days per year N and some reasons of variations of N in different locations of Georgia is given in Amiranashvili et al. [9-15].

For example, trends of the mean number of fog days per year to one meteorological station in Eastern Georgia, Western Georgia and Georgia in 1936-1990 are negative and are satisfactorily described by the nonlinear equations of the third order. In Eastern Georgia in comparison with Western Georgia the decrease of the number of the fog days per year in 1936-1990 occurred less intensively [9-11]. In different localities of Georgia the mainly reasons of variations of number of fog days per year are different. However, for some regions (for example Senaki, Sukhumi) variations of number of fog days are weakly connected with variations of the meteorological parameters and air pollution. In Tbilisi, Anaseuli and Tsalka the mainly reasons of changeability of N are air pollution. In Telavi the mainly reasons of variation of N is atmospheric pollution and air relative humidity. However the share of air pollution in the N variations is 2.6-6.9 times higher than share of the air relative humidity (respectively in Tbilisi 4.5 times, Anaseuli – 6.9 times, Telavi – 2.6 times) [12].

In [13] the detailed statistical analysis of number of days with the fog (N), duration of fogs (T), number of days with the haze (P) and duration of haze (Q) in Dusheti (Georgia) in 1941-1990 are present. Thus, for all four indicated parameters the autocorrelation has a significant effect on the value of the standard error of annual average. The correlation relationships between T and N, Q and P, P and N, Q and T are obtained. The long-term variations of monthly, year and half year values of N, T, P and Q are studied. In particular, the clearly expressed trend of the N, T, P and Q is not observed. However, as a whole in 1941-1990 there is a tendency of the decrease of the number of days with the fogs and duration of fogs. An increase in the number of days with the haze and the duration of haze at the same time is observed.

The aerosol pollution of atmosphere has a definite effect on fogs and haze duration. With an increase in the pollution of atmosphere the duration of fogs during the week-days and weekends becomes identical, whereas the duration of haze during the week-days becomes less than into the weekends. With an increase in the air pollution for the week-days the duration of fogs does not change, but during week-days it is increases. For the haze duration another picture is observed. During the week-days the duration of haze is decreases, but during week-days it is does not change [15].

In [16] results of an analysis of the influence of fogs on air pollutions in Tbilisi (the capital of Georgia) in December – February 2009-2011 at the windless weather are presented. In particular it is obtained, that in cases with fog in comparison with cloudless atmosphere the mean values of radon content in air and sub-micron aerosol concentration increase by 14 and 116 %, bat values of small ions and ozone concentration - decrease by 17 and 69 % respectively (air in the fogs is dirtier than in the cloudless weather).

This work is a continuation of the mentioned investigations and concerns the investigation of fog regimes in and around Tbilisi.

Because of safety concerns, fog occurrences are associated with disruptions in air traffic at airports and navigation in marine ports. Unforeseen reductions in airport capacity associated with reduced ceiling and visibility lead to significant cost increments to the large air carriers [17]. For this reason, fog has many times been responsible for the cancellation or postponement of flights, until the weather conditions improve. Fog is formed in almost every part of the earth if given suitable synoptic and geographical conditions. Fog is a limitation of horizontal visibility below

1000 meters, which is caused by the accumulation of condensation and sublimation products of vapor in surface layers. Accordingly, the intensity of fog can be “very strong” (50m.), “strong” (50-150 m), “moderate” (200-500 m), or ”weak” (500-1000 m) [18].

In its genesis fog is both inter air-mass and frontal (figure 1). Fog can be formed by evaporation as well as by cooling of the air. This cooling can be caused by radiation and advection factors. Such conditions are created by the following: central parts of anticyclones; anticyclonic col; small gradient pressure fields; front parts of occlude cyclones; and, warm sectors of cyclones. Fog also can be formed during the invasion of cold air behind cyclones. Fog is also formed by orographic factors (height and form of relief), reservoirs, industry, and urbanization.

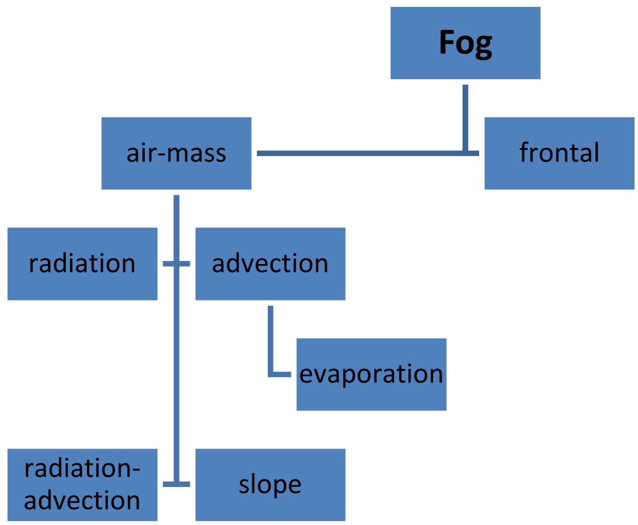

Fig 1. Fog classification scheme.

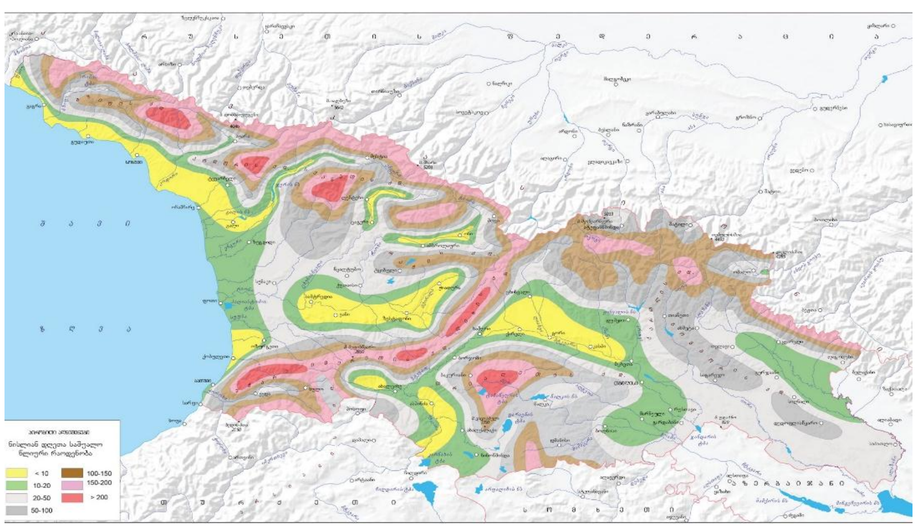

Fig.2. Foggy days in the territory of Georgia (Source: National Atlas of Georgia, 2012) [20].

Distribution of foggy days and its regime are complex in the territory of Georgia. This is caused by the impact of aerosynoptic conditions on the orografic features. Fog is formed throughout the year in Georgia and is characterised by diverse intensity (fig. 2). Fog is prolonged in the Georgian winter period. Foggy days are characterised by high indexes, especially mountainous locations: for instance, on the average, 194 days of fog in Jvari pass (2395 m.); in Mamisoni pass (2854 m.), 223 days; and lastly in Mt.Sabueti (1242 m.) 258 days [19].

Study area, method and data description

The aim of this paper is to study regimes of fog in urban areas and to determine its variation. In our research we used 5 years (2012-2016) of meteorological bulletins (SYNOP and METAR) from two meteorological stations (MS): Tbilisi (WMO code 37545) (403 m.s.l.), and Tbilisi airport (ICAO code UGTB) (495 m.s.l.). Material was downloaded from the website www.ogimet.com. We analyzed each 3 hours SYNOP (Surface Synoptic Observations) for the MS Tbilisi and 00:30 min. METAR (Aviation Routine Weather Report) for the MS Tbilisi airport. Prevailing visibility was used for MS Tbilisi airport (Figure 3). It is worth mentioning that fog was not simultaneously observed in both stations during the investigated period. Even of more interest to note, in the bulletin of MS Tbilisi, fog was not indicated at all. The visibility, as well as other weather phenomena groupings, were not identified in the SYNOP of MS Tbilisi, from 3:00 PM to 03:00 AM [UTC]. This time period is often characterized by a high probability of creating fog. This discrepancy can be explained by two possible reasons: firstly, observation on visibility had not been provided by sensors, and secondly, fog had not been observed at the station.

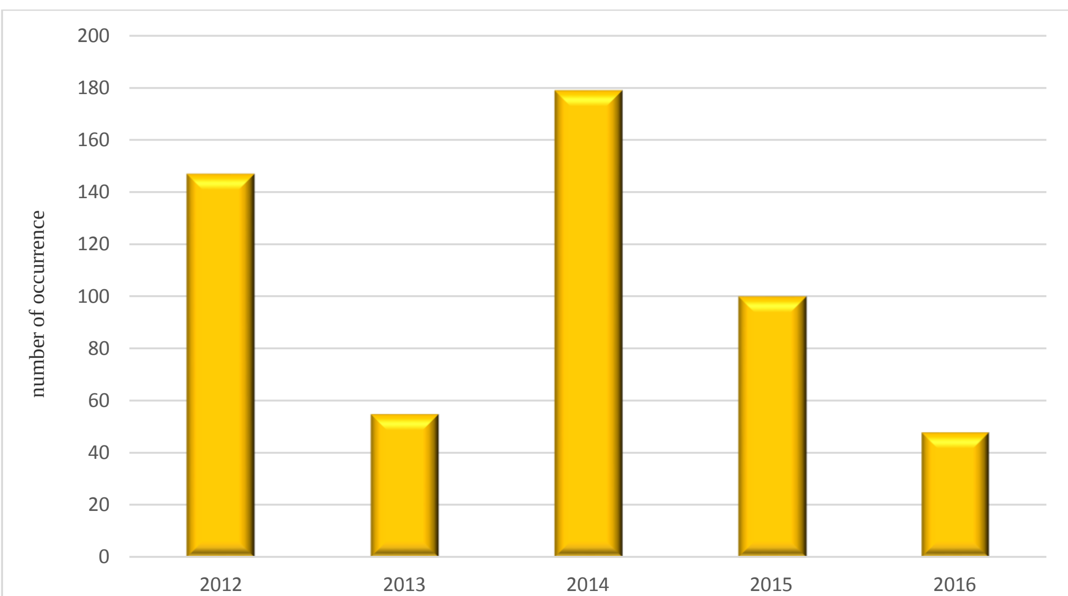

Fig. 3. Number of occurrence of fog in METAR. MS Tbilisi airport.

We studied the regime of fog only at the MS Tbilisi airport. We analyzed the following characteristics of fog: quantity of foggy days per months, duration (hours), periodicity of foggy days in different dates, fog gradation, and number of occurrences of fog. For a determination of changes in these characteristics, we compared 2012-2016 data to the mean of 1936-1965.

The area where MS Tbilisi Airport is located is a transitional zone from the outer Kakheti upland to the plains of Kvemo Kartli, adjoining the left side of the steppe of Gardbani [21]. The northern and northeast parts of the airport territory are bounded by rolling hills, which belong to Samgori valley. The surrounding terrain features a complex topographic relief with alternating or merging rolling hills and mountain ridges. Lochini river gorge is situated near the airport. It helps to form and develop fog during agreeable synoptic conditions. According to the long-term data (1936-1965) given in a climatological summary of [19], fog occurs every month of the year except for July, at the MS Tbilisi airport. In our research time range of 2012-2016, fog had only occurred from November to March (5 months). From this period of days, fog duration is characterized best by the months of December, January and February. In March the fog duration was for only a very short period, mainly only 2 days in 2012, totaling 1 hour and 30min, and in 2013 for one day also totaling for 1 hour and 30min. It did not occur in March of 2014 nor in 2015, while in 2016 three days were foggy for a total of 2 hours. As can be seen from our data, distribution of foggy days varies year by year and to determine any trends of periodicity is very difficult.

Results and discussion

Analysis of foggy days weather charts (500 hpa, surface map) revealed that every time when fog occurred at MS Tbilisi airport, the Southern Caucasus had been under the influence of an upper level ridge (figure 4 a), while on surface chart (figure 4 b) anticyclone conditions were shown to have been developed (we present weather maps for 16 February, 2016 because of prolonged fog continuously, 16 hours and 30 min). Pressure gradients were directed from the east (the Caspian Sea), to the west (the Black Sea), in what we call an “Eastern Circular Process” [22]. Mainly southeasterly direction (130-160°) light breezes (4-6 kt) were blowing. This baric condition makes favorable situations for fog at MS Tbilisi airport, but this does not mean that every time such synoptic conditions occur that fog will be observed. Without doubt one can say that in such synoptic conditions the weather forecaster can state that in cold periods of the year, or in early spring, horizontal visibility can be limited if not by the fog, then by the mist (horizontal visibility form 1000m to 5000m).

In the research period 2012-2016, air-mass genesis-fog (radiation, radiation-advection, advection) had occurred at MS Tbilisi Airport. The fog had developed in the morning time around 22 UTC and lasted until 06UTC. According to the available material of 2012-2016, in most cases before the fog appeared there had been a clear sky. Radiation, cooling, and advection of warm air masses from the south increased condensation products in the air, which was followed by a dropping of air temperature up to dew point and a relative humidity exceeding 95%. This condition resulted in fog at the MS Tbilisi Airport.

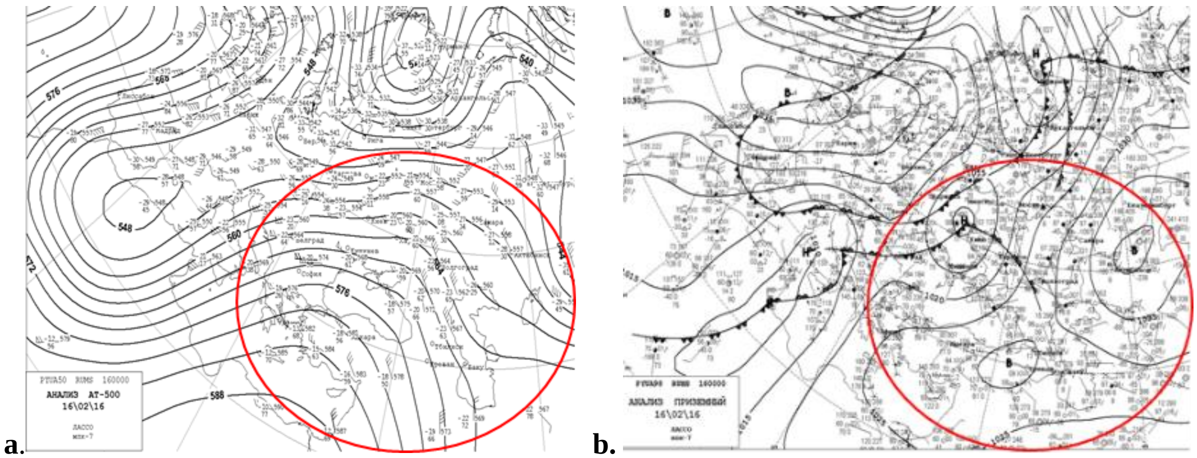

Fig. 4. Synoptic situation – a. absolute topographic 500hpa chart; b. surface chart (source: www.kcgms.ru/unimas/).

