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NUMERICAL MODELING OF THE DYNAMICS OF THE AIR FLOW AND THE STUDY OF SOME OF ITS ENERGY CHARACTERISTICS

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Abstract. Abstract. Based on a three-dimensional hydrostatic mesoscale model, the air flow over the complex relief of the South Caucasus (Georgia) is studied. Numerical experiments have shown a strong influence of the Likhi Range on the movement of monsoon air currents between the Main and Lesser Caucasus Ranges. Besides, in order to use the effect of an increase in the speed of the air flow after the flow around the Likhy Range, the strong wind regime and its statistical characteristics in the region of the Rioni River for the period 1960-2021 were studied. It was determined that in terms of energy, the main range of wind speeds for the Kutaisi region is 16-20 m/s, which provide automatic operation of wind farms and are an important basis for the development of wind farms in the western regions of Georgia.

Keywords and phrases: Modelling, air flow, Georgia, energy, wind farms.

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Wind energy is not used properly in Georgia [1]. Even though wind power is unsustainable, it is a renewable source of energy and modern energy management techniques must be used to manage and match the supply and demand of wind power. At the very least, small wind and solar power plants should be more actively used to supply electricity to remote mountainous off-grid isolated areas, of which Georgia abounds. Therefore, it is necessary to more carefully, comprehensively study the wind energy potential of Georgia, taking into account natural phenomena (whims of nature), in order to better organize the electricity grid to meet supply and demand and be ready for possible forecast changes in energy production. As is known, wind energy is the kinetic energy of moving air (also called wind) flowing through an imaginary surface of area A in time t: [2]

$$E=\frac{1}{2}mv^2=\frac{1}{2}(Avt\rho)v^2=\frac{1}{2}At\rho v^3, \quad E=\frac{1}{2}\frac{1}{T}\int_0^T \rho v^3(t)dt, \tag{1}$$

where v is the wind speed, ρ is the density of air. Avt is the volume of air passing through A (which is considered perpendicular to the direction of the wind), $Avt\rho$ is therefore the mass m passing through A. Equation (1) shows that the wind energy in the open air flow is proportional to the third power of the Equation (1) shows that the wind energy in the open air flow is proportional to the third power of the wind speed (the available power increases by a factor of eight when the wind speed is doubled) and has great potential for use in the energy sector

Remote observations of the territory of the Caucasus from near space clearly indicate the formation of a natural channel that facilitates the transfer of atmospheric masses from west to east and back [3,4]. Indeed, observations show that there is a convenient passage between the Main and Lesser Caucasus Ranges with the only obstacle located in the central part of the strip (Likhi Range, connecting the ridges of the Main and Lesser Caucasus) to facilitate the transition of atmospheric masses (in Georgia, the processes of western and eastern circulation prevailed (70%)) between the Black and Caspian Seas [4]. Thus, the study of the structural variability of meteorological fields in the lower layers of the atmosphere during the transfer of atmospheric masses from the Black Sea to the Caspian Sea and vice versa, taking into account the orographically heterogeneous earth's surface, is an urgent task for Georgia using numerical modeling.

Using non-stationary, nonlinear full system of hydro-thermodynamics designed for a "dry atmosphere" to the terrain-following system [4], the problem of atmospheric mass transfer in the natural channel between the Main and Lesser Caucasus Ranges was studied. Numerical calculations executed by the two-step Lax-Wendroff method [5] have shown that the western and eastern air currents undergo significant changes under the influence of the orography of the Caucasus. Namely, the analysis of the eastern air currents have shown an increase in the amplitudes of the waves of air currents and even the formation of weak wind eddies over the Likhi Ridge. A similar pattern is observed over the windward side of the Likhi Range, and it is especially noticeable an increase in wind speed of about 14-16 m/s (with a background speed of 10 m/s) over the Colchis Lowland due to the influence of the orography of the Likhi Range. An analysis of the calculations have shown that with an increase in altitude (from z = 5000 m to z = 10000 m), the influence of the Likhi Range weakens, and the direction of the air flow gradually returns to its background direction, nevertheless, the influence of the orography of the Likhi Range on the moving air flow can be clearly seen already at an altitude of 10 km by the deviation of the air flow path and an increase in the speed of the air flow over the mountains of the Likhi Range and the Kolkhi (Colchis) lowlands.

