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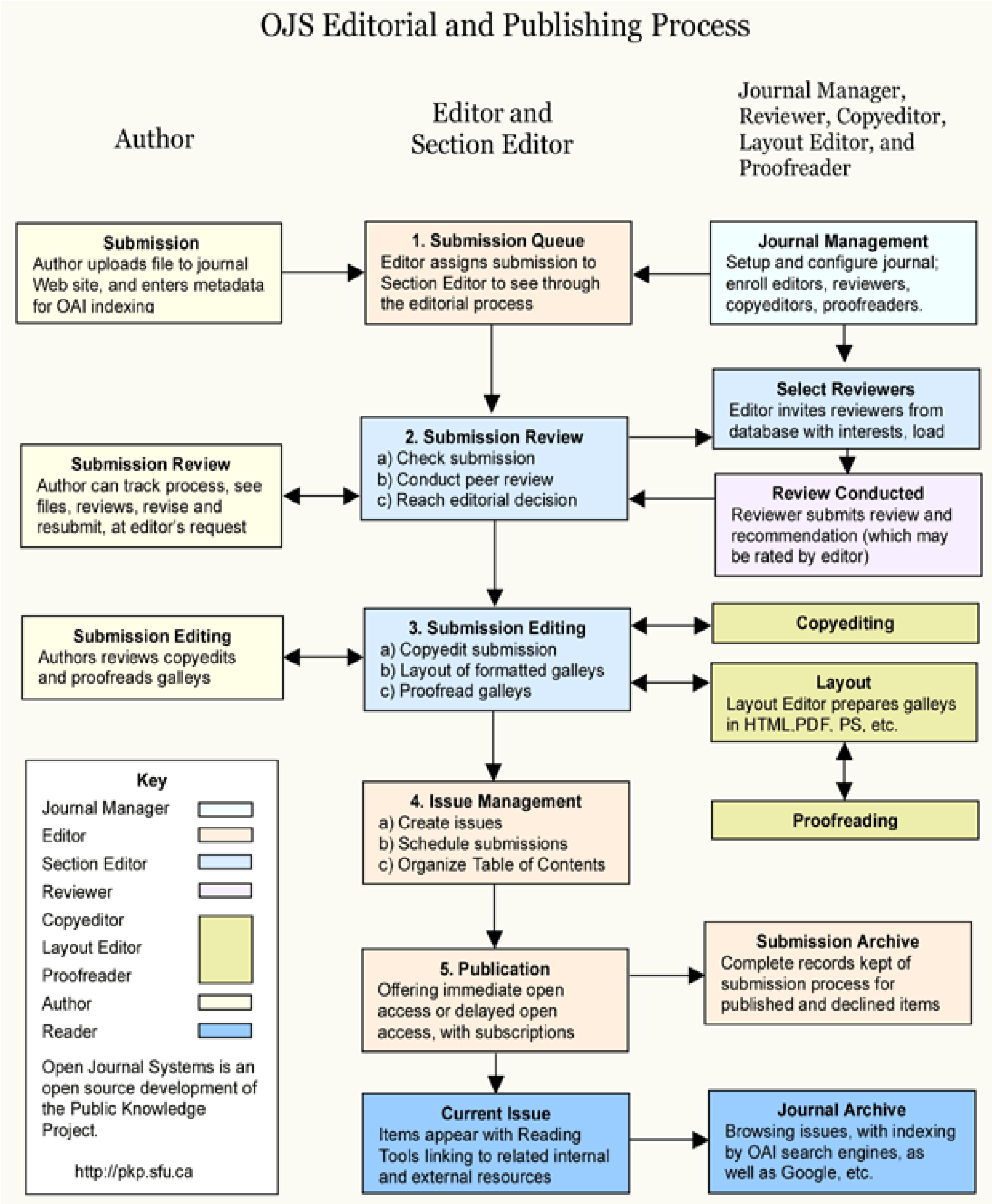

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Reaction of the Hydrodynamic Network on the Earthquake Preparation Process in Georgia

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ABSTRACT

The article contain information about several hydrodynamic anomalies were observed during earthquake in Racha (04.11.2020 17:10, Mag = 4.2, Depth = 2km, Lat. 42.48°; Long. 43.41°) on the multiparametric monitoring network of M. Nodia institute of Geophysics. Data were analyzed by the special program which gives possibility to exclude the influence of geological factors by the common value of tidal variations. Was analyzed reaction of parameters to the earthquake preparation process.

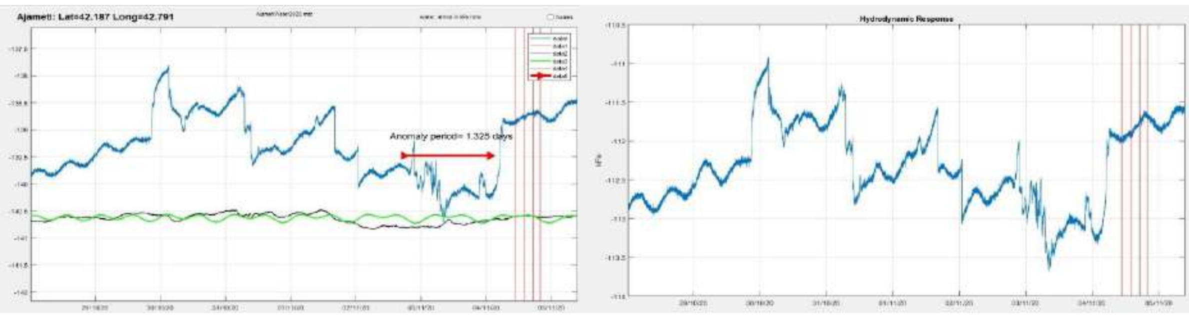
Key words: *hydrodynamic anomalies, seismic event precursors.*

1. Introduction

Georgia is very vulnerable to various natural disasters, including earthquakes [1]. Significant number of works on the registration of earthquakes and the detection of their possible precursors is here carried out [2-10]. Multiparametric data (water level, atmosphere pressure, temperature) were recorded with a minute frequency, in the deep boreholes located on the territory of Georgia. Observations were carried out using the special equipment providing measurement of deformation up to 10^{-8} degrees [11-12]. In order to exclude the influence of geological factors, the data from various stations were rated against the common value of tidal variations [13-14]. Variation and reaction of parameters to the earthquake preparation process [15-19] were analyzed.

2. Data Analysis

Let us consider the changes in parameters during the preparation of the earthquake ("Racha", 04.11.2020 17:10, Mag = 4.2, Depth = 2km, Lat. 42.48°; Long. 43.41°) in the period from 29.10.2020 to 06.11.2020 for five stations.



a b

Fig.1. a - Water level, atmospheric pressure and tidal variations at the Ajameti borehole. Vertical line marks an earthquake. b- Hydrodynamic Response.

The first of them - "Ajameti", is located 60 km from the epicenter, the second, "Kobuleti", is located 154 km from the epicenter, "Lagodekhi" - at 247 km, "Nakalakevi" - at 117 km, and finally "Oni" is located in epicentral area.

Anomaly was revealed on Ajameti station before 4 November 2020 earthquake, 5 days earlier. Water level falling can be seen on the graph (Fig.1 a, b). Earthquake happened in 60 km far from the station. The duration of the anomalous period is fixed on figure.

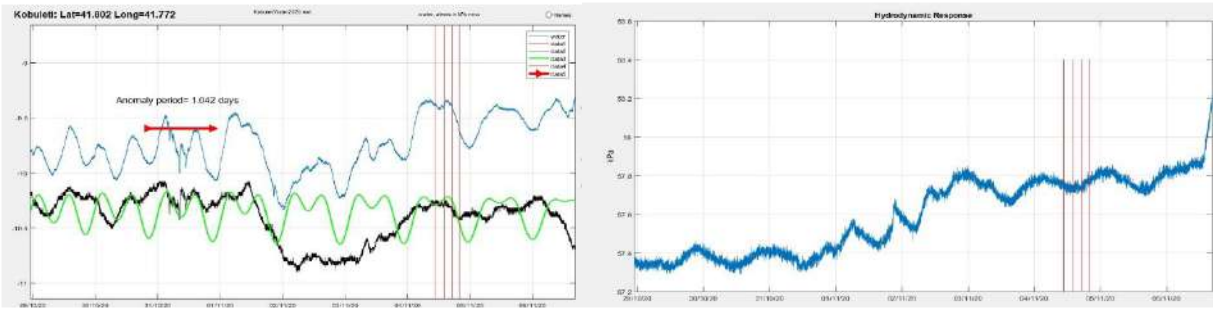


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Fig.2. a - Water level, atmospheric pressure and tidal variations at the Kobuleti borehole. Vertical line marks an earthquake. b- Hydrodynamic Response.

At Kobuleti borehole, which is 154 km away from the epicenter, the anomaly was observed 4 days prior to the earthquake. The duration of the anomalous period is shown on figure.

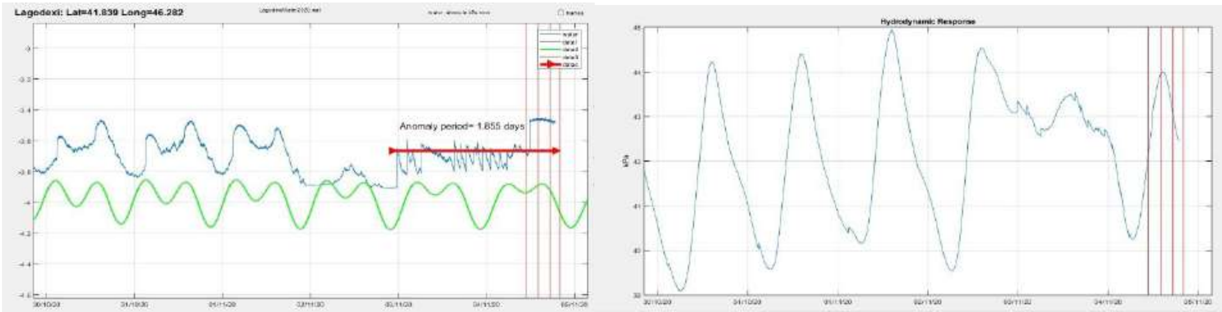

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Fig.3. a - Water level and tidal variations at the Lagodekhi borehole. Vertical line marks an earthquake. b- Hydrodynamic Response.

In Lagodekhi, which is 247 km away from the epicenter, we observed an anomaly that continued for 2 days.

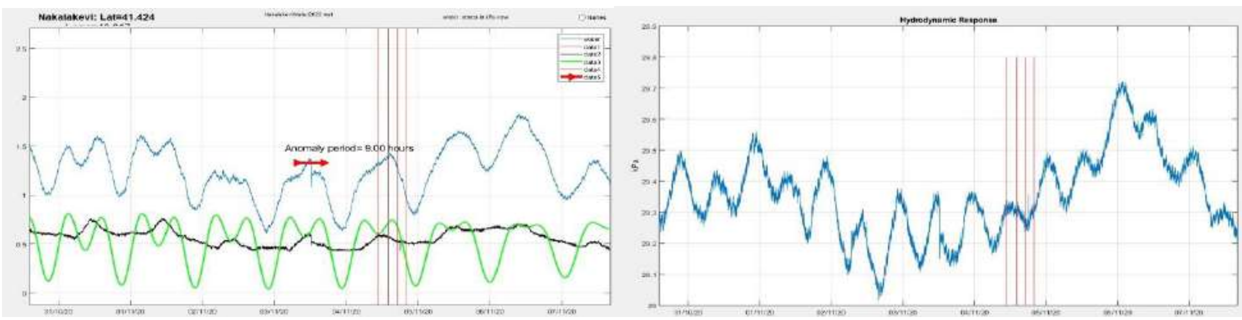

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Fig.4. a - Water level, atmospheric pressure and tidal variations at the Naqalaqevi borehole. Vertical line marks an earthquake. b- Hydrodynamic Response.

Anomaly was observed in Naqalaqevi borehole 1 day earlier before event of 4 November 2020. The Earthquake occurred in 117 km far from a station.

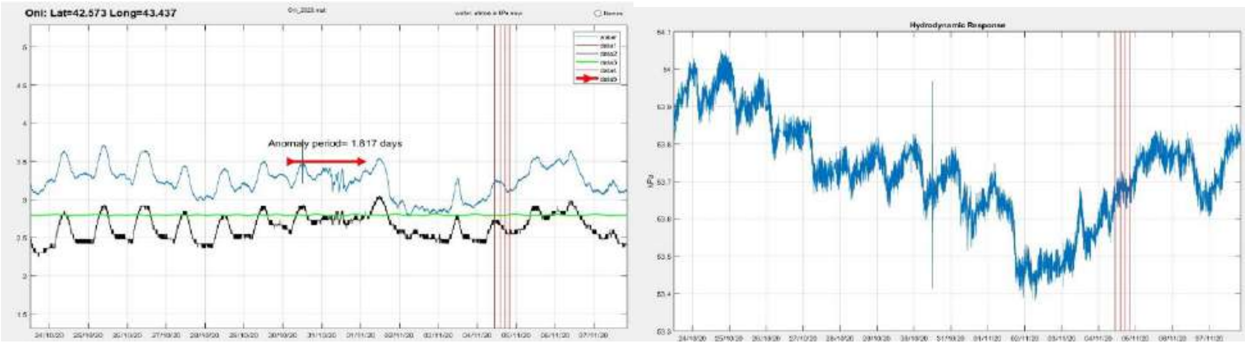

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Fig.5. a - Water level, atmospheric pressure and tidal variations at the Oni borehole. Vertical line marks an earthquake. b- Hydrodynamic Response.

At Oni station anomaly behavior was 5 day earlier before the earthquake and continued for 2 days. Earthquake epicenter was located in 10 km far from the station.

3. Conclusion

Results of data analysis demonstrate the informatively of water level as an indicator of tectonic activity. Variations in hydrodynamic parameters are caused by the earth stress. During normal period it change according tidal variation and has “background” value. Before seismic event character of variation changed above “background” value, as indicator of tectonic activity. During the observed time period were fixed earthquake with Magnitude 4.2, between 60-150 km from the station, occurred on the territory of Caucasus.

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გ. მელიქაძე, თ. ჯიმშელაძე, გ. კობზევი, ა. ჭანკვეტაძე

რეზიუმე

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Реакция гидродинамической сети на процессы подготовки землетрясений в Грузии

Г.И. Меликадзе, Т. Дж. Джимшеладзе, Г.Н. Кобзев, А. Ш. Чанкветадзе

Резюме

Статья содержит информацию о гидродинамических аномалиях в период землетрясения в Рача (04.11.2020 17:10 Маг. =4.2) по данным наблюдений мультипараметрическом мониторинговой сети Института геофизики им. М. Нодиа. Данные проанализированы с помощью специальной программы. С целью исключения влияния геологических факторов, данные с различных станций были откалиброваны с помощью значений приливных вариаций. Осуществлен анализ вариаций и реакции параметра на процесс подготовки землетрясения.

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Radon Distribution on the Territory of West Georgia

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ABSTRACT

Quantitative assessment of radon distribution in West Georgia has been carried out. According to field data in more than 100 water and soil samples there is high content of radon.

Key words: *Rn mapping, out-door radon.*

Introduction

According GNSF project FN-19-22022 “Radon mapping and radon risk assessment in Georgia” during 2020-year authors carried our field work in order to quantify the radon distribution, ascertain geological factors influencing on the out-door radon concentrations some geographical areas of Central Georgia.

Method

When undertaking the gas Rn survey, the particular attention was paid to the multiple active zones of faults and areas of elevated geo-chemical background of uranium and quicksilver. Mobile group conducted the Radon researches by Alpha-Guard measurement device. Rn content was measured in any type of water source (boreholes, wells and springs) and in the soil aeration zone in several regions of Guria and Imereti. All observation sites were fixed by GPS measurements.

The key method for fulfillment the project is Radon mapping based on application of geochemical methods [1-3]. Connection of anomalies to geological and hydro-geological structures, is analyzed using GIS technology.

Results

Results of analyses on radon concentration were marked on topographic and geological maps. After that the field data were digitized and transferred into GIS-system. On the basis of these data the map of Rn content in water and soil were compiled using GIS technique (Fig.1).

Areas of anomalously high Rn exhalation both in water and in soil were revealed in Tskhaltubo, Kuttaisi, Vani, Bagdadi, Chokhatauri and Ozurgeti regions. In order to understand the nature of these anomalies it is necessary to analyze all factors that influence intensity of Rn exhalation and lead to high risk of its accumulation.

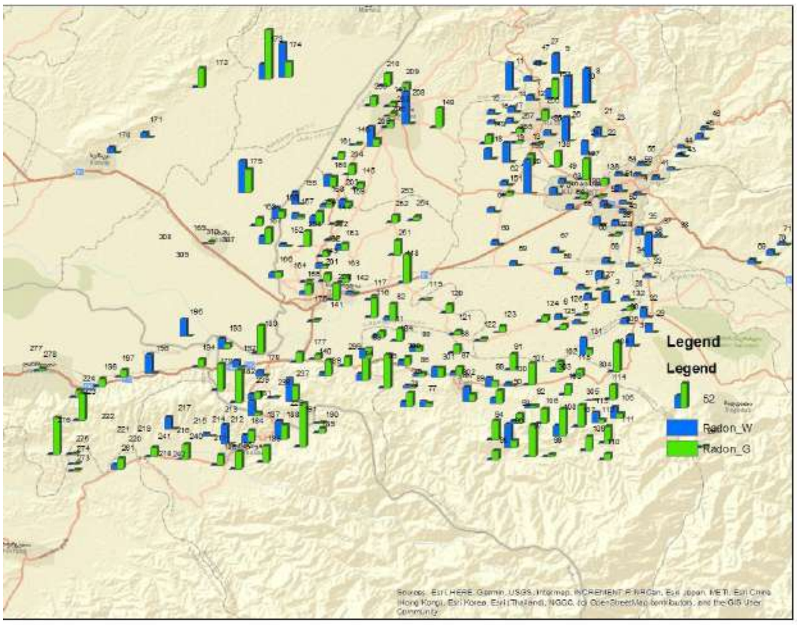

Fig. 1 Sampling points location on the territory.

These factors are lithology and geological structures of the region, presence of tectonic faults, presence of radioactive elements in the rocks, hydrogeological and geomorphological structures of the region, soil characteristics etc (Fig.2).

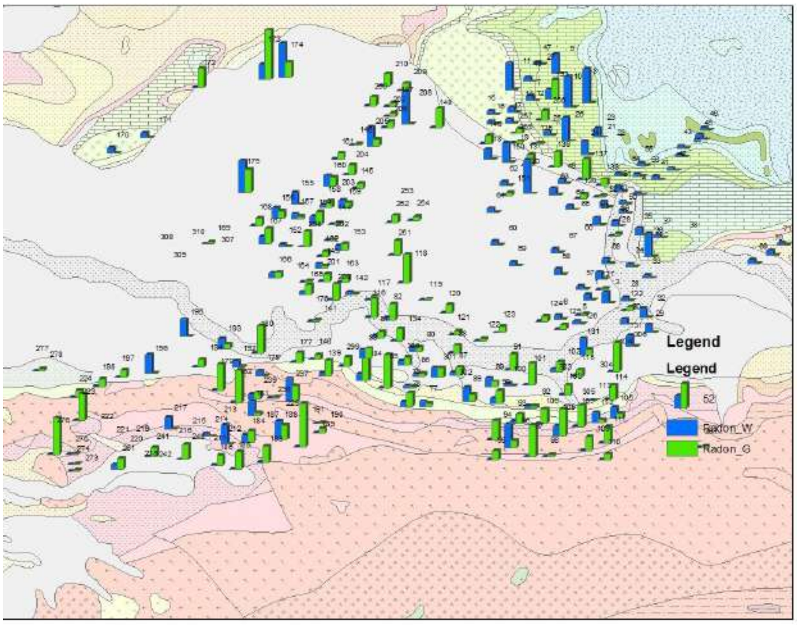

Fig. 2 Radon distribution on the geological map

The Northern and Central part of the tested area belong the geological point of view to the Kutaisi sub-zone of the Georgian plate and the Southern part – to the Adjara-Trialeti folded system.

On the North territory there are Lower Cretaceous rocks, which contain fissure and fissure-karstic type of pressurized ground water (regions of Tskaltubo and Kutaisi); the characteristic example is the low-radioactive thermal waters of Tskaltubo resort (50-70 Bq/l). Here the springs have large debit (200-220 l/s).

In this area to the north of Kutaisi we found a band of elevated radon content in the soil (22-26 KBq/m^3), which should be related to the presence of dikes of the crystalline rocks and systems of faults, developed on this territory. At the same time the content of radon in the water is low, which can be explained by influence of near surface groundwater circulation in this zone.

The recharge of the aquifer takes place in the northern elevated areas; then the aquifer plunge under the Quarternary layers and its discharge takes place at the contact area of Georgian plate and Adjara-Trialeti folded system, where a lot of transversal faults are found. This is also confirmed by the existence in this zone of low-radioactive thermal waters at the resorts Sulori, Amaghleba and Vani.

In the south and south-west part of test area, i.e. in the Adjara-Trialeti folded system (regions of Vani, Chokhatauri and Ozurgeti), in the volcanic and sediment rocks of Middle Eocen we observe karstic-fissure and fissure pressurized groundwaters of low radioactivity. The terrain here is of erosion-peneplain type.

Similar to Tskaltubo region here also are observed high values of Rn content in the soil (22-58 KBq/m^3); this can be explained by high gas permeability of rocks and geomorphology of the area. As to the Rn content in water, it is a bit less (16-22 Bq/l) than in Tskaltubo region and cover much less area due to the fact that here mostly the shallow groundwater's are observed; these waters are characterized by shallow circulation system and they are not discharged on the surface (situation is alike to that in the North, where groundwater is in limestone rocks of Cretaceous age).

Conclusions

Peculiarities of distribution of Rn on the territory of West Georgia was studied and anomalous areas were outlined. The elevated exhalation of Rn is the result of draining of Lower Cretaceous and Middle Eocene aquifers by rising springs and boreholes.

Acknowledgement

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რადონის განაწილება დასავლეთ საქართველოს ტერიტორიაზე

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რეზიუმე

დასავლეთ საქართველოს ტერიტორიაზე განხორციელდა რადონის გავრცელების შესწავლა. საველე კვლევებით დაფიქსირდა რადონის მაღალი კონცენტრაცია 100-ზე მეტ სინჯში.

Распределение радона на территории Западной Грузии

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Резюме

Было проведено изучение распределения радона на территории Западной Грузии. Полевыми исследованиями зафиксированы высокие значения радона более чем в 100 пробах.

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Ultrasonic Tomography and Pulse Velocity for Nondestructive Testing of Concrete Structures

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ABSTRACT

The purpose of these research was to study the current state of the Tsageri catchment by geophysical methods. One such method is the ultrasound method. This method can measure and calculate the elastic parameters of the object of study without damaging it. We measured the propagation velocities of ultrasonic longitudinal (P) and shear waves (S) at the studied object. Then, material density (ρ), Poisson's ratio (ν) and Young's modulus (E) were calculated based on the measured speed. Ultrasonic devices, availability in our laboratory, can be used for the so-called tomography, "coverage" from the one side with the help of reflected waves. In this case, it is possible to identify voids of certain sizes, inhomogeneous regions in the body under study, and to distinguish regions of different densities (weakened).

Key words: *tomography, ultrasonic, P-wave, S-wave, nondestructive testing*

Introduction

Tomography is an emerging technique for non-destructive evaluation of concrete. The objective of tomography is to provide visualization, either by cross section or three dimensional structure of the structure interior, so that better identification of anomalous regions and determination of physical properties of the measured region can be achieved [7].
In analogy to visible and ultraviolet light, the terms sound and ultrasound are used to describe the propagation of a mechanical perturbation in different frequency ranges. Ultrasound corresponds to a mechanical wave propagating at frequencies above the range of human hearing (conventionally 20 kHz). Ultrasound and sound waves propagate in fluids (gases and liquids) and solids. In particular, the wave propagation depends on the intrinsic elastic properties of the medium as well as on its mass density [10]. Ultrasonic testing uses high-frequency sound waves to conduct examinations and measurements. In addition to its widespread use in engineering applications (e.g., defect detection / evaluation, material characteristics, etc.), ultrasounds are also used in the medical field. In general, ultrasound testing is based on the recording and quantification of reflected waves (pulse-echo) or transmitting waves.

A ultrasonic pulse-echo test concentrates on measuring the transit time of ultrasonic waves traveling through a material and being reflected to the surface of the tested medium. Based on the transit time or velocity, this technique can also be used to indirectly detect the presence of internal flaws, such as cracking, voids, delamination or horizontal cracking, or other damages [9].

Each of the two types is used under certain conditions [4,5]. In our scientific research, we use acoustics for geophysical and geotechnical research [1,3,5]. In this paper we present scientific-applied studies in the field of geomechanics using acoustic methods [6].

Equipment and software for ultrasound examination

We used ultrasound equipment produced by the Swiss company (PROCEQ, https://www.proceq.com/) for geophysical work, called Pundit PL-200 and Pundit PL-200PE. Ultrasonic testers (Pundit PL-200 and Pundit PL-200PE) are used to study concrete, wood and stone materials and structures using non-damaging acoustic control methods. Equipment and methods can be used: to study internal defects and cracks, heterogeneities and voids in materials, to calculate material modulus, stiffness and Poisson's ratio.

