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Some Results of the Joint Research of the M. Nodia Institute of Geophysics, TSU and Institute of Hydrometeorology, GTU from 2019 to 2023 and Prospects for their Further Development

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ABSTRACT

A brief information on joint research of the M. Nodia Institute of Geophysics, TSU and the Institute of Hydrometeorology, GTU, conducted in 2019–2023 and the prospects for their further development are presented.
Key words: *Hydrometeorology, climate, experimental modeling of atmospheric processes, bioclimate, ecology.*

Introduction

Over the past decades, the institutes of geophysics and hydrometeorology have conducted and are conducting important joint research on a wide range of atmospheric physics issues, in particular such as natural radioactive tracers in the atmosphere; air pollution; atmospheric electricity, thunderstorm-hail processes; climate change in Georgia; assessment of bioclimatic resources of Georgia; assessment of the risk of hydrometeorological disasters; radar meteorology; weather modification, etc. In addition to scientific work, attention was also paid to the popularization of atmospheric research [1].

The results of joint research have been published in both domestic and international journals and collections, and presented at conferences of various levels. Thus, in 2008, at the initiative of the institutes of geophysics and hydrometeorology, a major international conference, “Climate, Natural Resources, and Natural Disasters in the South Caucasus”, was held within the framework of the International Year of Planet Earth [1].

The one of most important results were obtained in large-scale studies of modern climate change in Georgia, which were launched in 1996 jointly with the Vakhushti Bagrationi Institute of Geography and continue to this day. First of all, an inventory of greenhouse gases was conducted in Georgia, spatial and temporal variations in the fields of air temperature, precipitation, cloudiness, aerosol air pollution, equivalent-effective air temperature, surface cover and other climate-forming parameters were studied, and an assessment was made of expected changes in air temperature in Tbilisi for the next few decades and the effects of these changes on human health [2-8]. It is noteworthy that in 2009, a group of leading scientists (K. Tavartkiladze, Institute of Geography; N. Begalishvili, Institute of Hydrometeorology and A. Amiranashvili, Institute of Geophysics) were awarded the Georgian National Prize for a series of works in the field of climate change in Georgia.

The second most important result was achieved in 2015, when, as a result of extensive preparatory work, the anti-hail service, which had ceased to exist in 1989, was restored in Kakheti over the area of approximately 650 thousand hectares [9-12].

The restored anti-hail system includes: contemporary meteorological radar Meteor 735CDP10 of firm Selex ES; central remote-control station with the change personnel; the automated system of the fire control; 85 rocket launching sites; the autonomous automated rocket guns; anti-hail rockets; scientific group; the group of the maintenance of radar and rocket guns. The test probation of system showed the prospect of its further use for dealing with the hail. The physical and economic effectiveness of anti-hail works in 2015 year, in spite of the limited quantity of means of action (rockets), it was not worse than it is earlier in the years with the action. It is significant that if in the past in Kakheti personnel of anti-hail service comprised more than 800 people, at present this work it ensures only 30 people. Subsequently is assumed an increase in the shielded from the hail areas, and also, besides the anti-hail works, the use of radar for monitoring of dangerous hydrometeorological processes in eastern Georgia and adjacent to its territories of Armenia and Azerbaijan [12].

A brief information on joint research of the M. Nodia Institute of Geophysics, TSU and the Institute of Hydrometeorology, GTU, conducted in 2019–2023 is presented below.

Materials and methods

The data of the ground based hydrometeorological network of the National Environment Agency of Georgia, radar Meteor 735CDP10 of firm Selex ES of the anti-hail service in Kakheti and satellite observations of the Earth Observation Mission are used. Various data on environmental pollution were obtained through direct instrumental measurements and the use of chemical analysis.

Data analysis was 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. Numerical modeling methods were used to simulate the spread of impurities in the atmosphere. GIS technologies were used to create the maps.

Results

During 2019-2023, a total of 53 scientific papers were published [13-66], including four monographs [14,35,36,46] and one book [34]. Joint research was conducted in such areas as weather modification [13,21,45], climate change [17,25,30,33,44,46,48,55,56,59], natural disasters [18,23,24,26,41,42,47,49-54,57,65], adverse meteorological phenomena [16,19,20,22,32,43,58,60,64], environmental pollution [34-40], bioclimate [14,15,27-29,31,61-63].

A brief overview of some of the works are presented below.

The works [13,21,45] present an analysis of scientific and practical work on the artificial impact of weather on Georgia in the past and present (fighting against snow, regulating the activity of lightning in clouds, dissipating fog, artificial regulation of precipitation, etc.). The prospects for the further development of these works are discussed [13].