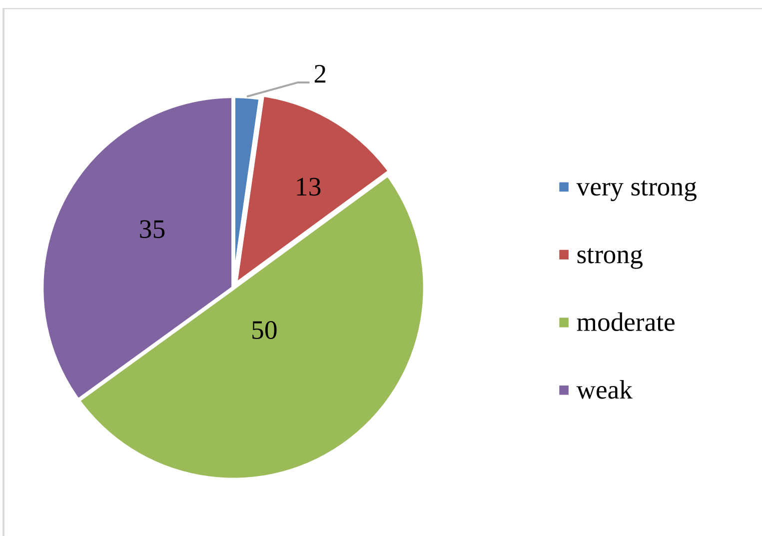

Fig 5. Intensity of fog by percentage, 2012-2016. MS Tbilisi Airport.

We analyzed 529 aviation weather reports (METAR) for this investigation (figure 5). It was revealed that from November to March the lowest index (2%) was concerned with visibility at 50m. The largest index (50%) was focused on moderate gradations (500-1000m).

One of the most important characteristics of fog is its duration (hours), intensity, and its change in time. As an example we give here data of fog which occurred on 8 February 2013 (table 1). From this table below the fog's changing nature can be noted.

Table 1

Visibility indexes of 8 February 2013. MS Tbilisi Airport.

time UTC (+4hr)	visibility (m)
17:30	50
18:00	50
18:30	50
19:00	50
19:30	100
20:00	100
20:30	300
21:00	300
21:30	600
22:00	600

Table 2

Quantity of foggy days. MS Tbilisi Airport, 2012-2016.

Year	November	December	January	February	March	Sum
2012	4	11	9	6	2	32
2013	3		5	4	1	13
2014	3	10	5	2		20
2015	4	1	7	2		14
2016				2	2	2

Table 3

Average Quantity of foggy days. MS Tbilisi Airport, 1936-1965.

Month	Quantity of days
1	7
2	5
3	4
4	1
5	0.3
6	0.2
7	
8	0.1
9	0.2
10	2
11	3
12	7
annual	30

note: figure less than 1 indicates, the fog was not detected every year

As was mentioned above, for a determination of the changeability of the regime characteristics of fog, we compared 2012-2016, and 1936-1965 years data, with each other [19]. It revealed a very interesting picture. Mainly, that fog had been observed only during the 5 months of November through March, in 2012-2016 (table 2), while almost during the full 30 years (1936-1965) fog was observed in every month except that of July, at MS Tbilisi airport, but from May to September it was not detected every year (table 3).

As shown in Table 3 the annual index of foggy days is 30. To detect the dynamics of this parameter we calculated deviations for each year, not from the annual figure, but from those 5 months sum, when fog was detected during 2012-2016 (figure 6). It equaled 26 days during the 5 months recorded. From diagram 6 it is well shown that every year except 2012, the quantity of foggy days was significantly low compared with long-term data. It means that the quantity of foggy days has been decreasing in Tbilisi.

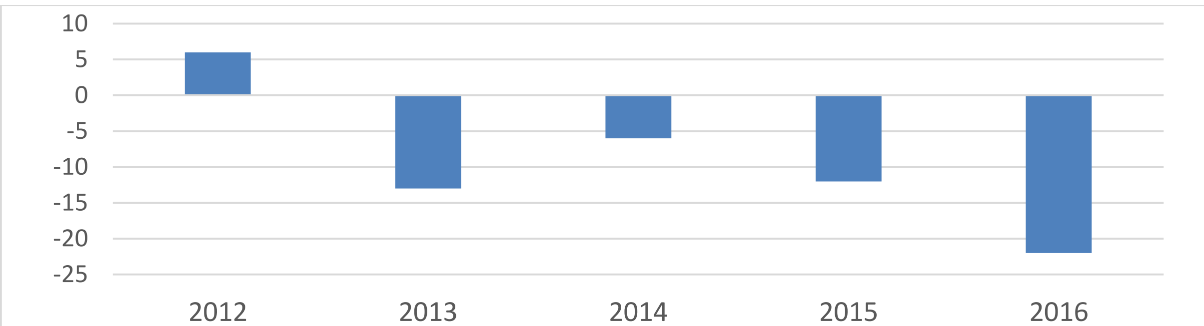

Fig. 6. Deviation of quantity of foggy days from 1936-1965 data (equaled 26) from MS Tbilisi Airport.

Table 4

Periodicity of foggy days by months in different dates. MS Tbilisi Airport, 2012-2016.

Month / Data	**11**	**12**	**1**	**2**	**3**
1-2			2	1	2
3-4					
5-6					
7-8	1	3	1	3	
9-10	3	1		3	
11-12	2	1	2	2	1
13-14		4		1	
15-16		2		1	
17-18		1	1	3	
19-20	1	3	1		
21-22	3	3	3		1
23-24		2	2		
25-26		1	3	1	1
27-28	2		5	1	
29-31	2	2	4		

The research revealed that the last third of every month is characterized with a frequency of foggy days (Table 4).

One of the main characteristics of fog is its duration by hours. The analysis of research (2012-2016) and long-term (1936-1965) periods by these parameter has revealed that in 5 months of research the period of fog duration expressed by hours was significantly reduced (table 5) compared to long-term data.

Table 5

Average duration of fog (hours). MS Tbilisi Airport.

Months	**1**	**2**	**3**	**11**	**12**
long-term	45	23	15	15	45
2012-2016	22	15	2	6	21

According to the criteria we used from this research period it is worth distinguishing 2 dates, the 21-22nd of January 2015 – when the duration of fog was continuously 14 hours and 30 minutes, and the 16-17th of February 2016 – when the fog duration was continuously 16 hours and 30 minutes. Because of such prolonged fog, some international flights were postponed at Tbilisi International airport. According to long-term data the average duration of fog in January is 44.9 hours, and in February 22.9 hours. As it is seen, those parameters also showed decreases.

Conclusions

Our study of fog regimes for the MS Tbilisi Airport has shown that during the 2012-2016 period the characteristics of this phenomena experienced changes. Mainly, that the quantity of foggy days according to months, as well as its duration (hours), has decreased over this time. Such conclusions were made by the assessment of 529 aviation weather reports (METAR). The research apparently indicates that there are ongoing changes in fog regimes, but without many stations' long-period data evaluation it is very hard to distinguish if this process is similar in other parts of the country, or not. Due to the complicated nature of fog genesis and its development, it is very important to further study this topic, according to data from meteorological stations located in the many different climate zones of Georgia.

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ნისლის დინამიკა თბილისში

ნ.ლომიძე, ნ.სუქნიძე

რეზიუმე

სტატიაში განხილულია ქალაქის პირობებში ნისლის რეჟიმი და დადგენილია მისი ცვლილება. ამოცანის შესასრულებლად გამოყენებულია ორი მეტეოსადგურის - თბილისი ქალაქის (მმო-ს კოდი - 37545) (ზ.დ. 403 მ) და თბილისი აეროპორტის (იკაო-ს ინდექსი - UGTB) (ზ.დ. 495 მ) 5 წლის (2012-2016 წწ.) SYNOP-ისა და METAR-ის კოდით შედგენილი მიწისპირა მეტეოროლოგიური დაკვირვების შეტყობინებები. ნისლის მახასიათებლებს შორის განხილულ იქნა: ნისლიან დღეთა რაოდენობა თვეების მიხედვით, ხანგრძლივობა (საათებში), ნისლიან დღეთა განმეორებადობა სხვადასხვა თარიღებში, ნისლის გრადაცია, ნისლის შემთხვევათა რიცხვი. ნისლის ამ მახასიათებლების ცვლილების დასადგენად 2012-2016 წლის მონაცემები შედარებულია 1936-1965 წლების საშუალო მნიშვნელობასთან.

Динамика тумана в Тбилиси

Н. Ломидзе, Н. Сукнидзе

Резюме

В статье приведены данные изучения режима тумана в условиях города и определены ее изменения. Для исследования были использованы пятилетные (2012-2016 г.г) данные двух метеорологических станций: города Тбилиси (ВМО код - 37545) (высота 403 м. над уровнем моря) и аэропорта Тбилиси (ИКАО индекс - UGTB) (высота 495 м. над уровнем моря). Данные наземных метеорологических наблюдений брались в виде кодов SYNOP и METAR сообщений. Были рассмотрены следующие характеристики туманов: количество дней с туманом по месяцам; их продолжительность (в часах); повторяемость туманных дней в различных датах; градация тумана; количество случаев тумана. Для установления изменений тумана и его характеристик мы сравнили данные, полученные за 2012-2016 годы с усредненными данными, полученными за 1936-1965 годы.

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Special Features of Changeability of Daily Sum of Precipitation in Tbilisi in 1957-2006

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Abstract

Wide-ranging studies of contemporary climate change in Georgia were begun in 1996 and they continue on the present time. First of all the inventory of greenhouse gases in Georgia was carried out, spatial-temporary variations in the fields of temperature, precipitation, cloudiness, aerosol air pollution, surface cover and other climate-forming parameters were studied. Later there have been begun works on forecasting of air temperature and precipitation change in some region of Georgia.

In particular results of detailed statistical analysis of the average semi-annual and annual values of precipitation in Tbilisi for the period 1957-2006 are presented earlier. In the indicated period of time the weak positive trend of precipitation in the cold period of year was observed. A trend of precipitation for warm half-year periods was not observed. For a year the weak tendency of an increase of the precipitation was observed.

In this work, which presents the continuation of the foregoing studies, some results of the standard statistical analysis of observational data of the Hydrometeorological department of Georgia of daily sum of precipitation (DSP) in Tbilisi in 1957-2006 are represented.

Thus, the statistical structure of atmospheric precipitation with daily intensity of 0.1-2, 2.1-5, 5.1-15, 15.1-30 and >30 mm and annual quantity of days without and with precipitation for the ten five-year time intervals from 1957-1961, 1962-1966,…, to 2002-2006 is studied.

The weak positive and positive trend of DSP respectively for the ranges of 5.1-15 and 15.1-30 mm was observed. The negative and weak negative trend of DSP respectively for the ranges of 0.1-2 and 2.1-5 mm was observed. The trend of DSP with an intensity of >30 mm was not observed.

***Key words**:* Climate change, urban climate, precipitation.

Introduction

Researching intensity and distribution of precipitations has always been the most actual problem among well-known atmospheric events. It became even more important on the background of the ongoing process of climate change. Precipitation is a basic source for moistening earth's surface. It belongs to those meteorological elements, which play an active role in water-water vapor circulation. Therefore in Georgia, as in other countries, to studies of atmospheric precipitations was always given special attention. For example, study of the precipitation climatology, their statistical structure and distribution on the territory of Georgia in the works [1-4] were carried out. The detailed data about the climatology of precipitation in Tbilisi in the book [5] are represented.

In the work [6] for the specially selected region of Eastern Georgia with 18 meteorological stations the analyses of statistical structure of spring-summer precipitation were carried out. The correlations between data from every single station are established, corresponding correlative matrix is built, and relevant analysis (including dividing the region) is done.

And some works the influence of the anthropogenic pollution of the atmosphere of the regime of precipitation was studied [7, 8]. In particular it is obtained that in the Kakheti region of Georgia during the week days a values of solid and liquid precipitations is higher than into the holydays.

The important stage of an investigation of precipitation with wide-ranging studies of contemporary climate change in Georgia was connected. These studies in 1996 were begun and they continue on the present time. First of all the inventory of greenhouse gases in Georgia was carried out, spatial-temporary variations in the fields of temperature, precipitation, cloudiness, aerosol air pollution, surface cover and other climate-forming parameters were studied. In particular it was obtained that in different regions of Georgia trends of annual sum of precipitation can be as constant, so positive and negative [9]. Later there have been begun works on forecasting of air temperature and precipitation change in some region of Georgia [10].

In particular results of detailed statistical analysis of the average semi-annual and annual values of precipitation in Tbilisi for the period 1957-2006 are presented in [10]. In the indicated period of time the weak positive trend of precipitation in the cold period of year was observed. Trend of precipitation in warm half-year periods are not observed. Clearly expressed trend of precipitation for a year are not observed also. It is observed the weak tendency of an increase in the precipitation with the little significant level of linear correlation coefficient.

Information about atmospheric precipitations for the development of the bioclimatic characteristics of territories has great importance. For example, during the calculation of the most widely known and applied tourism climate index proposed by Mieczkowski [11] data about atmospheric precipitations are necessary. This index is combination of seven factors and parameters with max value 100. In this case the share of the role of precipitation in the values of tourism climate index can reach to 20 %.

So, under the more-less similar thermal conditions of the atmosphere the decisive role in the values of tourism climate index (TCI) have the value of precipitation. For example, because of the increased values of precipitation in Batumi (capital of the Adjarian Autonomous Republic, Georgia) [12], values of tourism climate index here are lower than in Tbilisi and Anaklia (Georgia) [13-15]. Besides Batumi atmospheric precipitations substantially influence on values of TCI also in other localities of Adjara (Kobuleti, Khulo, Goderdzi) [16].

In Baku (Azerbaijan), Erevan (Armenia) and many cities of Iran (Mahabad, Jolfa, Marageh, etc,) the value of precipitation is lower than in Tbilisi, Batumi and Anaklia. Accordingly in Tbilisi, Batumi and Anaklia value of tourism climate index is lower than in the indicated cities in Azerbaijan, Armenia and Iran [17]. Thus the data about the precipitation find wide application with the certification of the health resort and tourist resources of territories in the aspect of their bioclimatic conditions [15, 18].

Excess precipitation contributes to the appearance of floods. The critical values of precipitation per 12 hours, that cause disastrous water flows, flooding in rivers and in dry ravines are: in seaside regions of Western Georgia – 130 mm and more, in the central and western part of Colchis lowland and adjoining mountains slopes – 100 mm and more, on the remaining part of Western Georgia, on the Southern slopes of Larger Caucasus – 80 mm and more, on the remaining part of Eastern Georgia – 60 mm. Using these critical values, the recurrence rates of disastrous heavy rains are calculated and corresponding flash flood hazard maps are compiled [19-21].

