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EXPECTED CHANGES OF THE NUMBER OF DAYS WITH HAIL IN TBILISI TO 2085

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Abstract: *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. 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.

Key words: *Number of days with hail, moving average, long-time predicted.*

Introduction

The study of hail processes in Georgia, as one of the hail-prone regions of the world [1-3], has always attracted the attention of specialists in this country in meteorology, climatology and atmospheric physics. A large number of works are devoted to this problem, covering a wide range of studies, such as: hail climatology and analysis of damage from it [1-5], modeling and mapping the distribution of hailstones by average maximum size in the territory of Kakheti (Georgia) [6, 7], development ways to influence hail processes [8], etc.

Currently, significant assistance in intensifying these studies is provided by the creation of the first database for Georgia on natural disasters (including hail processes), accessible to a wide range of scientists [9].

Using this database, a number of new studies of hail processes in Georgia have already been carried out [10-12].

In particular, in [11] some results of a statistical analysis of the number of days with hail during the warm half-year in Tbilisi from 1891 to 2021 are presented. The temporal variability of the measured values of the number of days with hail, as well as the moving averages of the number of hail days for 3, 5, 7, 9, and 11 years, has been studied. It is found that the time course of all the indicated series of observations is negative and is described by the linear regression equation. At the same time, the level of linear correlation between years and the measured number of days with hail, as well as moving averages of the number of hail days, increases as the averaging range increases up to 11 years (from -0.22 to -0.63, respectively).

This work is a continuation of the study [11]. Below an example of Tbilisi, using special statistical method, predictive estimates of the number of days with hail and its moving average values to 2050 and 2085 are given (taking into account the periodicity in the pre-forecast time series).

Study area, material and methods

Study area – Tbilisi (the capital of Georgia).

The work uses catalog data [9] on the number of days with hail in the warm season of the year (April-October) in Tbilisi from 1891 to 2021 and their estimated 3, 5, 7, 9, and 11 year moving averages, reported in a previous study [11].

Forecasting the number of hail days and their moving averages was performed using the AAA version of the exponential smoothing (ETS) algorithm taking into account the periodicity in the pre-forecast time series [13].

Analysis of forecast data was carried out using standard methods of mathematical statistics [14]. The following notations and abbreviations are used. Max – maximum value, Min – minimum value, Mean – average value, St Dev standard deviation, Cv – coefficient of variation (Cv = 100· St Dev/Mean, %), Count – number of forecast years.

The designations below: HD – number of days with hail, HD_Calc, HD_3_Calc... HD_11_Calc are the central points of the forecast of real HD values and their moving averages for 3, 5, 7, 9 and 11 years. HD_Upp_Calc, HD_3_Upp_Calc... HD_11_Upp_Calc – 95% upper forecast level.

The periodicity of time series was determined using the program "Mesosaur". 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.

Results and discussion

Results in Fig. 1-5 and Table 1-2 are presented.

Example of variability of forecast values of the number of days with hail and its seven-year moving average in Tbilisi from 2022 to 2050 and from 2022 to 2085 respectively in Fig. 1 and 2 are presented.

