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Articles

Estimation of the Maximum Possible Magnitude of Hurricanes on the Territory of Georgia

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Abstract

Based on the data from the catalog of natural disasters in Georgia for the period 1961–2022, which we compiled, the maximum possible magnitudes of hurricanes in various geographical conditions of Georgia were estimated. Statistical methods for processing climatological data were used. The assessment of the maximum possible magnitude of hurricanes was made on the basis of an empirical probability curve showing the probability or probability of exceeding a given value among the total set of a series. A zoning map of the territory of Georgia by the maximum possible magnitudes of hurricanes was developed. There are two areas with the highest maximum magnitude reaching 6. These are the southern part of the Likhi Range in western Georgia and a small area of the flat part of Kvemo Kartli in eastern Georgia. In some areas, hurricanes with a magnitude of 5 and 5.5 are possible. In a significant part of the territory of Georgia, the maximum magnitude of hurricanes can reach 4.5.

Keywords: hurricane, probability, recurrence, period, magnitude.

1. Introduction

The strongest gusts of wind recorded on Earth are associated with tornadoes and reach speeds of up to 500 km/h. If a tornado of this strength passes through a populated area, then practically nothing will remain of it (Kakovo maksimal'noe..., 2024). In Australia, on Barrow Island, a wind gust speed of 113 m/s was recorded (Cyclone, 2024), and on Mount Washington in New Hampshire, the wind gust speed was 103 m/s (Kravchuk, 1993). Winds of about 90 m/s have been recorded at the US Air Force Base in Greenland and on Adelie Land in Antarctica (Veter, 2024). On the Gulf Coast, wind speeds reach over 80 m/s (Jagger, Elsner, 2006). In Florida, in the city of Miami, hurricane-force winds of 50 m/s have been recorded (Malmstadt et al., 2010).

Hurricanes pose a danger to Georgia. Research into hurricane winds in Georgia has a long history, although the most significant work has been completed in recent years. The article (Elizbarashvili et al., 2013) for the period 1961–2008. The statistical structure of hurricane winds was studied, the number of days and duration of hurricane winds were determined, their empirical distribution functions and area sizes were studied, the monograph (Elizbarashvili, Elizbarashvili, 2012)

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considered the geography, structure, area and dynamics of hurricane winds, the article (Elizbarashvili et al., 2023) assessed the spatial distribution of hurricane winds, calculated the maximum economic losses and constructed a map of expected risks, the article (Elizbarashvili et al., 2023) studied the statistical characteristics of hurricane winds over Georgia for the period 1961–2022. In this article, the maximum possible magnitudes of hurricanes in various geographical conditions of Georgia are estimated based on observations for the period 1961–2022 and others.

2. Materials and methods

The article uses materials from the catalog of natural disasters in Georgia (Varazanashvili et al., 2023). These data comply with the standards of the World Meteorological Organization. All measurements of wind speed were carried out at a height of 10 m above the ground. In the catalog, the strength of a hurricane is expressed through magnitude (M), which is defined as a value proportional to wind speed, the proportionality coefficient is conventionally taken as 0.1 s/m. Statistical methods for processing climatological data are used. The long-term risk of dangerous hurricanes is assessed based on the empirical probability curve, showing the probability or probability of exceeding a given value among the total set of the series. The coordinates of the probability curve were calculated directly from the values of the initial series of observations; for each member of the series, the empirical probability was determined using the Gauss formula:

$$P = m / n * 100\ \%,$$

where m is the number of hurricane cases of a given magnitude, n is the total number of hurricane events.

3. Discussion

Figure 1 shows the probability curves of the maximum magnitude of hurricanes in different zones of Georgia, characterized by different wind speed regimes, and with different values of frequency, intensity and magnitude of hurricanes, as well as their approximation by a polynomial of varying degrees.

