Characteristics of Heat Index Extreme Events in Mesoamerica and Caribbean Region

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Introduction

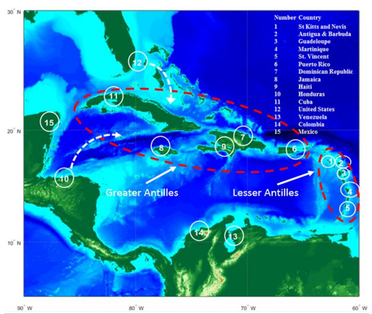
A Heat Index Extreme Event (HIEE) is a persistent period of excessively hot weather event and varies according to the climate characteristic of each region. Thus, a HIEE is been characterized for having a significant temperature deviation from the normal climate conditions of a given region. The Heat Index are attributed to increments in air temperature and high relative humidity. In several countries, the extreme events mostly occur during summer and typically correspond to the rainfall season, where high temperature and relative humidity are combined in such a way the rainfall is suppressed creating high pressure with extreme hot weather. It has been documented that extreme heat events put a lot of stress on the human body and can lead to serious health conditions such as heat exhaustion, heat stroke, or death from hyperthermia, agricultural devastation, and significant consumption of energy due to increased use of air conditioning.

Estimation of Heat Index

There are several methods to estimate heat index. In this work we adopted the NWS approach, described in Anderson et al. (2013). They analyzed whether each algorithm produced heat index values consistent with Steadman's original apparent temperature (Steadman 1979) and found that the algorithms were inconsistent across studies. They concluded that the NWS algorithm provides reproducible and consistent environmental results. In the MAC region few estimates of heat index fall outside of the expected domain derived by Steadman (1979) and in those cases the heat index values were adjusted to the maximum values derived by the NWS (NOAA/NWS, 2016).

Heat Index Extreme Event (HIEE)

An extreme heat event is usually based only on daily maximum air temperature above a certain value that persisted for several days. However, the maximum air temperature does not account for the human perception temperature, and some human stresses derived from both temperature and humidity is missing. Thus, for places with high values of relative humidity, a more accurate definition of extreme heat events should be based on the heat index, which is the combination of air temperature and relative humidity. This is especially important when weather conditions contribute to prolonged thermal perception from the daytime to nighttime and maintain this extreme hot event for several days.



Data Sets

Thirty five years (1980-2014) of hourly data from 15 ground stations were used to perform heat wave analyses. The Global Historical Climatology Network (GHCN), the Cooperative Observed Network (COOP Network) and other sources for weather station data are included in a single place called the National Center for Environmental Information (NCEI, 2016). Data extracted from ground stations were used to study the characteristics and frequency of the extreme heat events in the MAC region. Ground station data recorded the real and inherent behavior of the atmosphere and reveals the actual climate variability.

Definition of a HIEE in the MAC region

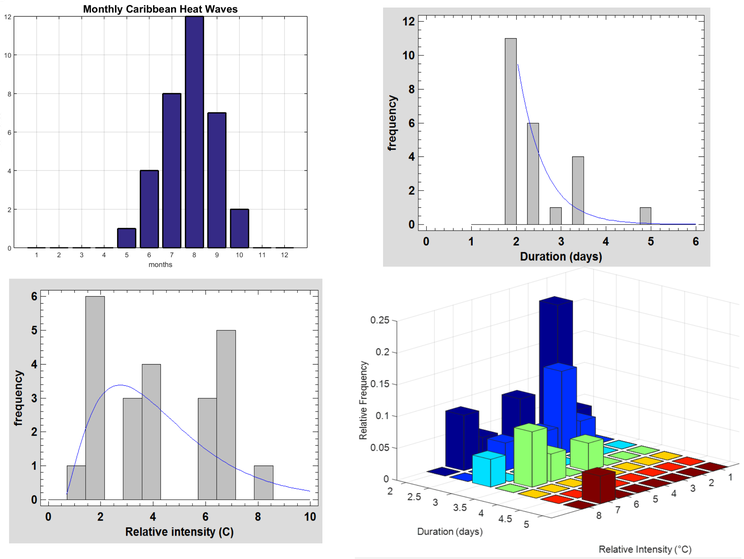
This work focuses on understanding the extreme hot events in the MAC region (5-30 °N and 90-60 °W) and how these events have evolved throughout time. The Caribbean is divided into the Lesser and Greater Antilles islands, and Mesoamerica includes parts of Mexico, Central America and the North part of South America. The HIEE in the MAC region is defined in terms of heat index rather than pure air temperature because most of the year there are high values of air temperature and relative humidity at the surface. HIEE definition must include observations of the hot behavior during day and night times. This is a critical weather conditions since there are events with many consecutives days in which the maximum daytime heat index exceeds the threshold percentile in the MAC region. Therefore, the HIEE in the MAC region is defined as an extraordinary hot event that the maximum-daytime heat index and the minimum-nighttime heat index both exceed the corresponding 98th percentiles and this hot event must persist for at least during 2 consecutive days.

	Lesser Antilles Islands		Greater Antilles Islands		Mesoamerica	
98th percentile for the minimum heat index	32 °C	90 °F	29 °C	84 °F	30 °C	86 °F
98th percentile for the maximum heat index	42 °C	108°F	44 °C	111 °F	50 °C	122 °F

Thresholds for 98th percentile for a station located in the MAC region.