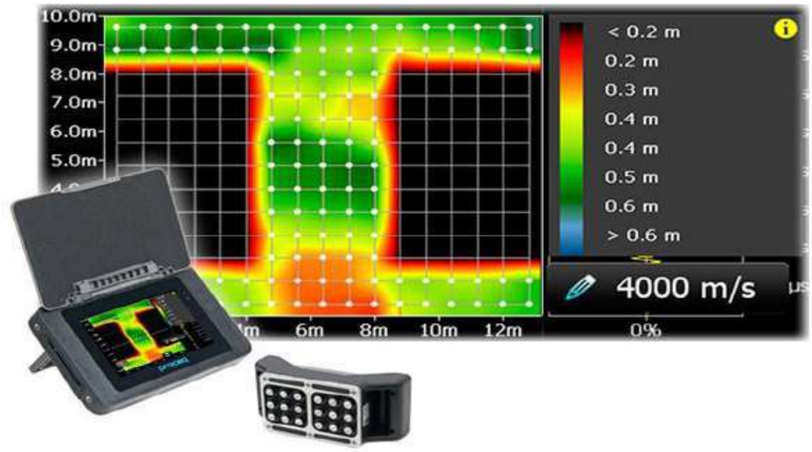
Pulse Echo Transducer - Pundit PL-200PE

The Pulse Echo transducer is a shear wave transducer designed for single-handed and two-handed operation. It is particularly suited to testing where access is limited to a single side. It can be used to perform several types of testing (scanning):

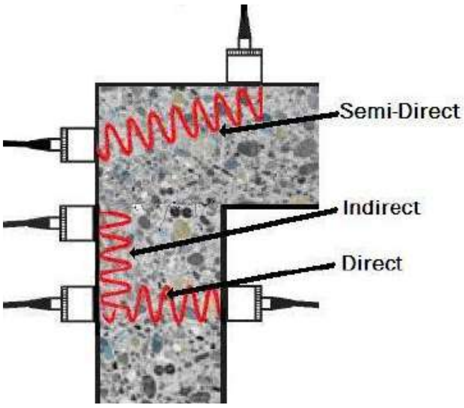
B-Scan
A cross-sectional view perpendicular to the scanning surface is provided. It facilitates the search for pipes, cracks, voids, etc.
State-of-the-art image processing for improved image quality.
Cursor placement allows a direct readout of the slab thickness and the location of hidden objects or defects.

A-Scan
A-Scan allows direct analysis of the raw signal. Digital filters for better echo visibility and noise suppression. Automatic readout of slab thickness (Echo tracker).

Area Scan
Contour map of results over a concrete surface, either Velocity or thickness values can be mapped.



The Pundit PL-200 offers three methods of transmission. These can be seen in the image below.



Direct transmission: Optimal configuration with maximum signal amplitude. The most accurate method for determining pulse velocity.

Indirect transmission: The signal amplitude is about 3% of the direct transmission signal amplitude.

Indirect (semi-direct) transmission: Sensitivity is somewhere between the first two methods. The length of the road is measured from center to center.

Ultrasonic research methods

In our case, we used ultrasonic sounding with piezoelectric 54 kHz sensors. Piezoelectric transverse wave sensors with a frequency of 250 kHz were also used, and piezoelectric sensors with a frequency of 50 kHz were used for ultrasound tomography. With the help of sensors in such frequency ranges, it is possible to study the structure of a solid and concrete at a depth of 50-60 cm, and in some cases even up to 1 m.

Performing ultrasound examinations

Ultrasound examinations were performed on the load-bearing piers and walls of the Tsageri catchment (Fig. 1). Approximately 100 sites were selected in the vertical direction on the walls of the building where the mechanical properties of the concrete were studied.

a.

b.

Fig. 1. a) Tsageri catchment. 1 - East wall, 2 - First (east) pier, 3 - Second (central) pier, 4 - Third (west) pier and 5 - West wall. b) A picture of the ultrasound work on the load-bearing piers and walls of the catchment dam.

Data processing

Ultrasound waveform and tomographic (B-scan) recordings (Fig. 2) were processed using (PL-Link) standard software.

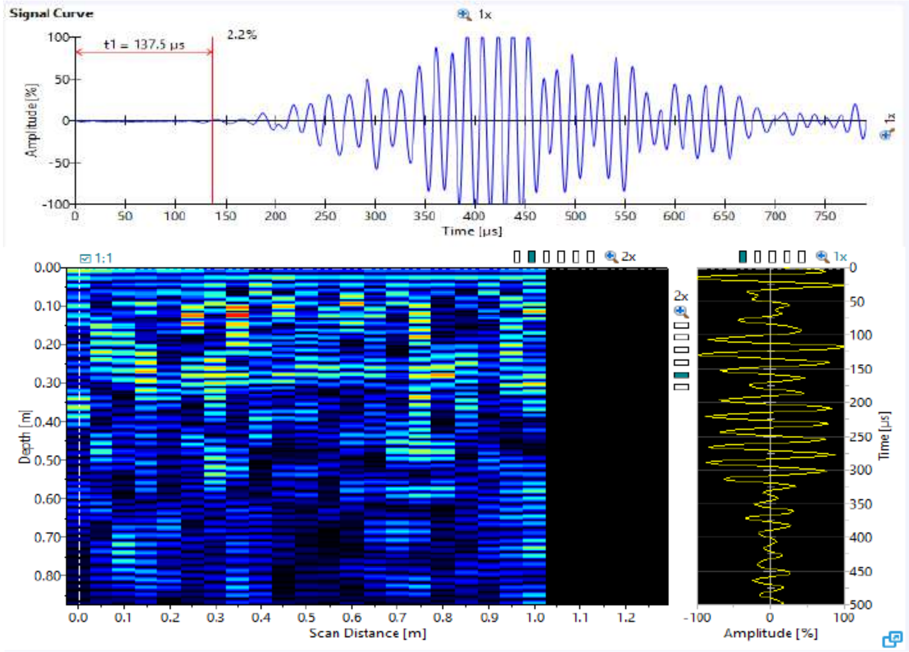


Fig.2. Ultrasound waveform (upper) and tomographic (lower) recordings.

On the records of oscillograms, the separation of longitudinal and transverse waves took place, their velocities were determined and various elastic parameters were calculated on the corresponding profiles. T On the processing and analysis of tomographic recordings (B-scans) took place us to identify possible voids, heterogeneous and weakened areas in the concrete.

Results of ultrasound examinations

About 100 precincts were processed. The image presented for each precinct is indicated by brown lines indicating the relevance of the tomographic images to the profiles. The yellow lines indicate the correspondence of the longitudinal velocities and the Poisson ratio with the profiles. The probable damaged areas localized by the velocity measurement are highlighted in blue, while the probable damage and weakening localized at different depths in the concrete pavement are marked in red by scanning. Here we present two of the location.

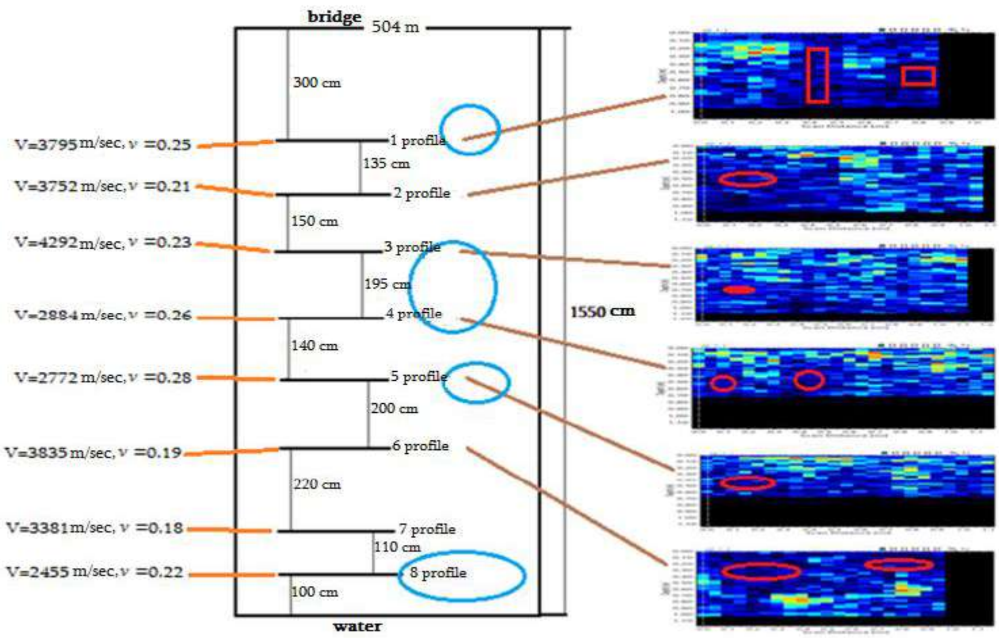


Fig.4. Profiles and tomographic records of one areas of the catchment.

Ultrasound testing works were performed on eight profiles at this site. Longitudinal (P) wave velocities in different profile ranges vary from 4292 m / s to 2455 m / s, transverse 2541 m / s to 1483 m / s, Poisson's ratio (ν) from 0,26 to 0 , At 18 intervals, and the Ju ng modulus (E) - (11639-39857) in the MPa interval.

One and more measurements of ultrasonic wave velocities were performed on all profiles in this area. They are made on concrete slab, on "poured concrete" and in the area of transition from concrete to tile. As the transition from the upper profiles of the precinct to the lower profiles, a gradual change in the speed of the ultrasonic wave will be observed. The velocity values are reduced in the vicinity of the third and fourth profiles. The values of the Poisson's ratio change in the range of 0.21-0.28 in the areas of the top five profiles, which probably indicates a weakening of the concrete structure in these areas. The velocity decreases particularly in the vicinity of the eighth (bottom) profile, which probably means damage to the concrete at this site or deterioration of its structure in this part of the pier [8].

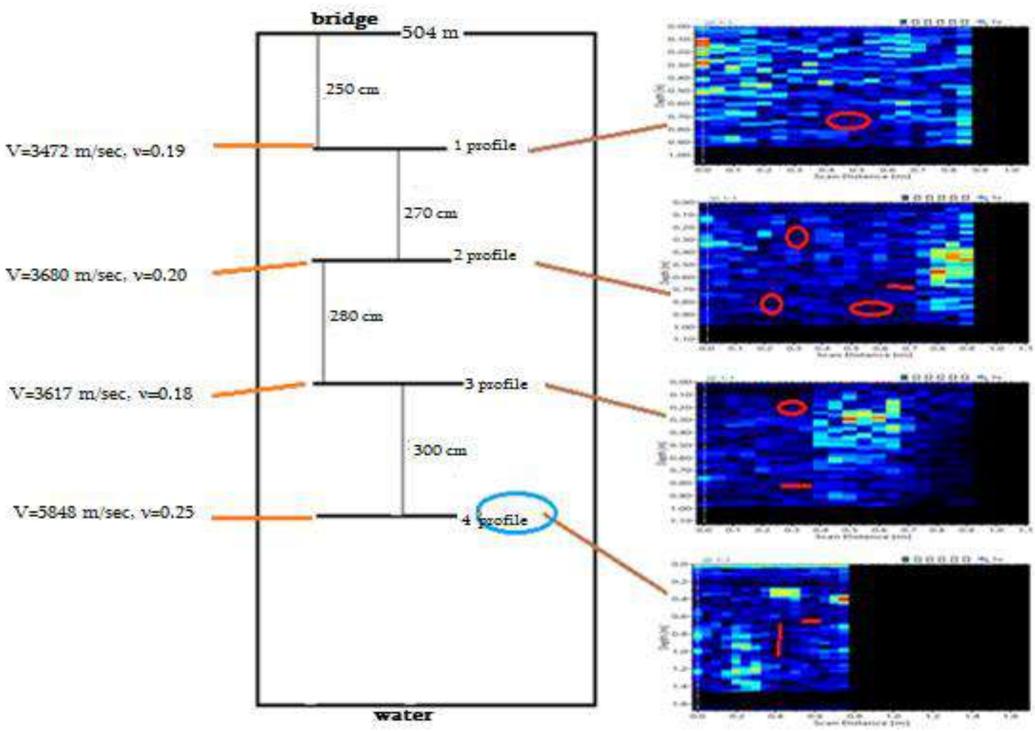


Fig.5. East wall (on the side of the dam) profiles of the first catchment tower and tomographic record of some profiles.

At this site (Fig.5) ultrasonic measurements were performed on three profiles along the wall and on the fourth profile on granite stones. Normal values of the Poisson's ratio (0.18-0.20) were be observed on all profiles and almost all measuring points, indicating the stability of the mechanical parameters of the concrete - its good condition. Ultrasound tomography (B-scan) was also performed on this incision. Deep lesions of different nature were observed in the tomographic images of all profiles, at different depths, as indicated in the images. In the tomographic images, in addition to the marked areas, dark colored areas was observed, which should indicate their weakening [8].

Comparison of the data presented in the two precincts (Fig.4, Fig.5) shows that they are relatively different precincts. The mechanical parameters of the bearing concretes in these areas differ from each other and indicate different mechanical states of the different catchment areas.

Conclusion

1. Modern methods of ultrasound examination and tools used have been found to be effective in assessing the condition of concrete structures constructing piers and walls. To evaluate and investigate visually imperceptible cracks, concrete structure and physical-mechanical properties.

2. The values of the elastic parameters calculated based on the measurement results vary within different values. Ultrasound tomographic scan images are also different. Anomalous areas are clearly visible on them. These anomalous areas should be related to changes in the structure of the concrete.
3. A sharp change in the values of Poisson's ratio should also be associated with a change in the rigidity of the material of the studied objects and its structure.
4. In general, it can be said that the results of the survey of the studied objects confirm that the physical-mechanical parameters are more anomalous in the areas adjacent to the lower, washed-erosion areas than in the areas of concrete slabs above. The concrete structure here should be more modified and characterized by less strength.

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ულტრაბგერითი ტომოგრაფია და იმპულსის სიჩქარე ბეტონის ნაგებობების დაუზიანებელი შეფასებისათვის

ნ. ვარამაშვილი, ბ. ასანიძე, მ. ჯახუტაშვილი

რეზიუმე

კვლევების მიზანი იყო ცაგერის წყალშემკრების თანამედროვე მდგომარეობის გეოფიზიკური მეთოდებით შესწავლა. ამ მეთოდების ერთ-ერთი სახეა ულტრაბგერითი კვლევების მეთოდი. ამ მეთოდით შესაძლებელია საკვლევი ობიექტის დრეკადი პარამეტრების გაზომვა და გამოთვლა, მისი დაზიანების გარეშე. საკვლევ ობიექტზე ხდებოდა ულტრაბგერითი გრძივი (P) და განივი (S) ტალღების გავრცელების სიჩქარეების გაზომვა. შემდეგ გამოთვლილი სიჩქარეების საფუძველზე

მასალის სიმკვრივის (ρ) პუასონის კოეფიციენტის (ν) და იუნგის მოდულის (E) გამოთვლა. ულტრაბგერითი ხელსაწყო-დანადგარების საშუალებით შესაძლებელია საკვლევი გარემოს ე.წ. ტომოგრაფია, მისი „გაშუქება" ცალი მხრიდან არეკლილი ტალღების საშუალებით. ამ შემთხვევაში შესაძლებელია საკვლევ სხეულში არსებული, გარკვეული ზომის სიცარიელეების, არაერთგვაროვანი უბნების დაფიქსირება და სხვადასხვა სიმკვრივის (შესუსტებული) უბნების გამოყოფა.

Ультразвуковая томография и скорость импульса для оценки без повреждений состояния бетонных конструкций

Н. Д. Варамашвили, Б. З. Асанидзе, М. Н. Джахуташвили

Резюме

Целью исследования было изучение современного состояния водосбора Цагери геофизическими методами. Один из видов этих методов - метод ультразвукового исследования. С помощью этого метода можно измерить и рассчитать упругие параметры объекта исследования, не повредив его. На месте исследования были измерены скорости распространения ультразвуковых продольных (P) и поперечных (S) волн. Затем вычислены коэффициент Пуассона (ν), плотности материала (ρ) и модуль Юнга (E) на основе рассчитанных скоростей. С помощью ультразвуковых аппаратов можно изучать исследуемую среду, сделать томографию, "просвечивать" объект с одной стороны отраженными волнамы. В этом случае можно зафиксировать в исследуемом теле пустоты определенного размера, неоднородные участки и выделить (ослабленные) участки разной плотности.

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Vertical Electrical Sounding and Georadiolocation to Assess Groundwater Level During Orchard Cultivation

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ABSTRACT

Too high a level of groundwater, especially stagnant, is detrimental to all species of fruit trees and many berries. An excess of soil moisture worsens air exchange processes in the soil, the oxygen content decreases in it, which inevitably leads to death in the zone of the root system. As a result, the nutritional regime of fruit trees deteriorates, over time, their growth processes stop. Geophysical prospecting methods are very effective in determining the levels and thicknesses of groundwater layers. The article presents the work of the search for groundwater carried out in the Kakheti region (Sagarejo district). The methods of vertical electrical sounding and ground penetrating radar were used. Together, these two methods yielded reliable results at different search depths, which was additionally confirmed during the drilling process.

Key words: *Vertical electrical sounding (VES), georadar, groundwater*

Introduction

If the 19th century was dominated by the acquisition and defence of land (territory) and the 20th century was dominated by the acquisition and control of oil and energy resources, then the 21st century will be dominated by the politics of water. Globally, secure access to potable water has been identified as the key political, humanitarian and military flash point (8). Groundwater it is a subsurface water in the permanent aquifer closest to the earth's surface. They are formed due to the percolation through the soil of atmospheric precipitation and waters of nearby water bodies. Ground-water systems are continuous saturated systems made up of different earth materials. As a simplified classification, these saturated earth materials can be classified as either aquifers or confining beds. As previously defined, an aquifer contains sufficient saturated permeable material to yield significant quantities of water to wells and springs. A confining bed is a rock unit of very low hydraulic conductivity that restricts the movement of ground water either into or out of adjacent aquifers. A ground-water system can be made up of many aquifers and confining beds. The top boundary of the saturated ground-water system is the water table (6,7). Too high groundwater level is detrimental to all types of fruit trees, shrubs and other cultivated plants. Too high a level of groundwater, especially stagnant, is detrimental to all species of fruit trees and many berries. An excess of soil moisture worsens air exchange processes in the soil, the oxygen content decreases in it, which inevitably leads to death in the zone of the root system. As a result, the nutritional regime of fruit trees deteriorates, over time, their growth processes stop.

There are plants, trees that thrive in high groundwater levels conditions. Such plants helps to dry the moist soil.

For fifteen years now there has been a tendency to expand scientific research into the possibilities of geophysics in the agricultural sector. Unsurprisingly, this science can provide predictable agriculture, good groundwater control, accurate soil salinity estimates, and help map the surveyed soil. The use of geophysical methods is increasingly expanding the range - with their help, additional agricultural tasks are already being solved, such as the cultivation of high-quality grain crops, livestock waste management, forestry, the description of the hydrological characteristics of the soil, and in addition - the localization and assessment of underground infrastructure.

Vertical electrical sounding and georadiolocation methods are widely used to determine subsurface humidity and groundwater levels.

 The marked part of the agricultural-reclamation area adjacent to the village of Tokhliauri in Sagarejo region, Georgia was studied by georadiolocation profiling and vertical electrical sounding methods.

Georadiolocation prospecting

What is GPR? This is a modern device that solves a wide range of tasks using radar. It is mobile, compact, and its main feature is the ability to conduct non-destructive monitoring of the environment with high detail, which makes it unique among all geophysical equipment. GPR allows the operator to "see" through water, soil and stone. In any environment, the GPR is able to show voids and foreign bodies, changes in density and structure, hidden internal structures - any anomalies.

Agrarians use GPR, in particular, to assess ways to restore contaminated soils, to optimize fertilization in fields, in gardens and vineyards, to control the uniformity of irrigation.

The GPR emits ultra-wideband pulses in the meter and decimeter range of electromagnetic waves and receives signals reflected from irregularities, objects or other inclusions in the soil that have a dielectric conductivity different from the medium. The reflected signals are converted into digital form and displayed on the georadar display. The results can be viewed and processed on a computer. In order to obtain data from different depths, antenna units are used that operate at different frequencies. It is necessary to take into account the general rule: the lower the operating frequency of the antenna, the higher the signal penetration depth, but the lower the antenna resolution.

In our case, we use the GPR Zond 12- e with our standard receiving and transmitting antenna using a frequency of 75 MHz (Fig.1). To receive and process georadar data, we use the PRIZM 2.5 software.

a. b.

Fig.1. a) ground penetrating radar ZOND 12, b) measurement process

Three points were marked at the study area where was performed cross-sectional georadiolocation profiling. First point, a (0536279, 4613113). Second point, b (0536452, 4613083). Third point, c (0536708, 4613047).

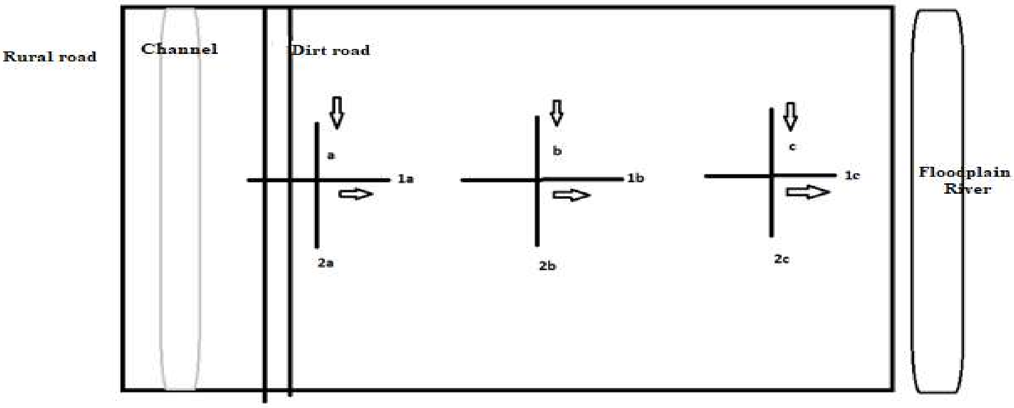

Fig.2. Study place and workplace location diagram.

Conditional drawing of the study area (Fig.2), with intersection points of cross-profiles and schematic placement of profiles.

The georadiolocation profile / (georadar section) shows the radio faces of the separated geological layers, measured in meters vertically and horizontally at a distance, which are presented in accordance with the sinphase texture of the electromagnetic field (4).

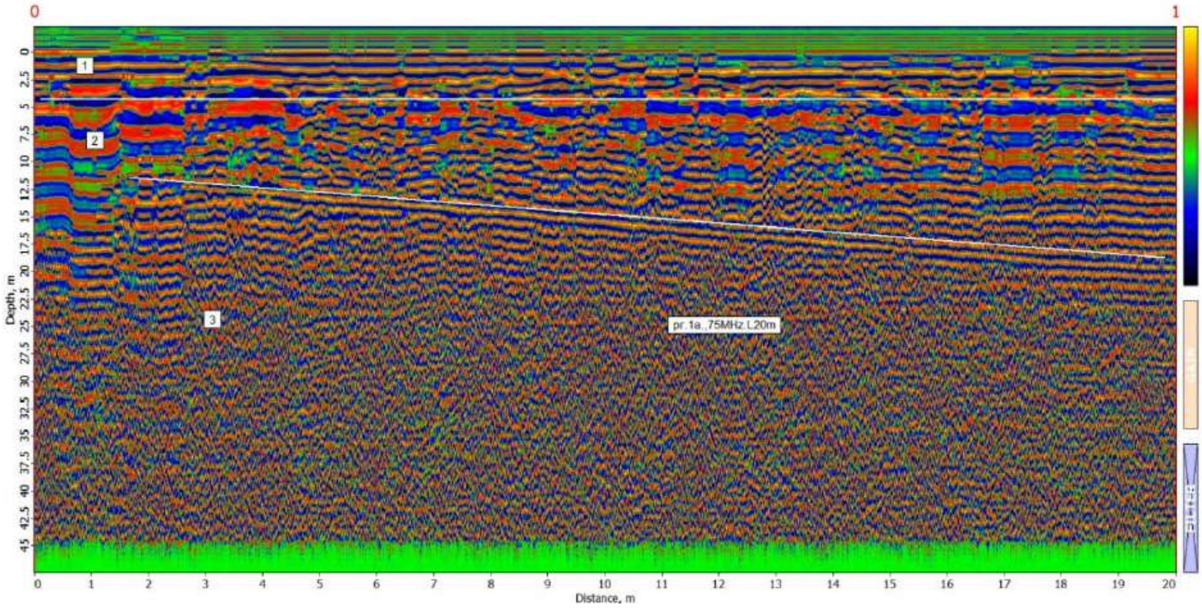

Fig.3. Georadiolocation profile was performed with Georadar 75 MHz dipole antenna, distance - 20 m. Profile 1a, directed normal to the river / floodplain.

Three georadiolocation layers were identified on Profile 1.a (Fig.3). The first layer is 5 m thick, the second layer begins from 5 m deep and extends to a depth of 10-17 m, the third layer starts at 10-17 m and extends below 45 m. Between the first and second layers there is a moistened, in places highly hydrated transitional boundary layer. The second layer bears the marks of hydration with little watering. Moisturization is observed in the presented part of the third layer.

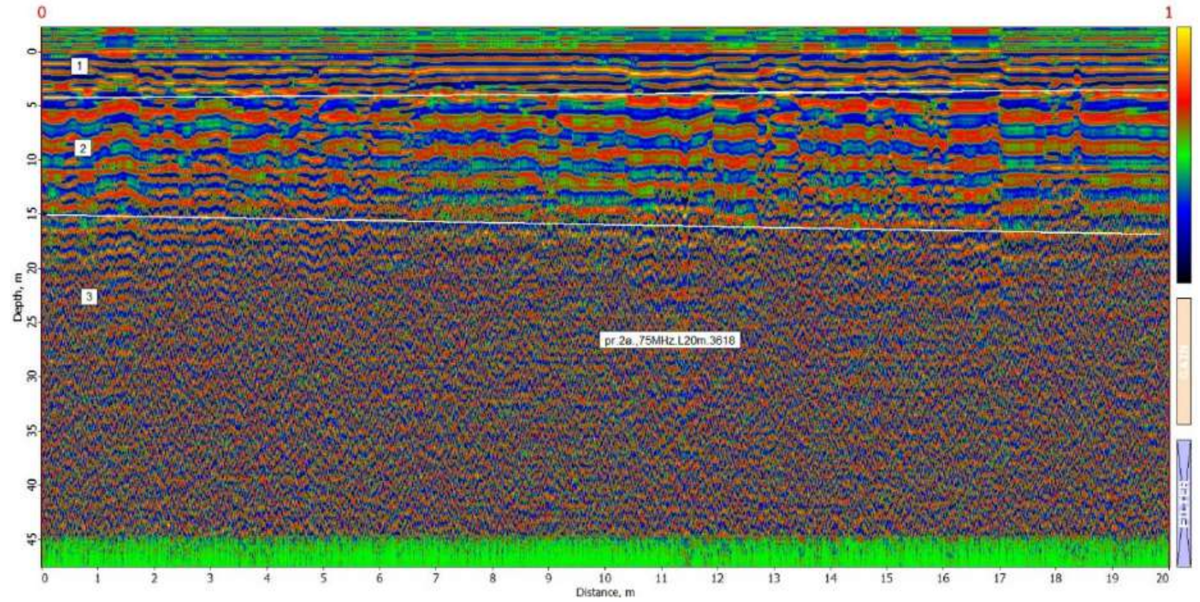

Fig.4. Georadiolocation profile was performed with Georadar 75 MHz dipole antenna, distance - 20 m. Profile 2a, directed tangential to the river / floodplain.