As it follows from the brief of literature revue, in Georgia there are sufficiently many works on a study of precipitation, including in Tbilisi. However, there is a certain deficiency in the studies of the changeability of atmospheric precipitations in different ranges of their intensity.

In this work, which presents the continuation of the foregoing studies, some results of the standard statistical analysis of observational data of the Hydrometeorological department of Georgia about daily sum of precipitation in different ranges of their intensity in Tbilisi in 1957-2006 are represented.

Study area and methods

Study area is Tbilisi city. Data of the Hydrometeorological department of Georgia about daily sum of precipitation in different ranges of their intensity in Tbilisi in 1957-2006 are used.

The statistical structure of atmospheric precipitation with a daily intensity of 0.1-2, 2.1-5, 5.1-15, 15.1-30 and >30 mm and annual quantity of days without and with precipitation for the ten five-year time intervals from 1957-1961, 1962-1966,…, to 2002-2006 is studied.

The following designations will be used below: Min – minimal values; Max - maximal values; Stdev - standard deviation; C_v - coefficient of variation (%); R - coefficient of linear correlation; α – the two-sided level of significance; α(R) - level of significance of R; K = 100·{Value(2002-2006)/Value(1957-1961) – 1} – value of relative changeability in the last five-year period of time in comparison with the first, calculated according to the equation of the regression of trend (%). The dimensionality of the precipitation (mm) in the text in the majority of the cases is omitted.

Results and discussion

Results in table 1-3 and fig. 1-5 are presented.

Table 1

Statistical characteristics of annual sum of atmospheric precipitation for the ten five-year time intervals from 1957 to 2006 in Tbilisi

Parameter	Total sum of precipitation	Daily intensity of atmospheric precipitation				
		0.1-2	**2.1-5**	**5.1-15**	**15.1-30**	**>30**
Min	445.7	36.6	67.1	154.0	95.3	37.9
Max	601.8	49.1	92.2	236.9	148.5	119.8
Mean	493.2	41.0	79.3	186.0	122.9	64.0
Stdev	52.5	4.2	8.3	25.3	19.3	23.6
C_v,%	10.6	10.1	10.4	13.6	15.7	36.8
R	0.21	-0.39	-0.25	0.22	0.44	0.03
α(R)	0.27	0.12	0.25	0.25	0.07	no sign
	Coefficients of the linear regression equation Y = a·X + b					
a	3.71	-0.54	-0.70	1.80	2.81	-
b	472.8	44.0	83.1	176.0	107.4	-
K,%	7.0	-11.1	-7.6	9.1	22.9	-

In the table 1 statistical characteristics of annual sum of atmospheric precipitation and annual sum of precipitation with a daily intensity of 0.1-2, 2.1-5, 5.1-15, 15.1-30 and >30 mm for the ten five-year time intervals from 1957 to 2006 in Tbilisi are presented. The coefficients of the equation of the regression of trend **Y = a·X + b** here are also given, where **Y** is mean annual amount of precipitation for the five-year interval of time, **X** - number of the interval of time from 1 to10 (1957-1961…2002-2006).

In the fig. 1-2 the graphs of trends of annual total sum of atmospheric precipitation and annual sum of precipitation in the different ranges of their intensity for the ten five-year time intervals from 1957 to 2006 in Tbilisi are given.

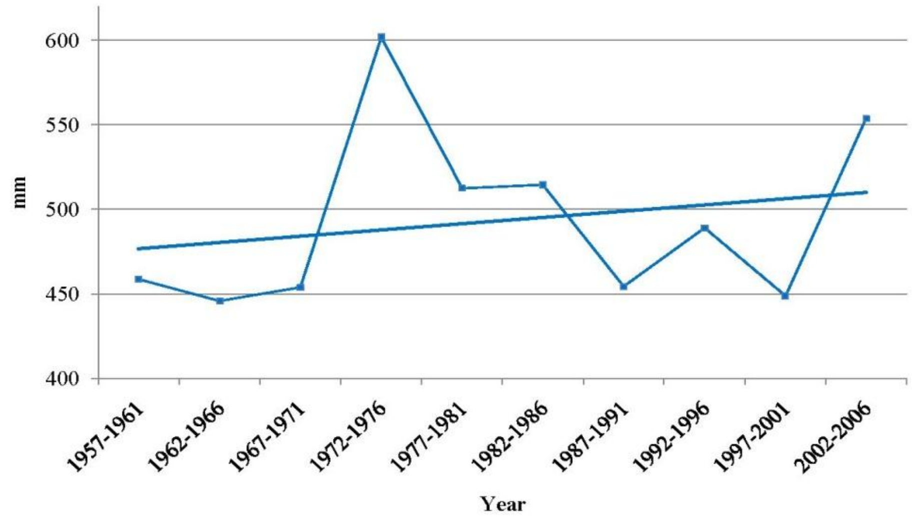

Fig. 1 Trend of annual sum of atmospheric precipitation for the ten five-year time intervals from 1957 to 2006 in Tbilisi

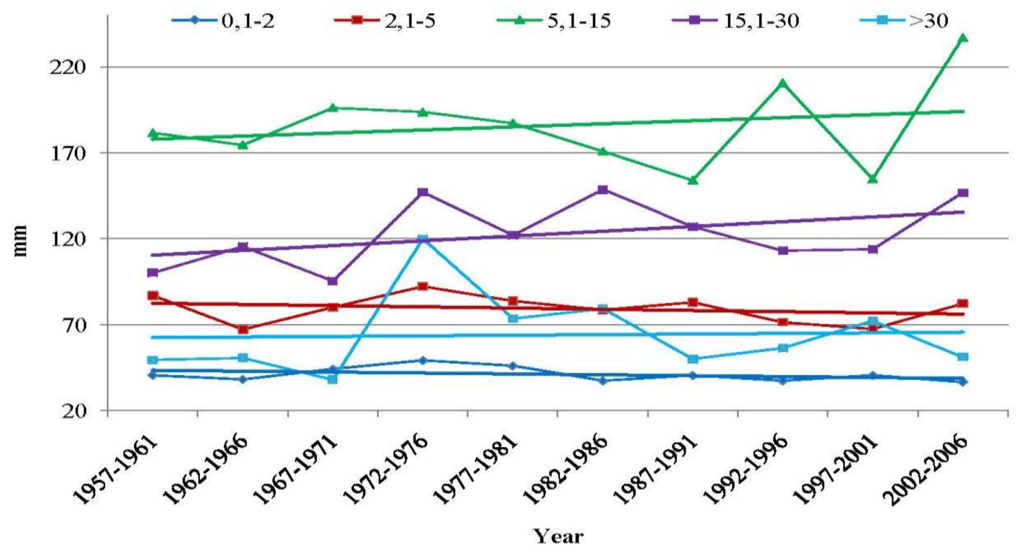

Fig. 2 Trend of annual sum of atmospheric precipitation in the different ranges of their intensity for the ten five-year time intervals from 1957 to 2006 in Tbilisi

In particular, as follows from table 1 and fig. 1-2, positive linear trends for the total sum of precipitation and precipitation in the range of their daily intensity of 5.1-15 and 15.1-

30 are observed. Trends the precipitation in the range of their daily intensity of 0.1-2 and 2.1-5 are negative. Not observed trend for precipitation with daily intensity >30.

The greatest increase in the precipitation in the last five-year period of time in comparison with the first for range 15.1-30 is noted (22.9%), the greatest decrease - for range 0.1-2 (-11.1%). An increase in the total sum of precipitation composes 7.0%.

In the table 2 statistical characteristics of the share of atmospheric precipitations in the different ranges of their intensity from the total sum of precipitation (below- the share of atmospheric precipitation) for the ten five-year time intervals from 1957 to 2006 in Tbilisi.

Table 2

Statistical characteristics of the share of atmospheric precipitations in the different ranges of their intensity from the total sum of precipitation for the ten five-year time intervals from 1957 to 2006 in Tbilisi (%)

Parameter	**Daily intensity of atmospheric precipitation**				
	0.1-2	**2.1-5**	**5.1-15**	**15.1-30**	**>30**
Min	6.6	14.6	32.2	21.0	8.4
Max	9.7	19.0	43.2	28.9	19.9
Mean	8.4	16.1	37.8	24.9	12.8
Stdev	1.0	1.6	4.3	2.5	3.6
C_v,%	11.3	9.8	11.4	10.2	27.8
R	-0.52	-0.51	-0.01	0.47	0.04
α(R)	0.05	0.05	no sign	0.07	no sign
	Coefficients of the linear regression equation $Y = a \cdot X + b$				
a	-0.16	-0.27	-	0.39	-
b	9.3	17.6	-	22.7	-
K,%	-16.1	-13.9	-	15.2	-

In the fig. 3 the graphs of trends of the share of atmospheric precipitations in the different ranges of their intensity from the total sum of precipitation for the ten five-year time intervals from 1957 to 2006 in Tbilisi are given.

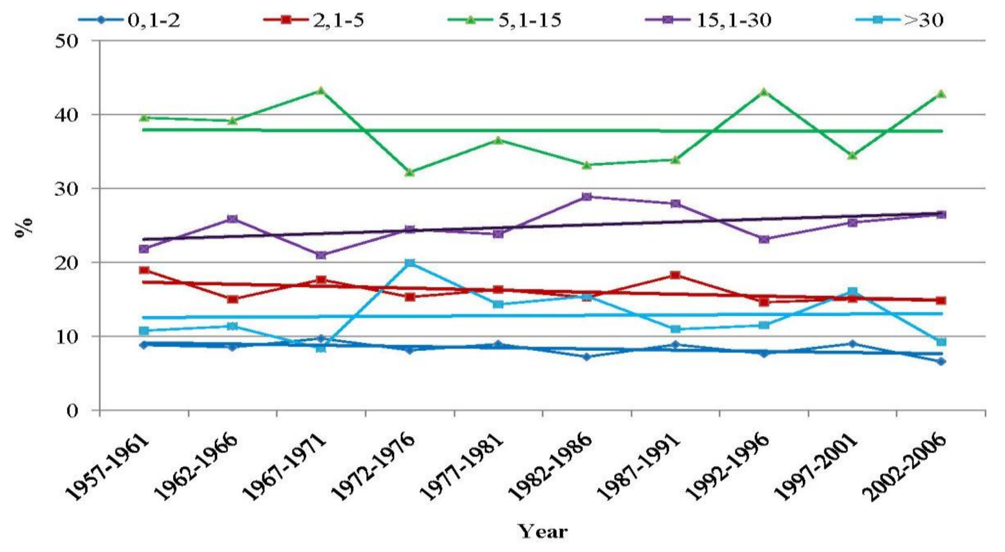

Fig. 3 Trend of the share of atmospheric precipitations in the different ranges of their intensity from the sum of precipitation for the ten five-year time intervals from 1957 to 2006 in Tbilisi

As follows from table 2 and fig. 3, the greatest contribution to the total sum of precipitation the precipitation with a day intensity of 5.1-15 is made (37.8%), smallest - with a day intensity of 0.1-2 (8.4%). Positive linear trends for the share of precipitation in the range of daily intensity 15.1-30 is observed only. Trends the share of precipitation in the range of their daily intensity of 0.1-2 and 2.1-5 are negative. Trends the share of precipitation with daily intensity 5.1-15 and >30 are not observed.

The greatest increase in the share of precipitation in the last five-year period of time in comparison with the first for range 15.1-30 is noted (15.2%), the greatest decrease - for range 0.1-2 (-16.1%).

Table 3

Statistical characteristics of annual quantity of days without and with precipitation for the ten five-year time intervals from 1957 to 2006 in Tbilisi

Parameter	**Without precip.**	**With precip.**	**Daily intensity of atmospheric precipitation**				
			0.1-2	**2.1-5**	**5.1-15**	**15.1-30**	**>30**
Min	249.6	87.2	35	20	17.8	4.4	1
Max	278	115.8	54.4	28.8	27.2	7.4	2.2
Mean	266.4	98.86	46.1	23.88	21.52	5.96	1.4
Stdev	8.3	8.3	6.7	2.6	2.7	1.0	0.4
C_v,%	3.1	8.4	14.6	10.9	12.6	17.0	26.1
R	0.68	-0.68	-0.89	-0.26	0.21	0.49	0.01
α(R)	0.005	0.005	0.001	0.22	0.27	0.05	no sign
	Coefficients of the linear regression equation $Y = a \cdot X + b$						
a	1.9	-1.9	-1.99	-0.23	0.19	0.16	-
b	256	109.1	57.04	25.13	20.49	5.05	-
K,%	6.5	-15.7	-32.5	-8.2	8.1	28.3	-

In table 3 statistical characteristics of annual quantity of days without and with precipitation for the ten five-year time intervals from 1957 to 2006 in Tbilisi are given

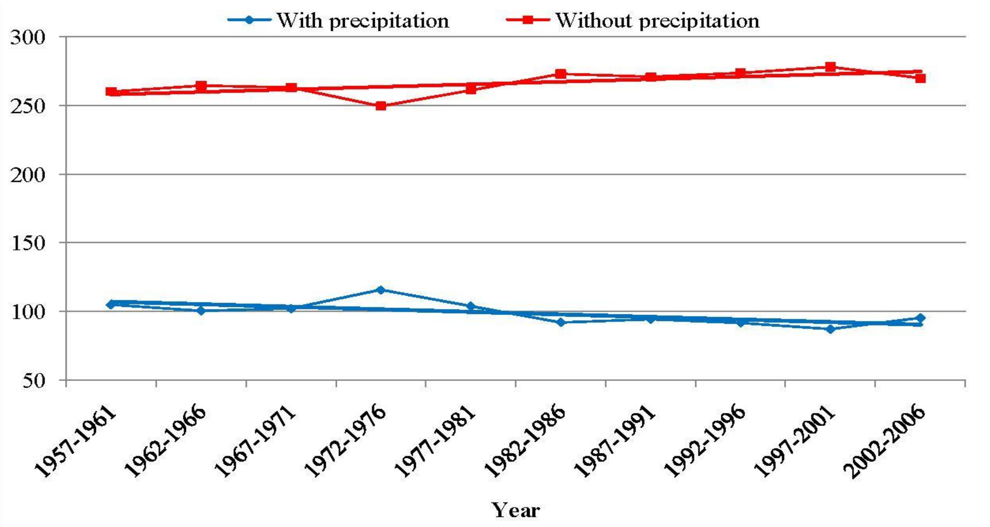

Fig. 4 Trend of annual quantity of days without and with precipitation for the ten five-year time intervals from 1957 to 2006 in Tbilisi

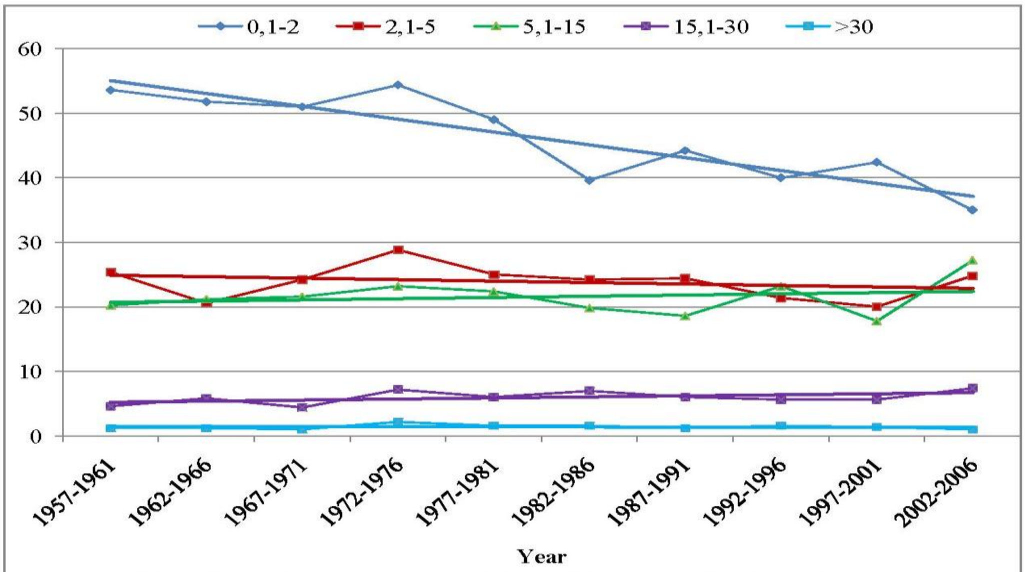

Fig. 5 Trend of annual quantity of days with precipitation in the different ranges of their intensity for the ten five-year time intervals from 1957 to 2006 in Tbilisi

In the fig. 4-5 the graphs of trends of the annual quantity of days without and with precipitation and days with precipitation in the different ranges of their intensity for the ten five-year time intervals from 1957 to 2006 in Tbilisi are given.

