Transformation of Level of Humidification in the Eastern Part of Cuba

Olesya Nazarenko[1*]

[1]Southern Federal University, Rostov on Don, 344090, Russia

Abstract. The work is devoted to analysing the transformation of humidification in a changing climate in the eastern part of Cuba, the case of Holguin (east of the island). The importance of the study is related to the need to study precipitation trends in certain regions. Based on the analysis of the long-term dynamics of annual precipitation values, relative humidity, and the number of days with precipitation, trends in the degree of moisture in the east of the island was established. The practical significance of the work lies in identifying and developing long-term weather forecasts and planning the economic and recreational development of the territory. The 1970–2020 period was considered. Changes in the amount of precipitation and days with precipitation were analysed. The moisture coefficient for the territory was calculated. The wettest and driest periods were identified, with the wettest being from 1981 to 1985 and the driest being from 1991 to 1995. The average rainfall for the wettest period was 1365 mm, while the average rainfall for the driest period was 335 mm. There was an increase in the number of days with precipitation from 39 days (1970) to 150 (2007). The maximum values of days with precipitation occurred in the period from 2006 to 2010. The calculated balance of humidification of the territory revealed heterogeneity of conditions of humidification of the territory. The maximum moisture deficit falls in the period from February to April, and the minimum – in June. The annual moisture balance was -653 mm. The territory is experiencing a lack of moisture.

1 Introduction

Global climate changes are significantly manifested in high latitudes. It is noted that global warming has also affected tropical areas, where the temperature has risen by 0.2–1 °C [1]. In the future, a temperature increase of 2°C is predicted [1].

The first studies of the climate of Cuba date back to 1794. They included the analysis of data on air temperature, pressure, and the state of the sky. Observations of meteorological indicators have been carried out in Havana since 1800. Papers were published on the trajectories of hurricanes in the Caribbean Sea and the climate of Cuba, but the main research began to be conducted in the second half of the 20th century. Maps of air temperature and precipitation distribution were compiled, and the climate of individual

* Corresponding author: ovnazarenko@sfedu.ru

areas was studied [2-4]. This work is devoted to analysing precipitation changes in the province of Holguin.

The island of Cuba belongs to the tropical islands of the West Indies, a group of the Greater Antilles. The relatively small territory of the island is characterized by significant diversity. This is the Antillean-Caribbean region of the folded Cordillera belt, characterized by the spread of young limestones. The terrain of the territory is flat with small elevations, and karst processes are widely developed. The vegetation cover is characterized by high endemism, richness, and diversity. The territory is dominated by typical savannas [2, 4].

Cuba is located south of the northern tropic and receives a significant amount of solar heat, which leads to slight temperature fluctuations. This is the trade wind Atlantic zone. The island is located in the western periphery of dynamic anticyclones. The greatest changes during the year occur with precipitation. The year is divided into two seasons – dry and rainy. The rainy season lasts from May to October. The dry season is from November to April [2].

2 Materials and methods

The research goal is to identify the features of precipitation changes in the city of Holguin in a changing climate. The research aims to identify trends in the amount and mode of precipitation in the east of the island. The average monthly precipitation in the city of Holguin is considered for the period from 1963 to 2020. The following data are considered: (1) relative humidity; (2) average monthly precipitation; (3) annual precipitation; (4) maximum daily precipitation; (5) number of days with precipitation. The research methodology included a statistical analysis of the precipitation regime according to the data of the weather station.

In order to assess the degree of humidification of the territory, the moisture coefficient (Cm) was calculated. It is the ratio between the amount of precipitation over a certain period and the amount of evaporation. The moisture coefficient is calculated by the following formula:

$$Cm = \Sigma P/E \tag{1}$$

Where: ΣP – the amount of precipitation for the period, mm; E – the evaporation rate, mm/month.

The evaporation rate is calculated according to the formula of N. N. Ivanov [5]:

$$E = 0.0018(25+t)^2(100-f) \tag{2}$$

Where: E – the evaporation rate, mm/month; t – the average monthly air temperature, °C; f – the relative humidity, %.

3 Results and Discussion

The paper considers the humidification conditions in the city of Holguin, Cuba (Holguin), which is located in the east of the island of Cuba and lies 147 m above sea level. The climate is tropical, humid-arid. There is more precipitation in summer than in winter.