Three georadiolocation layers were identified on Profile 2.a (Fig.4). The first layer is 5 m thick, the second layer begins from 5 m deep and extends to a depth of 15 m, the third layer starts at 15 m and extends below 45 m. Between the first and second layers there is a moistened, in places highly hydrated transitional boundary layer. The second layer bears the marks of hydration with little watering. Moisturization is observed in the presented part of the third layer.

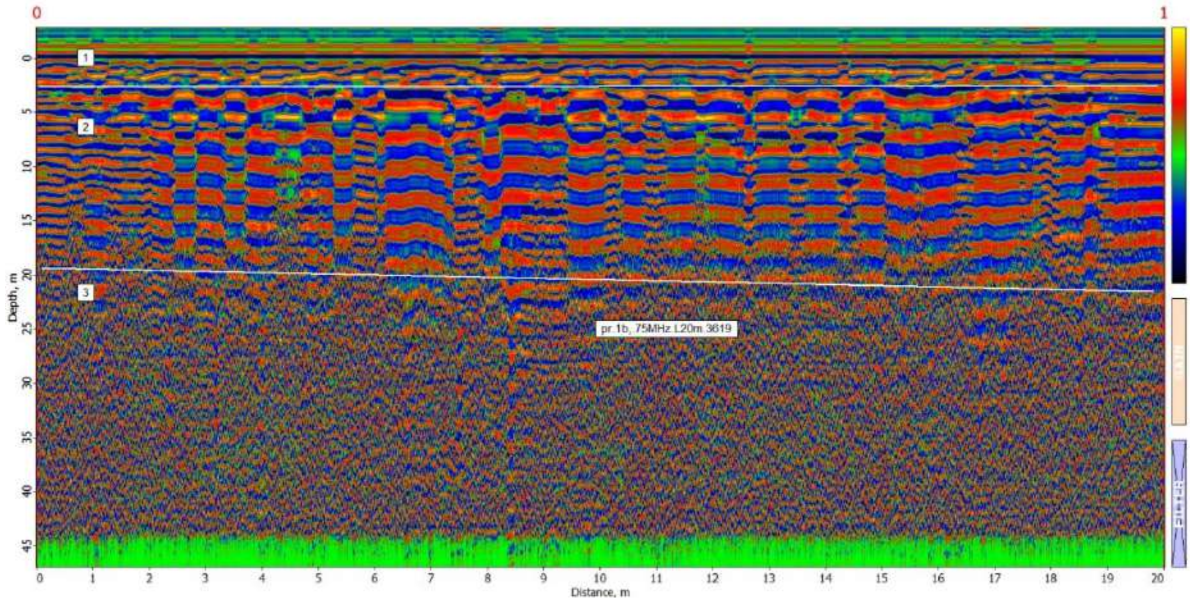

Fig.5. Georadiolocation profile was performed with Georadar 75 MHz dipole antenna, distance - 20 m. Profile 1b, directed normal to the river / floodplain.

Three georadiolocation layers were identified on Profile 1.b (Fig.5). The first layer is 3 m thick, the second layer begins from 3 m deep and extends to a depth of 20 m, the third layer starts at 20m and extends below 45 m. Between the first and second layers there is a moistened, in places highly hydrated transitional boundary layer. The second layer bears the marks of hydration with little watering. Moisturization is observed in the presented part of the third layer.

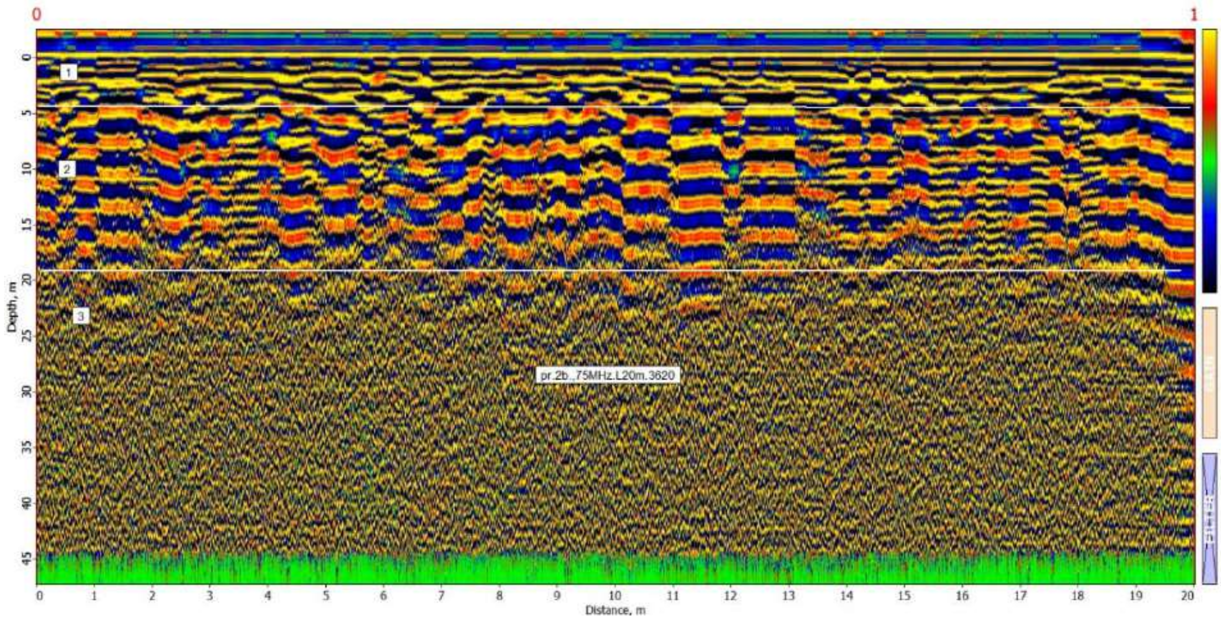

Fig.6. Georadiolocation profile was performed with Georadar 75 MHz dipole antenna, distance - 20 m. Profile 2b, directed tangential to the river / floodplain

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Three georadiolocation layers were identified on Profile 2.b (Fig.6). The first layer is 4-5 m thick, the second layer begins from 4-5 m deep and extends to a depth of 20 m, the third layer starts at 20 m and extends below 45 m. Between the first and second layers there is a moistened, in places highly hydrated transitional boundary layer. The second layer bears the marks of hydration with little watering. Moisturization is observed in the presented part of the third layer.

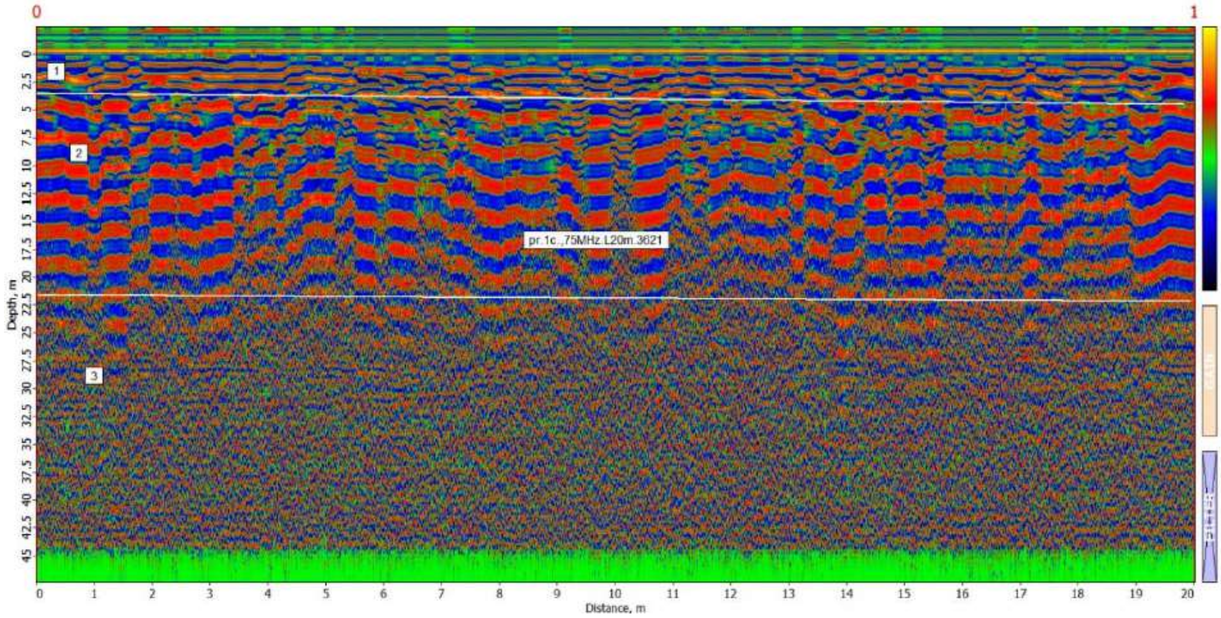


Fig.7. Georadiolocation profile was performed with Georadar 75 MHz dipole antenna, distance - 20 m. Profile 1c, directed normal to the river / floodplain.

Three georadiolocation layers were identified on Profile 1.c (Fig.7). The first layer is 3 m thick, the second layer begins from 3 m deep and extends to a depth of 22 m, the third layer starts at 22 m and extends below 45 m. Between the first and second layers there is a moistened, in places highly hydrated transitional boundary layer. The second layer bears the marks of hydration with little watering. Moisturization is observed in the presented part of the third layer.

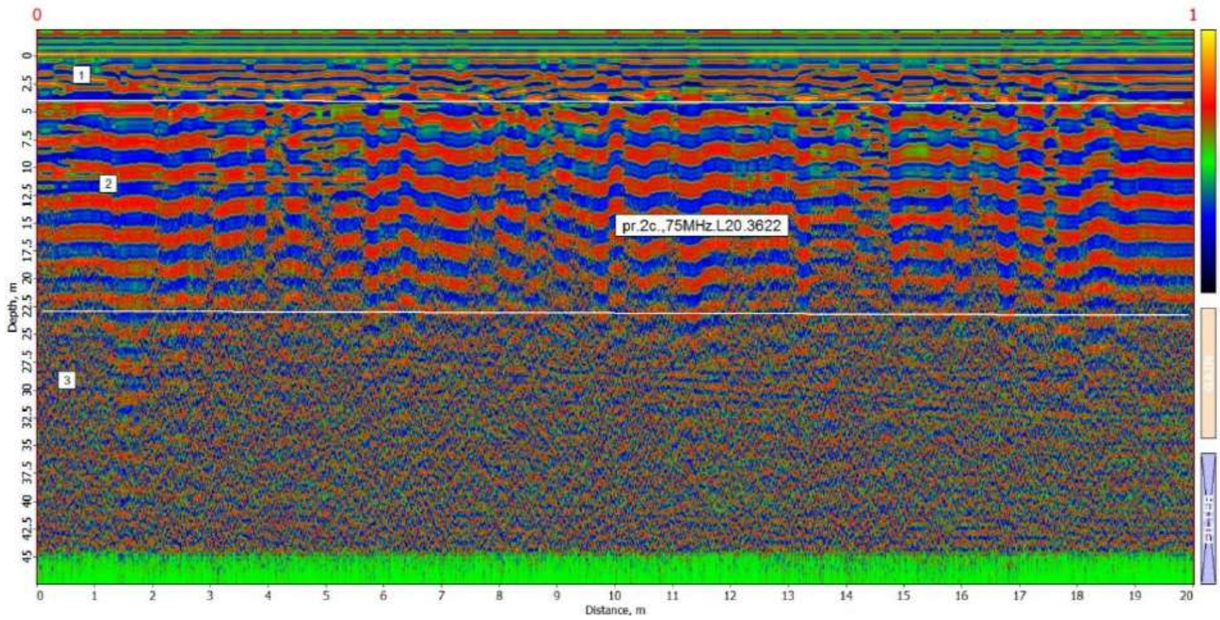


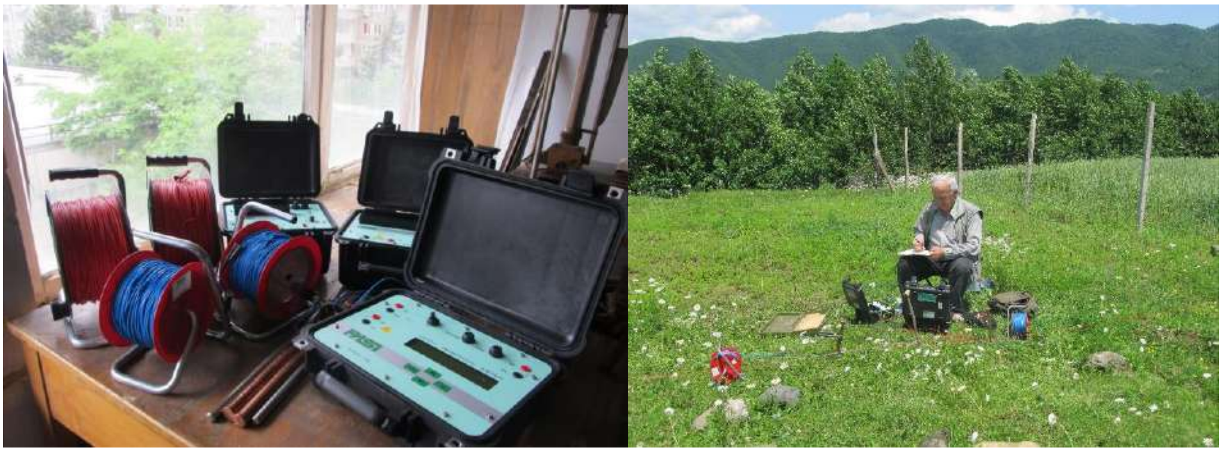
Fig.8. Georadiolocation profile was performed with Georadar 75 MHz dipole antenna, distance - 20 m. Profile 2c, directed tangential to the river / floodplain.

Three georadiolocation layers were identified on Profile 2.c (Fig.8). The first layer is 4-5 m thick, the second layer begins from 4-5 m deep and extends to a depth of 22 m, the third layer starts at 22 m and extends below 45 m. Between the first and second layers there is a moistened, in places highly hydrated transitional boundary layer. The second layer bears the marks of hydration with little watering. Moisturization is observed in the presented part of the third layer.

Electroprospecting (Vertical Electrical Sounding)

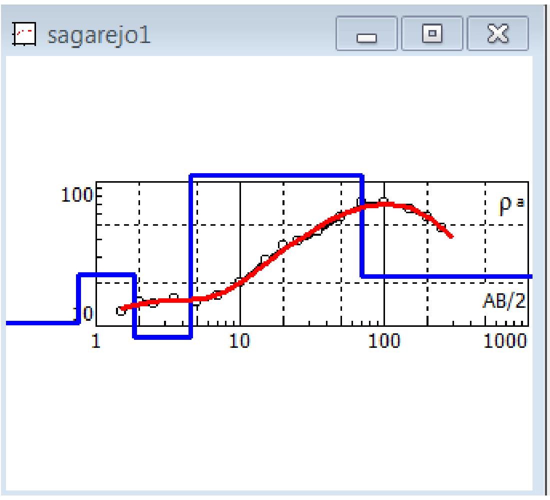
In electroprospecting (resistance method) is used artificial power source. The electricity reaches the ground through the power electrodes and the difference between the arised potentials is measured by the receiving electrodes on the earth surface. If the environment is homogeneous, the resistance method gives us true conductivity, which will not depend on the configuration of electrodes and the position of electrodes on the surface of the earth, since the true conductivity is a constant. In electric resistivity imaging (ERI) electric currents are injected into the ground and the resulting potential differences are measured at the surface, yielding information about the distribution of electrical resistivity below the surface. Finally this gives an indication of the lithological and structural variation of the subsoil (since resistivity depends on sediment porosity and pore water). In the shallow subsurface, the presence of water controls much of the conductivity variation. Measurement of resistivity is, in general, a measure of water saturation and connectivity of pore space (1,2,3,5).

Vertical electrical sounding was performed at points "a" and "b" (Fig. 2, Fig.9). The works were carried out by the Italian electrometer equipment (Earth Resistivity Meter PASI 16GL-N). Data processing was done through a certified IPI2WIN program.



a. b.

Fig.9. a) Earth Resistivity Meter PASI 16GL-N, b) measurement process



RMS=3.28%

N	ρ	h	d	Alt
1	10.6	0.75	0.75	-0.75
2	22.6	1.1	1.85	-1.852
3	8.46	2.72	4.57	-4.573
4	111	64.7	69.2	-69.25
5	22			

Fig.10. The curve of vertical electrical sensing and the distribution table in the depth of specific resistance are presented for the point "a" of study area.

According to the interpretation of VES (Fig.10), y up to a depth of 4.5-5 meter we have depleted clays , from 4.5-5 meters there is a high humidity, presumably moistured sand, which extends to about 70 meters.

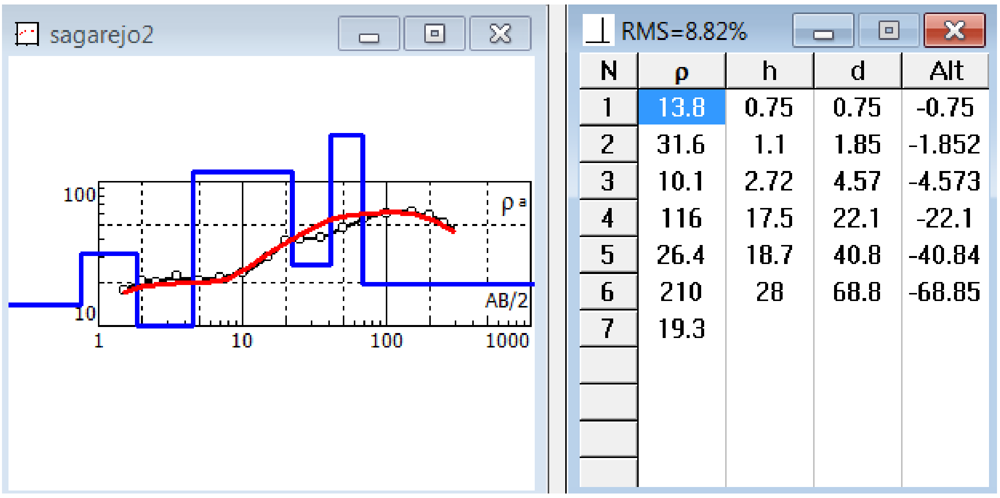


Fig.11. The curve of vertical electrical sensing and the distribution table in the depth of specific resistance are presented for the point "b" of study area.

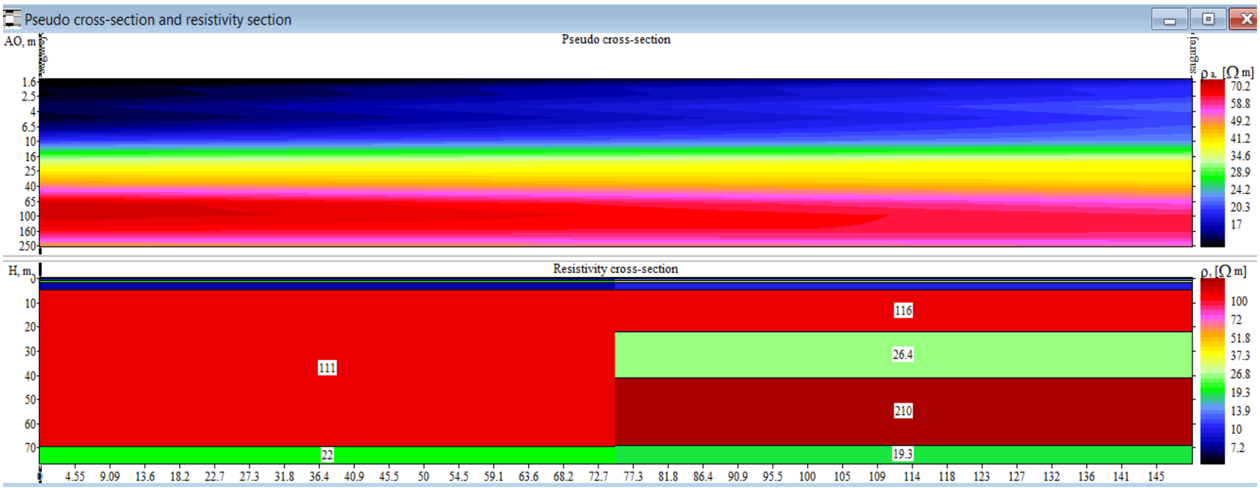


Fig.12. Profile of resistivity based on vertical electrical sensing curves.

According to the interpretation of VES (Fig.11), up to a depth of 4.5 meters, we have depleted clay from 4.5-5 meters there is a high humidity, presumably water-containing sand. The alternation of clayey and relatively dry sand starts from about 22 meters and extends to about 70 meters. A layer of clay-sand appears below 70 meters.

Conclusion

1.Georadiolocation and electrometric search methods are effective in determining groundwater levels and estimating moisture of the subsurface rock. Also, to evaluate the thickness of moistened areas.
2.Each of these methods has its limitations. In the complex they complement each other and can be used without geological restrictions.
3.Georadiolocation and electrometric surveys for the marked area revealed the following - (naturally) moistened, presumably water-saturated layer, which was marked from 4.5-5 m to 70 m. This was additionally confirmed during the drilling process.
4.Based on the above results, fruit varieties and garden cultivation methods will be selected.

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ვერტიკალური ელექტრული ზონდირება და გეორადიოლოკაცია გრუნტის წყლების დონის შესაფასებლად ხეხილის ბაღის გაშენების პროცესში

დ. ოდილავაძე, ნ. ვარამაშვილი

რეზიუმე

მიწისქვეშა წყლების ზედმეტად მაღალი დონე, განსაკუთრებით მდგარი წყლების, საზიანოა ყველა სახის ხეხილის და მრავალი კენკროვანისათვის. ნიადაგის ტენიანობის სიჭარბე აუარესებს ნიადაგში ჰაერის გაცვლის პროცესებს, მასში ჟანგბადის შემცველობა იკლებს, რაც აუცილებლად იწვევს ფესვთა სისტემის ზონაში სიკვდილს. შედეგად, ხეხილის კვების რეჟიმი უარესდება, დროთა განმავლობაში მათი ზრდის პროცესები წყდება. მიწისქვეშა წყლების დონეების და ფენების სიმძლავრეების დასადგენად ძალზედ ეფექტურია ძიების გეოფიზიკური მეთოდები. ნაშრომში წარმოდგენილია მიწისქვეშა წყლების ძიების პროცესი, რომელიც ჩატარდა კახეთის რეგიონში (საგარეჯოს რაიონი). გამოყენებული იქნა ვერტიკალური ელექტრული ზონდირების და გეორადიოლოკაციის მეთოდები. კომპლექსურად ამ ორი მეთოდის გამოყენებით მიღებული იქნა საიმედო შედეგები სხვადასხვა სიღრმეებზე, რაც შემდგომში დადასტურდა ჭაბურღილის გაყვანის პროცესში.

Вертикальное электрическое зондирование и георадиолокация для оценки уровня грунтовых вод при посадке фруктового сада

Д.Т. Одилавадзе, Н. Д. Варамашвили

Резюме

Слишком высокий уровень состояния грунтовых вод, особенно застойных, губителен для всех пород плодовых деревьев и многих ягодников. Избыток почвенной влаги ухудшает воздухообменные процессы в почве, в ней уменьшается содержание кислорода, что неизбежно приводит к отмиранию в зоне корневой системы. Вследствие этого ухудшается режим питания плодовых деревьев, со временем у них прекращаются ростовые процессы. Методы геофизического поиска очень эффективны при определении уровней и мощностей слоев грунтовых вод. В статье представлена работа поиска подземных вод, проведенный в регионе Кахетий (район Сагареджо). Использовались методы вертикального электрического зондирования и георадиолокации. В комплексе с этими двумя методами были получены надежные результаты на разных глубинах поиска, что было дополнительно подтверждено в процессе бурения.

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Karst Cavity Forms and Their Radio Images Revealed by Comparative Physical Modelling

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ABSTRACT

GPR surveys were conducted to select a safe location for the construction site in a limestone region. Using the theory of similarity of electromagnetic fields, the results of laboratory physical modelling were extended to field data. The survey data were interpreted with high accuracy for decoding underground objects.
The tasks set by the builders were solved on the basis of the geo-radar works: the less and most karst-damaged areas were identified.

Key words: *GPR, similarity of electromagnetic fields, comparative physical modelling.*

Introduction

The paper considers the issue of a certain building area in order to develop a capital construction on the mountainous territory of borough Khoni in West Georgia. The selected geological medium is presented as the lower and upper Cretaceous limestones, Neogene sandstones and clay, Quaternary boulder and clay. It is characterized with karst phenomena (Maruashvili, 1971). Therefore, geophysical /geo-radiolocation studies were required in order to verify the safe probable area for the building territory. The geo-radiolocation studies were conducted by GEORADAR Zond 12 with its set 75 MHz dipole antenna and the data were obtained and processed by means of software Prism 2.5.

Georadiolocation prospecting

Georadiolocation is a geophysical method that is based on the use of electromagnetic waves in the radio range to study the structure of the subsurface environment in areas such as geology, construction, agriculture, archeology, forensics, security, etc.Passing through the studied environment, waves are partially reflected from the interfaces between materials with different electrophysical properties (from the boundaries between layers of different soils, layers with different moisture content, from the levels of groundwater, voids, metal or concrete objects, boulders, etc.) and in a weakened form, they return to the surface, where they are captured by the receiving antenna, converted into digital form, processed and stored. When a georadar equipped with a displacement sensor and a path meter moves along the surface (or above the surface) of the investigated medium, an aggregate record of the received signals is formed - a GPR profile, or a georadarogram.

Materials and Methods

The investigations were carried out with GPR ZOND 12e equipped with 75 GHz transmissive/receiving antenna. The obtained results were processed using the software PRISM 2.5. Interpretations of the radiograms were conducted using the method of similarity of electromagnetic fields by comparative physical modelling for solution of direct and inverse problems developed by the authors. A direct problem is solved by laboratory modelling: the radio image of an object is determined by high or super-high frequencies and the result, due to the similarity of the radio images, is used to solve an inverse problem for the interpretation of the field material [1-10].