In particular, as follows from table 3 and fig. 4-5, positive linear trends for the annual quantity of total days without precipitation and days with of their daily intensity of 5.1-15 and 15.1-30 are observed. Trends of the annual quantity of total days with precipitation and days with of their daily intensity of 0.1-2 and 2.1-5 are negative. Trend for the annual quantity of days with precipitation with daily intensity >30 are not observed.

The greatest increase in annual quantity of days with precipitation in the last five-year period of time in comparison with the first for range of their daily intensity of 15.1-30 is noted (28.3%), the greatest decrease - for range 0.1-2 (-32.5%). An increase in the total annual quantity of days without precipitation composes 6.5%, an decrease in the total annual quantity of days with precipitation composes 15.7%.

Thus, in the investigated period of time a certain increase of total sum of precipitation was observed. At the same time in different ranges of their daily intensity the tendency of the changeability of precipitation was both the constant and positive and negative. The same relates to such investigated parameters, as the share of atmospheric precipitations in the different ranges of their intensity from the total sum of precipitation and the annual quantity of days without and with precipitation and days with precipitation in the different ranges of their intensity.

Conclusions

Investigation of climate changes and reasons for these is one of the most important problems of the present. Precipitation is a basic source for moistening earth's surface, and, correspondingly, one of the most important factors of support to life on our planet. Besides climate changes many of other factors with the changeability of atmospheric precipitations can be connected. For example, in the industrial regions this can be the heat islands, air pollution, the local special features of the dynamics of air masses, etc.

In different regions of Georgia long-term tendency of changeability of annual sum of precipitation has a complex nature: they can be as constant, so positive or negative. As in other countries air pollution has an effect on the precipitation regime in some regions of Georgia. In particular in the Kakheti region of Georgia air pollution influence on increase of the precipitations.

Tbilisi is megalopolis with all characteristic for such cities indicated special features. Therefore, climate variation in this city, and in particular the precipitation regime, has special interest for us. This investigation showed that long-term variations of the precipitations regime in Tbilisi have complex nature.

In the investigated period of time (1957-2006) a certain increase of total sum of precipitation was observed. At the same time in different ranges of their daily intensity the tendency of the changeability of precipitation was both the constant and positive and negative. The same relates to such investigated parameters, as the share of atmospheric precipitations in the different ranges of their intensity from the total sum of precipitation and the annual quantity of days without and with precipitation and days with precipitation in the different ranges of their intensity.

In the future the analysis of the possible reasons of the indicated special features of variations of the precipitation regime in Tbilisi will be carried out. In addition to this, the continuation of these studies on the more extensive material is provided.

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თბილისში დღიური ჯამური ნალექების ცვალებადობის თავისებურებანი 1957-2006 წლებში

ა.ამირანაშვილი

რეზიუმე

საქართველოს კლიმატის თანამედროვე ცვლილებების ფართომასშტაბური შესწავლა დაიწყო 1996 წელს და გრძელდება დღემდე. უპირველეს ყოვლისა ჩატარდა საქართველოში სათბური გაზების ინვენტარიზაცია, გამოკვლეულ იქნა ჰაერის ტემპერატურის, ნალექების, ღრუბლიანობის, ატმოსფერული ჰაერის აეროზოლური დაბინძურების, ზედაპირული საფარის და სხვა კლიმატწარმომქმნელი ფაქტორების ველების სივრცულ-დროითი ვარიაციები. მოგვიანებით დაიწყო სამუშაოები საქართველოს სხვადასხვა რაიონში ჰაერის ტემპერატურისა და ნალექების ცვლილებების პროგნოზირებისათვის. კერძოდ, თბილისში 1957-2006 წლების პერიოდში ჯამური ნალექების საშუალო ნახევარწლიური და წლიური მნიშვნელობების დეტალური სტატისტიკური ანალიზის შედეგები იყო წარმოდგენილი ადრეულ ნაშრომებში. დროის აღნიშნულ პერიოდში დაიკვირვებოდა ნალექების სუსტი დადებითი ტრენდი წლის ცივ პერიოდში. ნალექების ცვალებადობა წლის თბილ პერიოდში არ შეიმჩნეოდა. წლიური მონაცემებით შეიმჩნეოდა ნალექების მატების სუსტი ტენდენცია. მოცემულ ნაშრომში, რომელიც წარმოადგენს ადრინდელი გამოკვლევების გაგრძელებას, მოცემულია საქართველოს ჰიდრომეტეოროლოგიური დეპარტამენტის თბილისში დღიურ ჯამურ ნალექებზე დაკვირვებათა მონაცემების სტანდარტული სტატისტიკური ანალიზის ზოგიერთი შედეგი 1957-2006 წლებისათვის. კერძოდ, შესწავლილია ატმოსფერული ნალექების სტატისტიკური სტრუქტურა 0.1-2, 2.1-5, 5.1-15, 15.1-30 და >30 მმ დღიური ინტენსივობით და ნალექიანი და უნალექო დღეების წლიური რაოდენობა ათი ხუთწლიანი დროითი ინტერვალისათვის 1957-1961, 1962-1966, ...2002-2006 წლებამდე. დღიური ჯამური ნალექების სუსტი ზრდა და დადებითი ტრენდი დაიკვირვებოდა 5.1-15 და 15.1-30 დიაპაზონებისათვის შესაბამისად.სუსტი შემცირება და უარყოფითი ტრენდი დაიკვირვებოდა, შესაბამისად 0.1-2 და 2.1-5 დიაპაზონებისათვის. დღიური ჯამური ნალექების ცვალებადობა დროში ინტენსივობით >30 არ დაიკვირვებოდა.

Особенности изменчивости суточных суммы осадков в Тбилиси в 1957-2006 гг.

А.Г. Амиранашвили

Резюме

Широкомасштабные исследования современного изменения климата Грузии были начаты 1996 году и продолжаются в настоящее время. Прежде всего была проведена инвентаризации парниковых газов в Грузии, исследованы пространственно-временные вариации полей температуры воздуха, осадков, облачности, аэрозольного загрязнения атмосферного воздуха, поверхностного покрова и других климатообразующих факторов. Позже были начаты работы по прогнозированию температуры воздуха и изменения осадков в некоторых районах Грузии.

В частности, результаты детального статистического анализа средних полугодовых и годовых значений суммы осадков в Тбилиси в период 1957-2006 гг были представлены в ранних работах. В указанный период времени наблюдался слабый положительный тренд осадков в холодный период года. Изменчивость осадков в теплый период года не наблюдалась. По годовым данным наблюдалась слабая тенденция к увеличению осадков.

В данной работе, которая представляет продолжение предыдущих исследований, представлены некоторые результаты стандартного статистического анализа данных наблюдений гидрометеорологического департамента Грузии за суточной суммой осадков (DSP) в Тбилиси в 1957-2006.

В частности, изучена статистическая структура атмосферных осадков с суточной интенсивностью 0.1-2, 2.1-5, 5.1-15, 15.1-30 и >30 мм и годового количества дней с осадками и без осадков для десяти пятилетних временных интервалов с 1957 -1961, 1962-1966, ..., до 2002-2006 гг.

Слабый рост и положительный тренд DSP наблюдались для диапазонов 5.1-15 и 15.1-30 мм соответственно. Слабое уменьшение отрицательный тренд DSP наблюдались, соответственно, для диапазонов 0.1-2 и 2.1-5 мм. Изменчивости во времени DSP с интенсивностью >30 мм не наблюдалось.

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Reconstruction of Anti-Hail System in Kakheti (Georgia)

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Abstract

Large-scale experimental, experimental-production and production work on action on hail processes in Georgia was conducted in 1960-1989 (Kakheti, Southern Georgia) over the total area of approximately 1.2 million hectares. Positive effect changed in interval of 20 - 95% with average value of 75 - 85%. In those following quarter of century, after the curtailment of these works, damage to agriculture from the hail grew and returned to the level, which was to the beginning of anti-hail works. In 2015 year in Kakheti over the area of approximately 650 thousand hectares the work on actions on hail processes were renewed. The description of the restored anti-hail system is given which includes: contemporary meteorological radar Meteor 735CDP10 of firm Selex ES; central remote-control station with the change personnel; the automated system of the fire control; 85 rocket launching sites; the autonomous automated rocket guns; anti-hail rockets; scientific group; the group of the maintenance of radar and rocket guns. The test probation of system showed the prospect of its further use for dealing with the hail. The physical and economic effectiveness of anti-hail works in 2015 year, in spite of the limited quantity of means of action (rockets), it was not worse than it is earlier in the years with the action. It is significant that if in the past in Kakheti personnel of anti-hail service comprised more than 800 people, at present this work it ensures only 30 people. Subsequently is assumed an increase in the shielded from the hail areas, and also, besides the anti-hail works, the use of radar for monitoring of dangerous hydrometeorological processes in eastern Georgia and adjacent to its territories of Armenia and Azerbaijan.

***Key words**:* Weather modification, weather radar, anti-hail rockets, anti-hail system.

Introduction

To geophysical hazards belong: earthquakes, eruptions of volcanoes, landslides, mudflows, avalanches, mountain collapses; strong wind (storms, hurricanes, tornadoes, blizzards, etc.), intensive or long precipitation (rain, snow, hail), fogs, thunder-storms, high level of ultra-violet radiation, extreme air temperatures, droughts, etc.; floods, sea storms, typhoons, tsunami, intensive drift of ices, etc.; magnetic storms, falling of meteorites, cycles of solar activity, etc. [1,2].

Georgia - small mountain country with 15 climatic zones, in territory of which from time to time proceeds majority of the enumerated geophysical catastrophes. Therefore, special attention was always paid and is paid to the study of dangerous geophysical phenomena in Georgia [3].

Concerning hail damages, Georgia is one of the hail-dangerous countries of world. Therefore to the problem of hail in this country are dedicated numerous works, that covers the wide spectrum of studies, beginning from the climatology of hail [4-10], ending with the mechanisms of its formation [11,12] and with the methods and the results of action on the hail processes [13-16].

Taking into account the significant economic damage, brought by hail damages, in Georgia in the beginning of the fifties of past century the institute of Geophysics of the Georgian Academy of Sciences began works on the fight with the hail. Later to these works was connected Transcaucasian Hydrometeorological institute. In 1967 for the realization of production works on the fight with the hail on the base of the Alazany anti-hail expedition of the institute of Geophysics the militarized service of fight with the hail in the former Soviet Union was for the first time created. As a whole, large-scale experimental, experimental-production and production work on action conducted in 1960-1990 in the regions of Kakheti and southern Georgia over the total area approximately 1.2 million hectare (Kakheti – 800 thousand hectare, southern Georgia - 400 thousand hectare) [17,18].

Positive effect changed in interval of 20 - 95% with mean value of 75 - 85%. Sometimes, when action was conducted to the super-power "super-cellular" clouds, effect proved to be zero, i.e., was noted strong hail damage [17, 18]. Almost in all works were used the crystallizing reagents (AgI, PbI_2), in one region (southern Georgia) the action was conducted by the combined method (AgI, NaCl).

Together with the works on the fight with the hail other work on the weather modification (artificial calling of a precipitation, regulation of thunderstorm activity of clouds, artificial descent of avalanches, etc.) to the Soviet period in Georgia within several decades were carried out. In these works rocket, plane, artillery and other methods of active impact on dangerous hydrometeorological processes were used [12, 17, 18]. In 1989 the specified works were stopped. In the next years the damage to national economy as a result of negative impact of the listed hydrometeorological processes significantly increased [17-20].

In contrast to Georgia in many countries of world the work on the weather modification in the last 25 years intensively was developed [21-28]. Considerably were improved the means of action on the clouds and the equipment for observation on convective clouds (meteorological radars), etc. [21, 23, 24, 25, 27]. Automatic systems for the action on the hail clouds are developed. All this made it possible to increase substantially the effectiveness of anti-hail works, etc. [21 - 23].Protection from the hail is achieved almost in 50 countries of world over the total area of approximately 90 million hectares (Argentina, Austria, Bulgaria, Canada, China, Bosnia and Herzegovina, Germany, Greece, Macedonia, Moldova, Romania, Russian Federation, Serbia, Spain, etc.). In China anti-hail works are conducted in the territory of 42 million hectares. The countries weather modification system employs 47700 people, and has an arsenal including more than 7034 rocket launchers, more than 50 planes and nearly 6902 guns. In Russian Federation anti-hail works are conducted in the territory of 2.5 million hectares, etc. [21, 28, 29]. In Russian Federation in comparison with the Soviet period the physical effectiveness of anti-hail works grew on the average from 50-82 % to 82-92 % [21].

In Georgia in the subsequent years after the end of anti-hail works special attention was given to the thorough analysis of the obtained earlier material about the hail damages both in the regions with the active actions on the atmospheric processes and as a whole for the territory of the Georgia. In particular, a whole series of works was dedicated to the climatology of hail and changeability of hail damages in the territory of this country [3, 5-10].

It was detected that the areas, beaten with hail in Kakheti increased in the years after the curtailment of anti-hail works and even they became more than prior to the beginning of the work of anti-hail service [30].