The air temperature during the year varies slightly from 23.3°C (January) to 28°C (August). The average temperature is 25.6°C. The average amount of precipitation is 1,008 mm. The driest month is February (29 mm). The maximum amount of precipitation falls in October (149 mm).

Humidification in the province of Holguin is moderate (Cm = 0.61) but not uniform throughout the year: (1) meager (0.13–0.29; three months: January – March); (2) insufficient (0.3–0.59; four months: April, July, August, December); (3) moderate (0.6–0.99; three months: May, June, November); (4) sufficient (1.0–1.49; two months: September, October). There are dry (February, March) and wet (September, October) seasons. The probability of wet days in Holguín varies throughout the year, with precipitation falling at least 1 mm. The wettest season lasts for six months from May to November, and the month with the highest number of rainy days on average is October, with at least 7.5 rainy days per month. The drier season spans from November to May, and January has the fewest number of rainy days.

The authors carried out the analysis of precipitation changes according to the data of the Holguin weather station for the period from 1963 to 2019. They considered the daily and average monthly observation data. The amount of precipitation for different periods (month, season, year) was calculated as the sum of their daily amount for the required periods. It was revealed that the number of years with precipitation above and below the norm are equally distributed (24 years each), and two years correspond to the norm (1988, 2014) (Figure 1).

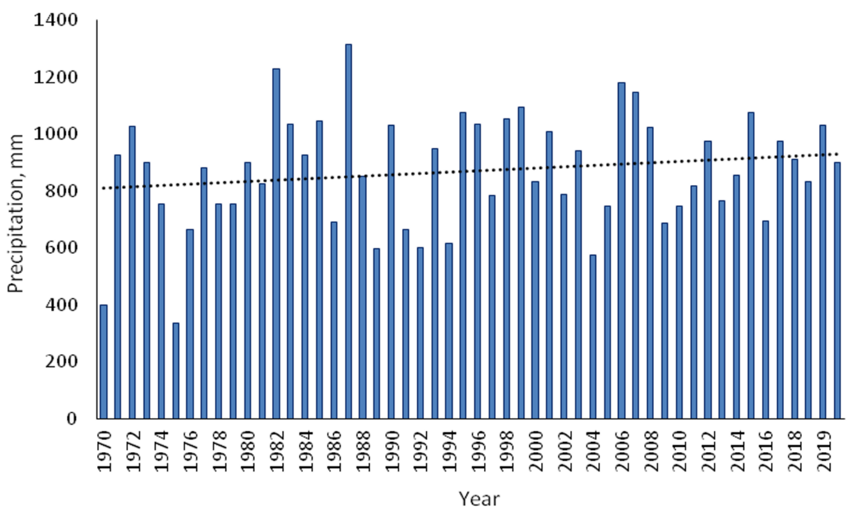

Fig. 1. Dynamics of precipitation changes for the period from 1970 to 2020.

The wettest period was from 1981 to 1985 when the average amount of precipitation was 1013 mm. The lowest amount of precipitation fell at the beginning of the 1991–1995 period (781 mm). The period after the 2000s is characterized by less precipitation than the average (Figure 2). During the period from 2000 to 2020, drier conditions prevailed, with 70% of years experiencing a lack of rainfall ranging from 12 to 441 mm.

The analysis of precipitation anomalies during the year shows that the years when precipitation was less than average prevailed (Figure 3). The smallest deviation from long-term values in the direction of increasing humidity occurred in February - March and amounted to only 25% (or only 10 years out of 40 were characterized by increased precipitation). The wettest was February 1983, when the deviation was 192 mm. The wettest March was recorded in 1998 when the deviation from the average values was 84 mm. Deviations in the direction of increasing moisture were most often recorded in August, with 43% of instances noted.

