

CLIMATE CHANGE INDICATORS FOR THE CARIBBEAN REGION. GENERAL TRENDS IN TEMPERATURE AND PRECIPITATION (1900 – 2009)

Abstract

It is important to evaluate how climate has varied and changed in the past. The 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 from 1900 to 2009 for countries that comprise the Wider Caribbean Region. Average temperature in the region ranged from 20 to 26.6°C. Mean historical monthly temperature from the last 19 years (1990 to 2009) has shown an increase in the average temperatures for all of the countries studied. On the average, rainfall has increased for the region during the last thirty years of this period. An increase in both the dry and rainy seasons was observed with most of the increase occurring during the dry season suggesting the possibility of a shift in the rain patterns. These trends will assist in the interpretation of climate change and the occurrence of global warming in the region.

Key Word:- Climate change; Caribbean region; temperature trend; rainfall trend

Introduction

The year of 2007 was of particular importance for the science of climate change, with the work done by IPCC¹ producing irrefutable evidence of climate change due to human activities, and putting an end to arguments on the scientific credibility surrounding global warming. The fourth IPCC Report reveals consistent trends of how the world's climate is evolving² towards increased warming with profound consequences for the global climate and, therefore, for human beings [6, 7].

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 underlying forces behind these patterns - are already changing [8]. 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 that regional rainfall projections indicate that an increase in rainy season as well as an increase in the dry season [9, 10].

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 the rising drought conditions, especially in the summers. This has led to water shortage on several islands. The rising of ocean water level has also resulted in the increase in salinity of coastal aquifers, reducing the availability

¹ The World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) in 1988. It is open to all member states of the UN and WMO. The role of the IPCC is to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options of adaptation and mitigation.

² The IPCC 4th Assessment Report (AR4) consists of four volumes released in the course of 2007. Compared to the 2001 report, the AR4 pays greater attention to the integration of climate change with sustainable development and the inter-relationships between mitigation and adaptation. Specific attention is given to regional issues, uncertainty & risk, technology, climate change & water. The Report consists of four sections namely: "The Physical Science Basis", "Impacts, Adaptation and Vulnerability", "Mitigation of Climate Change", and a summary report. <http://www.ipcc.ch/press/factsheet.htm>.

of fresh water through wells and springs. Also, the coastal mangroves and wetlands, which protect the coastlines of many Caribbean Islands from storms and floods, are disappearing by the rising sea water level. This poses an increasing 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 in the same country. Mountainous islands generally receive more precipitation than flat islands; the non-island countries of Central and South America region receive even less.

For the purpose of this study, the Wider Caribbean Region comprises the countries that are 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 border of Colombia, Venezuela, Guyana and Suriname, situated on the South American continent (Figure 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.



Figure 1. Caribbean Region

The region is in a state of increased vulnerability due to climate change. Higher temperatures, rises in sea level, and increased hurricane intensity threaten lives, property and livelihoods throughout the region. Area 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 are located there as well, including most hotels, hospitals, and electric power plants.

Temperatures and rainfall patterns are controlled by the trade winds, which blow mostly from the East. Rainfall tends to be evenly distributed throughout the year, but doubles during the months from May to October, which, unfortunately, coincides with hurricane season, as falls from November to April, with a driest period from January to April. Because of their latitudinal position the Region belongs to the Tropical

summer rainfall zone, according to Flohn's³ 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 is increasing dramatically and very cool days and nights are decreasing, while the extreme inter-annual temperature range is also decreasing⁴.

The following article ⁵ will present a comparison of temperature and precipitation data for selected countries of the Wider Caribbean Region.

Results and Discussion

Average temperatures data were obtained from The World Bank Group – Climate Change Knowledge Portal⁵. In order to determine if averages temperatures had increased with time, the average annual temperatures were divided into two groups. The first group covers the period from 1900 to 1989 and the second group covers the period from 1990 to 2009. The two group 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. A summary of the average monthly temperature, average maximum temperature, and average minimum temperature from 1900 to 1989 for the Wider Caribbean Region is shown in Table 1. In order to better visualize temperature changes, average monthly temperatures, average maximum temperature, and average minimum temperature from 1990 to 2009 are shown in Table 2.

Table 1. Average Temperature Table for the Wider Caribbean Region Countries (1900 – 1989)

Country	Belize	Jamaica	Haiti	Santo Domingo	US V.I.	Cuba
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

³ Flohn, H. (1950). Neue Anschauungen über die allgemeine Zirkulation der Atmosphäre und ihre klimatische Bedeutung; *Erkunde*, Vol. 4, p. 141 – 162.

⁴ UNEP (United Nations Environment Programme), 2008. *Climate Change in the Caribbean and the Challenge of Adaptation*. UNEP Regional Office for Latin America and the Caribbean, Panama City, Panama. Printed in Panama City, in October 2008.

⁵ The Climate Change Knowledge Portal - http://sdwebx.worldbank.org/climateportal/index.cfm?page=country_historical_climate&ThisRegion=LatinAmerica

⁶ Peterson, T. C., et al., (2002) Recent changes in climate extremes in the Caribbean region, *J. Geophys. Res.*, 107(D21), 4601, doi:[10.1029/2002JD002251](https://doi.org/10.1029/2002JD002251).