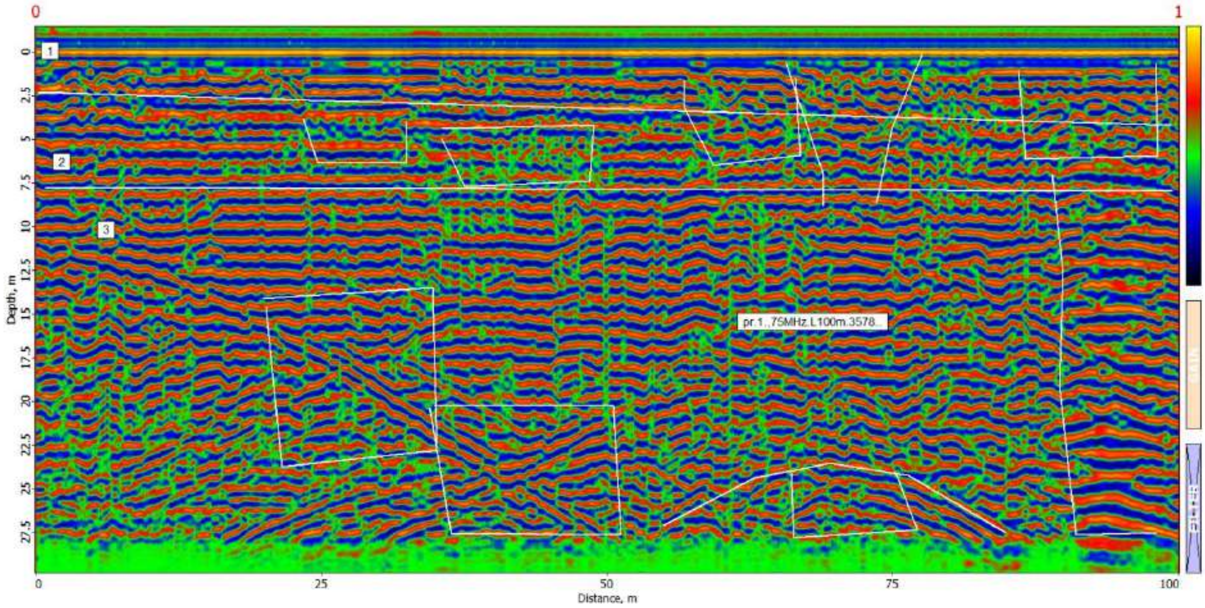

Fig. 1 shows Profile 1 conducted by means of geo-radar Zond 12 with 75 MHz dipole antenna. The length of the profile is 100 m.

According to the syn-phase axis texture we distinguished three geo-radiolocation layers in Profile 1: the first layer with 2.5 m thickness, the second layer from 2.5 m to 7.5 m, the third layer - below 7.5 m.

We distinguished the radio images of certain geological formations on the radiogram. Their locations are marked with white lines. The radio images corresponding to the cavity located at the boundary of the first and second layers at 50-75 m distances at 7.5-8 m depth are clearly seen; a cavity at 100 m distance at the end of the profile is also marked.

The radio image obtained as a result of laboratory physical modelling is shown in *Figure 2* for rectangular prism form (hole, box) cavity.

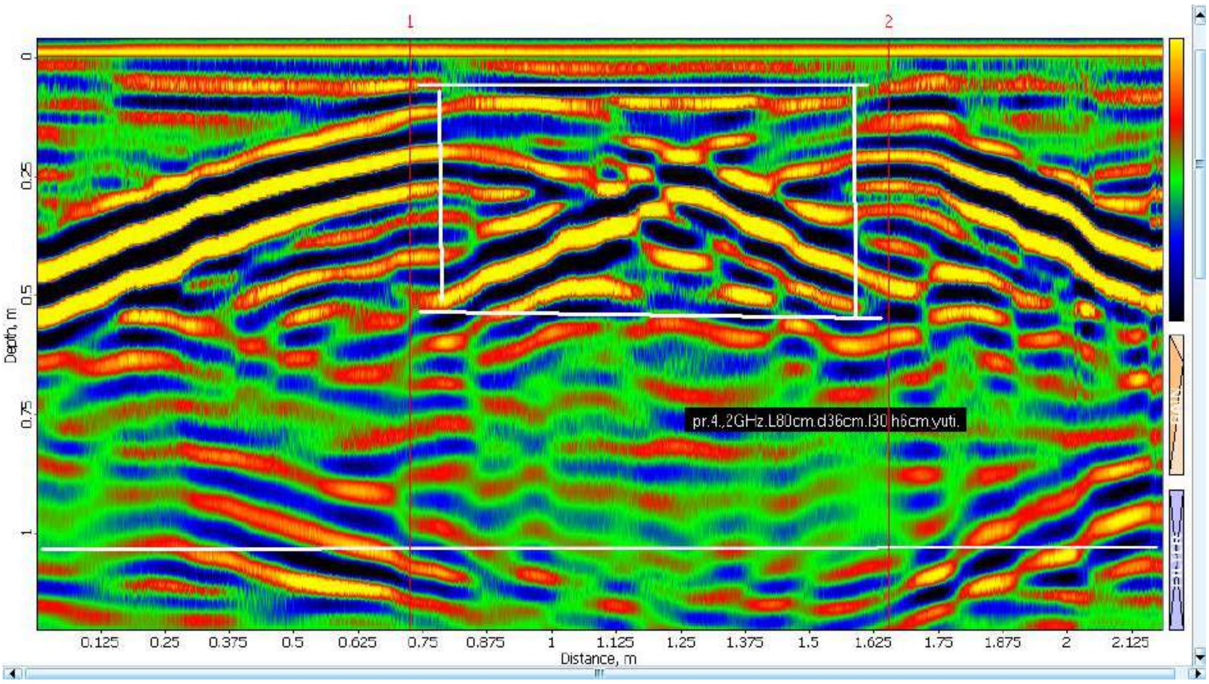

Fig. 2 shows the radio image of the laboratory model of the so-called “box” at the frequency 2 GHz.

The real sizes of the box are marked with white linear and vertical markers. The special form of the radio image (bow-tie) obtained as a result of overlapping the internal reflection and external refraction EM waves is marked within the white rectangle.

The electromagnetic waves radiated and received from the radar contain the information about the radio image formed by the overlapping of refracted and reflected from the hidden object waves. In the radiogram it is presented as a geometric form and texture of the syn-phase axes of the resulting overlapped electromagnetic waves, which are connected with the box form buried object. Namely, a part of the radio image formed by reflected waves has a parabola form and a part of the bow-tie type radio image is formed by the refracted waves. According to the principles of the electromagnetic field superposition they give an aggregate radio image characteristic of the existent cavity.

Let us go back to *Figure 1*. At 2.5-7.7 m depths in the second layer, we marked the forms of the disintegrated (crushed, destroyed) medium at 25-50 m distances.

In the third layer also at 25 and 50 m distances a bow-tie type special form is marked, which must correspond to the relevant size cavities with centres at 17 and 25 m depths.

At 25 m depth at 75 m distance a probable arch roof cavity was distinguished. At 100 m distance a medium containing cavities was distinguished by the texture and was marked by the vertical line.

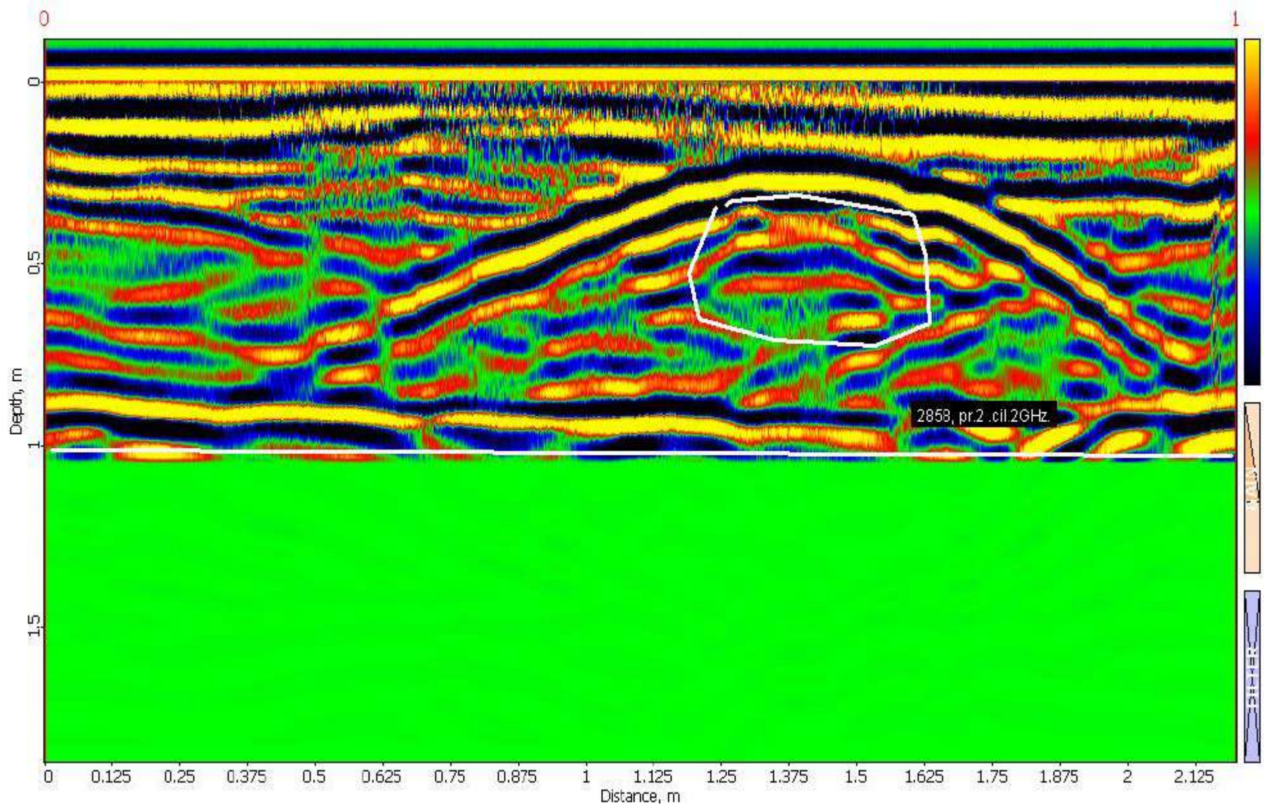

Fig. 2 shows a laboratory radio image of a cylindrical cavity (plastic tube) with an intensification option. The bow-tie was distinguished, which means a clearly reflected form under the parabola, i.e. the radio image proves the existence of the cavity for the "tube".

The "box" model, in regard with the tube, can be understood as a transformation of the tube into an extremely clear bow-tie.

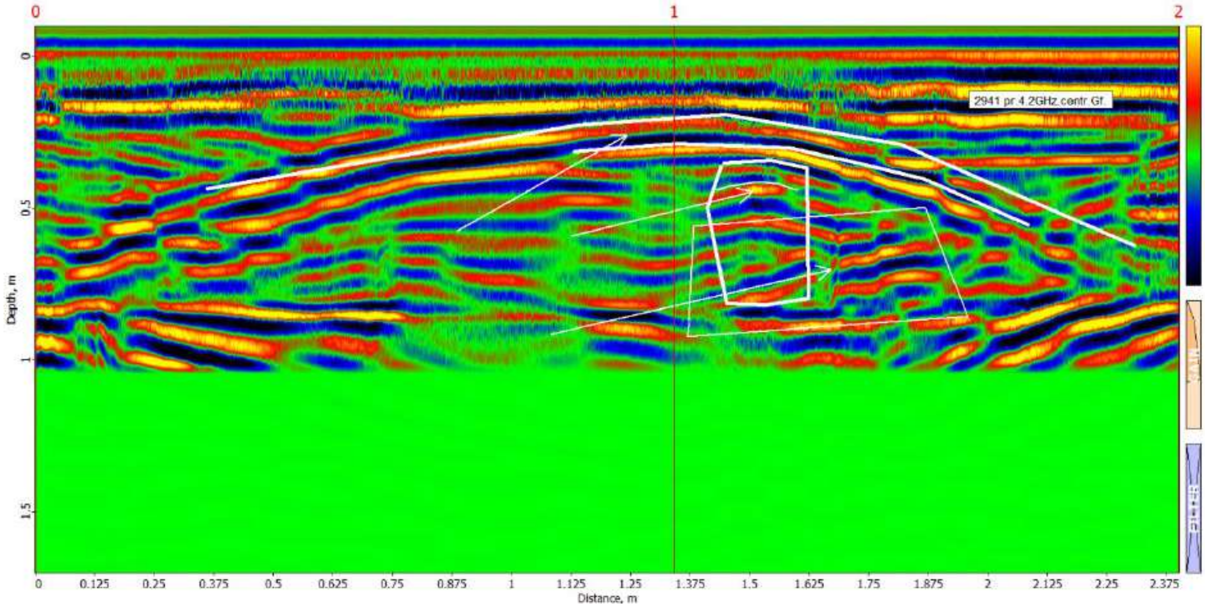

Fig. 3 shows a complex model for the large (0.5 m) and small diameter (0.15 m) tubes.

The main tube (0.5 m) filled with activated coal from below. It contains a small diameter empty tube (0.15 m) which is intersecting the model's central profile.

We marked the parabola formed by reflected waves with expansion to the right at 1.5 m distance and the centre of the small tube and the imperfect bow-tie below it at 0.5 m depth. We also marked the bow-tie between the right wall of the small tube and the internal side of the right wall of the large tube with 1.7 m centre and 0.6 m depth at the coordinates.

The model enables us to determine the object forming the parabola type radio image seen in *Figure 4* of the field radiogram, namely, we suppose it also must be formed by a complex structure (tube-in-tube type object).

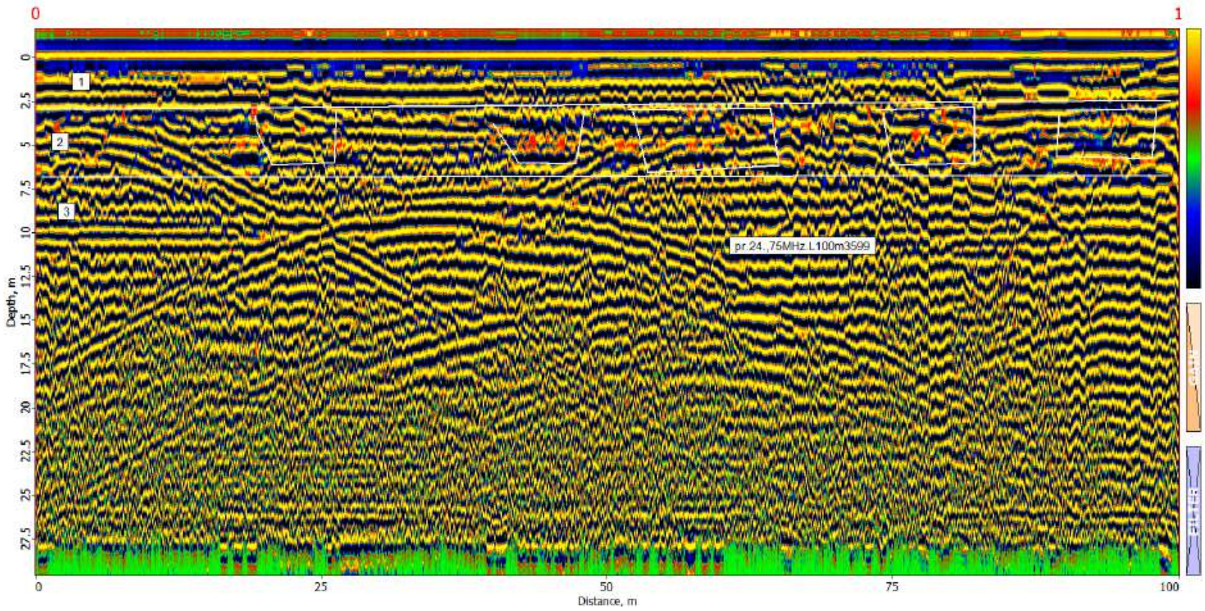

Fig. 4. The radiogram of Profile 24 received by means of the 75 MHz sensor antenna of the geo-radar. The length of the profile is 100 m.

We distinguished three main geo-radiolocation layers in Profile 24 according to the syn-phase axes texture. The thickness of the first layer is 2.5 m, the thickness of the second layer is 7.5 m and the third layer is located below 7.5 m depth.

The first layer is more or less homogeneous and partly disintegrated. The second layer contains the radio images of cavity type watered inhomogeneity. The third layer of the geo-radar section contains numerous reflection intersections, which might have be formed due to external electromagnetic field or a transformed arch type large tube cavity, which contains the radio image of a small tube cavity as in the laboratory model in *Figure 3*.

Any external electric filed source (transmission lines) is not observed on the study territory. It means that the radio image at 25-70 m distance and 7.5-20 m depth must be formed by a complex, large arch type underground object.

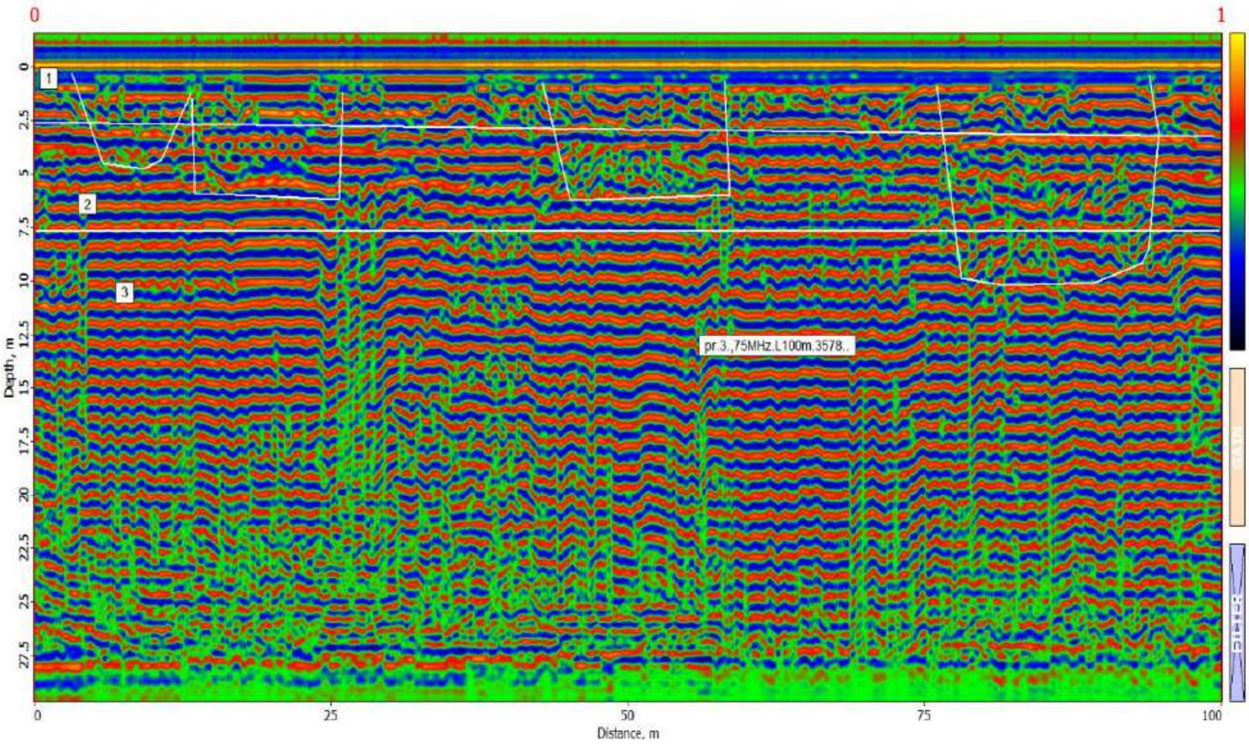

Fig. 5. The radiogram shows Profile 3 received by means of the 75 MHz sensor antenna of the geo-radar. The length of the profile is 100 m.

We distinguished three main geo-radiolocation layers in Profile 3 according to the syn-phase axes texture. The thickness of the first layer is 2.5 m, the thickness of the second layer is 2.5-7.5 m and the third layer is located below 7.5 m depth.

The radiogram shows the radio images of certain geological formations, which are marked by white lines. The radio images of the cavities located at the boundary of the first and second layers at 0-25 m and the anomalies distributed on the surfaces of the first, second and third layers at 75-100 m distance with depth 5-7-10 m depth are obviously seen.

The first layer at the distance 50 m at 0-2.5 m depth includes the syn-phase axes of relatively homogenous rocks with a cavity, below which there is a significantly disintegrated (eroded by water) medium distributed to 7.5 m.

The watered sites are located in the disintegrated areas of the marked cavities.

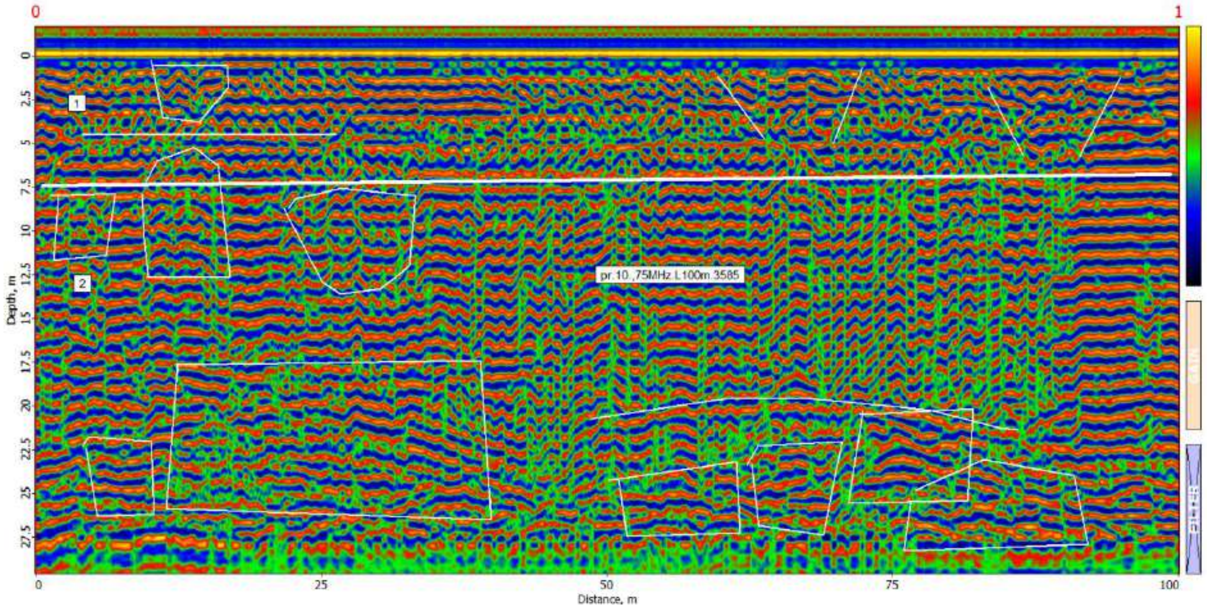

Fig. 6. The radiogram of Profile 10 received by means of the 75 MHz sensor antenna of the geo-radar. The length of the profile is 100 m.

We distinguished two geo-radiolocation layers in the Profile 10 according to the syn-phase axes texture. The thickness of the first layer is 5 m, the second layer is located at 7.5 m depth and below. The boundary between the layers is watery and disintegrated.

The first layer includes inhomogeneities, among them the radio images of funnel type objects at 60 and 80 m distances. The second layer contains the cavities with centres at 10-23-25 m depths. The radio images belong to different-size objects characteristic of cavities.

Conclusion

According to the Electromagnetic Fields Similarity Theory for geo-radiolocation frequency fields worked out by the authors the results of the laboratory physical modelling were applied to the radio images of the field data and were interpreted with high reliability to decode underground objects.
On the basis of the conducted works we distinguished the less and most karst-damaged areas number and informed the client about their location.
As is of the geo-radar works: the less and most karst-damaged areas were identified.

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კარსტული სიღრუის ფორმები და მათი რადიო სახეები, რომლებიც გამოვლენილია შედარებითი ფიზიკური მოდელირებით

დ.ოდილავაძე, თ.ჭელიძე

რეზიუმე

კარსტულ რაიონში ჩატარდა გეორადიოლოკაცოური კვლევები უსაფრთხო სამშენებლო მოედნის გამოსავლენად. ელექტრომაგნიტური ველების მსგავსობის თეორიის გამოყენებით ფიზიკური მოდელირების ლაბორატორიული კვლევის შედეგები გავრცელებულ იქნენ საველე მონაცემებზე. საველე მონაცემები ინტერპრეტირებულ იქნენ მაღალი სიზუსტით მიწისქვეშა ობიექტების გაშიფვრისათვის. მშენებელთა მიერ დასახული ამოცანა გადაწყვეტილ იქნა გეორადიოლოკაციურ სამუშაოებზე დაყრდნობით: გამოვლენილ იქნა კარსტით მეტად დაზიანებული და დაუზიანებელი მონაკვეთები.

Формы карстовых полостей и их радиоизображения, выявленные с помощью сравнительного физического моделирования

Д.Т. Одилавадзе, Т.Л. Челидзе

Резюме

Георадиолокационные исследования были проведены для выбора безопасного места для строительной площадки в известняковом районе. Используя теорию подобия электромагнитных полей, результаты лабораторного физического моделирования были распространены на полевые данные. Данные съемки были интерпретированы с высокой точностью для расшифровки подземных объектов.
Задачи, поставленные строителями, были решены на основе георадиолокационных работ: выявлены наименее и наиболее поврежденные карстом участки.

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Preliminary Results of a Study of the Relationship Between the Monthly Mean Sum of Atmospheric Precipitation and Landslide Cases in Georgia

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ABSTRACT

Preliminary results of the study of the influence of the mean monthly sum of atmospheric precipitation on landslides in Georgia are presented. In particular, it was found that with an increase in the monthly amount of atmospheric precipitation, there is a linear tendency for an increase in the number of landslides.

Key words: *Landslide, atmospheric precipitations*.

Introduction

Landslides occupy an important place among natural disasters. Landslide processes are dangerous in their almost ubiquitous distribution, the damage they cause, and the frequent accompaniment of human victims [1,2]. This problem is very relevant for Georgia, where the number of landslides included in the inventory reaches 7000 [3]. Therefore, special attention has always been paid to the study of landslide processes in Georgia [4-8].

Landslide phenomena depend on many processes, in particular on atmospheric precipitation [3,9,10]. The time scale of the influence of atmospheric precipitation on the provoking of landslides has a wide range - from several tens of minutes to several days, months and years (climatic time scale). In particular, in work [11] it was found that in Georgia with an increase in the annual sum of atmospheric precipitation, the tendency of increase in the number of landslides is observed in accordance with a second power of polynomial.