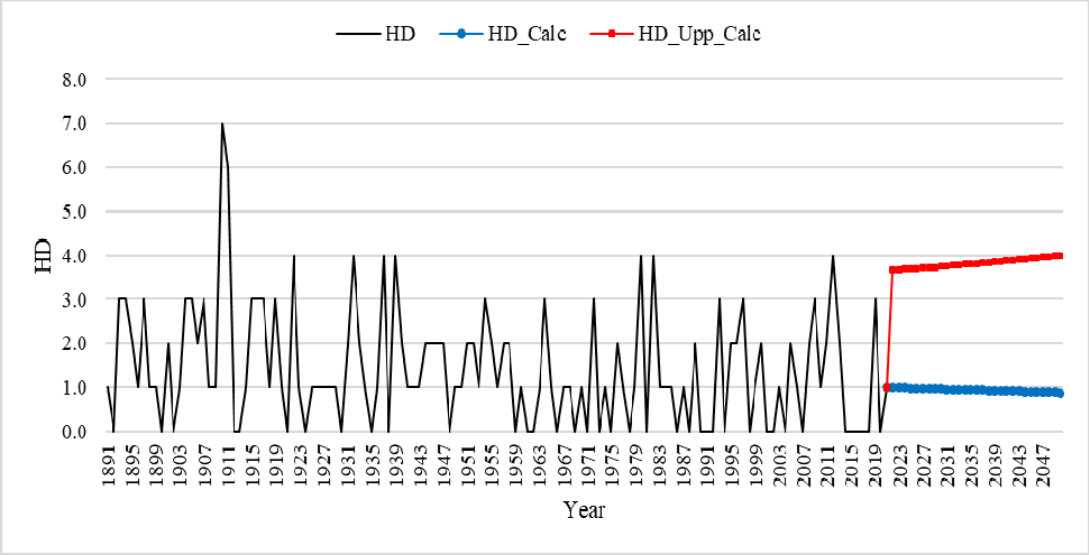

Fig. 1. Example of variability of forecast values of the number of days with hail in Tbilisi from 2022 to 2050.
HD is the original data from 1891 to 2021,
HD_Calc is the center points of the forecast and HD_Upp_Calc is the 95% upper level of the forecast.

Note that in the pre-forecast time series of the number of days with hail (Fig. 1) there is no clear peak in periodicity. In the pre-forecast time series of the seven-year moving average number of days with hail (Fig. 2), the peak periodicity occurs at 31 years. The absence and presence of periodicity is also respectively present in the calculated predictive values of the number of days with hail (Fig. 1 and 2).

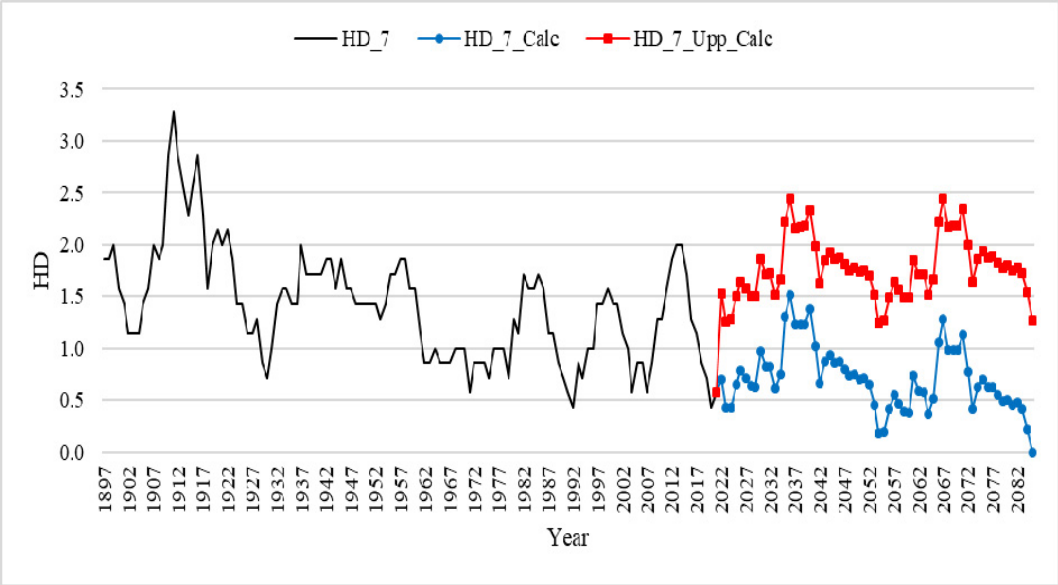

Fig. 2. Example of variability of forecast values of the seven-year moving average number of days with hail in Tbilisi from 2022 to 2085. HD_7 is the original data from 1897 to 2021, HD_7_Calc is the center points of the forecast and HD_7_Upp_Calc is the 95% upper level of the forecast.

In Table 1 statistical characteristics of the forecast values of the number of days with hail and their moving average values in Tbilisi (HD, HD_3 and HD_11 until 2050, the rest until 2085) are presented.

Table 1. Statistical characteristics of the forecast values of the number of days with hail and their moving average values in Tbilisi (HD, HD_3 and HD_11 until 2050, the rest until 2085).