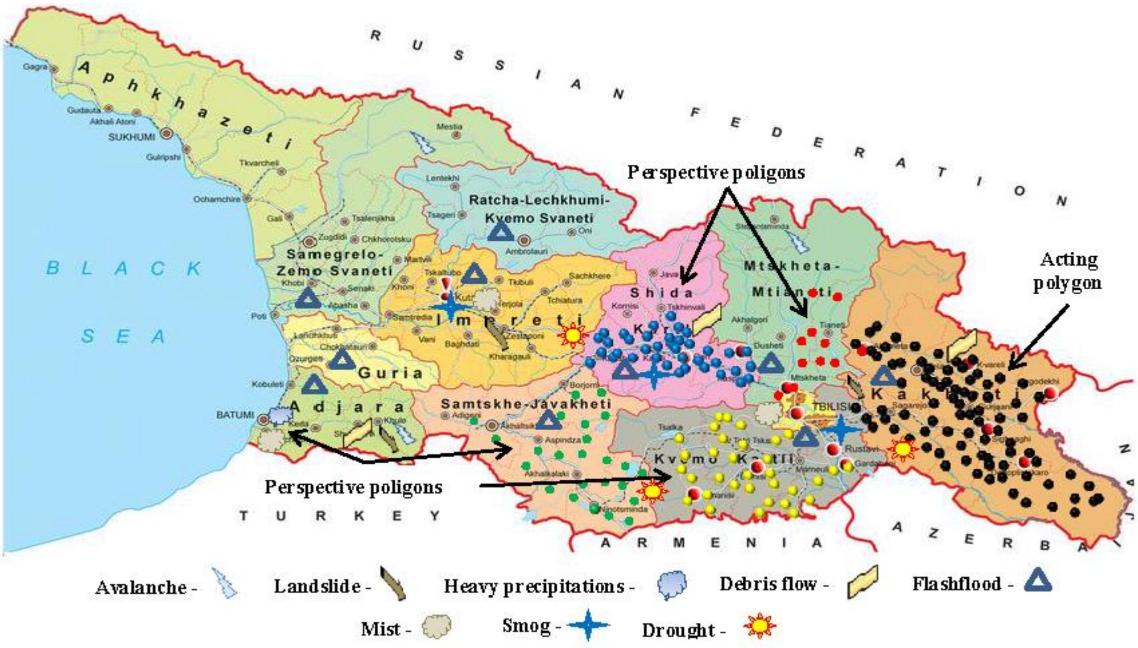


Fig. 1. Scheme for the development of works on weather modification in Georgia and related activities for active and passive prevention of some types natural disasters [13].

The next expansion the works in Georgia on weather modification is planned (Fig. 1).

Acting polygon - Kakheti (black points - rocket launchers). An increase in the number of missile points; installation of an additional radar covering the territory of Kakheti; creation of an expanded network of meteorological stations for ground monitoring of the results of active impacts on hail processes and precipitation, etc.

Planned polygons.

Kvemo Kartli (yellow points - rocket launchers). In this region in the past century was polygon on the territories of municipalities Tetritskaro, etc. In the environments of the territory of municipality Ninotsminda the work on an increase in the atmospheric precipitation was conducted.

Shida Kartli (blue points - rocket launchers). Polygon on the territory of municipalities Gori, etc.

Samtskhe-Javakheti (green points - rocket launchers). Polygon on the territory municipalities Aspindza, Adigeni, Akhalkalaki etc.

Mtskheta-Mtianeti (red points - rocket launchers). Polygon on the territory of municipalities Mtskheta, Tianeti, etc. In the environments of the territory of municipality Tianeti previously the work on an increase in the atmospheric precipitation was conducted.

Territory of the capital of Georgia - Tbilisi. Work on active actions on atmospheric processes with the use of rocket technology for purposes of safety of population here are forbidden. It is possible the use of aircraft technology for the hail suppression and to the atmospheric precipitation regulation. It is also possibly the arrangement of rocket points on the boundaries of city for the action on the hail processes out of its territory.

Ajara. It is planned to organize work to reduce excess rainfall using ground (rocket, aerosol generators, etc.) and aircraft technologies.

To improve the efficiency of weather modification works in Kakheti and their implementation in other regions of Georgia, it is planned to purchase several new meteorological radars. In particular, on the territory of eastern Georgia, it is planned to install 1-3 additional radars, which will be interfaced with the existing radar to Chotori.

Is assumed the expansion of scientific studies on the development of new and the improvement of the existing active and passive methods of the prevention of natural catastrophes (hail, thunderstorm, shower precipitation, flood, the dust storms, fogs, landslides, avalanche, frosts, drought, forest fires, etc.). Renewal of the tests of different existing, improved and newly created ice-forming and hygroscopic reagents, and also other artificial aerosol formations for the active actions on the clouds and the fogs, fight with the frosts, the smog (pollution of atmospheric air), etc. The production of anti-hail rockets with the improved ballistic characteristics is planned (increase in the effective radius of action, etc.).

In particular, in order to increase the efficiency of passive prevention of natural disasters, it is planned to build a regional model for the relationship of radar parameters with the above-mentioned dangerous hydrometeorological phenomena. This will allow for an early (several tens of minutes) warning of the population and relevant authorities about the upcoming dangerous hydrometeorological situation.

Examples of radar monitoring of hail processes, rainfall, and dust formation migration in eastern Georgia and its neighboring countries (Azerbaijan, Armenia) are presented in [12,51]. In the case of relevant interstate agreements, it is possible to organize an international service for short-term warning of the population and emergency structures about the possibility of dangerous meteorological phenomena.