This paper is a continuation of previous research [11]. The preliminary results of a study of the relationship between the variability of the mean monthly sum of atmospheric precipitation and landslide processes in Georgia is presented below.

Study area, material and methods

Study area – territory of Georgia.

The data of Georgian National Environmental Agency about the mean monthly sum of atmospheric precipitations for 39 meteorological stations and number of landslides are used. Period of observation: 1936-2015 for precipitation (80 years) and 2014-2018 for landslides (5 years). The locations of meteorological stations and their names in [11] is presented.

In the proposed work the analysis of data is carried out with the use of the standard statistical analysis methods.

The following designations will be used below: Mean – average values; Min – minimal values; Max - maximal values; St Dev - standard deviation; σ_m – standard error; Sum - monthly number of landslides over five years; Rel Sum - the ratio of the monthly number of landslides in five years to the total amount of landslides in five years,%; 99% _Low and 99%_Upp – 99% of lower and upper levels of the mean accordingly; R^2 – coefficient of determination; R – coefficient of linear correlation; α - the level of significance.

Results and discussion

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

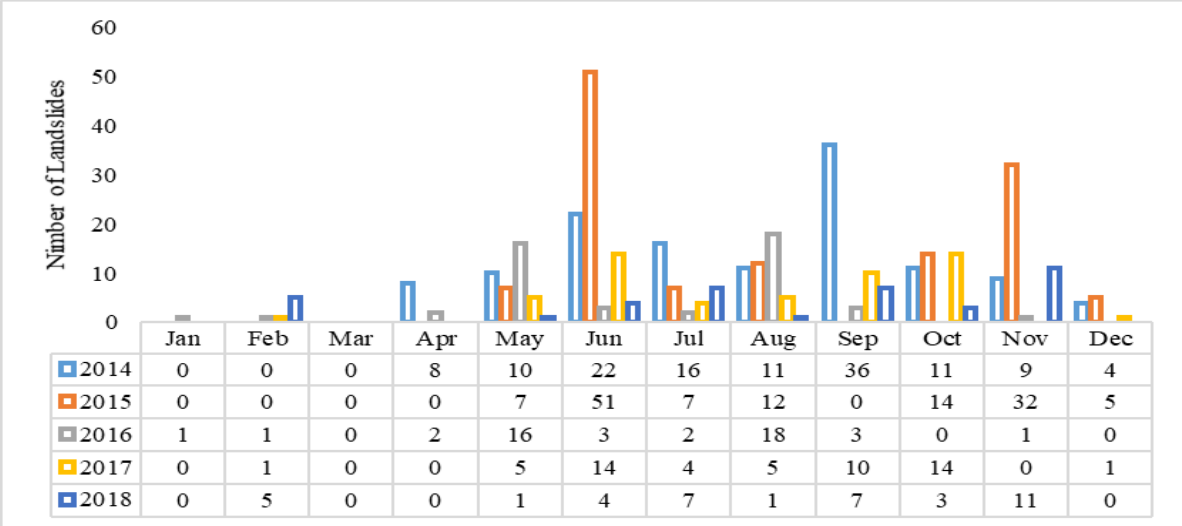


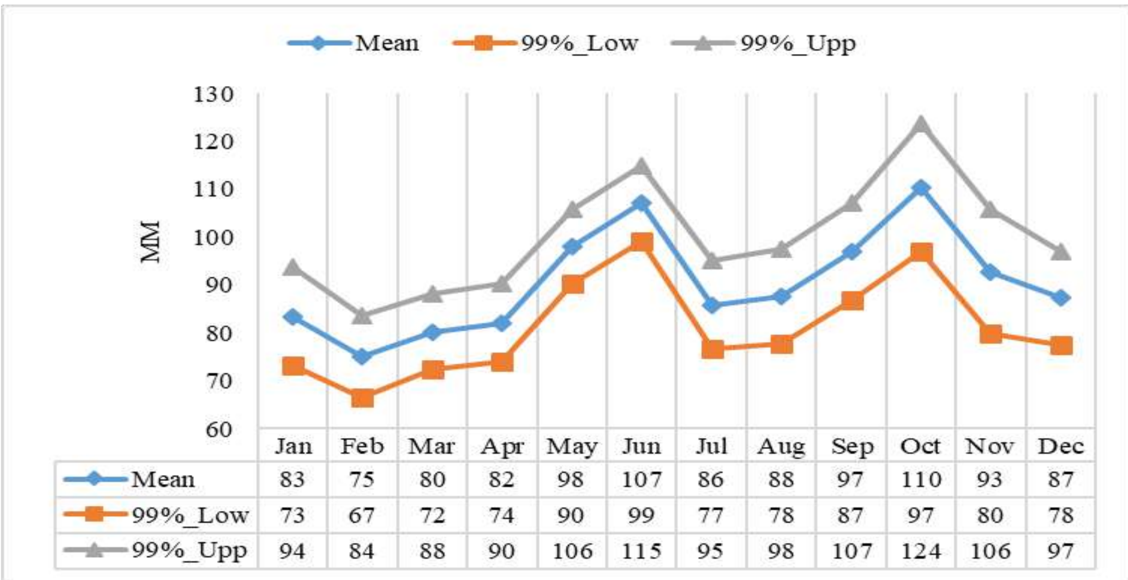
Fig. 1. Number of landslides in Georgia in different month in 2014-2018.

In fig. 1 data about number of landslides in Georgia in different month in 2014-2018 are presented. As follows from this figure, the maximum number of landslides (51) was recorded in June 2015. During the entire study period in March, no landslides were recorded. In just five years, 395 landslide cases were recorded.

Table 1. Statistical characteristics of number of landslide cases in Georgia in 2014-2018.

Parameter	Mean	Min	Max	St Dev	St Err	Sum	Rel Sum, %
Jan	0.2	0	1	0.4	0.2	1	0.3
Feb	1.4	0	5	2.1	1.0	7	1.8
Mar	no	no	no	no	no	no	no
Apr	2	0	8	3.5	1.7	10	2.5
May	7.8	1	16	5.6	2.8	39	9.9
Jun	18.8	3	51	19.6	9.8	94	23.8
Jul	7.2	2	16	5.4	2.7	36	9.1
Aug	9.4	1	18	6.6	3.3	47	11.9
Sep	11.2	0	36	14.4	7.2	56	14.2
Oct	8.4	0	14	6.5	3.3	42	10.6
Nov	10.6	0	32	12.9	6.4	53	13.4
Dec	2	0	5	2.3	1.2	10	2.5

In table 1 the statistical characteristics of number of landslide cases in Georgia in 2014-2018 are presented. In particular, as follows from Table 1, the largest number of landslides for five years (94) was observed in June, which is 23.8% of the total number of landslides for the indicated period of time. The most active period of landslides is from May to November (92.9% of all landslide cases).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	83	75	80	82	98	107	86	88	97	110	93	87
99%_Low	73	67	72	74	90	99	77	78	87	97	80	78
99%_Upp	94	84	88	90	106	115	95	98	107	124	106	97

Fig. 2. Monthly variation averaged to one meteorological station of Georgia of atmospheric precipitation in 1936-2015.

Data about averaged on 39 meteorological stations of Georgia monthly values of atmospheric precipitation in 1936-2015 in fig. 2 are presented. Note that Fig. 2 shows the general picture of the intra-annual distribution of monthly precipitation totals per one weather station in Georgia. Since the data in Fig. 2 were obtained by averaging the series of observations over 80 years, the indicated distribution is quite representative for several decades both before 1936 and after 2015.

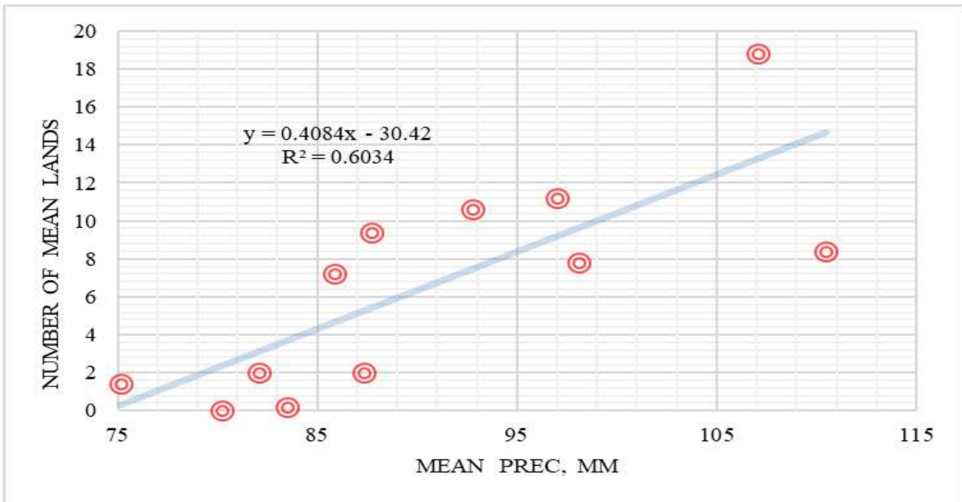


Fig. 3. Linear correlation between the monthly mean value of atmospheric precipitation averaged to one meteorological station and the mean monthly value of the number of landslides in Georgia in 2014-2018. (R = 0.78, α = 0.005).

Finally, in fig 3 data about connection between of monthly mean of atmospheric precipitation and monthly mean of landslide cases in Georgia are presented. This relationship with a high level of significance has a linear form. Note that the monthly effects of the influence of atmospheric precipitation on the number of landslides are more pronounced than the annual ones [11].

Conclusion

It is shown that with a monthly scale of averaging data on the amount of atmospheric precipitation and the number of landslides in Georgia, a clear linear tendency towards intensification of landslide processes with an increase in precipitation is noticeable**.** With this the monthly effects of the influence of atmospheric precipitation on the number of landslides are more pronounced than the annual ones [11].

These studies will be continued with a variety of scales of averaging ground-based and satellite observations in accordance with the Shota Rustaveli National Science Foundation of Georgia project FR-19-8190 "Assessment of landslide and mudflow hazards for Georgia using stationary and satellite rainfall data"

Acknowledgement

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საქართველოში საშუალო თვიური ნალექებისა და მეწყერთა შემთხვევათა შორის კავშირის შესწავლის წინასწარი შედეგები

ა. ამირანაშვილი, თ. ჭელიძე, ლ. დალაქიშვილი, დ. სვანაძე,
თ. წამალაშვილი, გ. თვაური

რეზიუმე

წარმოდგენილია საქართველოში მეწყერებზე ატმოსფერული ნალექების საშუალო თვიური რაოდენობის გავლენის შესწავლის წინასწარი შედეგები. კერძოდ, დადგენილია, რომ ატმოსფერული ნალექების თვიური რაოდენობის ზრდასთან ერთად შეიმჩნევა მეწყერთა რაოდენობის ზრდის წრფივი ტენდენცია.

Предварительные результаты исследования связи между среднемесячной суммой атмосферных осадков и случаями оползней в Грузии

**А. Амиранашвили, Т. Челидзе, Л. Далакишвили, Д. Сванадзе,
Т. Цамалашвили, Г. Тваури**

Резюме

Представлены предварительные результаты исследования влияния среднемесячного количества атмосферных осадков на оползни в Грузии. В частности, было получено, что с увеличением месячного количества атмосферных осадков наблюдается линейная тенденция увеличения количества оползней.

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On Some Weather Forecasting Models in Georgia

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ABSTRACT

Weather regional forecasting is the hard mathematical task especially for Georgian complex relief. Models of different complexity have been created and used to solve this problem. The results obtained from WRF and atmospheric non-stationary mesoscale models for complex orography of Georgia are presented in paper. Also existed and new approaches developed for better understanding meteorological events are discussed in conclusion.

Key words: *Numerical weather forecasting, hydrothermodynamical equations, complex orography regional forecasting systems, nonstationary mesoscale model*

1. Introduction

The relief of Georgia may be characterized by three sharply expressed orographic elements: in north Caucasus, in south – Georgian south uplands and lowland or intermountain depression located between those two risings. This one begins from The Black Sea shore by triangular Colchis Lowland and spreads up to eastern Georgia like the narrow strip. Between those two uplands small scaled orographic elements are allocated. Such complicated relief has its definite influence on air masses motion in atmosphere lower layers. Mainly western and eastern atmospheric processes prevailed over Georgian territory.

Due to complex orographic conditions and influence of the black Sea in Georgia exist most of Earths climatic types, from marine wet subtropical climate in west Georgia and steppe continental climate in east Georgia up to eternal snow and glaciers in high mountain zone of Great Caucasus, and also approximately 40% of observed landscapes. Current geodynamics and orographic properties of Georgia play an important role in formation of weather various patterns. Such complex relief conditions the formation and evolution of various scaled circulation systems and heterogeneous spatial distribution of meteorological elements. This is verified by the fact, that precipitation annual distribution has diverse type, with sharply expressed spatial inhomogeneities.

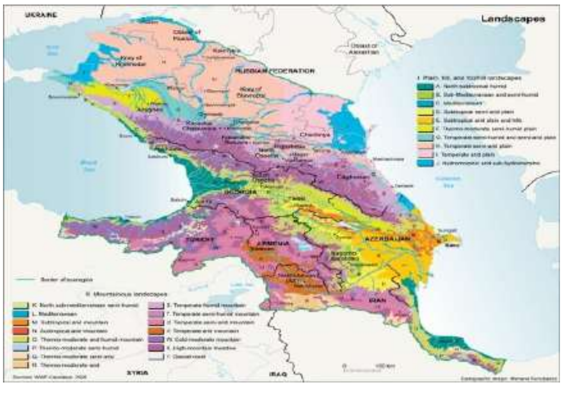


Fig.1. Climatic zoning of Caucasus region

The local circulation systems developed on the background of synoptical processes play significant role in the spatial-temporal distribution of weather determining parameters. The development of computing technique and modern sufficient methods to solve hydrodynamical differential equations leaded the creation of weather forecasting systems and gave possibility to simulate various scaled atmospheric processes. Among them mesoscale processes simulation system has been greatly developed. For present leading weather research centers develop and run real time global and regional forecasting systems. Based on mentioned modeling system Georgian weather forecasting service calculates main meteorological parameters on high resolution grid. Instead of above said operational service still needs creation of such methods that will be able to describe with high spatial-temporal decision and high quality of adequacy. This is conditioned by the fact that Georgia is mountainous country and consideration of relief in weather forecasting and modeling issues for Caucasus region is very urgent problem.

In Georgia there exist definite scientific experience in weather numerical forecasting methods, as well technological basis for use of modern models for their operational forecasting, but on preparation of short and medium-term forecasts, mainly is used various Prepayment background (mainly seven-day) forecasts issued by world's leading forecast centers obtained from special telecommunication systems and programs. Further, this information is synoptically treated for forecast region and nearby areas – considering local physical-geographical conditions. Therefore, it is natural that there is quite a severe problem in raising the issue of the reliability of the forecasts.

The computing optimal technology in numerical weather prediction methods is preferable to rely on the optimal parallelism of computing systems. In leading countries, weather forecasting massive parallelism is used in computer systems (such as supercomputers CRAY) – with large (millions or billions) working parallel processor. In this regard, the problem of weather forecasting module can be considered as the most advanced data-parallel processing technologies. In the 90s, the development of computational techniques has contributed to the explosive data parallel processing technology development, created new trends, making use of modern microprocessor technology achievements. Unfortunately, this period coincided in Georgia technical degradation, which led that the newly created lines were completely ignored (at present, there is almost no parallel programming experience in Georgia, as well as research in the commercial sector).

2. Methods

Weather numerical forecasting for whole Earth using atmosphere mathematical modeling requires huge data array transformation and complex calculations that, can’t be realized without a powerful computer technology. The application of such an abundance of information in atmospheric processes study leads to the management of acceptable outputs obtained based on the ability of, complex models. The specifics of the weather forecasting assignment requires expensive (a few million or more) high-tech support, which for today is possible only for developed countries. Global weather models, with large-scale (1000 km or more) description of the process give forecasts a week ahead of schedule. In other words, issue information about the weather baseline, but can't catch relatively small-scale processes, especially when the local weather is formed by processes such as convection. Such processes can’t be described in terms of global atmospheric models, which counting grid size is quite large, and therefore, the term of local weather patterns discernment is low. Despite the possibility that powerful computer systems are currently available, the local weather detection of acceptable accuracy to parse Earth using only global model is practically impossible. Thus, for local real weather prediction needs the development of regional (bounded area) models.

For short-term operational forecasting the use of confined area models became available in several national meteorological services. The range of those models is quite diverse from which special attention deserve regional mesoscale models also atmosphere dynamical models with artificial boundaries where model variables are defined from coarse value grid from global model outputs. Such models can describe real weather conditions invisible for global models that form in atmosphere small-scale processes.

Weather research and forecasting model (WRF) is weather numerical forecasting and atmosphere simulation system created as for research as operational application. The model is elaborated USA National Center for Atmosphere Research (NCAR), Mesoscale and Microscale Meteorological Division (MMM), NOAA, NCEP, ESRL, AFWA, Naval Research Laboratory, CAPS, and etc. It is used in following fields: real-time numerical forecasting, data assimilation, physical parameterization research, regional climatic simulations and etc [1].

Local area (space) model structure may be divided in dynamical and physical package. Its configuration for Caucasus region considers relevant adjustment of physical package such as local landscape-geographical properties (including: relief parameters, landuse and soil types, soil temperature, plant seasonal distribution and etc.). Dynamical core provides general circulation processes transformation influenced by Caucasus relief and proximity of The Black and Caspian Seas resulting in local established weather. The specification of those processes is possible by optimal configuration selection of schemes describing physical processes. Besides ARW provides introduction of higher spatial-temporal resolution horizontal grid that focuses on target sub-region and significantly increases model resolution (from 15km to 5 km.) [2].

Complex relief of Caucasus significantly influences on weather formation thus relief consideration in model is one of most important assignment. It may be realized by relief parameterization or statistical type or by using both of them. As calculations show Caucasus orographic is considered at high level in regional model that is proved by atmosphere boundary level pressure forecasting.

- Clearly fixed local circulation formation in west Georgia during western circulation processes;
- Also well fixed high pressure area formation in River Mtkvari valley during eastern processes and on the contrary – low pressure area in Rioni River gorge (Colchis lowland)

Mentioned facts give possibility to predict with high accuracy the beginning and end of western and eastern incursions on Georgian territory also their intensity, specifically western and eastern wind power in Mtkvari and Rioni rivers.

Model simulation outputs and analysis are given below.

The main synoptical processes and related weather patterns are: western, eastern, anticyclone state established by air masses bilateral invasion and wave perturbations in southern frontal zone. Kain-Fritsch convective cloud parameterization scheme was used (deep and non-deep convection intercellar scaled scheme) and WSM3 microphysical scheme, also YSU (Yonsei University) planetary layer scheme. The subgrid has been embedded in research model WRF ARW. Main area covered whole Caucasus region and subarea was fixed over Georgian territory with 5km resolution and 145X115 knots.

The circulation process evolution has been discussed that occurred on November 4, 2009, when air masses have been invaded from the Black Seaside resulting in snowstorm in Tbilisi. According weather observation data wind maximal velocity was more than 30m/sec resulting in temperature decreasing and precipitation in Georgia. As the front moved eastward very quickly above mentioned weather extreme conditions lasted only for several minutes. Subsequently in eastern Georgia was established anticyclone parietal impact long period with weak winds and rain as well as frog.

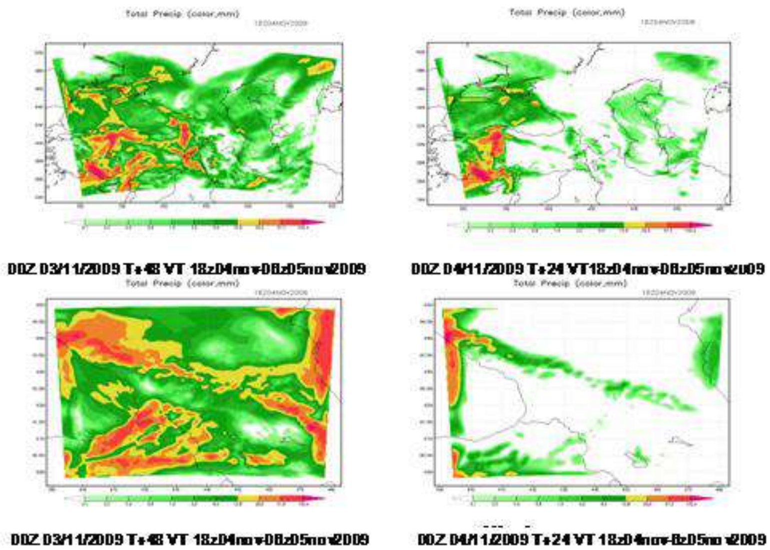


Fig.2. Precipitation distribution from WRF model for different moments

Despite above discussed method that undoubtedly is step forward national weather service still requires development of forecasting methods. Numerical forecasting models based on complete hydrothermodynamical equations give possibility detail involve physical factors describing atmospheric phenomena that greatly influenced or sometimes define atmospheric circulation processes. The consideration of those factors in numerical models provides improvement forecasting quality. Realization of weather forecasting issue on confined area is characterized by definite difficulties. Such is the formulation of boundary conditions on the borders of forecasting area. The lack of meteorological data on region borders influenced researches to seek problem solution different ways. By using telescopization or embedded grid method became one of the most effective mean for this. Except boundary conditions telescopization method gives possibility to solve those main issues that are essential for weather forecasting on confined area. Specifically reducing spatial grid step on target area in such way that didn't increase model realization time, also detail describe region orographic features, realize interconnection between largescale, regional and mesoscale meteorological processes using bilateral and unilateral interaction of solutions from different grids.

Based on atmospheric processes nonstationary mesoscale model [3] for Georgian territory the peculiarities of mesoscale flows in troposphere under conditions when undisturbed background flow undergo significant transformations and atmospheric circulation regime has been changed by another one.

Model equation solving area which's sizes among X and Y axis compose 830km and 690km is shown of fig.3. On same figure is given relief elevation revealing that integral area is characterized by sharply expressed orographic elements. Those are: Caucasus in north, Georgian southern uplands on south and placed between those two risings lowland or intermountain depression, which begins from the Black Sea coast – triangle shaped Kolkheti Lowland and extends to east Georgia in the form of narrow line. Among those two uplands a number of small scaled elements have been placed. Such relief type has definite influence on air masses motion in atmosphere lower layers over Georgian territory. 30 computing level was on vertical and on each level grid knot amount among X and Y axis compose 84 and 70 with 10km horizontal step.

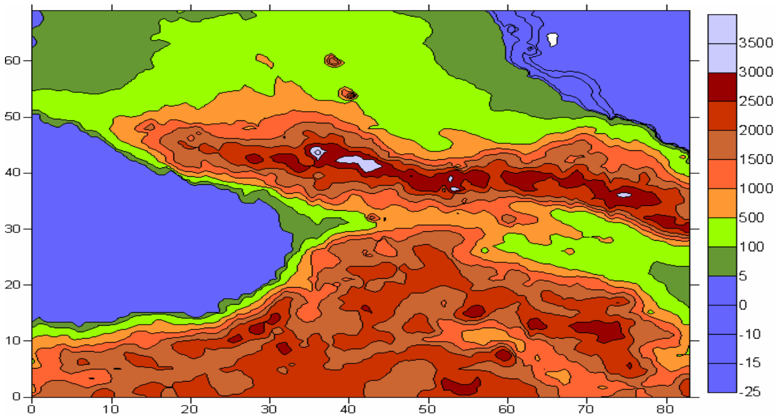
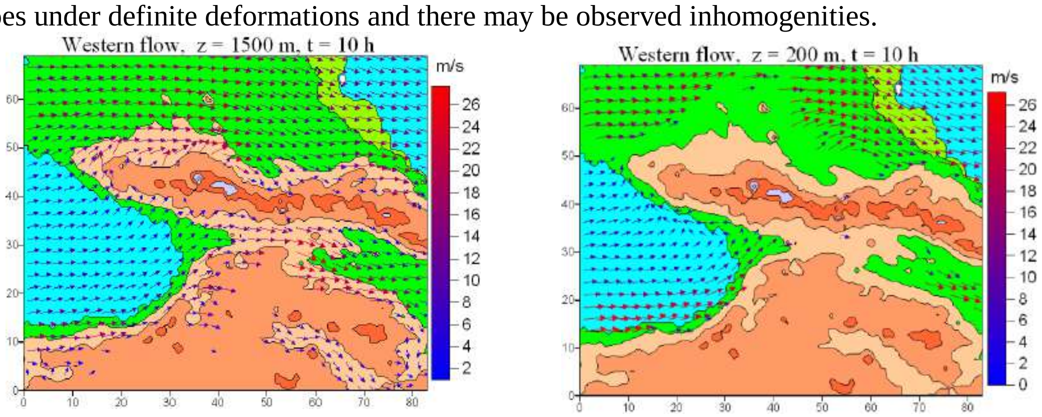


Fig.3. Georgian relief used in nonstationary mesoscale model and equation solution area.

The disturbed flow field on 200, 1500, 3000 and 5000m elevation for t=10h or before nonstationary transformation of background flow is presented on fig.4. The picture reveals that western background flow undergoes under definite deformations and there may be observed inhomogenities.



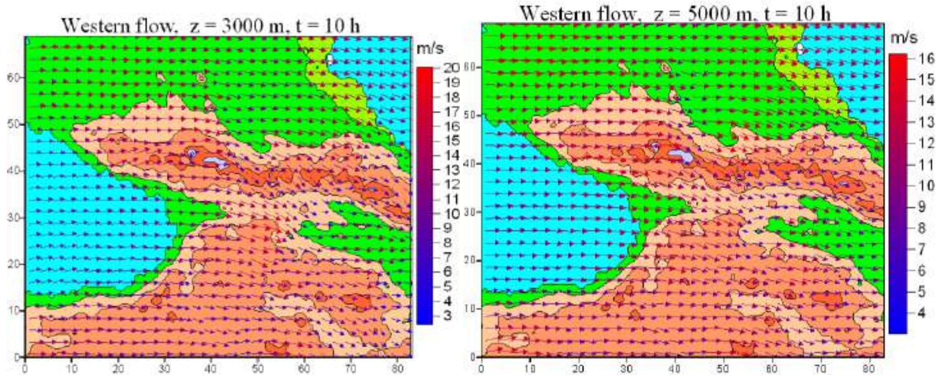


Fig 4. Simulated flow field for 10h. at different elevations.