The empirical radar models of unicellular, multicellular and super-cellular convective cloud were created, the detailed maps of the distribution of the radar parameters of convective clouds above the territory of Kakheti were built [16]. The concept of interaction of aerosols with the convective clouds and the stimulations of the processes of the formation of the condensation and crystallization nuclei in them taking into account electrical, ionizing and other processes, which take place in the atmosphere and the clouds was proposed. It is assumed on the basis of concept that this interaction must be characterized by the regional special features, caused by both the physical conditions for the processes of forming the cloudiness, and by physical chemistry properties of aerosol-gas air pollution [12,31,32].

It was established that ionization of atmosphere by the natural and anthropogenic sources (radionuclides - radon, etc., cosmic radiation, the gamma emission of soil) plays the significant role in the formation of second aerosols in the atmosphere, including of the condensation nuclei, which have a great effect on the formation of the microphysical structure of clouds [32-34].

The evaluations of the influence of anthropogenic (including radioactive) pollution of the atmosphere on the intensity of thunderstorm and hail processes, and also the precipitation regime, showed that the relation of this pollution with the phenomena of the atmosphere indicated they have fairly complicated nature. However, as a whole the aerosol pollution of the atmosphere led to the intensification of the intensity of hail damages and, correspondingly, to the decrease of effectiveness in the anti-hail works [35-37].

The annual intensity of hail processes in Kakheti depends substantially on the aerosol pollution of atmosphere, although his dependence has fairly complicated nature. As a whole an increase in the nonradioactive aerosol pollution of atmosphere leads to the intensification of the intensity of hail damages and respectively to the decrease of the effectiveness of the action of anti-hail works. This effect appears also in daily variations in the intensity of hail processes. In Kakheti during the week-days the areas struck by hail, a logarithm of the multiplier of maximum radar reflectance, a quantity of liquid and solid precipitation are higher than into the weekends. Analogous situation also in the North Caucasus (mass, energy and a quantity of fallen hailstones during the week-days are higher than into the weekends). Increase in the fraction of the drop embryos of hail and decrease of the fraction of groats embryos (increase in the probability of an increase in the hail by the mechanism of warm rain) during the week-days in comparison with the weekends here occurs. In all likelihood in the period of the realization of anti-hail works in the former Soviet Union the effect of the anthropogenic pollution of atmosphere in the changeability of the intensity of hail processes bore regional nature. It is proposed while performing of work on active actions on atmospheric processes to consider the factor of anthropogenic air pollution [37].

In Kakheti (Georgia) and in the North Caucasus (Russia) in the period from 1968 through 1988 the effects of the decrease of effectiveness in the anti-hail works with an increase in the general aerosol pollution of the atmosphere were observed (Aerosol Optical Depth and the Turbidity Factor of the Atmosphere accordingly). In Kakheti this effect was mainly connected with the tendencies of an increase in the pollution of the atmosphere, and in the North Caucasus - with variations random components in the general aerosol pollution of the atmosphere [38].

On the serious influence of air pollution on the regime of precipitation in work [28] is noted also. It is shown, that anthropogenic aerosols might contribute significantly to the observed reduction of precipitation over northern China, and provide a possible feedback cycle of aerosol loading and precipitation that produces considerable harmful impacts on air quality, the hydrological cycle, crops, and other environmental problems. Statistical analyses of historical precipitation and aerosols data have revealed that deeper precipitation clouds can be influenced by aerosols in the form of precipitation suppression. In particular, the suppression effect is stronger over mountainous areas than over plains, and the influence of anthropogenic aerosols on convective precipitation possibly plays an important role in summer over northern China.

Taking into account the importance of works on the artificial regulation of atmospheric processes in Georgia, including fight with the hail, before the government of the country repeatedly was raised the question in the need for the renewal of these works [17, 18]. Finally, in 2013 years preliminary decision about the restoration in Georgia of works on the weather modification was accepted, and first of all - anti-hail service in Kakheti. New development stage of scientific and practical searches in the region of the active action on the atmospheric processes in Georgia began from this point on.

Analytical studies of the contemporary methods of action on the convective processes, the organizational structure of the recreated service of fight with the hail taking into account new achievements in the region of active actions on the atmospheric processes were carried out [25, 26, 39-42].

Taking into account that the problem of the sharp shortage of specialists for weather modifications arose after 25 years of the interruption of the work of anti-hail service, it was decided with the aid of the Institute of geophysics with the support of Scientific-Technical center "Delta" within the brief periods to conduct training the corresponding personnel.

As a result, with the support of the government of Georgia, to the active operation of Scientific-Technical center "Delta", the collaborators of institute of geophysics and institute of hydrometeorology, the work of anti-hail service in Kakheti on 28 May 2015 was restored [43]. The description of the renovated anti-hail service in Kakheti is presented below.

Results and discussion

The restored Anti-hail system consists of:

1. Contemporary weather radar Meteor 735CDP10 of firm Selex ES with a special software.
2. Central control station with the change personnel.
3. Automatized fire control system.
4. 85 rocket launching sites.
5. The autonomous automated rocket launching device SD-26 and SD-52.
6. Anti-hail rocket.
7. Scientific group.
8. The group of the maintenance of radar and rocket guns.

The weather radar is a C-band, dual polarized Doppler radar, which generates all the data to forecast hail-producing thunderstorms. All that information plus the databases of hail-consisting clouds used by the software with the specific algorithms to generate the areas, where the silver iodide reagent is to be dispersed (fig.1).This radar placed in Eastern Georgia in the village Chotori on 1090m height from sea level. Its actual area is 70-100 km, but working radius is more than 200 km with good data quality (fig. 2).

Fig. 1. Weather radar Meteor 735CDP10.

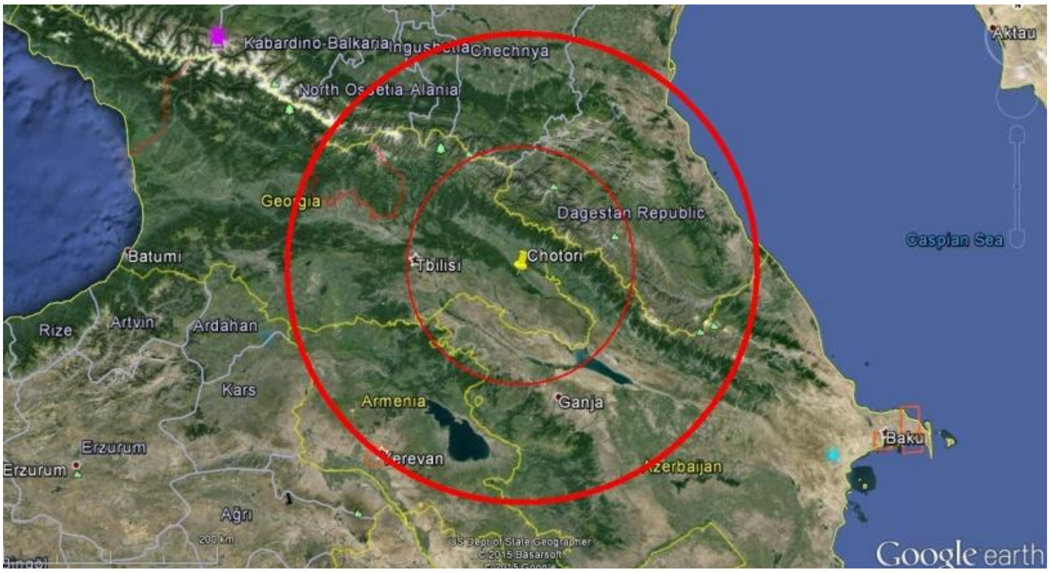

Fig. 2. Radar location in Kakheti.

The central control station is a dislocation place for the personnel, where all the information from weather radar and rocket launching sites are gathered, processed and where the automatized fire control system is. The automatized fire control system receives the data and the areas of seeding from the special software of weather radar, defines optimal launching site, the number of rockets needed and sends the orders to the proper launching devices (fig. 3).The central control station is located in Tbilisi (80 km from Chotori).

The radar monitoring of hail processes, analysis of meteorological situation in the region of action according to the data of radiosondes [44], and also all other works on conducting of operations on the distance action on the clouds produces group of 4 operators (16 operators to 4 groups).

In the work of anti-hail service is provided the participation of the scientific organizations (institute of geophysics, institute of hydrometeorology, etc.), which must exercise scientific methods leadership of works, participate in the instruction of personnel, carry out the analysis of obtained data, improve the existing procedures of action on the atmospheric processes, develop new, etc.

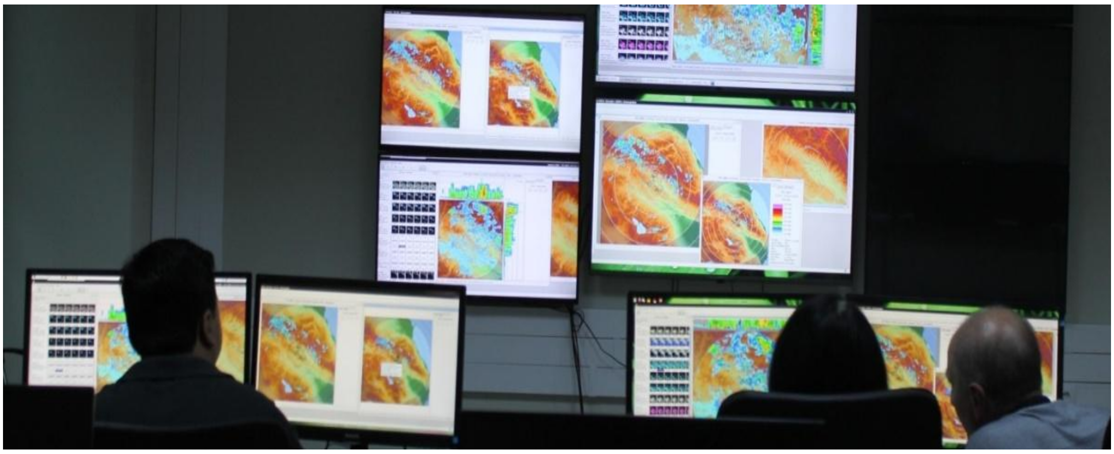

Fig. 3. The central control station.

To protect the whole region of Kakheti (650 thousand hectares), it is required to place 85 launching points – one in every 10 km, which is a working range of anti-hail rocket. There is a rocket launching device, solar panel, grounding and security systems installed on the launching site. The launching device carries 26 anti-hail rockets, aims to any given direction and fires (fig. 4).The launchers at the heights from 205 to 1775 m above sea level placed. In the range of heights from 205 to 375 m located 20 launchers, from 376 to 625 m - 37 launchers, from 626 to 875 m - 19 launchers, from 876 to 1125 m - 3 launchers and from 1275 to 1775 m - 3 launchers too [41].

Fig. 4. The autonomous automated launching device SD-26.

The anti-hail rocket SK-6 the production of Macedonia (fig. 5)is an unguided, 55 mm rocket, which carries 40 gram of silver iodide reagent and disperses it at an altitudes of 2.0 - 4.5 km, for 28-32 seconds [41,42]. Some parameters of anti-hail rocket SK-6 represented lower. The number of rockets needed during one year estimated to be 5000 units.

Fig. 5. Anti-hail rocket SK-6.

Anti-hail rocket SK-6 parameters.

- Rocket quantity in launching device SD-26 or SD-52: 26-52 rocket
- Elevation: 55-80°
- Traverse: 360°
- Rocket diameter: 55 mm
- Rocket weight: 3445 gram
- Rocket maximum velocity: 600 m/sec
- Shoot maximum distance (elevation 55°): 7200 meter
- The maximum from sea level (elevation 80°): 6000 meter
- The outlet of reagent from the rocket at a temperature -10°C – $1.28 \cdot 10^{16}$ particles

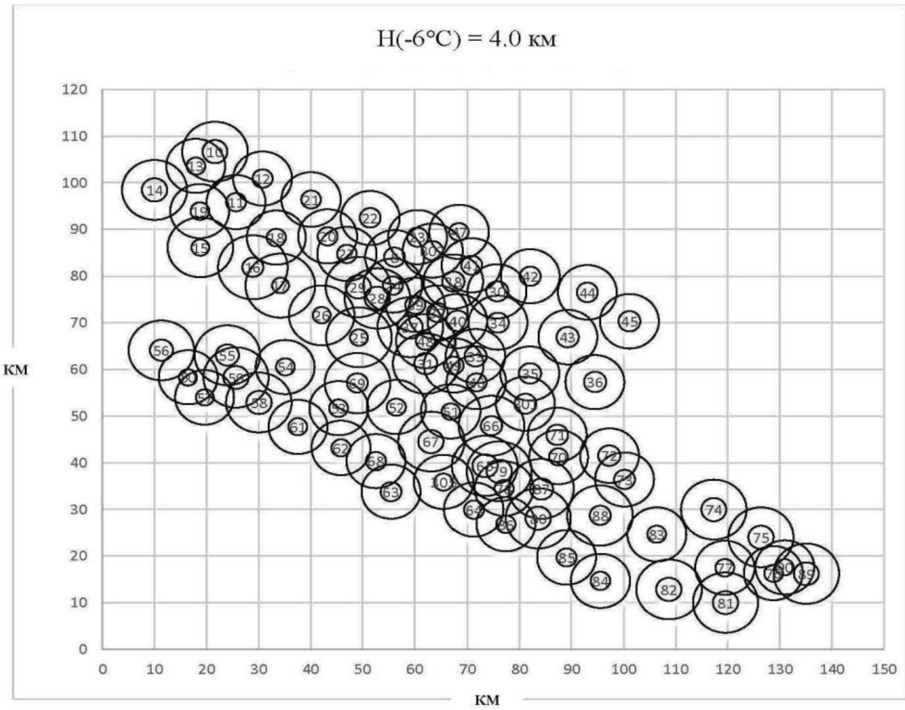

Fig. 6. Optimum areas of cloud seeding by the crystallizing reagent for the pointsof action by anti-hail rockets SK-6 in the protected territory in Kakheti. Height of the isotherm -6°C = 4.0 km. In the center of circle - number of the point of action.

Optimum areas of cloud seeding by the crystallizing reagent depend on the height of the arrangement of launchers and level of isotherm -6°C (fig. 6). As follows from fig. 6

distribution of the optimum areas of cloud seeding by reagent is unevenly. Basic reason for this - the insufficiently long courses of the rocket SK-6. Therefore, in near future the production of anti-hail rockets with the improved ballistic characteristics is planned (increase in the effective radius of action, etc.).

The special feature of the indicated launcher is the possibility of changing in quantity and diameter of containers (stems) for the anti-hail rockets, and the possibility of distance focusing on the angle of elevation and along the azimuth also of successive starting. Installation successfully underwent the first test probations. In 2015- 2016 it is planned to accomplish a production of the improved version of these installations taking into account the arrangement of an optimum quantity ofstems, protective housings for them from atmospheric precipitations, the improved program of the distance starting of rockets, etc. It is assumed also to create several mobile versions of launchers.

Finally in fig. 6-11 some examples of radar surveillance of the clouds are presented.