In conclusion, it is noted that in connection with global changes (climate warming, an increase in the number of natural disasters), works on the weather modification is of particular relevance. In the last century, Georgia was one of the flagships of these works. After the restoration of the activities of the anti-hail service in Kakheti, which proved to be effective with minimal maintenance, there appeared prospects for further development of work on weather modification also in other regions of Georgia.

In the foreseeable future, it is planned to elaboration both active and passive methods of natural disasters preventing [13].

A number of works are devoted to the problems of climate change in Georgia (precipitation, cloudiness, wind, air temperature, etc.)[17,25,30,33,44,46,48,55,56,59].

In the monograph [46] the natural factors causing the formation and variability of weather, as well as one of the important problems of modernity, climate change and causing reasons are studied in the complex manner using modern technologies. The data of the ground based hydrometeorological network and satellite observations of the Earth Observation Mission are used. The impact of climate change on the number of sectors of the country's economy (construction industry, tourism, healthcare, education and others) has been evaluated. The monograph has both scientific and practical value. The monograph is intended for specialists working in this field and the wide society. It can be used as the supplementary handbook for students of the Faculty of Natural Sciences of higher education institutions.

Statistical data on meteorological parameters associated with the Holiday Climate Index (mean monthly maximum air temperature, mean monthly relative air humidity, cloud cover, monthly precipitation, wind speed) in thirteen mountainous regions of Georgia (Bakhmaro, Bakuriani, Borjomi, Goderdzi, Gudauri, Khaishi, Khulo, Lentekhi, Mestia, Pasanauri, Shovi, Stepantsminda, Tianeti) from 1956 to 2015 are presented in [30]. In particular, the changeability of the indicated meteorological parameters into 1986÷2015 in comparison with 1956÷1985 for above enumerated points is studied.

The results of a statistical analysis of the monthly, semiannual and annual values of total cloudiness G in Tbilisi in 1956-2015 are represented in [33]. In particular, it was found that in the period from 1986 to 2015 compared to the period 1956-1985 in Tbilisi for all months and periods of the year (with the exception of August and December - no change of G values, and October - increase of cloudiness), there is a decrease of the values of total cloudiness. The linear trends of total cloudiness were studied for the period from 1956 to 2015. It is shown that the largest decrease of G values in 2015 compared to 1956 relative to the average value of total cloud cover in 1956-2015 was observed in June: -20.3%, the smallest - in April: -6.4%.

Predictive estimates of the number of hail days (HD) and their moving averages (for 3, 5, 7, 9 and 11 years – HD_3…HD_11) per warm period of year to 2050 and 2085 an example of Tbilisi was performed in [48]. Forecasting was carried out using the AAA version of the exponential smoothing (ETS) algorithm taking into account the periodicity in the pre-forecast time series. In particular, the following results were obtained. For the time series of the measured number of days with hail and HD_11 years, no pronounced peak in periodicity is observed. For time series HD_3, the periodicity is 14 years, HD_5 – 32 years, HD_7 and HD_9 – 31 years. In the period from 2022 to 2050, the range of variability of the average values of the central points of the forecast for the number of days with hail and the values of their 95% upper level is as follows: HD - from 0.9 to 3.8, HD_3 - from 1.0 to 3.0, HD_11 – from 1.0 to 1.6. In the period from 2022 to 2085, the range of variability of the average values of the central points of the forecast for the number of days with hail and the values of their 95% upper level is as follows: HD_5 - from 0.4 to 3.0, HD_7 - from 0.7 to 1.8, HD_9 - from 0.5 to 3.

The research results of the variability of the mean max annual air temperature at 39 locations in Georgia against the background of global climate change in 1956-2015 are presented in [55]. The statistical characteristics of the mean max annual air temperature in the period 1956-2015 (T), 1956-1985 (T_1) and 1986-2015 (T_2) for each point were studied.

It has been established that in the second period compared to the first, there is a significant increase in the average max air temperature at the 29 stations from 0.3˚C (Stepantsminda) to 1.2˚C (Bakuriani); for Shovi this difference is 1.1˚C. It is shown that between the T_1, T_2 values and the terrain height there has been observed the high inverse linear correlation and regression relationship there. At the same time, the lines of the regression equations are parallel with the increasing in the second period compared to the first by 0.6 ˚C.

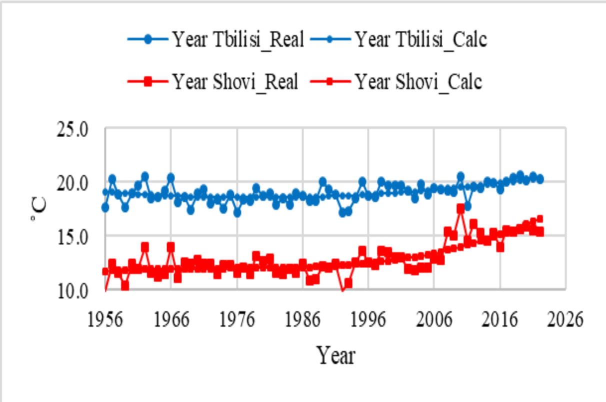
It is shown, that a significant value of $(T_2 - T_1)/T$ changes from 2.0 % (Chokhatauri) to 11.0% (Bakuriani); for Shovi this indicator is 8.4 %. The significant value $(T_2 - T_1)/T$ increases with terrain height in accordance with a second power polynomial

Some results of comparative analysis of the average maximum annual, seasonal and monthly air temperature variability in Tbilisi and Shovi during 1956-2022 against the background of global warming in [56] are presented. The statistical characteristics of the mean max annual, seasonal and monthly air temperature in the period 1956-2022 (T), 1956-1985 (T_1) and 1993-2022 (T_2) for each point were studied.