On Fig. 5and 6 are presented simulated western flow at 200 m and 1500 m for different time moments. From those figures it is evident how relief influenced flow field.

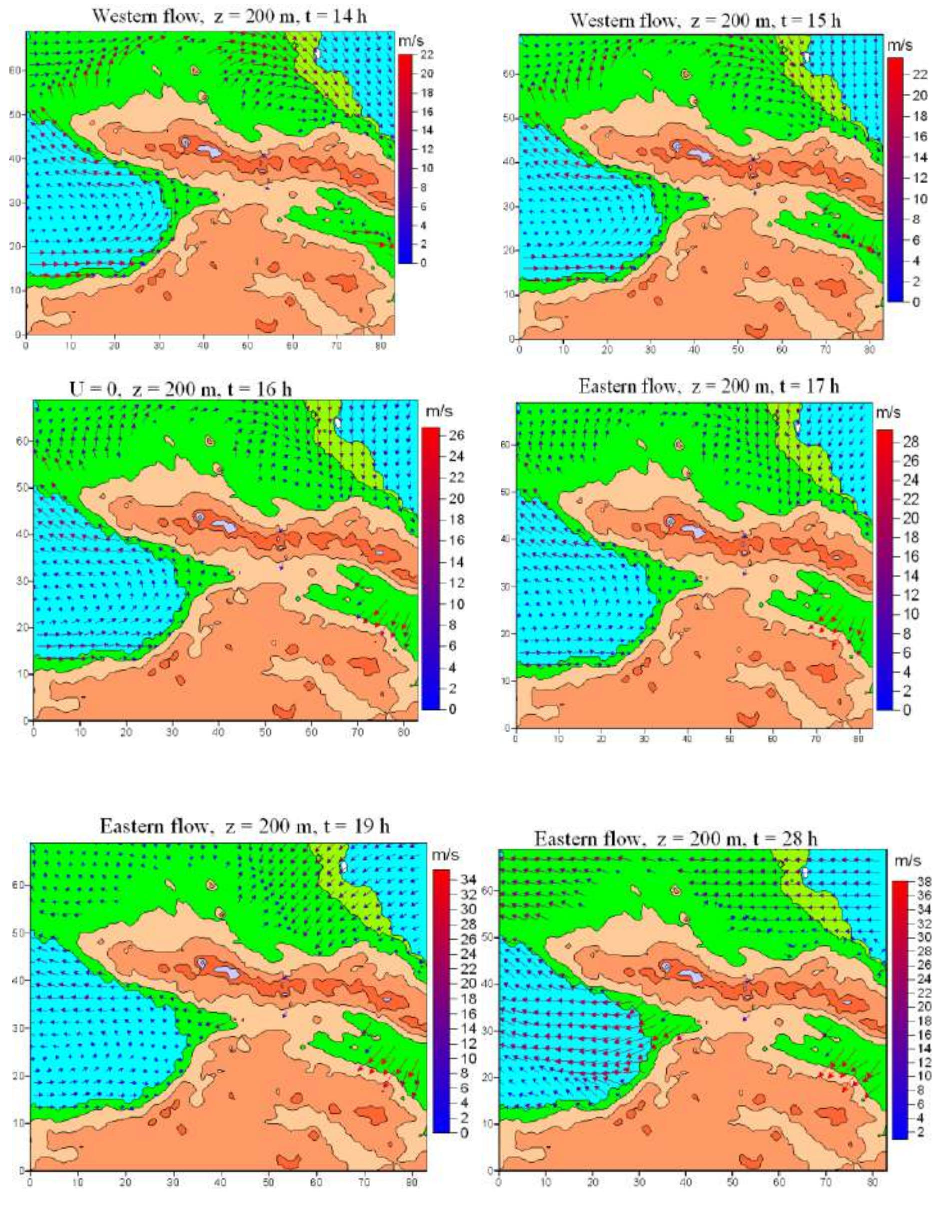


Fig 5. Simulated flow field at 200 m for different time moments.

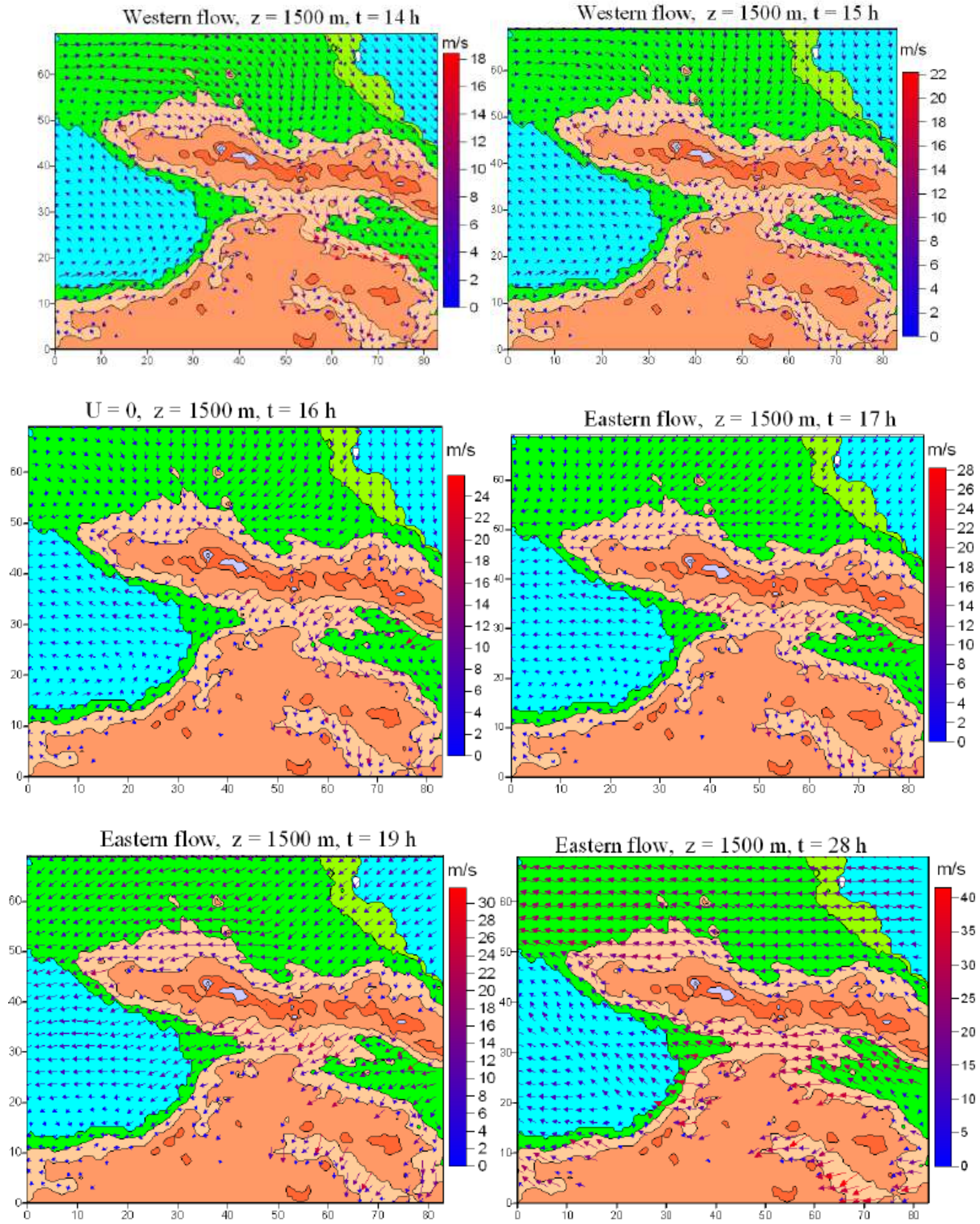


Fig 6. Simulated flow field at 1500m for different time moments

3. Conclusion.

The impact of the complex terrain is the decisive factor on local circulation processes and its detail consideration in weather forecasting models should be required. The presented two different models WRF and atmospheric nonstationary mesoscale model outputs show how it influences on precipitation and temperature fields formation. It is preferably to use other existing software packages and methods to ensure model justification and carry out adjusting –calibration towards real observations.

Except above presented models many efforts and methods have been dedicated to the problem of precipitation formation and convective cloud evolution processes for Georgian conditions. Among others it is remarkable to mention operational thermohydrodynamical convective cloud model created for research of natural and artificial precipitation formation and can be used in weather modification [4,6]. In model for crystallization and melting processes have been introduced new parameterization schemes. One of most important precipitation formation microphysical process – coagulation describing integral-differential equations have been analytically solved considering income of cloud particles. The results evidently showed redistribution of ice crystals and rain drops in cloud dispersive medium.

Many researchers and scientists remark that in weather forecasting models detail considering of cloud microphysics would be preferable but as they are microscale processes usually parameterization schemes are used. The some peculiarities of microstructure of cloud formations have been discussed using quantum disperse forces or Van-Der-Vaal's forces that are typical for water particles. To obtain the expression for interaction potential the wave functions of basic and exited states of clusters and dispersion matrix have been introduced describing by virtual photon. It has been turned out that virtual photon interaction causes potential holes and barriers that are decreased by height and width. The isolated long wave quants may be the radiation that is generated throughout observed microphysical processes. The cluster may be presented as multipole system. The multipole is the system composed by couple opposite charges that have definite symmetry type. The simplest is the dipole. If the transition is forbidden in dipole approach it may happen in higher approaches – quadruple (electric) or magnetic dipole. Their probability is approximately 10^6 times less than dipole. To search out transition probability of cluster from basic state into exciting or virtual one interacting with electromagnetic field the identification of Einstein factors have to be needed.

This new approach can lead research series in different microphysical processes such as phase transitions, electric processes and etc.

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საქართველოში ამინდის პროგნოზის ზოგიერთ მოდელების შესახებ

მ. ტატიშვილი, ზ. ხვედელიძე, დ. დემეტრაშვილი

რეზიუმე

ამინდის რეგიონალური პროგნოზი რთული მათემატიკური ამოცანაა, განსაკუთრებით საქართველოს კომპლექსური რელიეფისთვის. ამ პრობლემის გადასაჭრელად შეიქმნა და გამოყენებულია სხვადასხვა სირთულის მოდელები. წინამდებარე სტატიაში მოყვანილია WRF–ისა და ატმოსფერული არასტაციონარული მეზოსკალის მოდელებისგან მიღებული შედეგები საქართველოს რთული ოროგრაფიისთვის. დასკვნაში ასევე განხილულია შექმნილი და ახალი მიდგომები მეტეოროლოგიური მოვლენების უკეთ შესასწავლად.

О некоторых моделях прогноза погоды в Грузии

М.Р. Татишвили, З. В. Хведелидзе, Д.И. Деметрашвили

Резюме

Региональное прогнозирование погоды - сложная математическая задача, особенно для сложного рельефа Грузии. Для решения этой задачи созданы и используются модели разной сложности. В статье представлены результаты, полученные с помощью WRF и атмосферных нестационарных мезомасштабных моделей для рельефа Грузии. В заключении обсуждаются также существующие и новые подходы, разработанные для лучшего понимания метеорологических явлений.

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Some Characteristics of Hail Processes in Kakheti (Georgia) According to Radar Observations into 2016-2019

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ABSTRACT

The paper presents the results of a statistical analysis of such parameters of hail processes for separate municipalities of Kakheti in the period from 2016 to 2019, as: the maximum height of hail clouds, the maximum diameter of hailstone in clouds, the number of hail clouds of various categories, repetition of hail clouds of various categories, the mean hail hazard relative ratio G. In particular, it was found that during the study period , the greatest hail hazard was observed in the Gurjaani municipality (G = 1.74), and the smallest in the Dedoplistskaro municipality (G = 0.39).

Key words: *hail clouds, hailstone, hail clouds category, hail hazard relative ratio.*

Introduction

Georgia is a small mountainous country where almost all types of natural disasters occur, including hydrometeorological [1]. Among natural disasters in Georgia, hail processes occupy one of the leading places, especially in Kakheti [1-3].

From 1967 to 1989, production works were carried out in this region of Georgia to protect agricultural crops from hail using rocket technologies [4- 6]. These works were renewed in 2015 [7,8].

The anti-hail service is equipped with a modern meteorological radar "METEOR 735 CDP 10 - Doppler Weather Radar", which allows to control many processes in the atmosphere associated with cloud formations [9-12]. In addition to using the radar in operational work, the analysis of radar observation data for various atmospheric processes is carried out.

For example, in recent five years in a number of works were represented the preliminary results of radar studies of hail processes [13-18], rainfall [19-22] and dust formation migration [23, 24] in Eastern Georgia and its neighboring countries (Azerbaijan, Armenia).

In particular, in our last work [25], according to the data of radar observations in Kakheti in 2016-2019, the following characteristics of hail clouds were established for this region: repetition of category of hail clouds, mean max diameter of hailstones in the clouds of different category, dependence of mean values of max diameter of hailstones in the clouds on mean values of max altitude of the radio echo of clouds.

This work is a continuation of the study [25]. Results of the analysis of radar observation of data about number of hail clouds of different category, the max diameter of hailstones, the max height of the radio echo of hail clouds and mean hail hazard relative ratio for separate municipalities of Kakheti in 2016-2019, are presented below.

Study area, material and methods

Study area – separate municipalities of Kakheti region of Georgia (Akhmeta, Gurjaani, Dedoplistskaro, Telavi, Lagodekhi, Sagarejo, Signagi, Kvareli). Data of meteorological radar "METEOR 735 CDP 10 - Doppler Weather Radar" of Anti-hail service of Georgia about the max diameter of hailstones

D_o (mm) and the max height of the radio echo of hail clouds H_m (km) - radar products HAILSZ (Size) and MAX (dBZ) [11,12] - are used.

Period of observation: April-October, 2016-2019. The area of shielded from the hail territory - 800000 hectares. The categories of clouds (objects of action, four categories) in the correspondence with [2] were determined. The hail hazard relative ratio G in Kakheti municipal educations were calculated with use the data about numbers of clouds in each category, to the correspondence with [2] also.

$$G = (0.1 \cdot n_1 + 0.3 \cdot n_2 + 1.0 \cdot n_3 + 5.0 \cdot n_4)/(0.1 \cdot N_1 + 0.3 \cdot N_2 + 1.0 \cdot N_3 + 5.0 \cdot N_4)$$

Where: n_1 …. n_4 - the number of clouds by category in separate municipalities of Kakheti, N_1…. N_4 - the number of clouds by category on the whole in Kakheti.

Thus, the value of G is the ratio of the hail hazard of separate municipalities of Kakheti to the hail hazard of Kakheti as a whole.

For the data analysis the standard statistical methods are used. The following designations of statistical information are used below: Mean – average values; Min – minimal values; Max - maximal values; St Dev - standard deviation; σm - standard error; Cv = 100·St Dev/Mean – coefficient of variation, %; Count - number of cases; 99% _Low and 99%_Upp – 99% of lower and upper levels of the mean accordingly.

Results

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

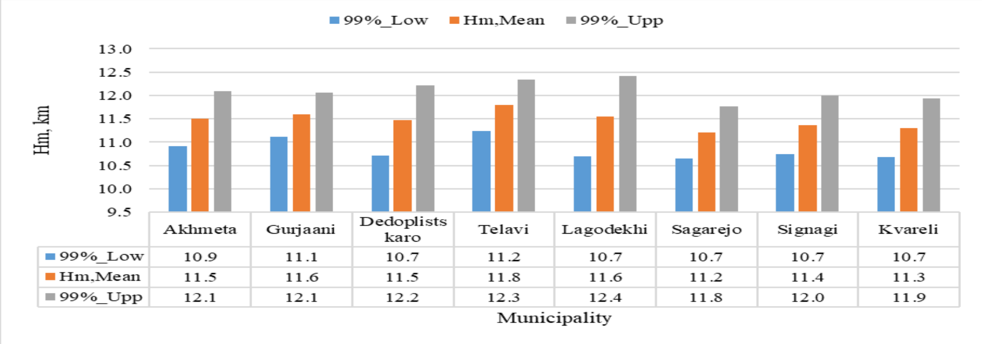
In table 1 and fig. 1,2 the statistical characteristics of Hm and Do of hail clouds in separate municipality of Kakheti are presented. As follows from table 1 and fig. 1,2 mean values of Hm changes slightly, from 11.2 km (Sagarejo) to 11.8 km (Telavi). Mean values of Do changes substantially, from 16.0 mm (Dedoplistskaro) to 21.5 mm (Gurjaani).

Hail clouds with a maximum height of 18.0 km were observed in the municipalities of Lagodekhi and Sighnagi. Hailstones with a maximum diameter of 63.1 mm were observed in the Lagodekhi municipality.

Table 1. Statistical characteristics of Hm and Do of hail clouds in separate municipality of Kakheti

Municipality	Akhmeta		Gurjaani		Dedoplistskaro		Telavi	
Parameter	Hm, km	Do, mm	Hm, km	Do, mm	Hm, km	Do, mm	Hm, km	Do, mm
Mean	11.5	16.2	11.6	21.5	11.5	16.0	11.8	18.3
Min	7.0	0.9	6.8	0.9	7.0	0.9	6.0	0.9
Max	16.0	48.3	17.0	53.9	16.0	35.8	17.0	43.0
St Dev	2.2	9.6	1.9	9.9	2.1	8.9	2.1	9.9
σm	0.2	1.0	0.2	0.9	0.3	1.3	0.2	1.0
Cv (%)	18.9	59.6	16.5	46.1	17.9	55.6	17.7	53.8
Count	92	92	110	110	51	51	96	96
Municipality	Lagodekhi		Sagarejo		Signagi		Kvareli	
Mean	11.6	19.4	11.2	17.3	11.4	19.0	11.3	17.4
Min	7.0	2.9	5.0	2.9	7.0	0.9	7.0	0.9
Max	18.0	63.1	16.0	48.3	18.0	43.0	16.0	35.8
St Dev	2.2	10.5	2.1	10.2	2.4	9.9	1.9	8.8
σm	0.3	1.6	0.2	1.1	0.2	1.0	0.2	1.1
Cv (%)	19.0	54.4	18.7	59.0	20.7	52.3	16.5	50.4
Count	44	44	95	95	95	95	60	60

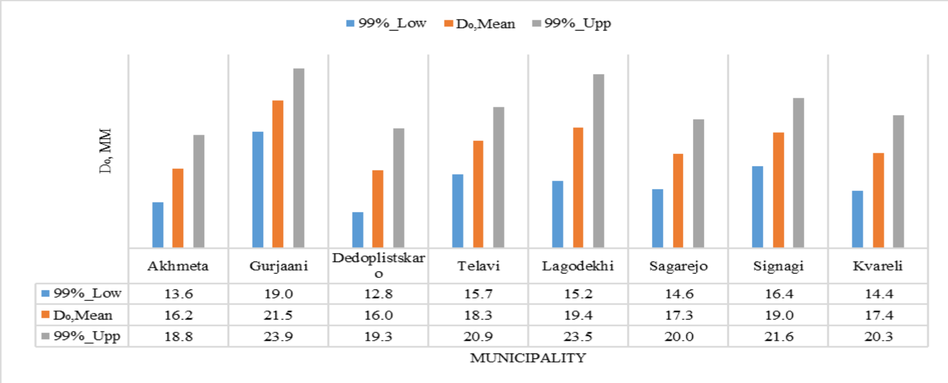
Variations in Hm values are insignificant: the coefficient of variation varies from 16.5% (Gurjaani and Kvareli municipalities) to 20.7% (Signagi municipality). Variations in Do values compared to variations in Hm values are significantly higher: the coefficient of variation changes from 46.1% (Gurjaani municipality) to 59.6% (Akhmeta municipality).



	Akhmeta	Gurjaani	Dedoplistskaro	Telavi	Lagodekhi	Sagarejo	Signagi	Kvareli
99%_Low	10.9	11.1	10.7	11.2	10.7	10.7	10.7	10.7
Hm,Mean	11.5	11.6	11.5	11.8	11.6	11.2	11.4	11.3
99%_Upp	12.1	12.1	12.2	12.3	12.4	11.8	12.0	11.9

Fig. 1. Mean maximum height of hail clouds in Kakheti by municipal educations.

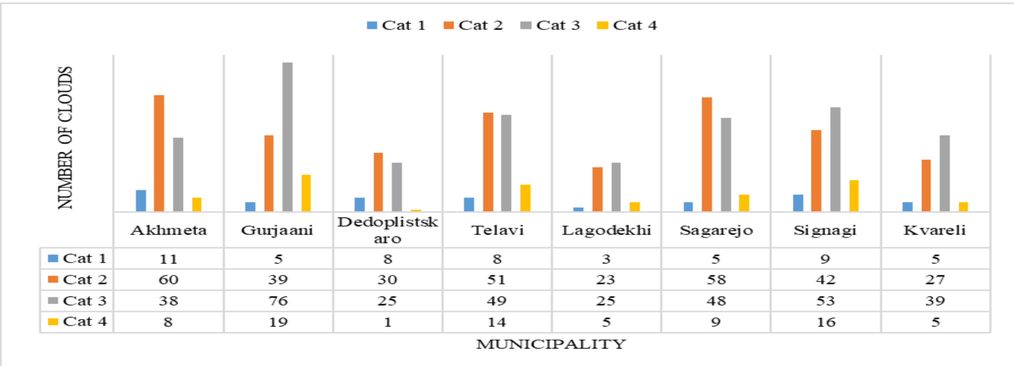
Fig. 1 shows that the range of variation from the lower to the upper 99% levels of the confidence interval of the mean for the Hm values is as follows: from 10.7 km (all municipalities except Akhmeta, Gurjaani and Telavi) to 12.4 km (Lagodekhi municipality).



	Akhmeta	Gurjaani	Dedoplistskaro	Telavi	Lagodekhi	Sagarejo	Signagi	Kvareli
99%_Low	13.6	19.0	12.8	15.7	15.2	14.6	16.4	14.4
D_0,Mean	16.2	21.5	16.0	18.3	19.4	17.3	19.0	17.4
99%_Upp	18.8	23.9	19.3	20.9	23.5	20.0	21.6	20.3

Fig. 2. Mean maximum diameter of hailstone in clouds in Kakheti by municipal educations.

Fig. 2 shows that the range of change from the lower to the upper 99% levels of the confidence interval of the mean for Do values is as follows: from 12.8 mm (Dedoplistskaro municipality) to 23.9 mm (Gurjaani municipality).



	Akhmeta	Gurjaani	Dedoplistskaro	Telavi	Lagodekhi	Sagarejo	Signagi	Kvareli
Cat 1	11	5	8	8	3	5	9	5
Cat 2	60	39	30	51	23	58	42	27
Cat 3	38	76	25	49	25	48	53	39
Cat 4	8	19	1	14	5	9	16	5

Fig. 3. The number of hail clouds of various categories in Kakheti by municipal educations.

As follows from fig. 3, the smallest number of hail clouds of the second category is observed in the municipality of Lagodekhi (23), the third category - in the municipalities of Dedoplistskaro and Lagodekhi (25 each), the fourth category - in the municipality of Dedoplistskaro (1)

The highest number of hail clouds of the second category is observed in the Akhmeta municipality (60), the third category - in the Signagi municipality (53), the fourth category - in the Gurjaani municipality (19).

Fig. 4. Repetition of hail clouds of various categories in Kakheti by municipal educations, %. On top – 1 category; on the right - 2 category; below - 3 category; on the left - 4 category.

Fig. 5. Mean hail hazard relative ratio G in Kakheti by municipal educations (G for Kakheti = 1).

From fig. 4 follows, that the smallest repetition of hail clouds of the second category is observed in the municipality of Gurjaani (28.2%), the third category - in the municipality of Akhmeta (32.6%), the fourth category - in the municipality of Dedoplistskaro (2.0%)

The highest repetition of hail clouds of the second category is observed in the Akhmeta municipality (51.1%), the third category - in the Gurjaani municipality (54.5%), the fourth category - in the Signagi municipality (13.7%).

Finally, as follows from Fig. 5, during the study period the greatest hail hazard was observed in the Gurjaani municipality (G = 1.74), and the smallest in the Dedoplistskaro municipality (G = 0.39).

Conclusion

In the near future, it is planned to continue the studies presented in this article. In particular, the monthly distribution of the maximum height of hail clouds, the maximum diameter of hailstone in clouds, the number of hail clouds of various categories, repetition of hail clouds of various categories, etc. will be studied.

It should be noted that the time-series of observations of the specified parameters of hail clouds is only five years. Therefore, in the future, as new data are received, the results of their statistical analysis will be refined.

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კახეთში (საქართველო) სეტყვის პროცესების ზოგიერთი მახასიათებელი რადარის დაკვირვების მიხედვით 2016-2019 წწ.

ა. ამირანაშვილი, ვ. ჩიხლაძე, ნ. კვესელავა,
ნ. ქვილითაია, ი. საური, შ. შავლაყაძე

რეზიუმე

ნაშრომში მოყვანილია 2016 -2019 წწ. კახეთის ცალკეული მუნიციპალიტეტებისთვის სეტყვის პროცესების ისეთი პარამეტრების სტატისტიკური ანალიზის შედეგები, როგორიცაა: სეტყვის ღრუბლების მაქსიმალური სიმაღლე, სეტყვის მარცვლების მაქსიმალური დიამეტრი ღრუბელში, სხვადასხვა კატეგორიის სეტყვის ღრუბლების რაოდენობა, სხვადასხვა კატეგორიის სეტყვის ღრუბლების განმეორადობა, საშუალო ფარდობითი სეტყვასაშიშროების კოეფიციენტი G. კერძოდ, მიღებულია, რომ აღნიშნულ პერიოდში სეტყვის ყველაზე დიდი საშიშროება დაფიქსირდა გურჯაანის მუნიციპალიტეტში (G = 1.74), ყველაზე დაბალი - დედოფლისწყაროს მუნიციპალიტეტში (G = 0.39).

Некоторые характеристики градовых процессов в Кахетии (Грузия) по данным радиолокационных наблюдений в 2016-2019 гг.

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Н. Р. Квилитая, И. П. Саури, Ш. Т. Шавлакадзе**

Резюме

В работе представлены результата статистического анализа таких параметров градовых процессов для отдельных муниципалитетов Кахетии в период с 2016 по 2019 гг., как: максимальная высота градовых облаков, максимальный диаметр градин в облаках, количество градовых облаков различных категорий, повторяемость градовых облаков различных категорий, средний относительный коэффициент градовой опасности G. В частности, получено, что в исследуемый период времени наибольшая градовая опасность наблюдалась в муниципалитете Гурджаани (G=1.74), наименьшая - в муниципалитете Дедоплисцкаро (G=0.39).