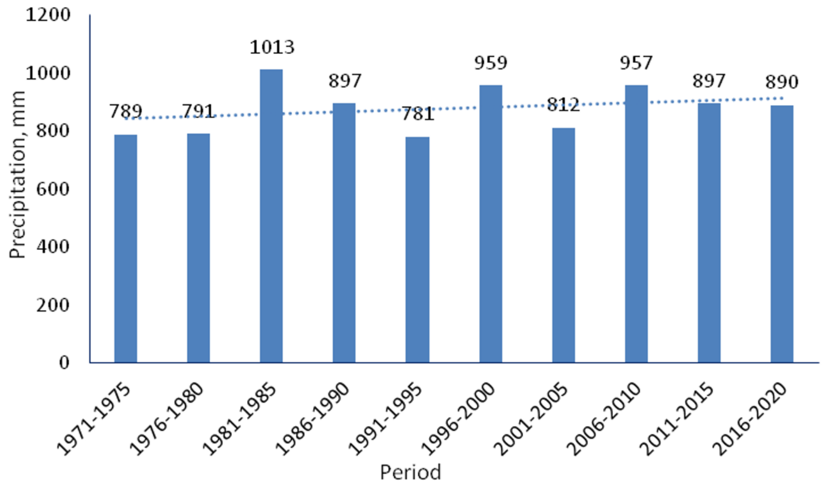

Fig. 2. Dynamics of precipitation changes for the period from 1971 to 2020.

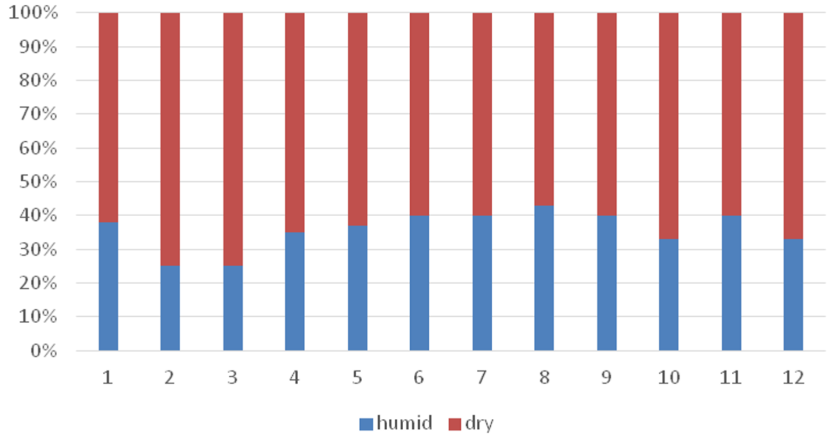

Fig. 3. Precipitation anomalies during the year.

Statistical analysis of long-term changes in precipitation showed that the highest values of the standard deviation (δ, mm) were observed in the last decade and amounted to 287 mm. The lowest coefficient of variation W (10%) is typical for the 1971–2020 period, and the highest – for 2018 (97%) (Table 1). Comparative analysis of the annual variability in 2006 and 2004 showed that the variability increased from 65% to 97%.

Table 1. Statistical analysis of precipitation changes.

Period	M, mm	W, %	δ, mm
Year	84	50	42
1971–2020	866	10	83
2010–2020	742	39	287

The extreme years for the last 20 years in terms of precipitation are 2006 (1,178 mm) and 2004 (540 mm) (Table 2).

Table 2. Changes in precipitation in extreme years (2006, 2004).

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
2004	17	4	54	29	69	5	51	-	176	51	57	28
2006	28	36	2	10	159	78	48	160	28	236	248	146

The number of days with precipitation (Figure 4) gradually increased, from a minimum number of 39 days (1970) to 150 (2007). Since 1977, the number of days with precipitation exceeded 100 days per year and did not fall below during the period under review. The minimum number of days was in 1998 (108 days) and 2019 (111 days).

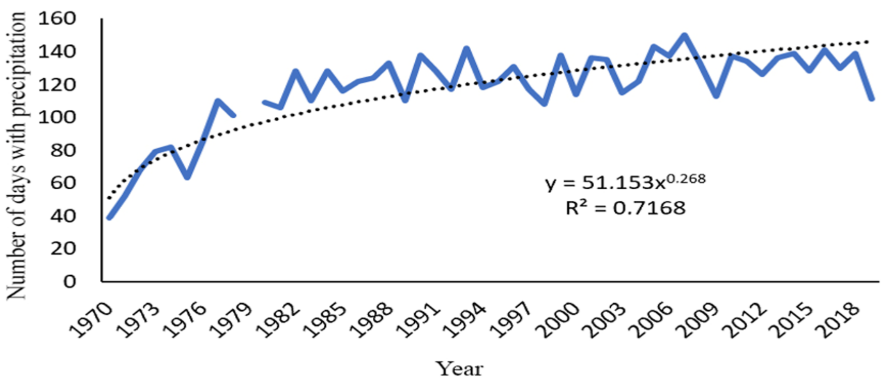

Fig. 4. Change in the number of days with precipitation.