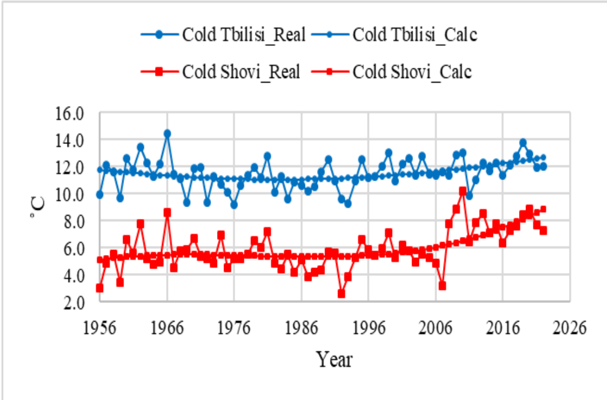
It is shown that compared to Tbilisi, climate warming in Shovi is much more significant. For example, the increase in the mean annual max air temperature in Tbilisi in 1993-2022 compared to 1956-1885 was 0.8 ˚C, while in Shovi it was 1.9 ˚C. The situation is similar for the warm and cold half of the year.

The maximum increase in the mean max monthly air temperature at both points was observed in August. At the same time, in Tbilisi - 1.9 ˚C, and in Shovi - 3.7 ˚C.

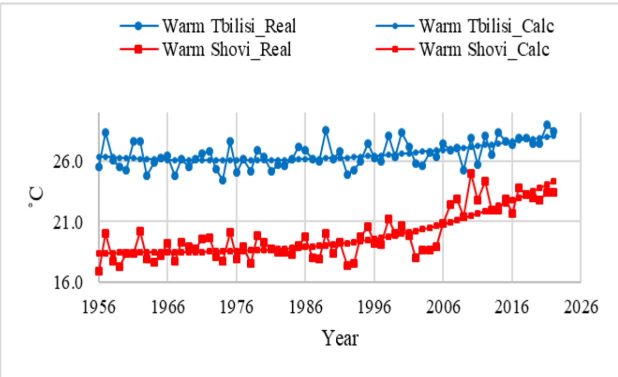
It is shown that the trend of the mean max annual and seasonal air temperature in 1956-2022 in Tbilisi is described by the second power polynomial, and in Shovi - by the third power polynomial (Fig. 2). Using these equations, the average annual rate of increase in air temperature at both points was calculated. In particular, it was found that in 2011-2020 this speed in Shovi is three times higher than in Tbilisi [56].



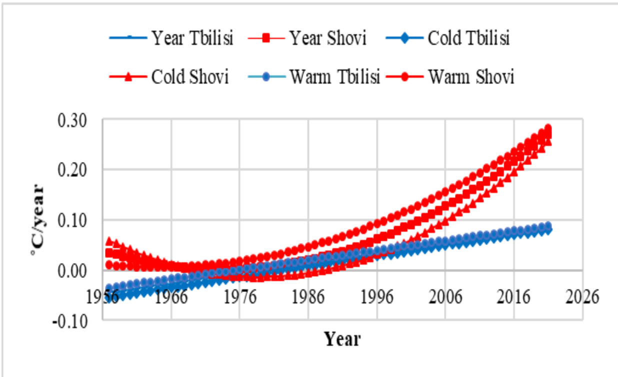
Trend of mean max annual air temperature in Tbilisi and Shovi in 1956-2022.



Trend of mean max air temperature in Tbilisi and Shovi in cold period in 1956-2022.



Trend of mean max air temperature in Tbilisi and Shovi in warm period in 1956-2022.



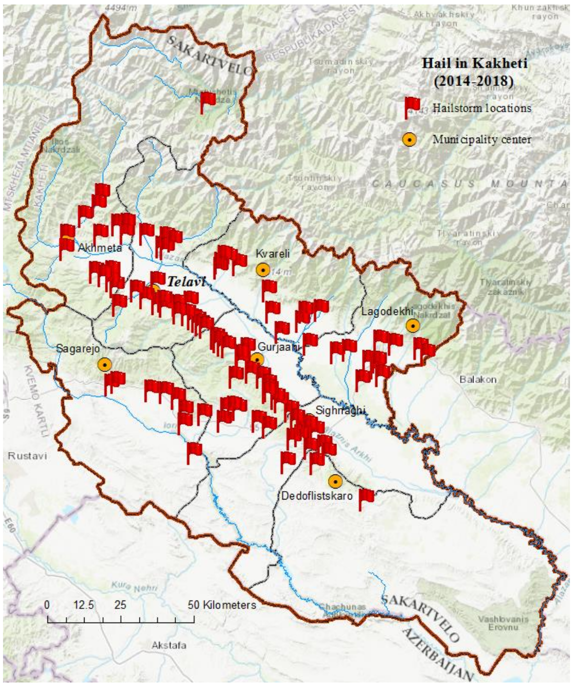
The mean max air temperature change rate in Tbilisi and Shovi in three periods of the year from 1956 to 2022.