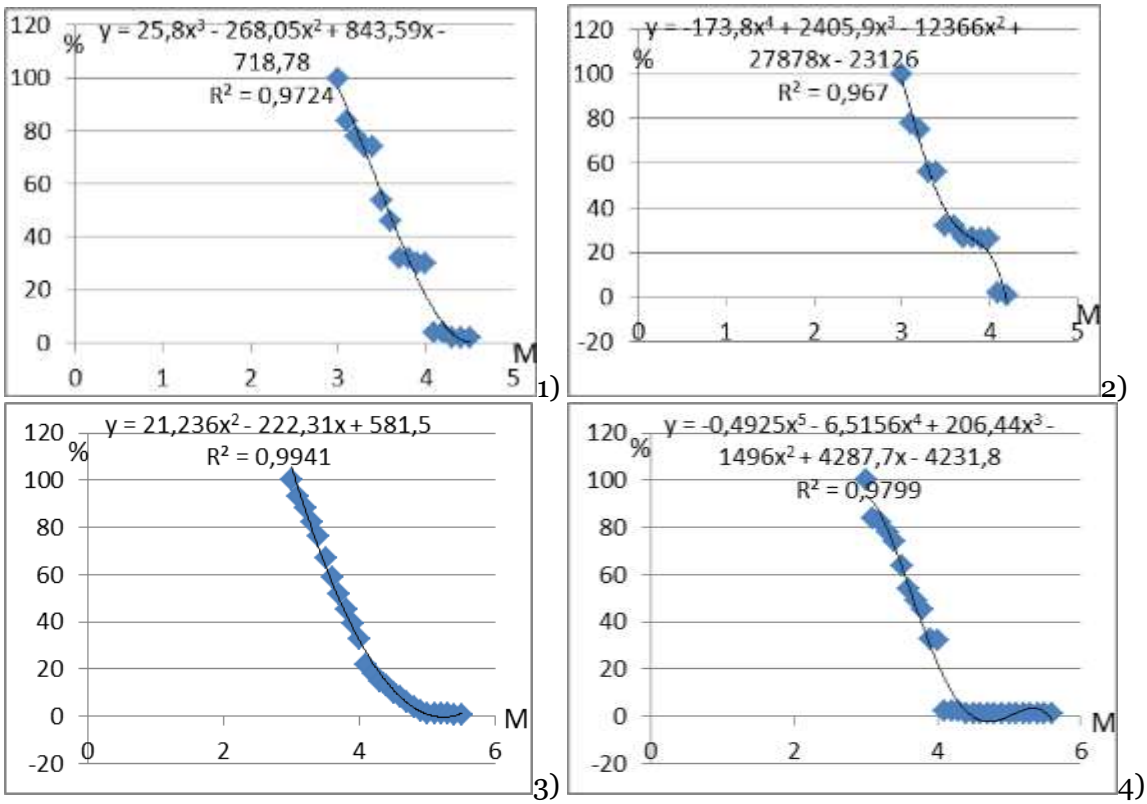

Fig. 1. Curves of maximum hurricane magnitude probability and their approximation by polynomials of varying degrees: 1) Senaki; 2) Mta-Sabueti; 3) Tbilisi; 4) Udabno. R2 – determination coefficient

From Figure 1 it follows that the coordinates of the points calculated directly from the values of the initial series of observations are well approximated by polynomials of varying degrees. The determination coefficient is significant and exceeds 0.96. Thus, the obtained equations can be used to calculate the magnitude of hurricanes of any probability.

Table 1 presents the values of observed and expected, according to our expert estimates, hurricane magnitudes and the corresponding probability in different hurricane activity zones of Georgia.

Table 1. Values of observed and expected hurricane magnitudes (Mmax) and the corresponding probability (P%) and recurrence periods in zones of different hurricane activity: 1 – most active, 2 – less active, 3 – least active. Zone 1 – the Main Caucasus Range, the Likhi Range, as well as small areas of the interior of the Colchis Lowland and the flat part of Kvemo Kartli. Zone 2 – the intermountain depression of Georgia – the Black Sea coast, the Colchis Lowland, the Imereti Upland, the plains and foothills of Eastern Georgia, with the exception of a small area of the interior of the Colchis Lowland and a small area of the flat part of Kvemo Kartli, which are included in zone 1. Zone 3 – the western part of the Meskheti Range, a significant part of the Trialeti Range and the Akhalkalaki Plateau