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Impact of Short-Term Geomagnetic Activity on Weather and Climate Formation in Georgian Region

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ABSTRACT

The investigation of possible effect of powerful magnetospheric storms on the evolution character of meteorological processes in the atmosphere aiming to identify correlation between magnetospheric disturbances and meteorological variations is presented in paper. The investigation is preconditioned by the fact, that Georgia is prone to meteorological hazards and it is especially actual to investigate their causing physical processes.

Meteorological effects resulting from fluctuations in the solar wind are poorly represented in weather and climate models. Geomagnetic storm is a major disturbance of Earth's magnetosphere exchanging energy from the solar wind into the space environment surrounding Earth. These storms result from variations in the solar wind that produces major changes in the currents, plasmas, and fields in Earth's magnetosphere.

Geomagnetic indices are measure of geomagnetic activity occurring over short periods of time. They have been constructed to study the response of the Earth's ionosphere and magnetosphere to changes in solar activity. The correlation between geomagnetic storms and meteorological elements (temperature, precipitation, wind) have been carried out for Georgian region using meteorological observation and NASA's Solar Dynamics Observatory and NOAA Space Weather Prediction Center data. The results show that there exist dependence between weather parameters and geo-magnetic disturbances.

Key words: *Natural hydrometeorological disasters, weather forecasting, geo-magnetic index, correlation analysis.*

1. Introduction

The Sun is the source of the energy that causes the motion of the atmosphere and thereby controls weather and climate. Any change in the energy from the Sun received at the surface will affect Earth climate. During stable conditions there has to be the balance between the energy received from the Sun and the energy that the Earth radiates back into the Space. This energy is mainly radiated in the form of long wave radiation corresponding to the mean temperature of the Earth [1].

Solar transients; Solar Flares, Coronal Mass Ejections (CMEs), Solar Energetic Particles (SEPs) are the drivers of the Space Weather Effect in Geo-Space. When the gigantic cloud of plasma released through solar transient phenomena interacts with the Earth's magnetic environment it leads to the geomagnetic storms. Geomagnetic storms can be characterized by depression in the H component of geomagnetic field. This depression in H component of earth's magnetic field is caused by the Ring Current encircling the Earth in a westward direction. Earth's ionosphere responds to varying solar and magnetospheric conditions. During geomagnetic storm due to the compression of earth's magnetosphere by solar wind electric fields have been observed along the geomagnetic field lines to the high latitude ionosphere. Sometimes this electric field penetrates to low latitudes and energetic particles precipitate into the lower thermosphere and below, increasing ionospheric conductivity and expanding the auroral zone [2, 3]. These intense electric currents are responsible for the coupling of high latitude ionosphere with magnetosphere and the enhanced energy input leads to considerable heating of the ionized and neutral gases. There are two types of effects, in time scale, on the Earth produced by solar transients; prompt and delayed. Geomagnetic Storm effects are delayed effects due to cloud of particles ejected from Sun.

The sun undergoes cyclical (~22 year) pattern of magnetic pole reversals observable in the frequency of sunspot activity. This pattern is comprised of two ~11 year solar cycles phases. In the first phase, the sun's magnetic poles reverse polarity. In the second phase, the sun reverses the magnetic polarity again returning the poles back to its original polarity. Solar storm activity is strongly phase dependent. Accordingly Earth magnetic field is influenced by this reverse.

Solar flares are magnetically driven explosions on the surface of the sun. Approximately 8 minutes after solar flare occurs on the surface of the sun, a powerful burst of electromagnetic radiation in the form of X-ray, extreme ultraviolet rays, gamma ray radiation and radio burst arrives at Earth. The ultraviolet rays heat the upper atmosphere which causes the outer atmospheric shell to expand. The x-rays strip electrons from the atom in the ionosphere producing a sudden increase in *total electron content*. Solar flares produce satellite communications interference, radar interference, shortwave radio fades and blackout and atmospheric drag on satellite producing an unplanned change in orbit and other disturbances in upper atmosphere.

CMEs are vast clouds of seething gas, charged plasma of low to medium energy particles with imbedded magnetic field, blasted into interplanetary space from the Sun. When a CME strikes Earth, the compressed magnetic fields and plasma in their leading edge smash into the geomagnetic field. This produces temporary disturbance of the Earth's magnetosphere called a geomagnetic storm and the equatorial ring of currents, differential gradient and curvature drift of electrons and protons in the Near Earth region. The birthplace of CMEs are often seen to originate near the site of solar flares.

The severity of a geomagnetic storm depends on the orientation of Earth's magnetic field in relation to the solar storm magnetic orientation. If the particle cloud has a southward directed magnetic field it will be severe, while if northward the effects are minimized.

A CME can produce the following affects: electrostatic spacecraft charging, shifting of the Van Allen radiation belt, space track errors, launch trajectory errors, spacecraft payload deployment problems, surveillance radar errors, radio propagation anomalies, compass alignment errors, electrical power blackouts, oil and gas pipeline corrosion, communication landline & equipment damage, electrical shock hazard, electrical fires, heart attacks, strokes, and traffic accidents. Magnetospheric storm is a 1–3 day long phenomenon spanning all the magnetosphere regions, and it features sharp depressions in the magnetic field. During storms and substorms, the ionosphere undergoes rather significant Joule heating with a great power of precipitating energetic particles. Huge energy increases the ionosphere temperature and causes large-scale ion drifts and neutral winds [3].

The Sun continuously provides solar radiation to the Earth, and there is considerable variation in the spectral density. This radiation is sporadically modified by flare events that affect the magnetosphere, thermosphere, and ionosphere. The quasi-steady flow of the solar wind is also modified by coronal mass ejections (CMEs), which accelerate energetic particles and cause geomagnetic storms during subsequent impacts on Earth. Observations have suggested that energetic particle forcing may affect wave propagation, zonal mean temperatures, and zonal winds in the Northern Hemisphere winter stratosphere. However, the mechanisms by which these changes occur are *still not known*. As changes in the Earth's atmosphere occur, whether due to changes in solar forcing or in response to enhanced anthropogenic activity and increased greenhouse gas (GHG) concentrations, the energy balance of the Earth's atmosphere is altered and this affects its dynamics. Changes can occur in the propagation of atmospheric gravity waves, planetary waves, and tides, which play important roles in driving the general circulation of the middle atmosphere. The thermosphere-ionosphere system is known to vary substantially with altitude, latitude, longitude, universal time, season, solar cycle and geomagnetic activity, as a result of mechanisms inherent to the system, as well as a result of space weather. The primary driving mechanism is solar radiation (EUV and UV), but precipitation of charged magnetospheric particles and magnetospheric electric fields also have significant effects on the ionosphere-thermosphere system. The driving processes determine the density, composition, and temperature of the ionized and neutral constituents of the upper atmosphere.

The solar wind conditions that are effective for creating geomagnetic storms are sustained (for several to many hours) periods of high-speed solar wind, and most importantly, a southward directed solar wind magnetic field (opposite the direction of Earth's field) at the dayside of the magnetosphere. This condition is effective for transferring energy from the solar wind into Earth's magnetosphere.

The largest storms that result from these conditions are associated with solar coronal mass ejections (CMEs) where a billion tons or so of plasma from the sun, with its embedded magnetic field, arrives at Earth. CMEs typically take several days to arrive at Earth, but have been observed, for some of the most intense storms, to arrive in as short as 18 hours. Another solar wind disturbance that creates conditions favorable to geomagnetic storms is a high-speed solar wind stream (HSS). HSSs plow into the slower solar wind in front and create co-rotating interaction regions, or CIRs. These regions are often related to geomagnetic storms that while less intense than CME storms, often can deposit more energy in Earth's magnetosphere over a longer interval

2. Data and methods

The study area is Georgian region. The relief of Georgia is mountainous, sharply billowy, where large orographic raisings alternate with intermountain troughs. On the northern part of territory in direction from north-west to south-east Main Caucasus Ridge is stretching, its separate tops are above 5000m. At south part of the territory the South Georgian plateau is stretching. Between Main Caucasus Ridge and south Georgian Plateau the intermountain depression is located, which is presented by lowlands, plains and plateaus.

Complex orographic conditions and influence of the black Sea preconditioned the formation of great variety of climate and landscapes. Here exist most of Earths climatic types, from marine wet subtropical climate of west Georgia and steppe continental climate of east Georgia up to eternal snow and glaciers of high mountain zone of Great Caucasus, and also approximately 40% of observed landscapes. Thus those climatic zones condition formation of different dangerous hydrometeorological phenomena, namely: hailstone, heavy showers, flooding, thunderstorm, draughts, sea storms [4].

Georgia is prone to all types of natural hazards. The risk resulting from geohazards such earthquakes, landslides and meteorological hazards is considerably high; risk from hydrologic hazard as flash-floods also is significant.

The natural hydrometeorological disasters number for 1961-2010 years period is presented in Table1.

Table 1. Natural hydrometeorological events number for 1961-2010 period in Georgia

Period	Floods	Heavy showers >=30mm	Hailstone	Draughts	Strong winds >=30m/sec	Avalanche	Big snow
1961-1970	20	3	6	3	4	6	7
1971-1980	17	16	35	5	8	9	6
1981-1990	25	18	39	1	12	9	8
1991-2000	15	7	6	7	5	18	5
2001-2010	32	52	44	5	20	25	9

The natural disasters in Georgia have to be considered as the standing negative factor for the sustainable development of the state. The importance of aroused problems from abovesaid hazards stimulates the active investigation of reasons and physical processes involved in.

Since *NASA* launched Earth Observing System (*EOS*) program coordinated series of polar-orbiting and low inclination satellites for long-term global observations of the land surface, biosphere, solid Earth, atmosphere, and oceans []. *EOS* enables the improved understanding of the Earth as an integrated system. Considering large amount of information from satellites it became possible to revised atmosphere processes suggesting new approaches and hypothesis.

The aim is to investigate possible effect of magnetospheric storms on the evolution character of meteorological processes in the atmosphere, to study the correlation between magnetospheric disturbances and meteorological background variations. The Sun, together with the Earth's motion along its orbit, govern changes in the solar–terrestrial environment on time scales ranging from minutes to glacial cycles. Changes in Earth's climate have been the focal point of recent research in the solar–terrestrial physics (STP), and a special emphasis has been placed on the coupling between the troposphere (below 10–15 km altitude), middle atmosphere (10–100 km altitude), and near- Earth Geo-space (mesosphere, thermosphere, ionosphere, and magnetosphere), and solar activity.

The Kp index is probably the most widely used of all magnetic indices. It is intended to express the degree of "geomagnetic activity," or disturbance for the whole Earth, for intervals of three hours in Universal Time [5,6].

Time sequences of circulation patterns and parameters of solar activity are also subject of investigations. Intrusions into Atlantic and Europe were observed nearby geomagnetic-disturbance days. It was found that increasing of geomagnetic activity lead to the change of meridional flow into the zonal one of the atmospheric circulation in the mid-latitudes on the Northern Hemisphere (Bucha, 1988, 1991). It was also depicted that short-term and long-term changes in solar activity, the geomagnetic field and weather demonstrate very similar quasi-periodic variations

Total Electron Content (or TEC) is an important descriptive quantity for the ionosphere of the Earth. TEC is the total number of free electrons integrated between two points, along a tube of one meter squared cross section, i.e., the electron columnar number density. Affected by solar activity, Total Electron Content (TEC) describes the total number of free electrons present within one square meter between two points (i.e. between the receiver and satellite involved in measuring TEC). These maps are also used to monitor ionospheric weather, and to nowcast ionospheric storms that often occur responding to activities in solar wind and Earth's magnetosphere as well as thermosphere. The TEC in the ionosphere is modified by changing solar Extreme Ultra-Violet radiation, geomagnetic storms, and the atmospheric waves that propagate up from the lower atmosphere. The TEC will therefore depend on local time, latitude, longitude, season, geomagnetic conditions, solar cycle and activity, and troposphere conditions. TEC consideration in precipitation formation may be important.

To establish influence of geomagnetic activity on the formation of weather pattern geomagnetic indices achieve [6,8] and meteorological observation database for 2014-18 have been analyzed. The 4 location were chosen namely: Tbilisi- (Kartli Region), Batumi- Adjara Region, Telavi-Kakheti Region and last one in high mountain zone-Mta-Sabueti. The results showed that always weather pattern change: increase wind velocity; temperature change (decrease); precipitation amount increase follows geomagnetic activity. Here Tbilisi data is used.

3. Results and discussion

To identify connection between geomagnetic activity and meteorological processes 2014-17 period precipitation, wind, temperature observation data and geomagnetic indices daily data (http://SunSpotWatch.com) have been studied for Georgian conditions. Below presented charts show the correlation between meteorological parameters with geo-magnetic activity expressed in indices.

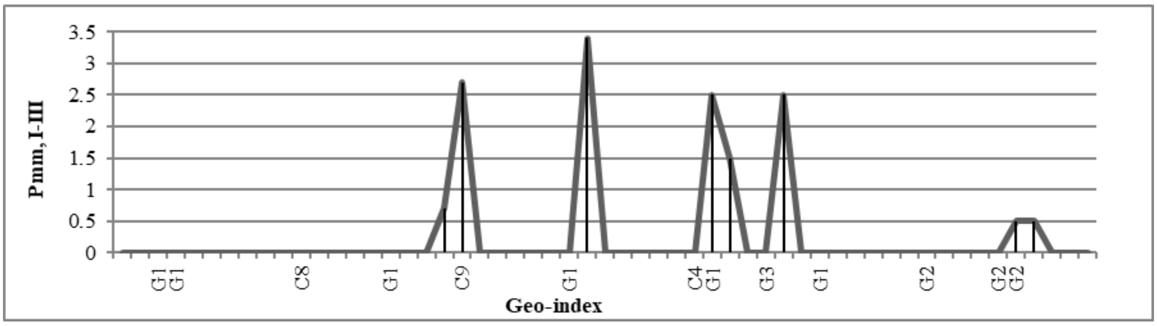

Fig.1a

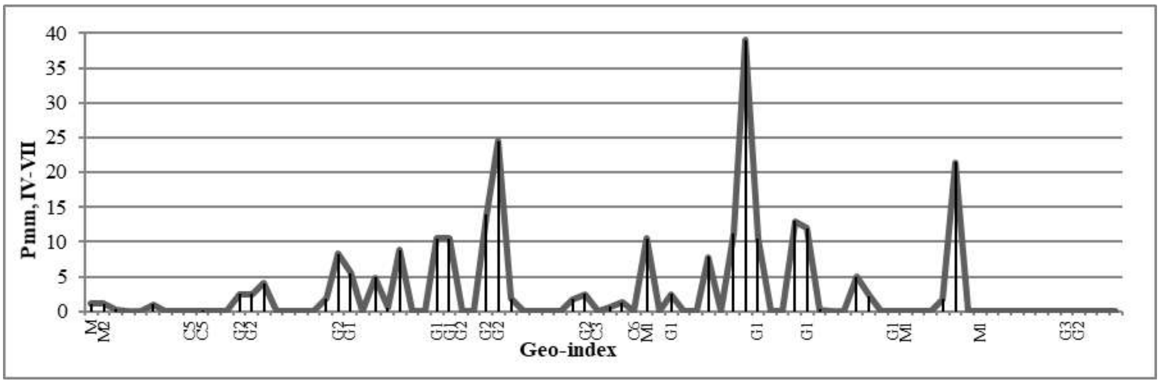

Fig.1 b

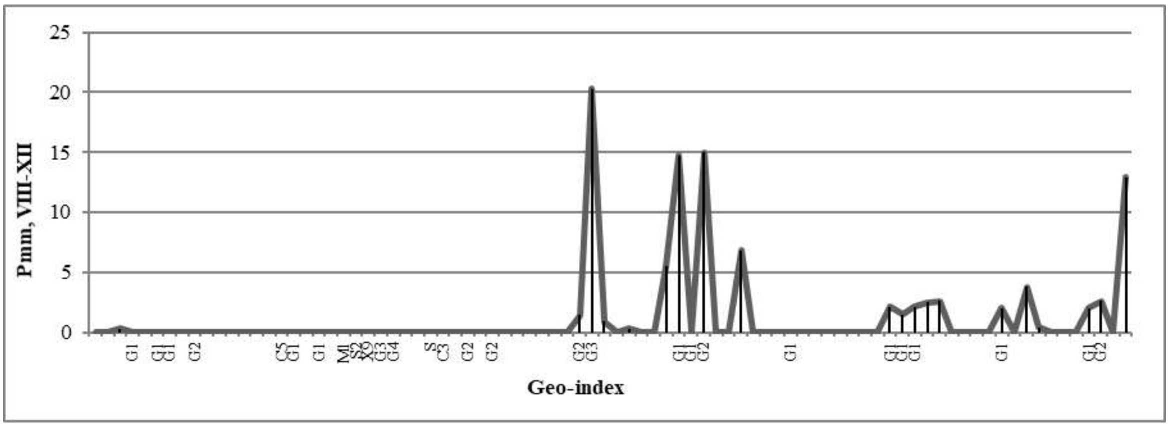

Fig.1 c

Fig.1 (a,b,c). Precipitation and geo-index correlation for Tbilisi point in 2017.

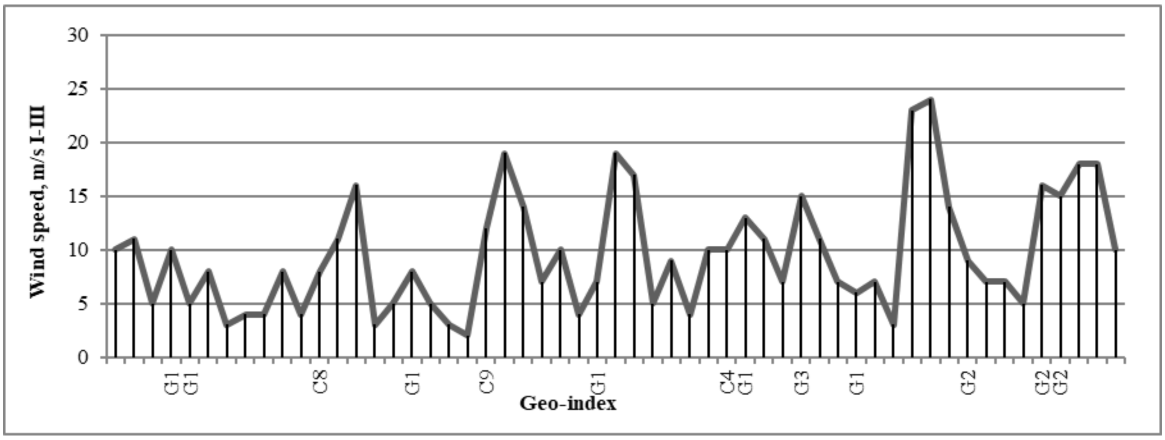

Fig.2. Wind speed and geo-index correlation for Tbilisi point in 2017 (I-III).

The analysis has been conducted for current, pre and aftershock 3 and 5 days. For meteorological parameters current day is crucial and 3-5 day time lapse is reliable for circulation processes. It is ascertained that during all magnetic storms south-west or south-east wave processes have been formed and strong storms create high pressure areas. Depending on the synoptic situation wave processes leads the formation of thunderstorm and heavy showers. In addition, through geomagnetic storms the direction of circulation processes may drastically be changed

The Vere River tragedy in 13 June, 2015 is clear evidence of how meteorological disaster triggered geo-hazard. On this day, flash-flood on Vere River flooded part of Tbilisi city, destroyed buildings, infrastructure, Zoo, many Zoo habitats and 18 humans were dead. After analyzing satellite data and synoptical situation it became clear what happened. During several days from 9 to 14 June 2 MEV high energy electrons penetrate atmosphere [7,8]. The abundant amounts of electrons create stable clusters in lower atmosphere resisting precipitation in fall. After they became so massive that couldn't resist gravitation the great amount of rain water has been fallen out from clouds, causing flooding [9,10].

It is not fully clear the physical mechanism of this correlation and the issue needs further investigation applying quantum filed theory that is more suitable for description of photon-photon or photon-charged particle interaction as during geomagnetic activity great amount of charged particles and photons penetrate atmosphere.

The most of water properties are preconditioned by the fact that three component atoms aren't placed on one line. Negative charge prevailed on oxygen atoms part and positive on hydrogen. Thus water molecule is electrically polarized. Among atoms and molecules acts force that always has attractive character. It is intermolecular dispersive or Van-Deer-Vaalse force. It is only one of the expressions of electromagnetic force. It acts among electrically neutral systems such as dipole or quadruple. In dipoles force reduces by r^4 inverse proportional and in quadruple by r^{-6}. It is not temperature dependent and its nature is quantum. By increasing dipole number their interaction increases [12].

4. Conclusion

From analyzing of historical records of meteorological observations and geomagnetic activity this correlation became more obvious. Many dangerous hydrometeorological event (flood, landslide) occurred over Georgian territory has driven by this activity, as the result of intensification of precipitation amount. Even hail processes intensification are the result of increasing atmosphere electricity and thunderstorm activity, that are produced by high energy charged particles intrusion into upper atmosphere [11].

These kinds of studies are essential in understanding of Earth magnetism and the Sun-Earth environment. It may be assumed that for weather forecasting the only existed numerical weather models aren't sufficient and they have to be enhanced by magnetic models to make forecasting more precise.

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მოკლევადიანი გეომაგნიტური აქტივობის გავლენა ამინდისა და კლიმატის ფორმირებაზე საქართველოს რეგიონში

მ. ტატიშვილი, ა. ფალავანდიშვილი

რეზიუმე

სტატიაში წარმოდგენილია ძლიერი მაგნიტოსფეროს ქარიშხლების შესაძლო გავლენის კვლევა ატმოსფეროში მეტეოროლოგიური პროცესების ევოლუციაზე, მაგნიტოსფეროს შეშფოთებებსა და მეტეოროლოგიურ ვარიაციებს შორის კორელაციის გამოსავლენად. კვლევა მნიშვნელოვანია

იმის გამო, რომ საქართველოში ხშირია საშიში მეტეოროლოგიური მოვლენები და განსაკუთრებით მნიშვნელოვანია მათ გამომწვევი ფიზიკური პროცესების შესწავლა.
მეტეოროლოგიური ეფექტები, რომლებიც გამოწვეულია მზის ქარის ვარიაციებით, ცუდად არის წარმოდგენილი ამინდისა და კლიმატის მოდელებში. გეომაგნიტური ქარიშხალი არის დედამიწის მაგნიტოსფეროს იძულებითი გარღვევა, მზის ქარიდან ენერგიის გაცვლა დედამიწის გარშემო არსებულ გეო-გარემოში. ეს ქარიშხლები წარმოიქმნება მზის ქარის ცვლილებების შედეგად, რაც იწვევს დედამიწის მაგნიტოსფეროში მიმდინარე დინებების, პლაზმისა და ველების მნიშვნელოვან ცვლილებებს.
გეომაგნიტური ინდექსები არის გეომაგნიტური აქტივობის საზომი, რომელიც ხდება დროის მოკლე მონაკვეთში. ისინი შეიქმნა დედამიწის იონოსფეროსა და მაგნიტოსფეროს რეაქციის შესასწავლად მზის აქტივობის ცვლილებებზე. გეომაგნიტურ შტორმებსა და მეტეოროლოგიურ ელემენტებს შორის კორელაცია ჩატარდა საქართველოს რეგიონისთვის მეტეოროლოგიური დაკვირვების მონაცემებისა და NASA–ს მზის დინამიკის ობსერვატორიისა (Solar Dynamics Observatory) და NOAA– ს კოსმოსური ამინდის პროგნოზირების ცენტრის მონაცემების გამოყენებით. შედეგები აჩვენებს, რომ არსებობს კავშირი ამინდის პარამეტრებსა და გეომაგნიტურ შეშფოთებებს შორის.

Влияние кратковременной геомагнитной активности на погоду и климатообразование в Грузинском регионе

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Резюме

Представлено исследование возможного влияния мощных магнитосферных бурь на характер эволюции метеорологических процессов в атмосфере с целью выявления корреляции между магнитосферными возмущениями и метеорологическими вариациями. Исследование обусловлено тем фактом, что Грузия подвержена опасным метеорологическим явлениям и особенно актуально исследовать вызывающие их физические процессы.
Метеорологические эффекты, возникающие в результате колебаний солнечного ветра, плохо представлены в моделях погоды и климата. Геомагнитная буря - это сильное нарушение магнитосферы Земли, обменивающееся энергией солнечного ветра с космической средой, окружающей Землю. Эти бури возникают в результате изменений солнечного ветра, которые вызывают серьезные изменения токов, плазмы и полей в магнитосфере Земли.
Геомагнитные индексы являются мерой геомагнитной активности, происходящей за короткие периоды времени. Они были созданы для изучения реакции ионосферы и магнитосферы Земли на изменения солнечной активности. Корреляция между геомагнитными бурями и метеорологическими элементами (температура, осадки, ветер) была проведена для региона Грузии с использованием данных метеорологических наблюдений и данных обсерватории солнечной динамики (Solar Dynamics Observatory) NASA и Центра прогнозирования космической погоды NOAA. Результаты показывают, что существует зависимость между погодными параметрами и геомагнитными возмущениями.

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On the Relationship of Annual Variations of the Intensity of Galactic Cosmic Rays with the Variability of Total Cloudiness, Atmospheric Precipitation and Air Temperature in Tbilisi in 1966-2015

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ABSTRACT

The paper considers the results of the study of the connection between annual variations of intensity of galactic cosmic rays and the changeability of the total cloudiness, atmospheric precipitation and air temperature in 1966-2015 in Tbilisi. The statistical characteristics of the indicated parameters (trends, random component, linear correlations between real and random components, etc.) are studied. In particular, it was found that, within the variation range, the contribution of the studied parameters to atmospheric precipitation variability is as follows: total cloudiness - 17.1%, real values and random components of cosmic ray intensity - 37.8% and 28.0%, respectively.

Key Words: *Climate change, galactic cosmic rays, cloudiness, atmospheric precipitation, air temperature, statistical analysis.*

Introduction

In Georgia, as elsewhere in the world, in recent decades, special attention has been paid to research on modern climate change. Spatial-temporary variations of the fields of air temperature and precipitations [1-5], cloudiness [6-8], solar radiation [9], air pollution [9,10] and other climate-forming parameters were studied. With the use of different statistical models the estimations of the expected changes of air temperature and atmospheric precipitations for the next decades for some regions of Georgia, including Tbilisi city, were carried out [11-16].