Fig. 2. Average annual and seasonal variations of air temperature in Tbilisi and Shovi in 1956-2022 [56].

Some results statistical analysis of the daily mean (W_{mean}) and max (W_{max}) wind speed for Tbilisi from January 1, 1971 to December 31, 2020 are presented in [59]. In 1971-2020 annual mean of W_{mean} was 1.5 m/sec, and W_{max} - 9.1 m/sec. In 1996-2020 compared with 1971-1995 annual mean of W_{mean} increased by 0.8 m/sec, and W_{max} - by 0.3 m/sec. Intra annual distribution of monthly average of daily mean and max wind speed Tbilisi in 1971-2020 has the form of a sixth power polynomial. Regression equations were obtained for the relationship between the repetition of mean daily and maximum wind speed in Tbilisi with the central points of wind speed on the Beaufort Wind Scale.

A significant number of works are devoted to the study of natural disasters [18,23,24,26,41,42,47,49-54,57,65] and adverse meteorological phenomena [16,19,20,22,32,43,58,60,64] in Georgia (blizzards, forest fires, hail, heavy precipitation, floods, heavy snow and avalanches, storms, hurricanes, landslides, etc.). Some of the works [42,50,51-53,57,60] were carried out using data from the first natural disaster catalog created in Georgia [41,47,49,54,65].

In particular, according to data from 2014 to 2018 the distribution in Kakheti region of Georgia of hail storms (Fig. 3), heavy rainfall, floods and floodings (Fig. 4) was study [23,24].



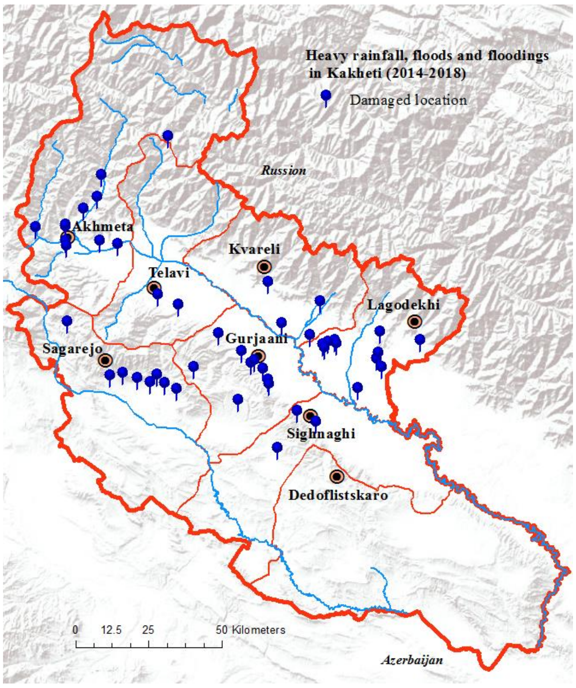


Fig. 3. Hail in Kakheti in 2014-2018 [23].

Fig. 4. Distribution of heavy rainfall, floods and floodings in Kakheti 2014-2018 [24].

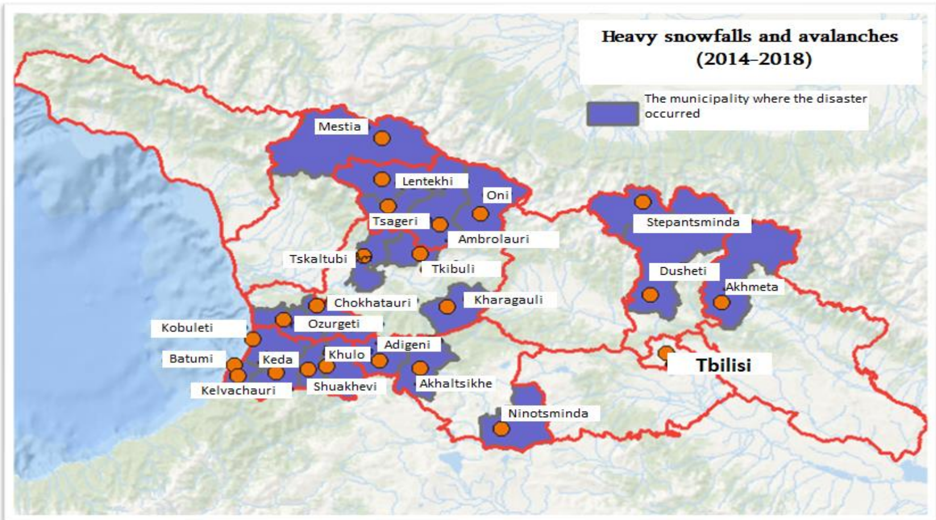


Fig. 5. Distribution of heavy snowfalls and avalanches in Georgia in 2014-2018 [43].