The average amount of precipitation over five-year periods also shows a steady increase (Figure 5). The maximum values of days with precipitation fall on the 2006–2010 period.

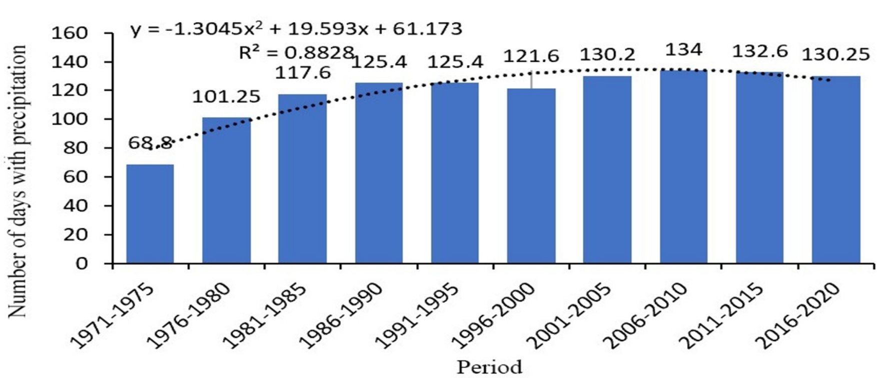

Fig. 5. Number of days with precipitation.

The moisture balance is calculated by the difference between the received precipitation and evaporation and shows the heterogeneity of the humidification conditions of the territory when the maximum moisture deficit falls on the period from February to April. During this period, there is little precipitation at high values of evaporation. The minimum moisture balance deficit occurs in June. Within three months, the city's moisture balance is positive (May, September, October). The annual moisture balance was -653 mm. The territory is experiencing a lack of moisture.

Cuba belongs to the Caribbean region, which receives less precipitation compared to the southern and western regions of the basin [6-7]. Analysis of changes for precipitation over the period from 1900 to 2015 shows a slight decrease in precipitation. However, the research notes that the trend is not statistically significant [8-9]. It is noted that periods of drought are distinguished for the entire Caribbean Sea basin, which partially coincides with studies in the province of Holguin [10-18]. For example, such periods were 1974–1977, 1997–1998, 2009–2010, and 2013–2016.

The analysis of precipitation changes at the Holguin weather station for the period from 1970 to 2020 showed a high degree of their change, but there is no unambiguous trend. There is a peak of precipitation, followed by a 5–10-year decline, followed by an increase in precipitation again. In the second half of the 20th century, there was a tendency to increase the amount of daily precipitation, which is especially evident when considering five-year periods. Similar trends are evident not only in the Caribbean countries but also in the steppe regions of southern Russia [19-20].

4 Conclusion

Climate change is a global phenomenon that requires careful monitoring and assessment of its impact on ecosystems. Based on the data collected by the Holguin weather station for the period from 1970 to 2020, there was a significant increase in the number of days with precipitation. The territory is experiencing a lack of moisture. The maximum moisture deficit falls in the period from February to April, and the minimum – in June. The annual moisture balance was -653 mm. The wettest and driest periods were identified, with the wettest being from 1981 to 1985 and the driest being from 1991 to 1995. The average rainfall for the wettest period was 1316 mm, while the average rainfall for the driest period was 335mm. There was an increase in the number of days with precipitation from 39 days (1970) to 150 (2007). Despite the fact that there have been no significant changes in the overall precipitation structure, there have been changes in both the amount and intensity of dangerous weather events. The practical significance of the work lies in identifying and developing long-term weather forecasts and planning the economic and recreational development of the territory. These changes will be further explored in future studies.

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