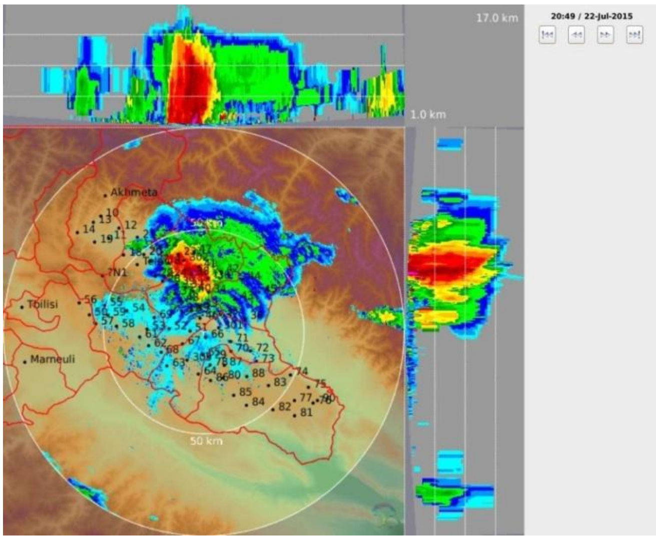

Fig. 6. Horizontal and vertical radar section of cloud 22.07.2015
in Kakheti in 20 hours of 49 min.

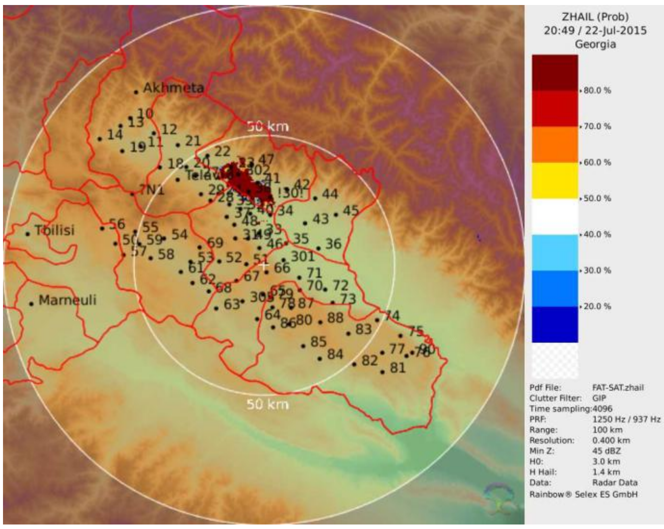

Fig. 7. Probability of hailstorm in cloud 22.07.2015 in Kakheti in 20 hours 49 min.

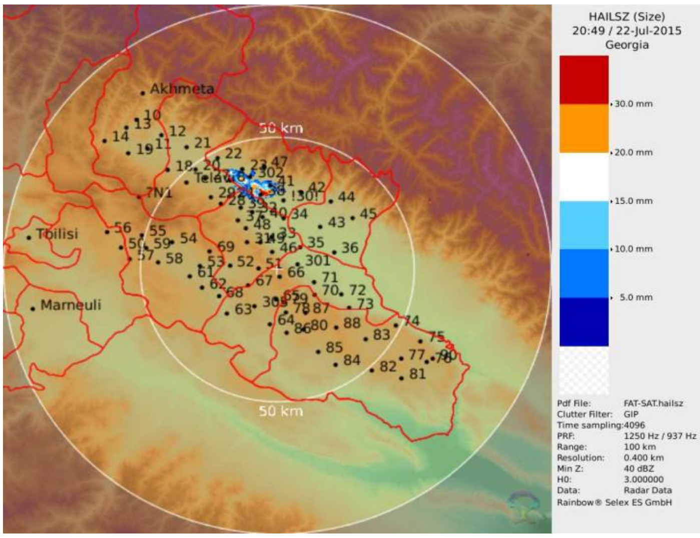

Fig. 8. Hailstones sizes in convective cloud 22.07.2015 in Kakheti in 20 hours of 49 min.

In fig. 6-8 fragments of radar surveillance of hail processes in Kakhetii (southeast from Telavi) 22.07.2015 20 hours of 49 min. are presented. As it follows from these figures, at the moment of observations the maximum altitude of hail cloud reached 17 km (fig. 6). The horizontal area of cloud with the probability of hailstorm of higher than 80% was approximately 50 km^2 (fig. 7). The horizontal area of cloud with the hailstones with the size more than 30 mm was approximately 2 km^2 (fig. 8).

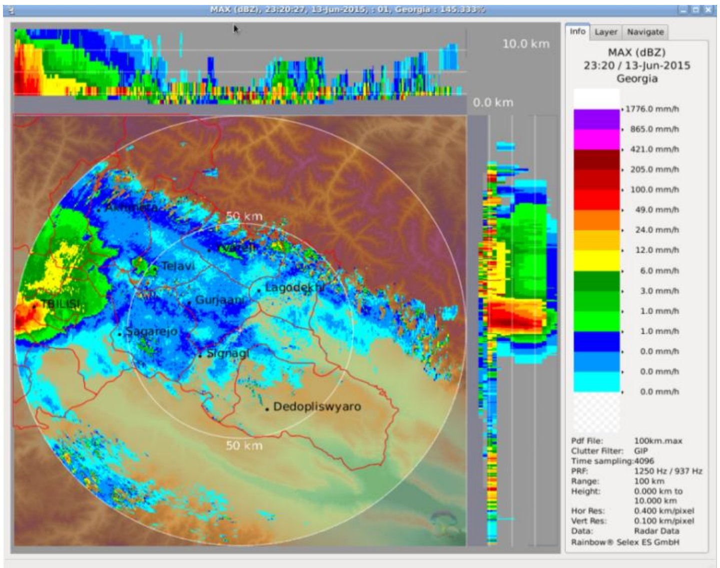

Fig. 9. Precipitation intensity from the thunderstorm cloud in the neighborhood of Akhaldaba 13.06.2015 in 23 hours 20 min.

In fig. 9-10 example of radar surveillance of the convective cloud in Akhaldaba region (southwest from the center section of Tbilisi) 13.06.2015 in 23 hours 20 min. depicts. As it follows from fig. 9, at the moment of observations the horizontal area of cloud with intensity of precipitation 50-100 mm/h was composed approximately 15 km^2, the horizontal area of cloud with intensity of precipitation more than 100-200 mm/h - 2 km^2.

For the clarity fig. 10 depicts 3D- picture of radar surveillance of this cloud. It should note, that during this day the cloud with the intensive rain and by thunderstorm was located on one and the same place of almost 5 hours. This led to the strong landslide, which overlapped river Vere, that flows in the direction to Tbilisi. The accumulated water subsequently broke through earthen mound, also, during several minutes one of the center sections of Tbilisi city, including zoo, they were flooded. Perished more than 20 people and a large quantity of animals. Essential damage was substituted to the infrastructure of city. Subsequently is provided the more detailed analysis of radar surveillance of the cloudiness and precipitation, which led indicated catastrophic event in Tbilisi.

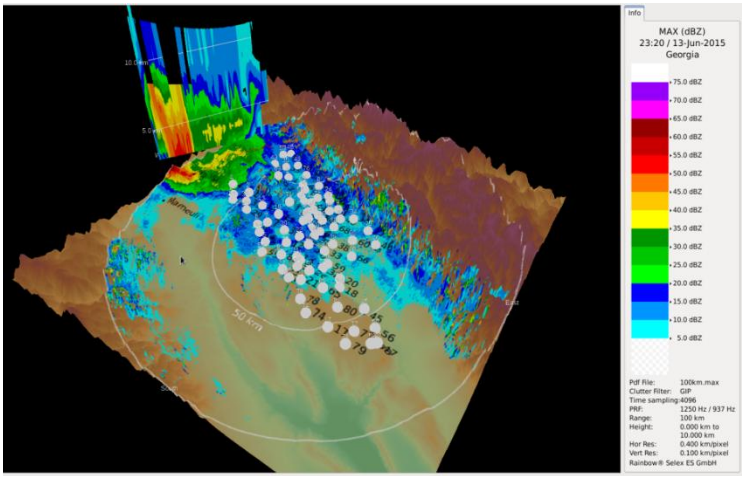

Fig. 10. 3D fragment of the radar picture of thunderstorm cloud in the neighborhood of Akhaldaba 13.06.2015 in 23 hours 20 min.

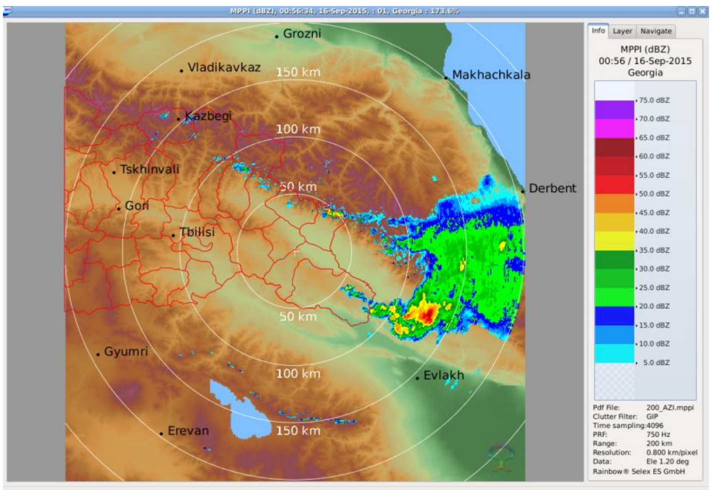

Fig. 11. Fragment of the radar picture of cloudiness above Azerbaijan 16.09.2105 in 0 hour 56 min.

Fig. 11 depicts example of radar surveillance of the cloudiness on the territory of Azerbaijan. As it follows from this figure, 16.09.2105 into 0 hour of 56 min. in 60 km north from Yevlakh city cloudiness with the horizontal area with the radar reflectance 50-60 dBZ of equal approximately 145 km^2 was observed.

Conclusions

After 25- years interruption in 2015 in Kakheti over the area of 650 thousand hectares of work on actions on hail processes were renewed. The contemporary anti-hail system of essential differs from that existed earlier in the Soviet period of time (contemporary meteorological radar and rocket launchers with remote control, etc.). Control of the processes of radar surveillance of the hail clouds in Kakheti and by rocket action on them is accomplished from Tbilisi. In the past in Kakheti the personnel of anti-hail service comprised more than 800 people, at present this work it ensures only 30 people. A constant improvement of methodological and technical components of anti-hail system is accomplished.

Subsequently is assumed an increase in the shielded from the hail areas, and also, besides the anti-hail works, the use of radar for monitoring of dangerous hydrometeorological processes in eastern Georgia and adjacent to its territories.

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სეტყვისსაწინააღმდეგო სისტემის აღდგენა კახეთში (საქართველო)

ა.ამირანაშვილი, ვ.ჩიხლაძე, უ.ძოძუაშვილი, ნ. ღლონტი, ი. საური

რეზიუმე

საქართველოში (კახეთი, სამხრეთი საქართველო) 1960 – 1989 წლებში 1.2 მილიონ ჰექტარის ფართობზე ტარდებოდა სეტყვის პროცესებზე ზემოქმედების მსხვილმასშტაბიანი საცდელი, საცდელ-საწარმოო და საწარმოო სამუშაოები. ზემოქმედების დადებითი ეფექტი იცვლებოდა 20 – 95% ის ინტერვალში საშუალო მნიშვნელობით 75 – 85 %. სამუშაოების შეწყვეტის შემდეგ სეტყვისგან მიყენებული ზარალი გაიზარდა და დაუბრუნდა იმ დონეს, რომელიც იყო ამ სამუშაოების დაწყების წინ.

2015 წელს კახეთში 650 ათას ჰექტარ ფართობზე სეტყვის პროცესებზე აქტიური ზემოქმედების სამუშაოები განახლდა. მოყვნილია აღდგენილი სეტყვისსაწინააღმდეგო სისტემის აღწერილობა, რომელიც თავის შემადგენლობაში მოიცავს გერმანული ფირმა Selex ES-ის Meteor 735CDP10 ტიპის თანამედროვე 5 სმ დიაპაზონის მეტეოროლოგიურ რადიოლოკატორს, დისტანციური მართვის ცენტრალურ პუნქტს, ცეცხლის მართვის ავტომატიზებულ სისტემას, 85 სარაკეტო გამშვებ პუნქტს, აღჭურვილს ავტონომიური ავტომატიზებული სარაკეტო გამშვები დანადგარებით, სეტყვასაწინააღმდეგო რაკეტებს და აგრეთვე პერსონალს, მათ შორის სამეცნიერო ჯგუფს, ლოკატორის და სარაკეტო გამშვები დანადგარების ტექნიკური მომსახურების ჯგუფებს.

სისტემის სატესტო გამოცდებმა უჩვენა სეტყვასთან ბრძოლის საკითხში მისი შემდგომი გამოყენების პერსპექტულობა. მიუხედავად ზემოქმედების საშუალებების (რაკეტების) სიმცირისა, 2015 წელს სეტყვასაწინააღმდეგო სამუშაოების ფიზიკური და ეკონომიური ეფექტურობა იყო არანაკლები, ვიდრე იმ წლებში, როდესაც ფუნქციონირებდა სეტყვასთან ბრძოლის სამსახური.

ნიშვნელოვანია ის გარემოებაც, რომ თუ საბჭოთა დროს კახეთში სეტყვასთან ბრძოლის სამსახურის პერსონალი შეადგენდა 800 კაცზე მეტს, დღეს ამ სამუშაოებს უზრუნველყოფს მხოლოდ 30 ადამიანი.

შემდგომში გათვალისწინებულია სეტყვისგან დასაცავი ტერიტორიების გაფართოება, და აგრეთვე, რადიოლოკატორის შესაძლებლობების გამოყენება აღმოსავლეთ საქართელოში და აგრეთვე აზერბაიჯანის და სომხეთის მიმდებარე ტერიტორიებზე საშიში ჰიდრომეტეოროლოგიური პროცესების მონიტორინგისათვის.

Восстановление противоградовой системы в Кахетии (Грузия)

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Резюме

Крупномасштабные опытные, опытно-производственные и производственные работы по воздействию на градовые процессы в Грузии проводились в 1960-1989 годах (Кахетия, Южная Грузия) на общей площади около 1.2 млн гектаров. Положительный эффект изменялся в интервале 20 - 95% со средним значением 75 - 85%. В последующие четверть века, после прекращения этих работ, ущерб сельскому хозяйству от града возрос и вернулся к уровню, бывшему до начала противоградовых работ.

В 2015 году в Кахетии на площади около 650 тысяч гектаров работы по воздействия на градовые процессы были возобновлены. Приводится описание восстановленной противоградовой системы, включающей: современный метеорологический радиолокатор Meteor 735CDP10 фирмы Selex ES; центральный пункт дистанционного управления со сменным персоналом; автоматизированную систему управления огнем; 85 ракетных пусковых площадок; автономные автоматизированные ракетные пусковые установки; противоградовые ракеты; научную группу; группу технического обслуживания радиолокатора и ракетных пусковых установок.

