



## **Climate Change Indicators for the Caribbean Region: General Trends in Temperature and Precipitation (1900–2009)**

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### **Author's contribution**

*The sole author designed, analyzed, interpreted and prepared the manuscript.*

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### **ABSTRACT**

It is important to evaluate how the climate has varied and changed in the past. Mean historical temperature and precipitation data can be mapped to show the baseline climate and seasonality by month for specific years. The information presented shows mean historical monthly temperature and precipitation data from 1900 to 2009 for the countries that comprise the Wider Caribbean Region. Average temperatures in the region ranged from 20 to 26.6°C. The mean historical monthly temperatures over a period of 19 years (1990 to 2009) indicated an increase in average temperatures for all of the countries studied. On average, rainfall increased in the region over the last 20 years of the study period. An increase in both the dry and rainy seasons was also observed; since most of the increase occurred during the dry season, this suggests the possibility of a shift in rain patterns. These trends will assist in the interpretation of climate change and the occurrence of global warming in the region.

**Keywords:** *Climate change; Caribbean region; temperature trend; rainfall trend.*

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## **1. INTRODUCTION**

The year 2007 was of particular importance for the science of climate change with the IPCC [1] producing irrefutable evidence of climate change due to human activity that put an end to debates on the scientific credibility of global warming. The fourth IPCC report reveals consistent trends indicating that the world's climate is shifting [2] towards increased warming; this will have profound consequences for both the global climate and human beings [2,3].

Scientists have long said that global warming is bound to interfere with snow and rainfall patterns because air and sea temperatures and sea-level atmospheric pressure — the forces underlying these patterns — are already changing [4]. Computer models have been used to demonstrate such changes, but direct observations are needed to validate the computer models. It is generally assumed that the surfaces of Earth's oceans will warm rather evenly in the tropics. This assumption has led regional rainfall projections to indicate an increase in precipitation in both the rainy season and the dry season [5,6].

Global warming's effect on rainfall in general is relatively well understood: as carbon dioxide and other greenhouse gases enter the atmosphere, they increase the temperature, which in turn leads to increases in the amount of water vapor in the atmosphere. When storm systems develop, the increased humidity prompts heavier rain events that become more extreme as the climate warms.

Due to the rising temperatures, the Caribbean is also facing a great threat from worsening drought conditions, especially in the summer. This has led to water shortages on several islands. Rising sea levels have also resulted in the increased salinity of coastal aquifers, which has reduced the availability of fresh water accessed through wells and springs. Moreover, the coastal mangroves and wetlands that protect the coastlines of many Caribbean islands from storms and floods are receding as sea water levels rise. This poses a growing threat to the vital infrastructure, settlements and facilities on the islands.

The amount of annual precipitation in the Wider Caribbean Region varies considerably, not only from country to country, but also within countries. Mountainous islands generally receive more

precipitation than flat islands, while the non-island countries of Central and South America receive even less.

For the purposes of this study, the Wider Caribbean Region is considered to comprise the countries that are found in the tropics, generally between latitudes 11 and 18 degrees north, from Suriname in the south to The Bahamas in the north. The region generally consists of island states, the countries of Central America that border the Caribbean Sea, and the Caribbean Sea borders of Colombia, Venezuela, Guyana and Suriname, which are situated on the South American continent (Fig. 1). The topography is generally rugged and mountainous, with small areas of flat land in coastal areas. Several islands are volcanic in origin, while others are comprised primarily of coral.

The region is facing a state of increased vulnerability due to climate change. Increasing temperatures, sea levels and hurricane intensity threaten lives, property and livelihoods throughout the region. Local rainforests, mangroves and beaches, important to tourists and residents alike, are extremely vulnerable to climate change. Most of the population lives in or near coastal zones, and most economic activity is found there as well, including most hotels, hospitals and electric power plants.