⁷ Alexander, L. V., et al. (2006), Global observed changes in daily climate extremes of temperature and precipitation, *J. Geophys. Res.*, 111, D05109, doi:[10.1029/2005JD006290](https://doi.org/10.1029/2005JD006290).

⁸ Frich, P., et al., (2002), Observed coherent changes in climatic extremes during the second half of the twentieth century, *Clim Res.*, Vol. 19: 193–212,

⁹ Hijmans, R. J., Cameron, S. E., Parra, J. L., Jones, P. G. and Jarvis, A. (2005), Very high resolution interpolated climate surfaces for global land areas. *Int. J. Climatol.*, 25: 1965–1978. doi:10.1002/joc.1276

¹⁰ Zhang, X., et al. (2005), Trends in Middle East climate extreme indices from 1950 to 2003, *J. Geophys. Res.*, 110, D22104, doi:[10.1029/2005JD006181](https://doi.org/10.1029/2005JD006181).

Country	Surinam	Martinique	Guadalupe	Trinidad Tobago	Bahamas	
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	
Country	Barbados	Grenada	Guatemala	Honduras	Nicaragua	
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	
Country	Costa Rica	Panama	Colombia	Venezuela	Guyana	Puerto Rico
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	25.9
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 Temperature Table for the Wider Caribbean Region Countries (1990 – 2009)

Country	Belize	Jamaica	Haiti	Santo Domingo	US V.I.	Cuba
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
Country	Surinam	Martinique	Guadalupe	Trinidad Tobago	Bahamas	
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	
Country	Barbados	Grenada	Guatemala	Honduras	Nicaragua	
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	

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Country	Costa Rica	Panama	Colombia	Venezuela	Guyana	Puerto Rico
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 average temperature difference from between 1900 to 1989 and 1990 to 2009 is shown in Table 3.

Table 3. Average temperature difference from between 1900 to 1989^a and 1990 to 2009^b

Country	Belize	Jamaica	Haiti	Santo Domingo	US V.I.	Cuba
Avg. Temp. °C ^b	25.7	25.6	25.3	24.9	26.1	25.7
Avg. Temp. °C ^a	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 ^b	26.6	25.7	26.1	25.6	26.0	
Avg. Temp. °C ^a	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 ^b	26.6	27.1	26.6	24.4	25.6	
Avg. Temp. °C ^a	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 ^b	25.5	25.6	24.8	25.8	26.0	25.4
Avg. Temp. °C ^a	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

The average temperature increase among all the countries studied between the periods of 1990 to 2009 and 1900 to 1989 was 0.90°C. The maximum increase was observed for the Guatemala, 3.4°C and the minimum increase was 0.1°C for Trinidad and Tobago. In order to determine if a gradual temperature increase occurred in the last one hundred and ten years we performed a t-test for the averages annual temperatures. With the exception of Cuba and Trinidad and Tobago, all the other countries showed a statistically significance differences in the annual averages temperatures at the 90% confidence interval and all the countries except Cuba, Trinidad and Tobago, and Belize at the 95 % confidence interval. This is in agreement with observations in other parts of the World and an indication of the climatic change trend.

A summary of the total rainfall from 1900 to 2009 for selected countries of the Wider Caribbean Region is shown in Table 4. In addition a ratio of rainy season/dry season was calculated; rainy season comprises the months of May to October and dry season are in the months of November to April. In order to better visualize rainfall pattern changes, total rainfall from 1990 to 2009 are shown in Table 5.

Table 4. Total Rainfall (inches) for the Wider Caribbean Region Countries (1900 – 2009)

Country	Total Rainfall	May-Oct. Rainfall	Nov.-April Rainfall	Ratio ^a
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

^a May-Oct. Rainfall/ Nov.-April Rainfall

Table 5. Total Rainfall (inches) for the Wider Caribbean Region Countries (1990 – 2009)

Country	Total Rainfall	May-Oct. Rainfall	Nov.-April Rainfall	Ratio ^a
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
Guadelupe	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

^a 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 ^b
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
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

^b (May-Oct. Rainfall/ Nov.-April Rainfall)₁₉₉₀₋₂₀₀₉/(May-Oct. Rainfall/ Nov.-April Rainfall)₁₉₀₀₋₂₀₀₉

The average rainfall increases in most of the countries for the last 30 years period of 1990 to 2009 when compared to the period of 1900 to 2009. The average increase was 3.22 inches for the region with a slight 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 as well as an increase in the dry season. The increase in rainfall and the shift in the rain patterns are also consistent with global warming patterns observed in other parts of the world.

Conclusion

Average surface temperature data for several Wider Caribbean countries showed an increase between the 1990 to 2009 average compared to the 1900 to 1989 average. The increase in temperature is an effect of global warming that is evident for this region of the world as well as for other parts of the world.

Average rainfall data for several Wider Caribbean countries showed an increase between the 1900 to 2009 average and the 1990 to 2009 average. The increase was observed in both the rainy season and the dry season. The 61 % increase in the average precipitation of the dry season is an indication that a

204 shift of the rain pattern for the region might be occurring. The increase in rainfall and the shift in rainfall
205 patterns is an effect of global warming that is evident for this region of the world as well as for other parts
206 of the world.