The results of the study of distribution on the territory of Georgia of heavy snowfalls and avalanches in 2014-2018 (Fig. 5) are presented in the work [43].

In [41,47,49,54,65] are present a new natural hazard database for the Republic of Georgia (GeNHs). This database includes a parametric catalogs of five types of natural hazard events (landslide, debris flow, flash flood, windstorm, and hail) causing significant economic loss and casualties in Georgia over the last decades and centuries, respectively. The compilation of these events is innovative as the entire country is covered, and it is timely and may be used by civil protection, risk managers, and other stakeholders in order to provide information for natural hazard and risk management as well as decision-making with respect to effective and efficient mitigation measures. The data included in the database was collected based on the minimum requirements of data quality. Data quality included information on the order of magnitude for each hazard type and the related frequencies, a magnitude classification and harmonization of the corresponding data was carried out to obtain magnitude classifications. For each natural hazard type and event, the most reliable values of the main parameters were collected and determined from the set of available information. These included date of occurrence (year, month, day), time of occurrence (hour), location of occurrence (geographical coordinates), magnitude and intensity where appropriate, affected area, and associated loss (number of fatalities; losses in terms of economic values). The database contains the following information. Landslides were collected for the period between 1900 and 2022, with 1635 events. The magnitude of landslides (MLL) was taken as the logarithm of its volume (in m^3), with a resulting range between 3.0 and 9.0. Debris flows were collected for the period between 1776 and 2022, with 880 events. Debris flow magnitudes (MDF) were taken as the logarithm of the maximum volume (in m^3) of debris material discharged during a single event, with a resulting range between 3.5 and 7.5. Flash floods were collected for the period between 735 and 2022, with 1098 events. Flash flood magnitudes (MFF) were taken as the logarithm of the water peak discharge (in m^3/sec), with a range between 1.5 and 4.0. Windstorms were collected for the period between 1946 and 2022, with 1563 events. Windstorm magnitudes (MHR) were taken as wind speed (in m/s) divided by ten, with a range between 3.0 and 6.0. Hail storms were collected for the period between 1891 and 2022, with 2186 events. Hail storm magnitudes (MHL) were taken as the hail grain size (in mm) divided by ten, with a range between 0.4 and 11.0. This database will provide key input for further improvements of hazard and risk assessment, for the assessment of human and economic losses resulting from such hazards, for assessing possible effects of climate change as well as for evaluating new forecasting and early-warning efforts. The GeNHs database is accessible online [65] and will be kept updated in the future.

Some of the works [42,50,51-53,57,60] were carried out using data from the catalog [65].

For example, in [42] statistical analysis of the number of days with hail in Georgia in 2006-2021 was carried out. Long-term variations of the number of days with hail during the warm season in Tbilisi in 1891-2021 was study in [50].

The results of the analysis of radar studies of hail processes over the territories of Georgia and Azerbaijan on May 28 and July 13, 2019 in [51] are presented. Based on the values of the maximum size of hailstones in clouds, using the Zimenkov-Ivanov model, the expected sizes of hailstones falling on the earth's surface are calculated. The degree of damage to vineyards, wheat and corn, depending on the size of the hail, was determined by summarizing the known data on damage to these crops at different kinetic energy of hail and data on the average kinetic energy of hail of different magnitudes. Based on this compilation, regression equations were obtained for the relationship between the degree of damage to these crops and the size of hailstones, which have the form of a sixth degree of a polynomial. According to this equation, calculations were made of the degree of maximum damage to vineyards, wheat and corn along the trajectories of hail clouds over the territories of Georgia and Azerbaijan. In Fig. 6 example of maximum vineyards damage locations in Georgia and Azerbaijan is presented.

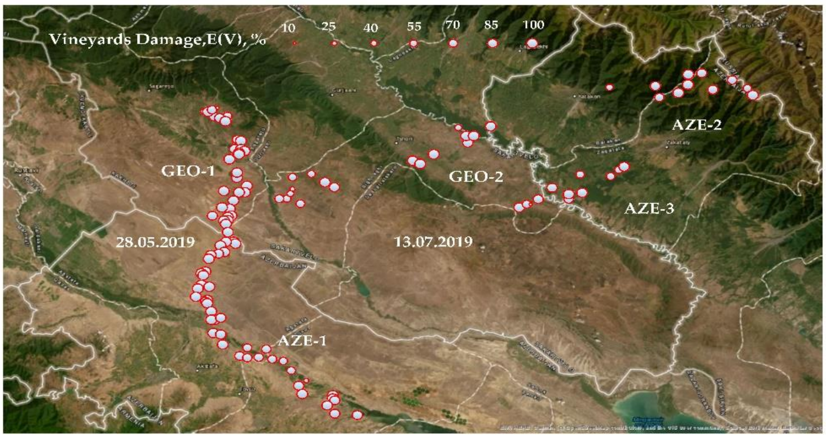


Fig. 6. Maximum vineyards damage locations in Georgia and Azerbaijan during the study period [51].