Temperatures and rainfall patterns are controlled by the trade winds that mostly blow from the east. Rainfall tends to be evenly distributed throughout the year but doubles between May and October, which, unfortunately, coincides with hurricane season, as falls from November to April, with the driest period occurring between January and April. Because of its latitudinal position, the region belongs to the tropical summer rainfall zone, according to Flohn's [7] genetic classification of climatic types. This zone is characterized by the dominance, according to season, of either the equatorial westerly winds bringing summer rain, or the tropical trade winds from the east. An analysis of data from the late 1950s to 2000 has shown that the number of very warm days and nights in the Caribbean are increasing dramatically while the number of very cool days and nights are decreasing, as is the extreme inter-annual temperature range [8].

The aim of this study is to determine whether the climate has varied in the Wider Caribbean Area by comparing the temperature and rainfall patterns for the years 1900 to 2009, and to



Fig. 1. Caribbean region

reveal if this can be related to climate change patterns observed in other parts of the world. The following article will present a comparison of temperature and precipitation data for selected countries of the Wider Caribbean Region.

## 2. MATERIALS AND METHODS

Average temperature data were obtained from the World Bank Group – Climate Change Knowledge Portal [9]. In order to determine if average temperatures had increased over time, the average annual temperatures were divided into two groups. The first group covered the period 1900–1989 and the second group covered the period 1990–2009. The two groups' averages were statistically compared. The test of significances for two unknown means and unknown standard deviations, known as the t-test, was used to compare the two averages.

## 3. RESULTS AND DISCUSSION

A summary of the average monthly temperatures, average maximum temperatures and average minimum temperatures for the Wider Caribbean Region countries for the period 1900–1989 is shown in Table 1 and the

averages for the period 1990–2009 are shown in Table 2.

A summary of the average differences in temperature from 1900–1989 and 1990–2009 is shown in Table 3.

The average temperature increase among all the countries studied between the periods of 1900–1989 and 1990–2009 was 0.90°C. The biggest increase was observed in Guatemala (3.4°C) and the smallest increase was observed in Trinidad and Tobago (0.1°C). In order to determine whether a gradual temperature increase took place over the last 110 years, we performed a t-test for the average annual temperatures. With the exception of Cuba and Trinidad and Tobago and Belize, showed statistically significant differences in their average annual temperatures at the 90% confidence interval, and all the countries, with the exception of Cuba, Trinidad and Tobago and Belize, showed statistically significant differences in their average annual temperatures at the 95% confidence interval. This finding aligns with observations made in other parts of the world and reflects climate change trends.

**Table 1. Average temperatures of the wider caribbean region countries (1900–1989)**

<b>Country</b>	<b>Belize</b>	<b>Jamaica</b>	<b>Haiti</b>	<b>Santo domingo</b>	<b>US V.I.</b>	<b>Cuba</b>
Avg. Temp. °C	25.0	24.7	24.2	23.5	25.1	25.1
Avg. Max. Temp. °C	25.8	25.5	25.1	24.6	26.2	25.7
Avg. Min. Temp. °C	24.1	24.0	23.3	22.6	24.3	24.2
Standard Deviation	0.32	0.29	0.41	0.45	0.49	0.27
% RSD	1.28	1.17	1.69	1.91	1.95	1.08
<b>Country</b>	<b>Surinam</b>	<b>Martinique</b>	<b>Guadalupe</b>	<b>Trinidad tobago</b>	<b>Bahamas</b>	
Avg. Temp. °C	25.6	24.1	24.3	26.0	24.4	
Avg. Max. Temp. °C	26.6	25.5	25.7	27.5	25.2	
Avg. Min. Temp. °C	24.9	23.6	23.8	25.4	23.5	
Standard Deviation	0.31	0.40	0.41	0.36	0.38	
% RSD	1.21	1.66	1.69	1.38	1.56	
<b>Country</b>	<b>Barbados</b>	<b>Grenada</b>	<b>Guatemala</b>	<b>Honduras</b>	<b>Nicaragua</b>	
Avg. Temp. °C	25.9	26.5	23.1	23.3	24.6	
Avg. Max. Temp. °C	26.6	27.7	23.8	24.2	25.4	
Avg. Min. Temp. °C	25.5	25.9	22.2	22.4	23.8	
Standard Deviation	0.26	0.34	0.29	0.36	0.33	
% RSD	1.00	1.28	1.26	1.54	1.34	
<b>Country</b>	<b>Costa Rica</b>	<b>Panama</b>	<b>Colombia</b>	<b>Venezuela</b>	<b>Guyana</b>	<b>Puerto rico</b>
Avg. Temp. °C	24.4	25.2	24.3	25.3	25.6	24.6
Avg. Max. Temp. °C	25.4	26.1	25.1	26.2	26.6	
Avg. Min. Temp. °C	22.9	24.0	23.8	24.7	25.0	23.8
Standard Deviation	0.28	0.31	0.24	0.29	0.30	0.50
% RSD	1.15	1.23	0.99	1.15	1.17	2.03