Results

The results extreme heat events are organized into three parts: The first part presents a procedure to estimate the 98th percentile for station. The second part describes the characterization of extreme heat index events based on duration and intensity; i.e., bivariate and marginal probability distributions are analyzed. The seasonal variations of extreme heat events are analyzed and the definition of extreme heat wave and the accumulated heat wave intensity are introduced in this part. The third part presents the analysis of annual frequency of extreme heat events as a potential response of the global climate change.



Figures shows Inter annual variability of extreme heat events based on 98 percentile, Distributions of heat wave duration and relative intensity and Bivariate probability distribution of duration and relative intensity of a heat index extreme events.

Characteristics of HIEE

The major characteristics of the extreme heat events are the duration and the intensity, and are the parameters that determine the severity of the hot events. Since the intensity depends on the local climate characteristics of the station a relative intensity is used in the analysis, instead of absolute intensity. The strength of hot events can be derived using the combination of intensity and duration of the hot events. Due to the fact that the intensity of a heat wave depends on the climate characteristics of the referring area the comparison among several extreme heat events should be performed in terms of the relative intensity. Thus, to rank the extreme heat events in terms of their strengths a single parameter must be derived based on the combination of duration and intensity, this parameter is introduced in this work and will be called the accumulated heat wave intensity (AHWI). This parameter takes into accounts both duration and intensity to accurately measure the strength of a heat wave, and is defined as follows:

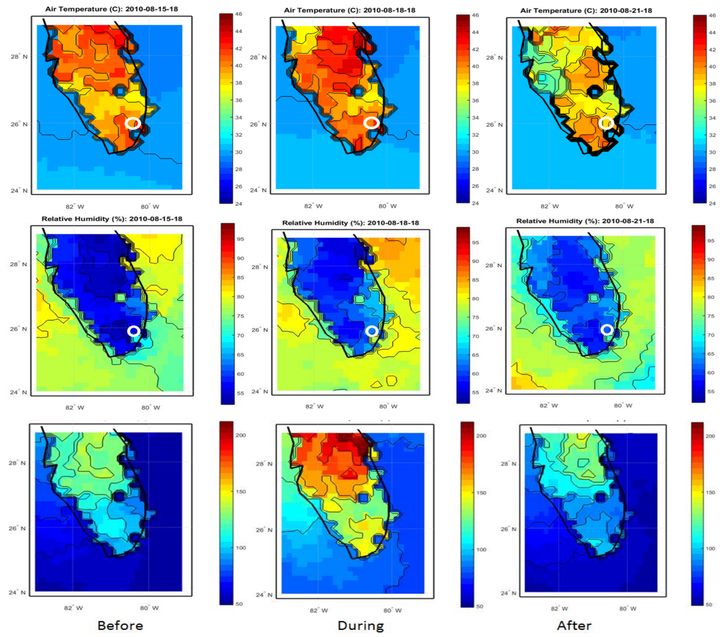
$$AHWI_j = \sum_{t=1}^{n} H_{i,j,t} - P_{98,j,t}$$

where $H_{i,j,t}$ is the heat index observed at hour t, and at the j^{th} geographical location; $P_{98,j,t}$ is the 98th percentile at hour t and computed at the j^{th} geographical location, and n is the duration of the heat wave expressed in hours.

HIEE rank	Station Number	Station and Country	Starting Date	Duration (days)	Accumulated HW Intensity (C)
1	14	Ernesto Cortissoz, Colombia	23-Oct-03	3	32
2	2	V.C. Bird, Antigua & Barbuda	16-Jul-95	5	26
3	2	V.C. Bird, Antigua & Barbuda	11-Aug-98	3.5	24
4	2	V.C. Bird, Antigua & Barbuda	8-Aug-95	3.5	23
5	10	Goloson, Honduras	7-Jun-95	2	18
6	11	Jose Marti, Cuba	1-Jul-92	2	18
7	2	V.C. Bird, Antigua & Barbuda	28-Jul-98	3.5	17
8	2	V.C. Bird, Antigua & Barbuda	13-Sep-98	3.5	17
9	1	Robert L. Bradshaw, St. Kitts and Nevis	6-Sep-05	2.5	16
10	14	Ernesto Cortissoz, Colombia	17-Oct-03	2	12

Ranking of the extreme heat events in terms of accumulated heat wave intensity.

To understand the behavior of the atmospheric variables during heat wave episodes it may be useful to observe the variables before, during and after the event. To perform this analysis the NARR data can be used as a potential source of information. The nearest grid to a given station was selected to compare observations versus reanalysis data of the following variables: relative humidity, and air temperature.



Figures show the air temperature, the relative humidity and Accumulated heat wave intensity. Images in the left, middle and right show the behavior of the variables before, during, and after the heat wave that occurred in the Miami station in August 17, 2010.

Summary

In this work , HIEE in the MAC region is defined as an extraordinary hot event that the maximum daytime heat index and the minimum nighttime head index both exceed the corresponding 98th percentiles for at least during 2 consecutive days. The thresholds for the minimum and the maximum heat index for the Lesser Antilles Islands are 32 ℃ and 42 ℃; for the Greater Antilles Islands are 29 ℃ and 44 ℃; and for Mesoamerica are 30 ℃ and 50 ℃, respectively.

A bivariate probability distribution of duration and relative intensity, and the corresponding marginal distributions, as well as the conditional probability distribution were developed. These distributions were used to derive practical applications. It was found the average duration was 2.57 days and standard deviation of 0.76 days. The maximum value of relative intensity during heat waves shows an average of 4.3 °C and standard deviation of 2.16 °C; where, relative intensity is the excess of heat index over the maximum threshold. It was found that 78% of heat waves last equal or less than 3 days, and 60% exhibit a relative intensity equal or fewer 4 °C.

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