Analysis data on catastrophic floods in the vicinity of Tbilisi was conducted in [52]. Results of statistical characteristics of hurricane winds over Georgia for the period 1961–2022 in [53] was presented. In [57] statistical analysis of the number of days with hail and damage to agricultural crops from it in Kvemo Kartli (Georgia) was carried out.

A number of works are devoted to the study of environmental pollution [34-40].

The monograph [36] examines the assessment of the ecological state, conditions of placement of industrial arsenic waste in the industrial regions of Racha and Kvemo Svaneti, and also defines the main and possible directions of spread of arsenic toxic waste pollution. Based on the results of expeditionary and ecochemical studies, a numerical model of distribution of arsenic concentrations in water and bottom sediments of the Lukhuni and Tskhenistskali rivers by stationary sources is presented.

As for air pollution, very important and labor-intensive environmental studies have been carried out [34,35,37-40]. The studies used portable mobile devices Aeroqual Series 500 and TROTEC PC220 for measuring PM2.5, PM10 microparticles and some meteorological fields (wind speed, temperature, relative humidity), owned by the Institute of Hydrometeorology. With the help of these instruments, the data obtained as a result of special expeditionary measurements were used in the numerical implementation of the model of atmospheric processes on the scales α and β and the equations of pollution transfer-diffusion in a continuous medium, developed at the Institute of Geophysics.

As a result, the spread of dust, PM2.5 and PM10 microparticles in the cities of Tbilisi, Rustavi and Kutaisi and their environs was studied.

The main features characterizing the process of microparticle spread in complex terrain conditions were studied. The zones of increased dustiness of cities were identified, differences in the spatial distribution of atmospheric air pollution in the winter and summer seasons were revealed. The time intervals when areas of increased concentrations are formed or the air self-purification process occurs were determined. The temporal and spatial changes in dust concentration in the lower part of the atmospheric boundary layer were studied. The distribution of PM2.5 and PM10 concentrations in the atmosphere of Tbilisi during the COVID-19 pandemic (2020-2021) was investigated [34,35,37-40].

The book [34] is devoted to the problems of numerical modeling of dust dispersion in the atmosphere of Georgia. It provides a mathematical model of dust transport-diffusion in the atmosphere, a system of corresponding equations is obtained, an algorithm for numerical integration of equations is given, and the results of the model implementation are analyzed. In particular, the features of transboundary, regional and local dust dispersion are studied, the influence of relief of various scales on the dust transport-diffusion process. The model can be successfully used for theoretical study of the dispersion of atmospheric pollutants in areas with complex relief.

The monograph [35] is dedicated to the problems of numerical modeling of the propagation of microaerosols PM2.5 and PM10 (Particulate Matter) in the atmosphere of Tbilisi. It includes a mathematical model of the transfer-diffusion of a passive ingredient into the atmosphere, an algorithm for the numerical integration of equations, and an analysis of the results of the model implementation. The propagation of PM2.5 and PM10 in the atmosphere of Tbilisi during a background light air was studied. The model can be successfully used for the theoretical study of the distribution of air pollutants in a complex terrain.

The works [15,27-29,31,61-63] and monographs [14,46] discuss the bioclimatic features of Georgia and the related modern problems of development of the resort and tourism industry. A methodology for assessing tourism and recreational resources taking into account the dynamics of climate change has been developed in detail. The potential of tourism and recreational resources of different regions of Georgia and the patterns of its distribution in time and space have been determined.

The monograph [14] is devoted to modern problems of tourism industry. The method of evaluation of tourism-recreational resources is taken into consideration in detail in terms of climate change dynamics. The potential of tourism-recreational resources are estimated of two different regions of Georgia. The work uses the results of the project of the European Union “Tourism development prospects in Guria”.

In [27] a comparative analysis of data on the monthly values of Tourism Climate Index (TCI) and Holiday Climate Index (HCI) in Tbilisi is presented. Period of observation – 1956-2015. Average monthly values of HCI for the entire observation period varied from 62.0 (“Good”, January) to 83.8 (“Excellent”, May). As in the case with the TCI, according to the HCI, the bioclimatic conditions in Tbilisi are favorable for resort and tourist purposes all year round. Comparison of the values and categories of the Tourism Climate Index and Holiday Climate Index shows that the intraannual variation of both indices is similar and has a bimodal form. However, given that the TCI is calculated for the socalled “average tourist” (regardless of gender, age, physical condition), the values and categories of this index is lower than the HCI values and categories.

In [28] the detailed information on the variability of the monthly values of the Holiday Climate Index (HCI) in Tbilisi in 1956-2015 are presented. It also presents data on the interval forecast of variability of HCI values in Tbilisi for the next few decades.