**Table 2. Average temperatures of the wider Caribbean Region countries (1990–2009)**

<b>Country</b>	<b>Belize</b>	<b>Jamaica</b>	<b>Haiti</b>	<b>Santo domingo</b>	<b>US V.I.</b>	<b>Cuba</b>
Avg. Temp. °C	25.7	25.6	25.3	24.9	26.1	25.7
Avg. Max. Temp. °C	27.7	27.1	26.9	26.5	27.7	28.0
Avg. Min. Temp. °C	23.1	23.8	23.2	22.7	24.3	22.9
Standard Deviation	1.62	1.12	1.37	1.36	1.28	1.91
% RSD	6.29	4.36	5.43	5.45	4.86	7.43
<b>Country</b>	<b>Surinam</b>	<b>Martinique</b>	<b>Guadalupe</b>	<b>Trinidad tobago</b>	<b>Bahamas</b>	
Avg. Temp. °C	26.0	26.6	25.7	26.1	25.6	
Avg. Max. Temp. °C	27.1	27.6	27.1	27.0	28.5	
Avg. Min. Temp. °C	24.5	24.9	23.4	24.8	22.8	
Standard Deviation	0.697	0.971	1.29	0.74	2.37	
% RSD	2.68	3.66	5.04	2.83	9.24	
<b>Country</b>	<b>Barbados</b>	<b>Grenada</b>	<b>Guatemala</b>	<b>Honduras</b>	<b>Nicaragua</b>	
Avg. Temp. °C	26.6	27.1	26.6	24.4	25.6	
Avg. Max. Temp. °C	27.9	28	28.1	25.9	26.8	
Avg. Min. Temp. °C	24.7	25.6	24.3	22.4	24.2	
Standard Deviation	0.90	0.86	1.50	1.20	0.90	
% RSD	3.39	3.17	5.63	4.93	3.50	
<b>Country</b>	<b>Costa rica</b>	<b>Panama</b>	<b>Colombia</b>	<b>Venezuela</b>	<b>Guyana</b>	<b>Puerto rico</b>
Avg. Temp. °C	25.5	25.6	24.8	25.8	26.0	25.4
Avg. Max. Temp. °C	26.8	26.5	25.4	26.5	27.0	27.0
Avg. Min. Temp. °C	24.3	24.7	24.1	25	25.3	23.3
Standard Deviation	0.783	0.571	0.401	0.448	0.522	1.35
% RSD	3.07	2.23	1.62	1.74	2.01	5.34

A summary of the total rainfall in selected countries of the Wider Caribbean Region in 1900–2009 is shown in Table 4. In addition, a ratio of rainy season to dry season was calculated: the rainy season comprises May to October and the dry season covers November to April. In order to better visualize rainfall pattern changes, total rainfall values from 1990 to 2009 are shown in Table 5. Tables 6 and 7 summarize

the rainfall differences between 1900-1989 and 1990-2009.