Тестовые испытания системы показали перспективность ее дальнейшего использования для борьбы с градом. Физическая и экономическая эффективность противоградовых работ в 2015 году, несмотря на ограниченное количество средств воздействия (ракет), была не хуже, чем ранее в годы с воздействием. Существенно, что если в прошлом в Кахетии персонал противоградовой службы составлял более 800 человек, в настоящее время эту работу обеспечивает всего 30 человек.

В дальнейшем предполагается увеличение защищаемых от града площадей, а также, помимо противоградовых работ, использование радиолокатора для мониторинга опасных гидро-метеорологических процессов в Восточной Грузии и прилегающих к ней территорий Армении и Азербайджана.

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Some New Data about the Bioclimatic Characteristics of the Village of Mukhuri (Western Georgia)

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Abstract

Some new data about the bioclimatic characteristics (Tourism Climate Index and light ions content in air) of the village Mukhuri (Western Georgia), useful for the development of the health resort-tourist potential of this locality are represented. It is shown that for the development of mass tourism the months from March through November are favorable. The results of measurements of light ions concentration in air near the bank of river Khobistskali, in Shurubumu karstic cave and forest showed the prospect of development in the indicated locality ionotherapy. It is noted that all months of year are suitable for the therapeutic and preventive tourism.

Key words: Tourism Climate Index, small ions, health resort- tourist potential

Introduction

Information about different bioclimatic characteristics of known and potential health resort - tourist zones has vital importance for an increase in the effectiveness of their therapeutic, rehabilitative, prevention and reducing properties [1-3]. In particular, they include the so-called Tourism Climate Index (TCI) [4,5], and also the concentration of light (small) ions [6-8].

TCI is a combination of seven parameters, three of which are independent and two in a bioclimatic combination:

$$TCI = 8\cdot Cld + 2\cdot Cla + 4\cdot R + 4\cdot S + 2\cdot W$$

Where Cld is a daytime comfort index, consisting of the mean maximum air temperature Ta, max (°C) and the mean minimum relative humidity RH (%), Cla is the daily comfort index, consisting of the mean air temperature (°C) and the mean relative humidity (%), R is the precipitation (mm), S is the daily sunshine duration (h), and W is the mean wind speed (m/s).

In contrast to other climate indices, every contributing parameter is assessed. Because of a weighting factor (a value for TCI of 100), every factor can reach 5 points. TCI values >= 80 are excellent, while values between 60 and 79 are regarded as good to very good. Lower values (40 – 59) are acceptable, but values < 40 indicate bad or difficult conditions for understandable to all tourism [4]. Data about TCI are used for the information on the "Average Tourist" and can be useful for the planning developments of mass tourism.

The content of light ions in the atmosphere (n_+ - positive ions concentration, n_- - negative ions concentration) plays important role in molding of the physiological state of population. Simultaneously light ions are the indicator of the purity of air [9,10]. If sum light ions concentration $n_{+/-}$ is < 600 cm^{-3} (n_+ =300, n_-= 300, less than the minimum level), their physiological action on the human organism is the following: fatigue, weakening attention, retarding of reactions, worsening of the memory, headache, the disturbance of the regime of blood pressure, etc. When $n_{+/-}$ is 1000-8000 cm^{-3} (n_+ =400-3000, n_-= 600-5000, minimally necessary – optimum levels) their physiological action on the human organism is positive and has preventive and therapeutic effect: optimization of blood pressure, positive influence on the course of the diseases of respiratory organs, such as bronchial asthma, also, antiseptic actions, etc. [11].

Optimum, useful for the health of the human concentration of light ions in air, usually is observed in the karstic caves, in the forests, in the mountain locality, near the coasts of rivers and seas, near waterfalls, etc. Therefore, for expanding the health resort-tourist potential of one locality or another, it is desirable to determine places with the increased air ionization. These places can be recommended for organizing the medical and preventive procedures [7,8].

The results of the studies TCI and light ions content in air in some locations of Georgia, which were carried out earlier, were represented in the works [3-8, 10-17]. The data about indicated bioclimatic the characteristics for the village Mukhuri (Western Georgia) are cited below.

The region of studies, material and methods

Village Mukhuri is a populated place in Western Georgia (42.6330 N, 42.1769 E, altitude: 272 m). Mukhuri located on the shore river Khobistskali. Distance from Mukhuri to the capital of Georgia Tbilisi - 240 km, to the capital of the Adjarian Autonomous Republic Batumi - 120 km, to the second in the value city of Georgia Kutaisi - 60 km, to the coast of Black sea - 55 km (fig. 1).

Mukhuri is famous as the health resort, with coniferous, mixed forest and alpine mountains. The cool and pure river Khobistskali divided the village with two sides. There are different kinds of fished in the river and also mineral waters runs in it. One of them is 9% - calcium chlorine - "Lugela", which is used for medical treatment– rachitis, allergy, blood bleeding, osteoporosis, skin rashes, parenchymal hepatitis, nephritis, stomatitis, conjunctivitis, also is used in cosmetology. Carbonaceus mineral water "Skuri" is located at a distance of 5 km length from the village Mukhuri, which is used for treatment of intestinal and urogenital organs.

The Shurubumu cave deserves the attention by its uniqueness and extent; its entrance is opened at 3 km away from the village of Mukhuri on the left bank of the Khobistskali River, where the thin layered limestones (0.2-0.3 m) of the Upper Cretaceous (turonuli) age come out on the earth's surface.

Data of Hydrometeorological Service of Georgia was used for the TCI calculation data. Light ions concentration (cm^{-3}) measurements with the aid of the portable ions counter of the production of firm "AlphaLab, Inc." are conducted. Radon content in air (the basic ionizer of air in the atmospheric boundary layer) with the aid of the portable device PB-4 was conducted.

Fig. 1. Location village Mukhuri in Georgia.

Results and discussion

Information about TCI category in fig. 2 and 3 are presented. Data about radon and small ions concentration in some locations of Mukhuri (fig. 4-7) in the table is presented.

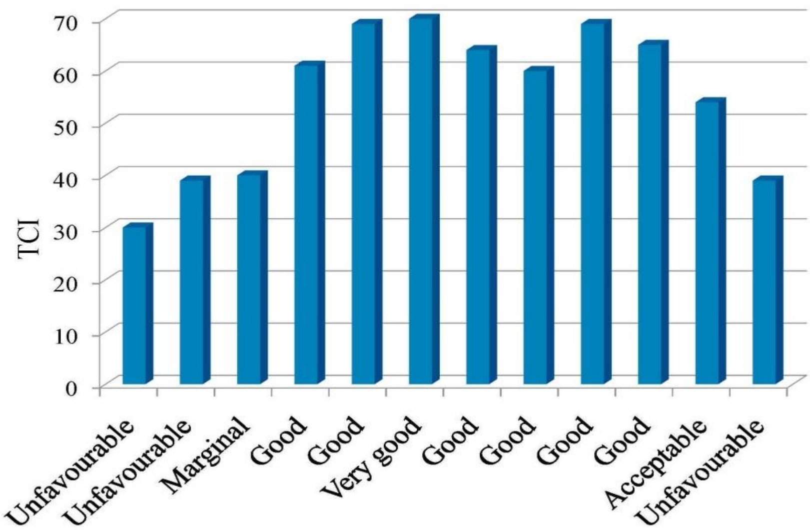

Fig. 2. The intra-annual distribution of Tourism Climate Index in Mukhuri.

As follows from fig.2 the intra-annual distribution of the TCI values for Mukhuri has bimodal nature with the extremum during June and September. It is known, that the bimodal type of distribution of TCI values in many other places is observed [14]. TCI categories change from “Unfavourable” (December, January, February) to “Very good” (June). For the development of mass tourism the months from March through November are favourable.

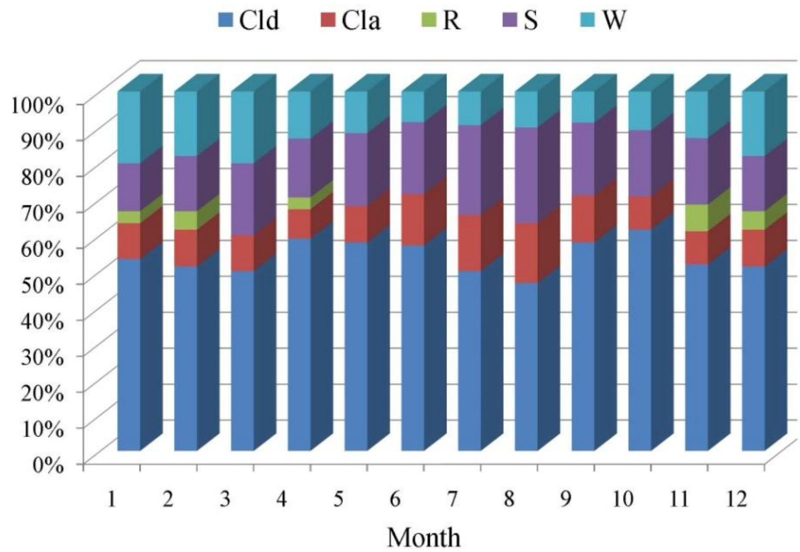

Fig. 3. Share of different components in Tourism Climate Index in Mukhuri.

As it follows from fig. 3 the values of daytime comfort index (Cld varied from 46.7 % 61.5 % with average value 54.0 %) and daily sunshine duration (S varied from 13.3 % to 7.4 % with average value 19.1 %) make the greatest share to the mean annual values of TCI in Mukhuri.

The values of daily comfort index Cla and precipitation R make the smallest share to the mean annual values of TCI (Cla varied from 8.2 % to 16.7 % with average value 11.4 % and R varied from 0 % to 7.4 % with average value 2.0 %).

As a whole, the relatively lowered values of TCI in Mukhuri (in comparison with Baku, Yerevan, Tbilisi, different location of Iran, Turkey etc.) are caused by more rainy climate, decreasing the contribution share R to the general value of TCI [14,18-22]. At the same time values of TCI in Mukhuri are close to their values for the cities Batumi, Kobuleti and Khulo, located on the coast area of Black sea [13, 15].

Table

Radon and small ions concentration in some locations of Mukhuri (September 2015)

Location	Radon Bq/m^3	Small ions, cm^{-3}			Coeff. of unipolarity **n_+/n_-**
		n_+	**n_-**	**$n_{+/-}$**	
At the entrance into the cave		315	1650	1965	0.19
Cave, 1 hall, center	9	250	1570	1820	0.16
Above the cave, forest	4	410	1100	1510	0.37
Near shore river Khobistskali		275-400	1160-1750	1435-2150	0.24-0.23
Court of apartment house near from the river		480	1750	2230	0.27

In the table results of measurements of radon and light ions concentration in some locations of Mukhuri (fig. 4-7) are presented.

Fig. 4. Measurement of the radon and light ions concentration at the entrance into the cave. In the foreground: A. Amiranashvili (to the left) and V. Chikhladze (to the right).

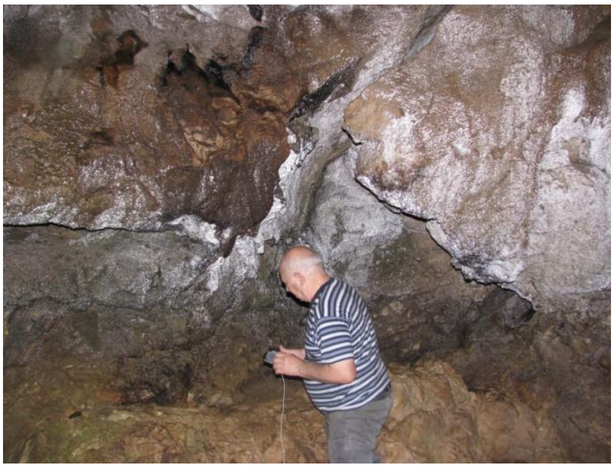

Fig. 5. Measurement of the light ions concentration in the cave (V. Chikhladze).

Fig. 6. Forest in the environments of cave. In the center: V. Chikhladze (to the left) and N. Bolashvili (to the right).

Fig. 7. One of the site of Khobistskali river.

As follows from the table, the light ions concentration in air near the bank of river Khobistskali, in Shurubumu karstic cave and forest are sufficiently high and generally correspond to category minimally necessary – optimum levels.

It should be noted that the first hall of Shurubumu cave (area - approximately 20 square meters, volume - approximately 60 cubic meters) is not isolated from the environment (fig. 4,5). Therefore in this cave the low concentrations of radon and correspondingly the low concentration of light ions for the karstic caves are observed [23, 24]. For applying the cave for therapeutic purposes it is necessary to install doors in the entrance of the cave. As a result, the concentration of radon and light ions considerably will be increased in the cave.

It should also be noted, that both the cave, forest near cave and some places near Khobistskali river, are located in the out-of-the-way places (fig. 6,7). Therefore for the possibility of the visiting the indicated objects for purposes of ionotherapy it is necessary to create the appropriate infrastructure (stairs, paths, benches for leisure, shelters from the rain, medical consultants, etc.). For ionotherapy (therapeutic and preventive tourism) all months of year will be suitable in this case.

Conclusion

Climate has a strong influence on the tourism and recreation sector and in some regions represents the natural resource on which the tourism industry is predicated. In this work the new data about such bioclimatic characteristics as "Tourism Climate Index" and small ions concentration for the village Mukhuri (Western Georgia) is obtained.

In the future we plan a more detailed study of the climate resources of this location for the tourism development.

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სოფელ მუხურის (დასავლეთ საქართველო) ბიოკლიმატურ მახასიათებლებზე ზოგიერთი ახალი მონაცემები

ა.ამირანაშვილი, ნ. ბოლაშვილი, ვ.ჩიხლაძე,
ნ.ჯაფარიძე, ქ.ხაზარაძე, რ.ხაზარაძე,
ზ.ლეჟავა, კ.წიქარიშვილი

რეზიუმე

მოყვანილია ზოგიერთი ახალი მონაცემები სოფელ მუხურის (დასავლეთი საქართველო) ბიოკლიმატურ მახასიათებლების (ტურიზმის კლიმატური ინდექსი და ჰაერში მსუბუქი იონების შემცველობა) შესახებ, რომლებიც სასარგებლო იქნება ამ ადგილის საკურორტო-ტურისტული პოტენციალის განვითარებისთვის. ნაჩვენებია, რომ მასობრივი ტურიზმის განვითარებისთვის ხელსაყრელია თვეები მარტიდან ნოემბრის ჩათვლით. მდინარე ხობისწყალის ნაპირებთან, შურუბუმის კარსტულ მღვიმეში და მიმდებარე ტყეში ჰაერში მსუბუქი იონების კონცენტრაციის გაზომვების შედეგებმა აჩვენა ხსენებული ადგილების პერსპექტულობა იონოთერაპიის განვითარების თვალსაზრისით. აღინიშნება, რომ სამკურნალო და გამაჯანსაღებელი ტურიზმისთვის წლის ყველა თვეა გამოსადეგი

Некоторые новые данные о биоклиматических характеристиках села Мухури (Западная Грузия)

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Резюме

Представлены некоторые новые данные о биоклиматических характеристиках (климатический индекс туризма и содержание легких ионов в воздухе) села Мухури (Западная Грузия), полезные для развития курортно-туристического потенциала этой местности. Показано, что для развития массового туризма благоприятными являются месяцы с марта по ноябрь. Результаты измерений коцентрации легких ионов в воздухе около берега реки Хобисцкали, в Шурубумской карстовой пещере и лесу показали перспективность развития в указанной местности ионотерапии. Отмечается, что для лечебного и оздоровительного туризма пригодны все месяцы года.