The monsoon type circulation is the largest among other circulations existing in Western Georgia. Besides, in the mountainous regions of Western Georgia, mountain-valley winds are present throughout the year, while in the warm season their frequency is quite high [2]. In addition to monsoon circulation, mountain-gorge winds, as well as Fionian-mechanical winds, are especially frequent for the Kutaisi region. Therefore, from an energy point of view, it is very important to carefully study the neighboring regions of the Likhi Range. Our goal is to determine the nature of strong winds (>15 m/s) based on statistical analysis in the Kutaisi region.

Currently, only the Gori wind power plant is operating in Georgia. It should be noted that it operates smoothly and its efficiency is 54%, which is a high figure for this type of station. The wind generator starts generating energy at a wind speed of 2-3 m/s. With an increase in wind speed, this power increases and reaches the rated power of the generator at a wind speed of 12-17 m/s. If the wind is stronger and its speed exceeds 25 m/s, the generator will turn off, as its speed will become unacceptable. Therefore, it became necessary to study data on strong and extreme winds (V <2-3 m/s and V ≥25 m/s) at the weather stations of Kutaisi, Mount Sabueti and Tkibuli in 1960-2021. An analysis of data from different types of weather stations shows that the data from Kutaisi weather stations are 2.5 and 7.5 times larger than the corresponding data from Tkibuli and Mta-Sabueti. Therefore, we tried to study the regime of strong winds and the statistical characteristics of the Imereti region using extensive and reliable data from the Kutaisi meteorological station, using mainly statistical methods. To better represent the wind energy potential of the region, we divided the 60-year interval (1960-2021) into intervals of 5 m/s and studied the distribution of average wind speeds and frequency (repeatability) of wind speed for each interval. In addition, it was necessary to study the distribution of absolute maximum wind speeds. However, for comparison, we studied the distributions of the absolute wind maximum not only for wind speeds over 25 m/s, but also for wind speed intervals of 16=20 m/s and 20-25 m/s.

Calculations have shown that the number of recurrences of the wind speed gradation of 16-20 m/s is small for the summer season, while for the remaining three seasons it was relatively high and the maximum value of the number of recurrences was recorded in February (53).

In addition, the frequency of wind speeds for the range of wind speeds of 16-20 m/s varies significantly by seasons of the year, with the highest frequency of speeds occurring in spring and autumn, and the lowest in summer than in winter. the frequency of wind speeds for wind speed intervals of 20-25 m/s is minimal only for the summer season, and for wind speed gradations >25 (m/s) the frequency of occurrence is similar, except that in this case the frequency of strong winds is relatively small.

Besides, winds of 16-20 m/s and 20-25 m/s are recorded during all seasons. And very strong winds (>25 m/s) do not occur in the summer season. It should also be noted that the wind values with intervals of 16-20 m/s and 20-25 m/s in summer are minimal compared to the wind values of other seasons.

Thus, it can be said that from an energy point of view, the main leading wind speed range for the Kutaisi region is 16-20 m/s, and dangerous wind values in intervals of 20-25 m/s, which are observed mainly in summer, are minimal. compared to the wind values of other seasons and from an energy point of view, this is not significant, since energy consumption at this time is minimal. The wind speed range of 16-20 m/s ensures maximum efficiency of wind energy use. Thus, from an energy point of view, speeds of such magnitude are important, which ensure the automatic operation of a wind power plant and are an important basis for the development of wind power plants in Western Georgia.

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