Data about long-term monthly average values of Holiday Climate Index (HCI) for 12 locations of Kakheti (Akhmeta, Dedoplistskaro, Gombori, Gurjaani, Kvareli, Lagodekhi, Omalo, Sagarejo, Shiraki, Telavi, Tsnori and Udabno) are presented in [29]. For 6 stations of this region (Dedoplistskaro, Gurjaani, Kvareli, Lagodekhi, Sagarejo and Telavi) detailed analysis of the monthly, seasonally and annually HCIs values over a 60-year period (1956-2015) are carried out. Comparison of monthly values of HCI and Tourism Climate Index (TCI) for four points of Kakheti (Dedoplistskaro, Kvareli, Sagarejo and Telavi) based on data from 1961 to 2010 are carried out.

The long-term monthly average values of Holiday Climate Index (HCI) for 13 mountainous locations of Georgia (Bakhmaro, Bakuriani, Borjomi, Goderdzi, Gudauri, Khaishi, Khulo, Lentekhi, Mestia, Pasanauri, Shovi, Stepantsminda, Tianeti) are presented in [31,46,63]. Detailed analysis of the monthly, seasonal and annual HCIs values over the 60-year period (1956-2015) are carried out. Comparison of HCI and Tourism Climate Index (TCI) monthly values for three locations (Goderdzi, Khulo and Mestia) based on data from 1961 to 2010 are carried out. The variability of the HCI in 1986-2015 compared to 1956-1985 was studied, and the trends of the HCI in 1956-2015 were also investigated. Using Mestia as an example, the expected changes in monthly, seasonal and annual HCI values for 2041-2070 and 2071-2100 year periods has been assested.

In article [61] discusses the impact of climate and its changes on the development of the tourism sector in Georgia. To evaluate tourism-recreational resources in Georgia for the first time several the Tourism Climatic Indexes were used, based on the combination of different meteorological elements (air temperature, atmospheric precipitation, relative humidity, average duration of sunshine). On the basis of the obtained data, correct decisions should be made when designing tours in different climatic zones against negative climatic events.

It is noted that the World Meteorological Organization (WMO) has organized a number of events to support tourism. It provides World Tourism Organization (WTO) members with early warnings about natural disasters, glacier recession, water resources and climate change. WTO closely cooperates with WMO. Forecasts of climate and extreme hydro meteorological events provided by the National Hydro meteorological Services are particularly important in today's world, as regional climate variations have emerged in the wake of global climate change.

Conclusion

In the future, it is planned to continue the above-mentioned joint research, as well as to combine efforts to solve new scientific and applied problems (experimental modeling of atmospheric processes, development of recommendations for adaptation to expected climate changes, improvement of existing methods of active influence on atmospheric processes and creation of new ones, assessment of the vulnerability of biological systems to air pollution, development of proposals for the prevention of natural disasters, intensification of work on the creation of a bioclimatic passport of resort and tourist zones of Georgia, intensification of educational activities for a wide range of people, etc.).

Particular attention is planned to be paid to issues of experimental modeling of atmospheric processes in a large cloud chamber of the Institute of Geophysics. In particular, the following experiments are planned [67]:

- Modeling of soil erosion processes;

- Modeling of slanting rains on buildings and structures [the work has begun, 68];

- Development of new and improvement of existing methods for creating various aerodisperse systems (neutral and charged fogs, aerosol formations, etc.);

- Modeling the influence of a complex of various meteorological and geophysical parameters (electromagnetic fields and radiation, ozone, meteorological elements, etc.) on living organisms and plants;

- Development of new and improvement of existing methods of influencing harmful characteristics of the atmosphere (dispersion of warm fogs; purification of air from aerosol and gas impurities; protection of living organisms and plants from high concentrations of ozone and levels of electromagnetic fields and radiation, including ultraviolet, etc.);

- Improvement of precipitation control methods.

It is also planned to train specialists in the field of experimental atmospheric physics and applied meteorology, as well as to improve the qualifications of interested persons in this field of science.

It is also planned to use the resources of this facility to conduct various educational and cognitive activities.

Considering the importance of the above studies, under appropriate conditions of state support, the possibility of participating in international projects and obtaining the status of an international laboratory is not excluded.

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წარმოდგენილია მოკლე ინფორმაცია თსუ, მ. ნოდიას სახ. გეოფიზიკის ინსტიტუტისა და სტუ, ჰიდრომეტეოროლოგიის ინსტიტუტის ერთობლივი კვლევების შესახებ ჩატარებული 2019-2023 წწ. და მათი შემდგომი განვითარების პერსპექტივებზე.
საკვანძო სიტყვები: ჰიდრომეტეოროლოგია, კლიმატი, ატმოსფერული პროცესების ექსპერიმენტული მოდელირება, ბიოკლიმატი, ეკოლოგია.

Некоторые результаты совместных исследований Института геофизики им. М. Нодиа, ТГУ и Института гидрометеорологии, ГТУ в 2019–2023 гг. и перспективы их дальнейшего развития

Н. Варамашвили, М. Пипия

Резюме

Представлена краткая информация о совместных исследованиях Института геофизики им. М. Нодиа, ТГУ и Института гидрометеорологии, ГТУ, проведенных в 2019–2023 гг. и перспективах их дальнейшего развития.
Ключевые слова: гидрометеорология, климат, экспериментальное моделирование атмосферных процессов, биоклимат, экология.