	HD_ Calc	HD_Upp_ Calc	HD_3_ Calc	HD_3_Upp_ Calc	HD_5_ Calc	HD_5_Upp_ Calc	HD_7_C alc	HD_7_Upp_ Calc	HD_9_ Calc	HD_9_Upp_ Calc	HD_11_ Calc	HD_11_Upp_ Calc
Max	1.0	4.0	1.8	3.9	1.5	4.6	1.5	2.5	1.1	4.1	1.1	1.7
Min	0.9	3.7	0.2	2.1	0.0	1.1	0.0	1.3	0.0	1.1	0.9	1.6
Mean	0.9	3.8	1.0	3.0	0.4	3.0	0.7	1.8	0.5	3.0	1.0	1.6
St Dev	0.04	0.10	0.49	0.51	0.36	0.84	0.31	0.29	0.27	0.80	0.07	0.04
Cv,%	3.8	2.6	49.8	16.8	89.9	28.1	43.5	16.4	51.0	26.7	7.0	2.2
Count	29	29	29	29	64	64	64	64	64	64	29	29

In particular, as follows from Table 1, 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 3.0.

In Table 2 data on forecast values for the number of days with hail and their moving average values in Tbilisi at three-year intervals from 2023 to 2050 and from 2023 to 2085 are presented. Note, that the 95% lower prediction value for all cases is 0.

Table 2. Forecast values for the number of days with hail and their moving average values in Tbilisi (HD, HD_3 and HD_11 from 2023 to 2050, the rest from 2023 to 2085).

	HD_ Calc	HD_Upp_ Calc	HD_3_ Calc	HD_3_Upp_ Calc	HD_5_ Calc	HD_5_Upp_ Calc	HD_7_C alc	HD_7_Upp_ Calc	HD_9_ Calc	HD_9_Upp_ Calc	HD_11_ Calc	HD_11_Upp_ Calc
2023	1.0	3.7	1.7	3.2	0.2	1.2	0.4	1.3	0.5	1.2	1.1	1.6
2026	1.0	3.7	1.4	3.0	0.0	1.1	0.8	1.6	0.6	1.6	1.1	1.6
2029	1.0	3.7	0.4	2.2	0.5	2.0	0.6	1.5	0.4	1.7	1.0	1.6
2032	1.0	3.8	0.5	2.4	0.5	2.2	0.8	1.7	0.7	2.2	1.0	1.6
2035	0.9	3.8	1.1	3.1	0.3	2.2	1.3	2.2	0.5	2.2	1.0	1.6
2038	0.9	3.8	1.7	3.9	1.0	3.0	1.2	2.2	1.1	3.0	1.0	1.6
2041	0.9	3.9	1.0	3.2	0.9	3.1	1.0	2.0	1.1	3.1	0.9	1.6
2044	0.9	3.9	0.2	2.6	0.3	2.6	0.9	1.9	0.6	2.8	0.9	1.7
2047	0.9	4.0	0.8	3.3	0.7	3.1	0.8	1.8	0.8	3.1	0.9	1.7
2050	0.9	4.0	1.2	3.8	0.6	3.1	0.7	1.7	0.5	3.0	0.9	1.7
2053					0.3	3.0	0.5	1.5	0.3	2.9		
2056					0.0	2.7	0.4	1.5	0.2	2.9		
2059					0.0	2.5	0.4	1.5	0.2	3.1		
2062					0.2	3.3	0.6	1.7	0.3	3.2		
2065					0.0	3.1	0.5	1.7	0.5	3.5		
2068					0.4	3.7	1.0	2.2	0.7	3.9		
2071					1.2	4.6	1.1	2.3	0.9	4.1		
2074					0.7	4.2	0.6	1.9	0.5	3.9		
2077					0.2	3.8	0.6	1.9	0.4	3.9		
2080					0.1	3.8	0.5	1.8	0.2	3.8		
2083					0.3	4.1	0.4	1.7	0.1	3.8		
2085					0.0	3.8	0.0	1.3	0.0	3.7		

Conclusion

In the future, similar forecast estimates of the number of days with hail will be carried out for other locations in Georgia.

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