When compared to the average rainfall in the period 1900–2009, the average rainfall experienced in most of the countries in this region increased over the last 20 years under examination (1990–2009). The average increase was 3.22 inches for the region, with a slight

**Table 3. Average temperature differences from 1900–1989<sup>a</sup> and 1990–2009<sup>b</sup>**

Country	Belize	Jamaica	Haiti	Santo domingo	US V.I.	Cuba
Avg. Temp. °C <sup>b</sup>	25.7	25.6	25.3	24.9	26.1	25.7
Avg. Temp. °C <sup>a</sup>	25.0	24.7	24.2	23.5	25.1	25.1
ΔT, °C	0.7	0.9	1.1	1.5	1.0	0.6
Country	Martinique	Guadalupe	Trinidad & tobago	Bahamas	Surinam	
Avg. Temp. °C <sup>b</sup>	26.6	25.7	26.1	25.6	26.0	
Avg. Temp. °C <sup>a</sup>	24.1	24.3	26.0	24.4	25.6	
ΔT, °C	2.5	1.4	0.1	1.2	0.4	
Country	Barbados	Grenada	Guatemala	Honduras	Nicaragua	
Avg. Temp. °C <sup>b</sup>	26.6	27.1	26.6	24.4	25.6	
Avg. Temp. °C <sup>a</sup>	25.9	26.5	23.1	23.3	24.6	
ΔT, °C	0.7	0.6	3.4	1.1	1.0	
Country	Costa rica	Panama	Colombia	Venezuela	Guyana	Puerto rico
Avg. Temp. °C <sup>b</sup>	25.5	25.6	24.8	25.8	26.0	25.4
Avg. Temp. °C <sup>a</sup>	24.4	25.2	24.3	25.3	25.6	24.6
ΔT, °C	1.1	0.4	0.5	0.5	0.4	0.8

**Table 4. Total rainfall (inches) for the wider caribbean region countries (1900–2009)**

Country	Total rainfall	May-Oct. rainfall	Nov.-April rainfall	Ratio <sup>a</sup>
Belize	77.52	56.84	20.68	2.75
Jamaica	82.36	51.60	30.76	1.68
Haiti	58.91	41.00	17.91	2.29
Sto. Domingo	56.24	36.03	20.21	1.78
US VI	85.06	51.64	33.42	1.55
Cuba	51.70	40.02	11.68	3.43
Martinique	99.57	60.44	39.13	1.54
Guadalupe	116.98	65.94	51.03	1.29
Trinidad & Tobago	70.62	46.71	23.91	1.95
Bahamas	48.63	33.03	15.9	2.12
Barbados	82.09	49.81	32.28	1.54
Grenada	58.83	39.61	19.23	2.06
Guatemala	96.14	59.32	37.09	1.60
Honduras	77.90	58.83	19.07	3.08
Nicaragua	124.22	83.66	40.56	2.06
Costa Rica	101.03	68.87	32.16	2.14
Panama	101.93	69.58	32.34	2.15
Colombia	102.09	62.03	40.06	1.55
Venezuela	74.79	55.42	19.37	2.86
Guyana	90.52	53.13	37.38	1.42
Surinam	91.19	47.04	44.15	1.07
Puerto Rico	80.81	50.98	29.84	1.71

<sup>a</sup> May–Oct. Rainfall/Nov. –April Rainfall

rainfall increase during the dry season over the rainy season. This increase in rainfall is in agreement with computer models for the region that indicate an increase in rainy season precipitation as well as an increase in precipitation in the dry season. The increase in rainfall and the shift in rain patterns are also consistent with global warming patterns observed in other parts of the world.