Zone	Station	Observed Mmax	Security P %	Return period, years	Possible Mmax	Security P%	Return period, years
1	Kutaisi	4.6	1.3	80	5	1	100
	Mta-Sabueti	4.2	1.5	66	4.8	1	100
	Mamisonsky pass	4.3	0.7	143	4.5	0.5	200
	Shovi	4	100	1	4.5	1	100
	Qazbegi	3.6	33	3.3	4	1	100
	Samgori	4	18	6	4.5	1	100
	Tbilisi	5.5	0.5	200	5.7	0.4	250
	Udabno	5.6	0.3	333	5.8	0.25	400
	Zekary pass	5.6	1	100	5.8	0.5	200
2	Sachkhere	4.8	60	1.6	5.0	1	100
	Paravani	5	4	25	5.5	1	100
	Gurjaani	4.8	50	2	5	1	100
	Bolnisi	3.5	17	6	4	1	100
	Akhalgori	4	44	2.2	4.5	1	100
	Akhmeta	4.5	33	3	5	1	100
	Pasanauri	4	12	8	4.5	1	100
	Dedoplisckaro	4	16	6.2	4.5	1	100
	Zugdidi	3.4	50	2	4	1	100
	Lagodekhi	3.3	100	1	4	1	100
	Chakvi	4	33	3	4.5	1	100
	Abasha (Khoni)	3.5	100	1	4	1	100
	Dmanisi	4.7	2.5	40	5	1	100
	Tkibuli	4	4.3	23	4.5	1	100
	Martvili	4.7	2.1	48	5	1	100
	Telavi	3.5	50	2	4	1	100
	Senaki	4.5	2.1	48	5	1	100
	Kvareli	4	33	3.3	4.5	1	100
	Tsnori	3	100	1	3.5	1	100
	Zestafoni	3.6	50	2	4	1	100
	Borjomi	4	66	1.5	4.5	1	100
	Sagarejo	3.4	100	1	4	1	100

Zone	Station	Observed Mmax	Security P %	Return period, years	Possible Mmax	Security P%	Return period, years
	Muhrani	4.4	3	33	5	1	100
	Poti	4	21	5	4.5	1	100
	Ureki	3.4	50	2	4	1	100
	Anaseuli	3.5	50	2	4	1	100
	Batumi	3.5	33	3	4	1	100
	Bakuriani	4	100	1	4.5	1	100
	Kobuleti	3.4	21	5	4	1	100
	Lebarde	3.4	100	1	4	1	100
	Gori	3.7	100	1	4.5	1	100
	Lanchkhuti	4	16	6	4.5	1	100
	Tianeti	4	100	1	4.5	1	100
	Tetritskaro	4	46	2.2	4.5	1	100
	Tskhvarichamia	3.4	100	1	4	1	100
3	Goderdzsky lane	4	42	2.4	4.5	1	100
	Bakhmaro	4	30	3.3	4.3	1	100
	Abastumani	3.4	100	1	4	1	100
	Akhaltsikhe	4	30	3.3	4.3	1	100
	Akhalkalaki	4	25	4	4.2	1	100
	Aspindza	4	100	1	4.2	1	100

It follows from Table 1 that in the most hurricane-active zone 1 the magnitude reaches 5.6 with a probability of 0.3-1 %, i.e. the recurrence period is about 100–333 years. In zone 2 the highest magnitude reached 5.0 with a probability of only 4 %, and the recurrence period is 25 years. The highest magnitude of hurricanes in zone 3 was recorded as 4.0 with a probability of about 40 %. Therefore, the recurrence period of this magnitude is about 2.6 years. Thus, in the coming decades, an increase in the magnitude of hurricanes in zone 3 to 4.5 is most likely, some increase in the magnitude of hurricanes to 5.5 in the long term is also possible in zone 2, and in zone 1 an increase in the magnitude of hurricanes to 6 is unlikely. Within each of the zones, especially in zone 1 and zone 2, in specific points, the values of the highest magnitudes of hurricanes differ significantly (Table 1). Their corresponding probabilities and recurrences also differ. This is due to the physical and geographical features of the location of the points. From the data in Table 1, it can be concluded that the expected maximum magnitudes of hurricanes can only occur in specific points of the corresponding zones. For example, in zone 2, where the highest expected magnitude of hurricanes is on average 5.5, it is most likely to occur at the Paravani station, where magnitude 5 is repeated every 25 years. In other points of the zone, magnitudes of this magnitude are unlikely. In zone 1, the maximum magnitude was recorded in Udabno and Zekari-5.6, and in Tbilisi, magnitude 5.5 was recorded. It is in these locations that magnitudes can increase to 5.8-6. In other locations of the zone, magnitudes of this magnitude are unlikely. As for zone 3, where the highest expected magnitude of hurricanes is possible 4.5, it can occur at any point in the zone.

Figure 2 shows a zoning map of the territory of Georgia according to the maximum possible magnitudes of hurricanes, compiled using the data in Table 1.