Cosmic radiation is one of the factors, which influence on climate change [17-21]. The possible mechanisms of this influence can be found in the works [9,17,18].

In Georgia studies of the climatic effects on cosmic rays also began recently. In particular, in the works [10,20,21] the effects of cosmic radiation on the formation in the atmosphere of the secondary aerosols, which have an effect on cloudiness, are studied. In the works [22,23] the inter-annual distributions of cloudless days and cloudless nights in Abastumani Astrophysical Observatory, at various helio-geophysical conditions, and their coupling with cosmic factors were studied. In the work [24], a study of the relationship between the annual variations in the intensity of galactic cosmic rays and the variability of cloudiness and air temperature in Tbilisi was carried out according to the data of 1963-1990.

This work is the continuation of the investigation [24]. Results of a study of the relationship between the annual variation in the intensity of galactic cosmic rays with the variability of total cloudiness, atmospheric precipitation and air temperature in Tbilisi in 1966-2015 are presented below.

Material and methods

The data of the National Environmental Agency of Georgia about the mean annual values of total cloudiness (G), annual sum of atmospheric precipitation and (P) and air temperature (T) in Tbilisi are used. Information about annual values of intensity of neutron component of galactic cosmic rays (CR) is obtained at the Cosmic Rays Observatory of M. Nodia institute of geophysics. The period of observation is 1966 - 2015.

In the proposed work, as in [24], the analysis of data is carried out with the use of the standard statistical analysis methods of random events and methods of mathematical statistics for the non accidental time-series of observations [25, 26].

The following designations will be used below: Min – minimal values, Max - maximal values, Range - variational scope, St Dev - standard deviation, Cv, % – coefficient of variation (Cv = 100·St Dev/Average), R - coefficient of linear correlation, R^2 – coefficient of determination, K_{DW} – Durbin-Watson Statistic, Rand – random component, α - the level of significance, Real - measured data. The curve of trend is equation of the regression of the connection of the investigated parameter with the time at the significant value of the coefficient of determination and such values of K_{DW}, with which the residual values are accidental.

A background component usually enters into the curve of trend. The value of background component is most frequently unknown. From the physical aspect, random component can be represented in the form: Rand = Res + absolute value of the min value of Res. In this case random components have positive values with the minimum value = 0 (if the value of background component is known, the min Rand will be = Back). Accordingly, Trend+Back (sum of the trend and background components of time series) will be a curve of equation of the regression of the connection of the investigated parameter and the time minus absolute value of the min value of Res. So, Real = (Trend+Back) + Rand.

Results and discussion

The results are given in tables 1-6 and fig. 1-4.

Table 1. Characteristics of trend of G, P, T and CR in Tbilisi in 1966-2015.

Variable	Form of the equation of regression	R^2 (with year)	K_{DW}
G	Third power polynomial	0.34 (α =0.001)	1.92 (α =0.05)
P	Third power polynomial	0.10 (α =0.02)	2.00 (α =0.05)
T	Linear	0.21 (α =0.003)	1.81 (α =0.05)
CR	Tenth power polynomial	0.73 (α =0.0001)	0.96 (α <0.01)

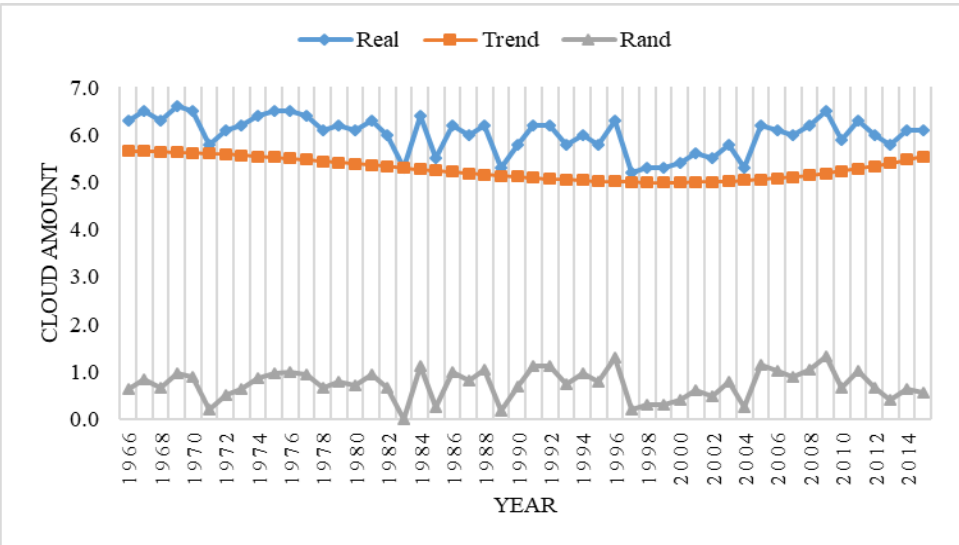

Fig. 1. Trend of the total average annual cloudiness in Tbilisi in 1966-2015.

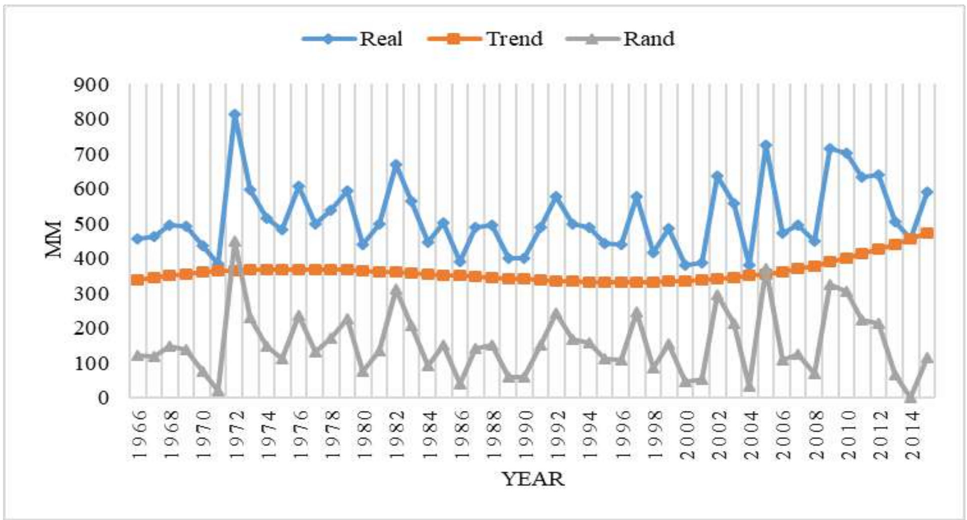

Fig. 2. Trend of the annual sum of atmospheric precipitation in Tbilisi in 1966-2015.

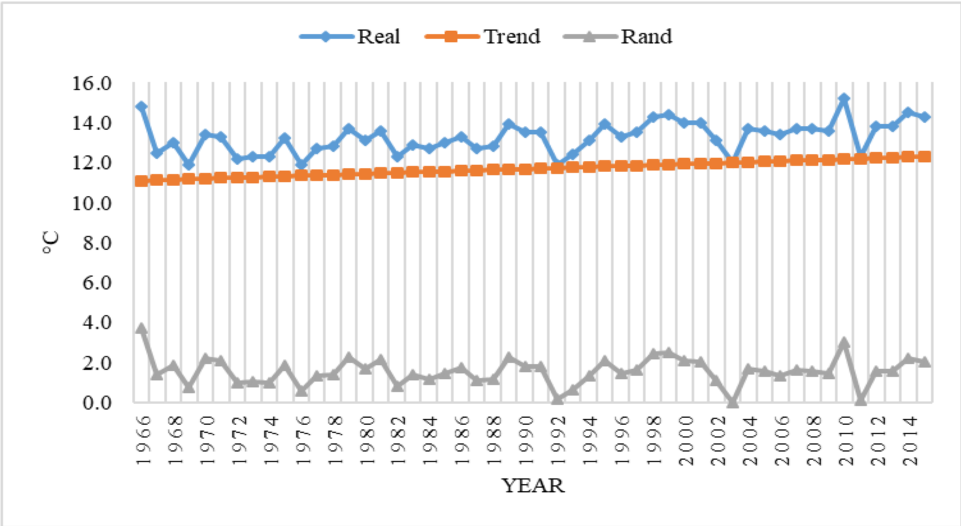

Fig. 3. Trend of the average annual air temperature in Tbilisi in 1966-2015.

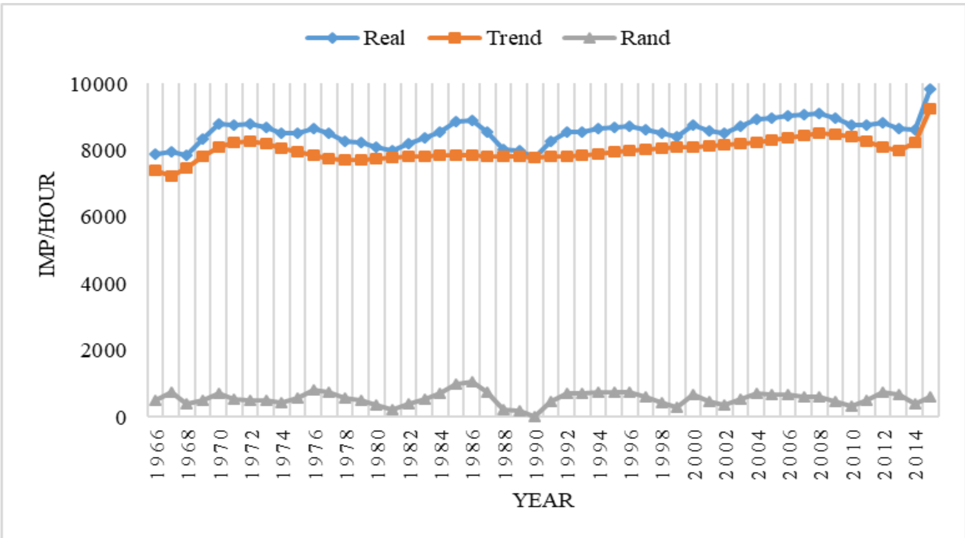

Fig. 4. Trend of the average annual intensity of galactic cosmic rays in Tbilisi in 1966-2015.

According to Table 1 and Fig. 1-4, trends of G and P takes the form of third power polynomial, trend of T is linear and trend of CR take the form of tenth power polynomial.

Table 2 shows the statistical characteristics of real data of G, P, T and CR in Tbilisi.

Table 2. The statistical characteristics of real data of G, P, T and CR in Tbilisi in 1966-2015.

Variable	G, cloud amount	P, mm	T, °C	CR, imp/hour
Max	6.6	813	15.2	9853
Min	5.2	379	11.9	7803
Range	1.4	434	3.3	2050
Average	6.0	516	13.3	8568
St Dev	0.39	100	0.78	382
Cv,%	6.4	19.3	5.9	4.5
Correlation Matrix				
	G	P	T	CR
G	1	0.19 (α=0.20)	-0.36 (α=0.01)	-0.04 (not sign)
P	0.19 (α=0.20)	1	-0.23 (α=0.10)	0.21 (α=0.15)
T	-0.36 (α=0.01)	-0.23 (α=0.10)	1	0.14 (α=0.25)
CR	-0.04 (not sign)	0.21 (α=0.15)	0.14 (α=0.25)	1

According to Table 2, the values of G vary from 6.6 to 5.2 (average = 6.0), values of P – from 813 to 379 (average = 516), values of T – from 15.2 to 11.9 (average = 13.3) and CR - from 9853 to 7803 (average = 8568).

The significant linear correlation between the following investigated parameters is observed: G with P (positive), T (negative); P with T (negative), CR (positive); T with CR (weak positive).

In Table 3 the statistical characteristics of the random components of G, P, T and CR in Tbilisi are presented.

Table 3. The statistical characteristics of random components of G, P, T and CR in Tbilisi in 1966-2015.

Variable	G, cloud amount	P, mm	T, °C	CR, imp/hour
Max	1.3	448	3.7	1063
Average	0.7	154	1.6	558
St Dev	0.3	94	0.7	200
Cv,%	56.6	34.4	42.2	52.5
Correlation Matrix				
	G	P	T	CR
G	1	0.14 (α=0.25)	-0.31 (α=0.03)	0.18 (α=0.20)
P	0.14 (α=0.25)	1	-0.35 (α=0.01)	-0.05 (not sign)
T	-0.31 (α=0.03)	-0.35 (α=0.01)	1	-0.23 (α=0.10)
CR	0.18 (α=0.20)	-0.05 (not sign)	-0.23 (α=0.10)	1

According to Table 3, max and average values of random components of investigation parameters are respectively equal: G - 1.3 and 0.7, P - 448 and 154, T – 3.7 and 1.6, CR – 1063 and 558.

The significant linear correlation between the following investigated parameters is observed (table 3): G with P (weak positive), T (negative) and CR (positive); P with T (negative); T with CR (negative).

Shares of the average values of random components in the average values of the real values of the studied parameters (fig. 1-4, table 2 and 3) constitute: for G – 12.3%, for P – 29.9 %, for T – 11.8 % and for CR – 6.5 %.

The equation of the multiple linear regression of the connection of air temperature and G_{rand}, P_{rand}, and CR_{rand} is represented below:

$$\mathbf{T = -0.52637 \cdot G_{rand} - 0.00244 \cdot P_{rand} - 0.00073 \cdot CR_{rand} + 14.43} \qquad (R^2 = 0.19,\ \alpha = 0.005)$$

Table 4 shows the data about contribution of variations in the values of G_{rand}, P_{rand}, and CR_{rand} to the changeability of T.

Table 4. Contribution of variations in the values of G_{rand}, P_{rand}, and CR_{rand} to the changeability of T.

Variable	In the limits of Range (%)	In the limits of St Dev (%)
G_{rand}	5.2	2.4
P_{rand}	8.2	3.5
CR_{rand}	5.9	2.2

According to Table 4, within the variation range, the contribution of the studied parameters to air temperature variability is as follows: random components of total cloudiness - 5.2%, random components of atmospheric precipitation – 8.2%, random components of cosmic ray intensity - 5.9%.

The equation of the multiple linear regression of the connection of total cloudiness and CR and CR_{rand} has the following form:

$$\mathbf{G = -0.00016 \cdot CR + 0.00042 \cdot CR_{rand} + 7.11} \qquad (R^2 = 0.036,\ \alpha = 0.2)$$

Table 5 shows the data about contribution of variations in the values of CR, and CR_{rand} to the changeability of G.

Table 5. Contribution of variations in the values of CR, and CR_{rand} to the changeability of G.

Variable	In the limits of Range (%)	In the limits of St Dev (%)
CR	5.3	2.0
CR_{rand}	7.4	2.8

According to Table 5, within the variation range, the contribution of the studied parameters to total cloudiness variability is as follows: cosmic ray intensity – 5.3%, random components of cosmic ray intensity - 7.4%.

The equation of the multiple linear regression of the connection of precipitation and G, CR and CR_{rand} is represented below:

$$\mathbf{P = 62.95 \cdot G + 0.095057 \cdot CR - 0.13584 \cdot CR_{rand} - 601.32} \qquad (R^2 = 0.137,\ \alpha = 0.01)$$

Table 6 shows the data about contribution of variations in the values of G, CR, and CR_{rand} to the changeability of P.

Table 6. Contribution of variations in the values of G, CR, and CR_{rand} to the changeability of P.

Variable	In the limits of Range (%)	In the limits of St Dev (%)
G	17.1	9.4
CR	37.8	14.1
CR_{rand}	28.0	10.5

According to Table 6, within the variation range, the contribution of the studied parameters to precipitation variability is as follows: total cloudiness - 17.1%, cosmic ray intensity – 37.8%, random components of cosmic ray intensity - 28.0%.

Conclusion

In the future, to compare the results obtained, similar works will be carried out for other locations of Georgia.

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გალაქტიკური კოსმოსური სხივების ინტენსივობის წლიური ვარიაციების კავშირის შესახებ საერთო ღრუბლიანობის, ატმოსფერული ნალექების და ჰაერის ტემპერატურის ცვალებადობასთან თბილისში 1966-2015 წლებში

ა.ამირანაშვილი, თ. ბაქრაძე, ტ. ერქომაიშვილი, ნ. ღლონტი, ი. ტუსკია

რეზიუმე

წარმოდგენილია გალაქტიკური კოსმოსური სხივების ინტენსივობის წლიური ვარიაციების საერთო ღრულიანობის, ატმოსფერული ნალექების და ჰაერის ტემპერატურის ცვალებადობასთან კავშირების კვლევის შედეგები თბილისში 1966-2015 წლებში. შესწავლილია აღნიშნული პარამეტრების სტატისტიკური მახასიათებლები (ტრენდები, შემთხვევითი მდგენელები, კორელაციური კავშირები რეალურ მონაცემებსა და შემთხვევით მდგენელებს შორის და სხვა). კერძოდ მიღებულია, რომ ვარიაციული განშლადობის ფარგლებში გამოსაკვლევი პარამეტრების წვლილი ატმოსფერული ნალექების ცვალებადობაში შემდეგია: საერთო ღრუბლიანობის რეალური მონაცემებისა – 17.1%, კოსმოსური სხივების ინტენსივობის რეალური მნიშვნელობებისა და შემთხვევითი კომპონენტებისა –37.8% და 28.0% შესაბამისად.

О связи годовых вариации интенсивности галактических космических лучей с изменчивостью общей облачности, атмосферных осадков и температуры воздуха в Тбилиси в 1966-2015 гг.

**А.Г. Амиранашвили, Т.С. Бакрадзе, Т.Г. Эркомаишвили,
Н.Я. Глонти, И.И. Тускиия**

Резюме

Представлены результаты исследования связи годовых вариаций интенсивности галактических космических лучей с изменчивостью облачности, атмосферных осадков и температуры воздуха в Тбилиси в 1966-2015 гг. Изучены статистические характеристики указанных параметров (тренды, случайные составляющие, корреляционные связи между реальными данными и случайными компонентами и др.). В частности, получено, что в пределах вариационного размаха вклад исследуемых параметров в изменчивость атмосферных осадков следующий: реальных значений общей облачности – 17.1 %, реальных значений и случайных компонент интенсивности космических лучей – 37.8 % и 28.0 % соответственно.

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Chronicle

YIIth International Scientific Conference „Modern Problems of Ecology"

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ABSTRACT

Information about the 7th international scientific conference "Modern Problems of Ecology", which was conducted from a distance by TSU, Mikheil Nodia Institute of Geophysics on September 26-28, 2020 is presented.
The conference was dedicated to the 180th anniversary of the birthday of Akaki Tsereteli.

Key words: *Ecology, natural disasters.*

Introduction

September 26-28, 2020 at TSU, Mikheil Nodia Institute of Geophysics from a distance was held an 7th international scientific conference "Modern Problems of Ecology".

The conference was dedicated to the 180th anniversary of the birthday of Akaki Tsereteli.

Conference Organizers

Academy of Ecological Sciences of Georgia, Georgian Apostolic Autocephalous Orthodox Church, Georgian National Academy of Sciences, Ivane Javakhishvili Tbilisi State University, Mikheil Nodia Institute of Geophysics TSU, Iakob Gogebashvili Telavi State University, Akaki Tsereteli State University.

Honorable Chairmen of the Conference: Metropolitan of Kutaisi-Gaenati Eparchy of Apostolic Orthodox Church of Georgia, President of Gelati Academy of Science **Reverend Ioane**; Head of the Department of Science and Development of the Ministry of Education, Science, Sport and Culture of Georgia, Academic Doctor of Humanities **Maia Shukhoshvili**; First Academician-Secretary of the Georgian National Academy of Sciences, Academician **Ramaz Khurodze**; President of the Academy of Ecological Sciences of Georgia, Academician **Marat Tsitskishvili**; Vice-president of Abkhazian Academy of Sciences, Rector of Akaki Tsereteli State University Academician **Roland Kopaliani.**
Chairman of the Conference: Vice-president of the Academy of Ecological Sciences of Georgia, Chairman of the Western Part of the Academy, emeritus-professor of the Akaki Tsereteli State University **- Teimuraz Adeishvili.**
Vice - Chairmans of the Conference: Professor **Avtandil Amiranashvili**, Mikheil Nodia Institute of Geophysics of Ivane Javakhishvili Tbilisi State University, Head of the Atmospheric Physics Department**;** Professor **Merab Khalvashi,** Rector of Batumi Shota Rustaveli State University; Professor **Elizbar Elizbarashvili,** Iakob Gogebashvili Telavi State University.
Scientific Secretary of the Conference: Associate Professor of Iakob Gogebashvili Telavi State University, Doctor of Geography, **Nana Berdzenishvili.**

Members of the organizing committee and editorial - publishing board:

Metropolitan of Kutaisi-Gaenati Eparchy of Apostolic Orthodox Church of Georgia, President of Gelati Academy of Science Reverend Ioane; Academician Tamaz Chelidze; Academician Ramaz Khurodze; Professor Marat Tsitskishvili; Professor Alexander Alexandrov (Bulgaria); Professor Teimuraz Adeishvili; Professor Roland Kopaliani; Professor Natela Tsiklashvili; Professor Avtandil Amiranashvili; Professor Elizbar Elizbarashvili, Professor Irma Shioshvili; Professor Magda Davitashvili; Professor Tamar Nadiradze; Professor Otar Kvaratskhelia; Associate Professor Nana Berdzenishvili; Associate Professor Magdana Jiqia; Associate Professor Malkhaz Mikaberidze; Doctor of the Academic degree in Physics Leonardo Khvedelidze; Associate Professor Nana Julakidze; Associate Professor Darejan Chkhirodze; Academic Doctor of Physics Nugzar Glonti; Associate Professor Tengiz Zhvitiashvili; Associate Professor Nunu Chachkhiani; Associate Professor Soso Tavberidze.

Conference Themes

- Introduction: this section discussed general environmental issues, including the state of environmental research in Georgia – 6 reports;
- Ecology of Landscape and Environmental Protection: 20 reports (3 – with participation of TSU, M. Nodia Institute of Geophysics [1-3]);
- Special Session Dedicated to the 100th Anniversary of the Birth of A.I. Kartsivadze and the 5th Anniversary of the Resumption of Work on Weather Modification in Georgia: 13 reports with participation of TSU, M. Nodia Institute of Geophysics [4-16];
- Physical-chemical and Cosmic Ecology: 16 reports (6 - with participation of TSU, M. Nodia Institute of Geophysics [17-22])
- Biomedical Ecology: 13 reports (3 - with participation of TSU, M. Nodia Institute of Geophysics [23-25]);
- Ecology of the Spiritual World: 8 reports;
- Tourism and Ecology: 4 reports (1 - with participation of TSU, M. Nodia Institute of Geophysics [26])
- Personals: 4 reports.

Because of COVID-19 pandemic all of 80 oral presentations were considered at the conference from a distance. The proceedings of this conference as a whole [27], as well as its individual works, are published and posted on the portal of the Institute of Geophysics, wich are included in the international electronic library data base ***DSpace,*** indexed in ***Google Scholar*** and ***Publish or Perish***.

At the end of the conference, a decision was made in which the achievements and shortcomings of the work in the field of ecology in Georgia were examined. In particular, it was decided to hold the next conference in 2022.

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YII - დე საერთაშორისო სამეცნიერო კონფერენცია „ეკოლოგიის თანამედროვე პრობლემები“

ნ. ღლონტი

რეზიუმე

წარმოდგენილია ინფორმაცია 7-დე საერთაშორისო სამეცნიერო კონფერენციაზე „ეკოლოგიის თანამედროვე პრობლემები“, რომელიც დისტანციურად ჩაატარა ივანე ჯავახიშვილის სახელობის თბილისის სახელმწიფო უნივერსიტეტის მიხეილ ნოდიას სახელობის გეოფიზიკის ინსტიტუტმა 2020 წ. 26–28 სექტემბერს.
კონფერენცია მიეძღვნა აკაკი წერეთლის დაბადების 180 წლისთავს.

YII–я международная научная конференция “Современные проблемы экологии“

Н.Я. Глонти

Резюме

Представлена информация о 7-ой международной научной конференции “Современные проблемы экологии“, которую прошла 26-28 сентября 2020 года дистанционно провел Институт Геофизики им. Михаила Нодиа Тбилисского государственного университете имени Иванэ Джавахишвили.
Конференция была посвящена 180-летию со дня рождения Акакия Церетели.

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To the Memories of Anzor Gvelesiani (1937-2020)

Anzor Iosif Gvelesiani was born on August 12, 1937 in Tbilisi.

In 1960 he graduated from Tbilisi State University with a degree in theoretical physics; in 1970 in Leningrad he defended his dissertation for the degree of candidate of physical and mathematical sciences; in 1980 - his doctoral dissertation in Tbilisi.

He worked at the Institute of Geophysics from 1961 until the end of his life (as a junior researcher, senior researcher, head of department, chief researcher).

Research interests: physics of clouds and atmosphere, ionosphere and magnetosphere, phase transitions in geophysical media.

Anzor Gvelesiani had several dozen scientific publications, including three monographs. Several Ph.D theses were defended under his scientific supervision.

On many years he was the Vice-Editor of Journal of the Georgian Geophysical Society, a member of the editorial board of the Transactions of Mikheil Nodia Institute of Geophysics.

He adored his work, in his field he was a specialist of the highest level, was always modest and responsive to colleagues, communicative, possessed inexhaustible optimism.

He was awarded the Order of Honor in 2013.

In addition to his main specialty, he loved art, ballet, poetry. He was a member of the Byron and Vakhtang Chabukiani societies. He often published popular works on ballet and poetry.

Anzor Gvelesiani died on December 12, 2020.

The memory of Anzor Gvelesiani will forever remain in our hearts.

Group of colleagues of Mikheil Nodia Institute of Geophysics of Ivane Javakhishvili Tbilisi State University

Information for contributors

Papers intended for the Journal should be submitted in two copies to the Editor-in-Chief. Papers from countries that have a member on the Editorial Board should normally be submitted through that member. The address will be found on the inside front cover.

1. Papers should be written in the concise form. Occasionally long papers, particularly those of a review nature (not exceeding 16 printed pages), will be accepted. Short reports should be written in the most concise form not exceeding 6 printed pages. It is desirable to submit a copy of paper on a diskette.
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    The text should be divided into sections, each with a separate heading or numbered consecutively.
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საქართველოს გეოფიზიკური საზოგადოების ჟურნალი

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