**Table 5. Total rainfall (inches) for the wider Caribbean Region countries (1990–2009)**

Country	Total rainfall	May-Oct. rainfall	Nov.-April rainfall	Ratio <sup>a</sup>
Belize	84.18	53.67	30.51	1.76
Jamaica	89.67	52.72	36.94	1.43
Haiti	63.61	42.04	21.27	1.98
Sto. Domingo	58.84	36.09	22.75	1.59
US VI	82.44	47.48	34.96	1.36
Cuba	53.39	40.58	12.81	3.17
Martinique	101.22	60.43	40.79	1.48
Guadalupe	120.10	73.14	46.96	1.56
Trinidad & Tobago	75.89	47.37	28.53	1.66
Bahamas	45.73	30.29	15.44	1.96
Barbados	88.60	53.54	35.06	1.52
Grenada	60.41	40.31	20.09	2.01
Guatemala	94.58	58.02	36.56	1.59
Honduras	78.81	58.94	19.87	2.97
Nicaragua	93.99	70.25	23.74	2.96
Costa Rica	117.78	82.52	35.23	2.34
Panama	110.07	74.74	35.33	2.12
Colombia	105.5	63.33	42.17	1.50
Venezuela	77.46	57.63	19.83	2.91
Guyana	94.18	55.76	38.42	1.45
Surinam	92.18	47.19	44.98	1.05
Puerto Rico	80.09	49.15	30.94	1.59

<sup>a</sup> May–Oct. Rainfall/Nov.–April Rainfall

**Table 6. Total rainfall (inches) differences for the wider caribbean region countries (1990–2009) and (1900–2009)**

Country	Δ Total rainfall	Δ May-Oct. rainfall	Δ Nov.-April rainfall	Ratio <sup>b</sup>
Belize	6.66	-3.17	9.83	0.64
Jamaica	7.31	0.12	6.18	0.85
Haiti	4.70	1.04	3.36	0.87
Sto. Domingo	2.60	0.06	2.54	0.89
US VI	- 2.62	- 4.16	1.54	0.88
Cuba	1.69	0.56	1.13	0.92
Martinique	1.65	- 0.01	1.66	0.95
Guadalupe	3.12	7.20	- 4.07	1.21
Trinidad & Tobago	5.27	0.66	4.62	0.85
Bahamas	-2.90	- 2.74	- 0.46	0.92
Barbados	6.51	3.72	2.78	0.99
Grenada	1.58	0.70	0.86	0.98
Guatemala	-1.66	-1.30	- 0.53	0.99
Honduras	0.91	0.11	0.80	0.96
Nicaragua	1.12	0.17	0.95	0.96
Costa Rica	16.75	13.65	3.07	1.09
Panama	8.14	5.16	2.99	0.99
Colombia	3.41	1.30	2.11	0.97
Venezuela	2.67	2.21	0.46	1.02
Guyana	3.66	2.59	1.04	1.02
Surinam	0.99	0.15	0.83	0.98
Puerto Rico	-0.72	-1.83	1.10	0.93

<sup>b</sup> May–Oct. Rainfall/Nov.–April Rainfall: 1990–2009; May–Oct. Rainfall/Nov.–April Rainfall:1900–2009

**Table 7. Summary of the total rainfall (inches) differences for the wider Caribbean Region countries (1990–2009) and (1900–2009)**

Country summary	Δ Total Rainfall	Δ May-Oct. Rainfall	Δ Nov.-April Rainfall	Ratio <sup>b</sup>
Average	3.22	1.19	1.95	0.95
Std. Deviation	4.29	3.80	2.67	0.11
% RSD	133	319	137	11.2
Maximum	16.75	13.65	9.83	1.21
Minimum	-2.9	-4.16	-4.07	0.64

#### 4. CONCLUSION

Average surface temperature data for several Wider Caribbean Region countries showed an increase in their 1990–2009 averages when compared to their 1900–1989 averages. This increase in temperature is an effect of global warming that is evident not only in this region, but also in other parts of the world.

Average rainfall data for several Wider Caribbean Region countries showed an increase between the 1900–2009 averages and the 1990–2009 averages. This increase was observed in both the rainy season and the dry season for this area of the world. The 61% increase in the average amount of precipitation during the dry season is an indication that a shift in the region's rain pattern might be occurring. The increase in rainfall and the shift in rainfall patterns is an effect of global warming that is evident not only in this region, but also in other parts of the world.

#### COMPETING INTERESTS

Author has declared that no competing interests exist.

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