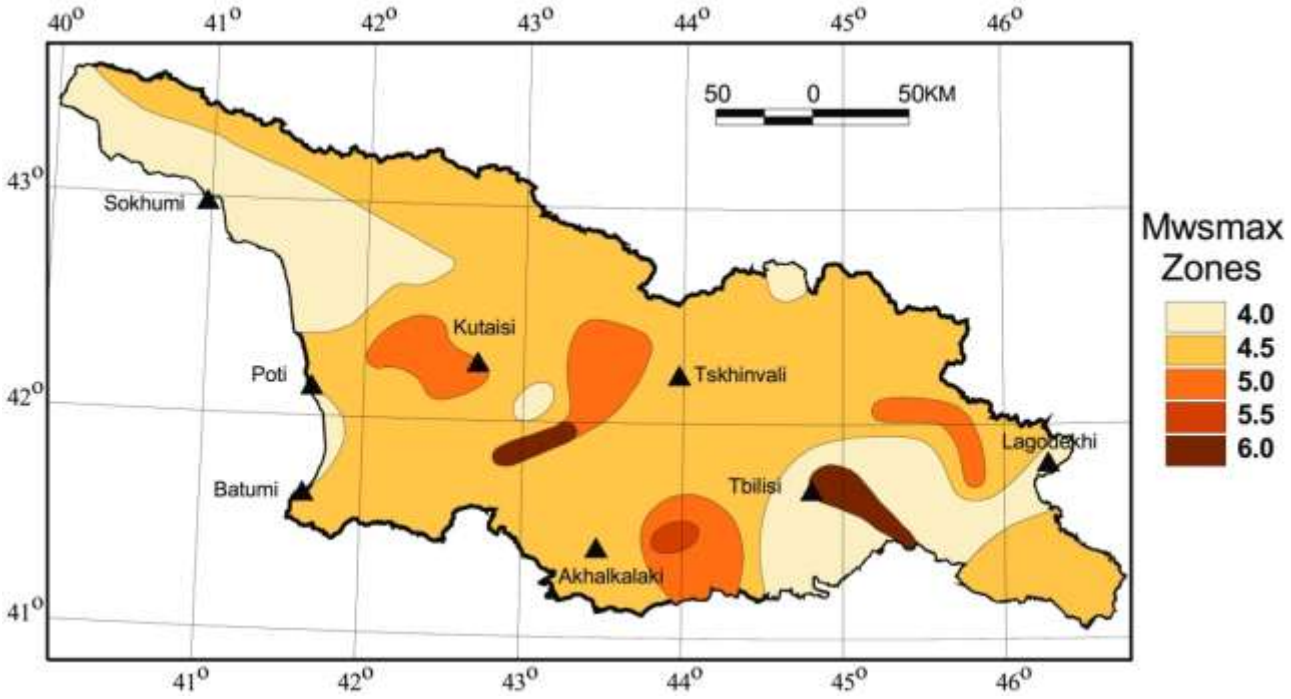

Fig. 2. Zoning of the territory of Georgia by the maximum possible hurricane magnitudes

The map highlights two areas with the highest maximum magnitude reaching 6. These are the southern part of the Likhi Range in western Georgia and a small area of the flat part of Kvemo Kartli in eastern Georgia. In some areas, hurricanes with magnitudes of 5 and 5.5 are possible. In a significant part of the territory of Georgia, the maximum magnitude of hurricanes can reach 4.5.

4. Conclusion

1. The curves of the probability of the maximum magnitude of hurricanes are well approximated by polynomials of the 5th degree. The determination coefficient is significant and exceeds 0.97.

2. In the most hurricane-active zone 1 the magnitude reaches 5.6 with a probability of 0.3-1 %, i.e. the recurrence period is about 100–333 years. In zone 2 the highest magnitude reached 5.0 with a probability of only 4 %, and the recurrence period is 25 years. The highest magnitude of hurricanes in zone 3 was recorded as 4.0 with a probability of about 40 %. Therefore, the recurrence period of this magnitude is about 2.6 years.

3. The expected magnitudes of hurricanes in these zones are in zone 1–5.8, in zone 2–5.5 and in zone 3–5 with a probability of 0.25-0.5 %, 1 % and 1 %. The recurrence periods of such magnitudes are 200–400 years, 100 years and 100 years, respectively. Thus, in the coming decades, an increase in the magnitude of hurricanes in zone 3 to 5 is most likely, some increase in the magnitude of hurricanes to 5.5 in the long term is also possible in zone 2, and in zone 1 an increase in hurricanes to 6 points is unlikely.

4. A zoning map of the territory of Georgia by the maximum possible magnitudes of hurricanes has been developed. There are two areas with the highest maximum magnitude reaching 6. These are the southern part of the Likhi Range in western Georgia and a small area of the flat part of Kvemo Kartli in eastern Georgia. In some areas, hurricanes with a magnitude of 5 and 5.5 are possible. In a significant part of the territory of Georgia, the maximum magnitude of hurricanes can reach 4.5.

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