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Some Bioclimatic Indices of the Health Resort-Tourist Complex of Bazaleti Lake (Georgia)

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Abstract

The data about equivalent- effective temperature of air (EET), content of light ions in air and chemical composition of water in Bazaleti Lake (Eastern Georgia) are represented. It is shown that in the hottest months (July, August) in Bazaleti Lake in comparison with Tbilisi the more comfortable for human health thermal conditions is observed. The content of light ions in air in Bazaleti Lake and in the limits of several hundred meters from it is above minimally necessary for the health of people, whereas in Dusheti ions concentration is less minimally necessary. The data about the chemical composition of water in the lake and in the spring, which is located in several kilometers from the lake, do not indicate the essential deflections from the standards for the drinking water.

Key words: Equivalent Effective Temperature, water chemical content, light ions, health resort- tourist potential

Introduction

For the complex characteristic of the health resort-tourist resources of localities in recent years is accepted conducting their certification. Special attention is paid also to the level of the pollution of environment, including air and waters [1, 2].

In Georgia similar systematized works was not carried out, although there are many works on the description of the fundamental characteristics of health resort-tourist resources. In particular, in recent years for different regions of Georgia studies of such important for the health of people bioclimatic characteristics as: air temperature [3,4], air Equivalent-Effective Temperature [4-11], Tourism Climate Index [12-16], light ions concentration in air [4, 16-22], surface ozone concentration [4, 23] etc., are carried out.

The bioclimatic properties of locality, and especially health resort-tourist zones, are frequently characterized by so-called equivalent-effective temperature of air (EET). EET is the combination simultaneously observed air temperature, relative humidity and wind speed, expressed by the conditional value of temperature, which creates the same sensation of heat as stagnant air at a relative humidity 100% and a specific temperature. EET create the same heat-sensation as stagnant air at a relative humidity 100% and a specific temperature. Six basic gradations of EET are separated: < 1° - Sharply coldly, 1-8° - Coldly, 9-16° - Moderately coldly, 17-22° - Comfortably, 23-27° - Warmly, > 27 ° - Hotly [8, 10, 24, 25].

The content of light ions in the atmosphere (n_+ - positive ions concentration, n_- - negative ions concentration) plays important role in molding of the physiological state of population. If sum light ions concentration $n_{+/-}$ is < 600 cm^{-3} (n_+ =300, n_-= 300, less than the minimum level), their physiological action on the human organism is the following: fatigue, weakening attention, retarding of reactions, worsening in the memory, headache, the disturbance of the regime of blood pressure, etc. When $n_{+/-}$ is 1000-8000 cm^{-3} (n_+ =400-3000, n_-= 600-5000, minimally necessary – optimum levels) their physiological action on the human organism is positive and has sanitation- preventive and therapeutic effect: optimization of blood pressure, positive influence on the course of the diseases of respiratory organs, bronchial asthma, antiseptic action, etc. [4,16].

The data about air equivalent-effective temperature, light ions concentration and water chemical content for the Bazaleti Lake (Eastern Georgia) are presented below.

The region of studies, material and methods

The Bazaleti Lake (Lat. 42.037º N, Lon. 44.679 E, Alt. 879 m a.s.l.) is a lake in eastern Georgia some 60 km northwest of the nation's capital Tbilisi and 5 km south of the town of Dusheti. It is used for fish culture, irrigation and recreation. The nearby village and the historical district around the lake are also known as Bazaleti. The surface area of the lake is 1.22 km² and its maximum depth is 7 m. (fig. 1, 2).

The area around the lake housed a flourishing medieval town and is surrounded by many legends. In 1626, the Battle of Bazaleti between two rival Georgian factions took place there.

Currently, the area is a popular recreational area served by a modern tourist complex.
It is known that Bazaleti Lake has an outflow but it has not been discovered. Locals claim that the water recirculates. They tell a story about a bull which was drowned in the lake and was later found in a well in the nearby village. According to local legend, a golden-haired child is lying in a golden crib on the bottom of the lake. The lake was formed from his mother's tears. The story is retold in a Georgian poem.

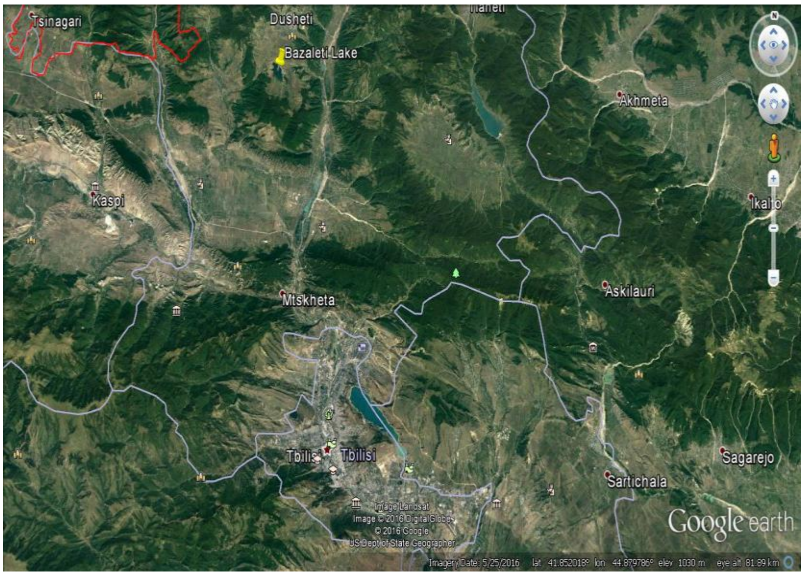

Fig. 1. Location Bazaleti Lake relative to Tbilisi.

Fig 2. Bazaleti Lake.

For the EET calculation data of Hydrometeorological Service of Georgia about the monthly average values of the air temperature, relative humidity and wind speed was used. Values of EET were calculated according to the formula, represented in [24, 25].

Light ions concentration (cm^{-3}) measurements with the aid of the portable ions counter of the production of firm "AlphaLab, Inc." are conducted.

The chemical analysis of water is executed on the chromatograph Shimadzu – HIGH PERFORMANCE LIQUID CHROMATOGRAPHY (HPLC).

Results and discussion

Information about EET in day hour in Tbilisi and Bazaleti Lake in table 1 is presented. Information about chemical composition of water in Bazaleti Lake and spring near lake in table 2 is presented.

Table 1

EET in day hours in Tbilisi and Bazaleti Lake

Month	Tbilisi		Bazaleti Lake	
	EET, grad	EET, heat-sensation	EET, grad	EET, heat-sensation
1	1.4	Coldly	-3.2	Sharply coldly
2	2.1	Coldly	-2.3	Sharply coldly
3	6.7	Coldly	3.2	Coldly
4	13.6	Moderately coldly	10.5	Moderately coldly
5	18.4	***Comfortably***	15.3	Moderately coldly
6	21.6	***Comfortably***	18.7	***Comfortably***
7	24.4	Warmly	21.9	***Comfortably***
8	23.9	Warmly	21.3	***Comfortably***
9	20.6	***Comfortably***	17.9	***Comfortably***
10	15.2	Moderately coldly	12.3	Moderately coldly
11	9.6	Moderately coldly	6.4	Coldly
12	4.3	Coldly	0.3	Sharply coldly

As follows from table 1 the values of EET in Tbilisi varied from 1.4° (January, gradation - "Coldly ") to 24.4° (July, gradation - "Warmly"). Values of EET in Bazaleti Lake varied from -3.2° (January, gradation - "Sharply coldly") to 21.9° (July, gradation - "Comfortably"). In Tbilisi monthly average in day hours values of EET with gradation "Comfortably" in May, June and September, in Bazaleti Lake – from June to September are observed. Thus, in the hottest months (July and August) in the Bazaleti Lake in comparison with Tbilisi comfortable for the health of people thermal conditions is observed.

The single measurements of the light ions concentration in air near the Bazaleti Lake and in Dusheti in summer 2015 showed the following:

- Near the lake, the sky is clear, wind speed is 1-2 m/sec: n_+ = 1400 – 1470 (average -1435) cm^{-3}, n_- = 1860 – 1960 (average -1910) cm^{-3}, $n_{+/-}$ = 3260 – 3430 (average - 3345) cm^{-3}.
- 300 meters from the lake: n_+ = 570 – 640 (average - 605) cm^{-3}, n_- = 1780 – 1820 (average - 1800) cm^{-3}, $n_{+/-}$ = 2350 – 2460 (average -2405) cm^{-3}.
- Dusheti: n_+ = 530 – 640 (average -585) cm^{-3}, n_- = 210 – 280 (average -245) cm^{-3}, $n_{+/-}$ = 740 – 920 (average -830) cm^{-3}.

As these measurements showed, near the lake and in the limits of several hundred meters from it the summary concentration of light ions in air changes from 2405 cm^{-3} to 3345 cm^{-3} (higher than minimally necessary level). In this case, the concentration of negative ions exceeds the concentration of positive (so-called "waterfall effect" caused by hydro-ionization [21]).

In Dusheti the summary concentration of light ions in air is equal 830 cm^{-3} (less than minimally necessary level). In this case the concentration of positive ions exceeds the concentration of negative, which usually is observed in the places, where the formation of ions mainly occurs due to gamma-radiation of soil, radon and cosmic radiation.

Table 2

The chemical composition of water in Bazaleti Lake and in spring near lake

Chemical composition	Concentration, Mg/L		The norms of drinking water, not are more Mg/L	Norms of irrigation water, not are more Mg/L
Location	Bazaleti Lake	Spring		
Ffluorides (F)	0.839	1.476	0,7	
Chlorides (Cl)	6.248	19.692	250	
Nitrites (NO_2)	0.010	0.132	0,2	
Bromine (Br)	0.112	0.156		0.1
Nitrates (NO_3)	0.143	63.24	50	
Phosphates (PO_4)	1.617	4.83		
Sulphates (SO_4)	8.353	31.554	250	
Lithium (Li)	0.011	0.024		0.3
Natrium (Na)	12.678	16.230	200	
Amonium (NH_4)	0.000	0.000		0.39
Potassium (K)	3.139	0.700		
Magnesium (Mg)	25.541	59.376	85	
Calcium (Ca)	17.681	20.624	140	

As it follows from table 2 that both samples of water (water from the Bazaleti Lake and water from the spring, located on the road, in 3.8 km to the east of lake, at the height of 711 meters a.s.l.), in comparison with the norms of drinking water, a comparatively high concentration of fluorine is noted. In the water from the spring the values of nitrates are high, while in the lake they are very insignificant. In the lake and in the spring water the concentration of such parameters as chlorides, sulfates, and also sodium and calcium is considerably lower than the tolerance levels. As far as the maximum permissible concentration of the parameters of water, which can be used for the irrigation, is concerned, in both samples is noted small exceeding of the content of bromine, and lithium also of amonium in the limits of standard [26].

Conclusion

In Georgia in recent years health resort-tourist industry is intensively developed. One of the places for the organization for people of leisure and tourism is Bazaleti Lake. Comfortable thermal conditions in the day hours here from June through September are observed. The preliminary data of the measurements of the content of light ions in air showed, that in the calm weather near the lake and its environments the ionization level of air above minimally of necessary, that favourably for the health of people.

At present vigorously is developed the infrastructure around the lake, which facilitates the use of this place for leisure and tourism the year round. Therefore it is important to maximally use bioclimatic resources of lake for expanding its health resort-tourist potential. In connection with this in the future, in particular, is expedient conducting the more detailed analyses of the distribution of the concentration of light ions near the lake and in its environments under the varied conditions of weather for the designation of places for their use for prevention, reducing and therapeutic purposes.

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ბაზალეთის ტბის საკურორტო - ტურისტული კომპლექსის ზოგიერთი ბიოკლიმატური მახასიათებელი

თ.ბლიაძე, ვ. ჩიხლაძე, ნ. ჯაფარიძე,
ქ. ხაზარაძე, რ.ხაზარაძე, გ. მელიქაძე,
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რეზიუმე

მოყვანილია მონაცემები ბაზალეთის ტბის მახლობლად ჰაერის ეკვივალენტურ-ეფექტური ტემპერატურის (ეეტ), ჰაერში მსუბუქი იონების შემცველობის და ბაზალეთის ტბის წყლის ქიმიური შემადგენლობის შესახებ. ნაჩვენებია, რომ თბილისთან შედარებით წლის ყველაზე ცხელი თვეების (ივლისი, აგვისტო) დროს ბაზალეთის ტბაზე დაიკვირვება ადამიანის ჯანმრთელობისთვის უფრო კომფორტული თერმული რეჟიმი. მსუბუქი იონების შემცველობა ტბაზე და რამოდენიმე ასეული მეტრის რადიუსში ადამიანის ჯანმრთელობისთვის მინიმალურად საჭირო ნორმაზე მეტია, მაშინ როდესაც დუშეთში იონების კონცენტრაცია მინიმალურ საჭიროზე ნაკლებია. მონაცემები ბაზალეთის ტბის წყალსა და რამოდენიმე კილომეტრში მდებარე წყაროს წყლის ქიმიური შემადგენლობის შესახებ არ უჩვენებენ არსებით გადახრას სასმელი წყლის ნორმებიდან

Некоторые биоклиматические показатели курортно - туристического комплекса озера Базалети (Грузия)

**Т.Г. Блиадзе, В.А. Чихладзе,Н.Д. Джапаридзе,
К.Р. Хазарадзе, Р.Р. Хазарадзе,Г.И. Меликадзе,
Н.Д. Варамашвили, С.Г. Вепхвадзе**

Резюме

Представлены данные об эквивалентно-эффективной температуре воздуха (ЕЕТ), содержании легких ионов в воздухе и химическом составе воды озера Базалети (Восточная Грузия). Показано, что в самые жаркие месяцы (июль, август) на озере Базалети по сравнению с Тбилиси наблюдается более комфортный для здоровья человека термический режим. Содержание легких ионов на озере Базалети и в пределах нескольких сотен метров выше минимально необходимой для здоровья людей нормы, тогда как в Душети концентрация ионов ниже минимально необходимой. Данные о химическом составе воды в озере и в роднике, находящемся в нескольких километрах от озера, не указывают на существенные отклонения от норм для питьевой воды.

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