Analysis of Heat Index and Heat Waves over the Caribbean

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The heat index is defined as the combination of air temperature and relative humidity in an attempt to determine the human-perceived equivalent temperature. In the current work we want to describe and analyze the heat index patterns, and trends, as well as the extreme variability of the heat waves in the Caribbean basin. Thirty one years of daily data from 1980 to 2010 were used to conduct heat index and heat waves analyses. The National Centers for Environmental Prediction (NCEP) Reanalysis data were used first to combine surface temperature with relative humidity to estimate heat index for the Caribbean. The NCEP data are given at every six hour a day; however, since this study focuses in heat index and extreme events only the surface temperature and relative humidity that occurred at 1800 UTC were used. The study area includes from 0^0 N to 30^0 N and -100^0 W to -60^0 W, and correspond to (13x18) 234 grids and each grid is 2.5 by 2.5 degrees. The heat wave in this work was defined as an extreme hot event with heat index equal or greater than the 99.5 percentile, and this extreme hot event must persist for at least two consecutive days. Caribbean exhibits 5 different patterns of heat index climatology, and one of them includes most the Grater Antilles, reveling unimodal climatology with annual mean and standard deviation of 82.7^0 F, 5.7^0 F, respectively. Puerto Rico and Hispaniola islands exhibit the largest and significant heat-index trend of $0.06^0\mathrm{F\,year^{-1}}$ and $0.03^0\mathrm{F\,year^{-1}}$, respectively. Preliminary results show that most of the heat waves over the Caribbean occurred in the following years: 1983, 1998, 2005 and 2010. Part of this ongoing research includes determining the impacts of the heat index and heat waves over the main Caribbean islands.

Temperature human perception does not depend on temperature alone it depends on the combination of temperature and relative humidity, and especially when both variables exhibit high values. . Thus, the heat index (HI) is combination of air temperature and relative humidity in an attempt to determine the human-perceived equivalent temperature. The National Oceanic and Atmospheric Administration/National Weather Service (NOAA/NWS) [http://www.srh.noaa.gov/ama/?n=heatindex. Jan 2015] defines the HI as the temperature feels like to the human body when relative humidity is combined with temperature. When HI index is 103^0 F or greater is dangerous and can cause heat cramps or heat exhaustion likely, and heat stroke with prolonged exposure and/or physical activity.

The main purpose of this work is to describe and analyze patterns, trends, and extreme variability of the heat index in the Caribbean basin.

Thirty one years of daily data from (1980 to 2010) were used to conduct HI analysis. The NCEP Reanalysis data are used first to combine surface temperature with relative humidity to estimate heat index for the Caribbean. Daily observation at 1800 UTC of surface temperature and relative humidity were used to derive climatology of HI and identify the most intense heat waves over the Caribbean islands. The study area includes from 0^0 N to 30^0 N and -100^0 W to -60^0 W, and correspond to (13x18) 234 grids and each grid is 2.5 by 2.5 degrees.

Ground data from weather stations were also collected from the great Antillean islands during the period of 1980 to 2014. Information from stations reveal some challenges; some data exhibit a shift over some particular time revealing change of instrument and in other cases present a change on location, or both, change in instrument and in location. Thus, in such cases the most recent data it is assumed to contain the most reliable information and a shit on the mean was imposed to mitigate the instrument change effects. Some stations also exhibit some missing data, and those case only the available information was considered to compute climatology and heat wave events. For instance, Puerto Rico has 20 active weather stations that contain some daily data during the studied period; however, there is only five stations that exhibited sufficient air and dew point temperatures over the studied 31-year period to properly conduct statistical analysis.

The climatology of HI for the 234 Caribbean grids and based on NCEP data are shown in Figure 1. This information considered all together may conduct to derive an incomplete analysis. Figure 1 exhibits large variability and a single climatological pattern for all grids may not properly revels the HI Caribbean behavior. For instance, during summer there is about 25^0 F of range variability and during winter increases to about 40^0 F. In addition there are some climatology grids that exhibit unimodal and others bimodal behavior. Thus, climatology patterns should be organized into homogenous climatology patterns to perform insightful analyses. There are several methods to conduct group classification. However, the group classification method are heavily depending on the number of the discriminant variables. In our case there is a large number of discriminant variables (365). Thus, one of the efficient methods that can handle a large number of discriminant variables is the Artificial Neural Network. Thus, in order to conduct a feasible and reliable analysis of the HI patterns the self-organized artificial neural network (ANN) was used. The self-organized ANN is a combination of mathematical and statistical tools to organize climatology patterns into groups that resemble similar patterns, and we call homogenous regions. The self-organized ANN reveals that the climatology index can be better organized into 5 climatological patterns and correspond to 5 different geographical regions. One of the limitations of this method is the assigned grids to a given homogenous group may vary in every run. To ensure consistency on results it is required to increase the training samples. Figure 2 shows the climatology zones and Figure 3 shows the homogenous climatological patterns.

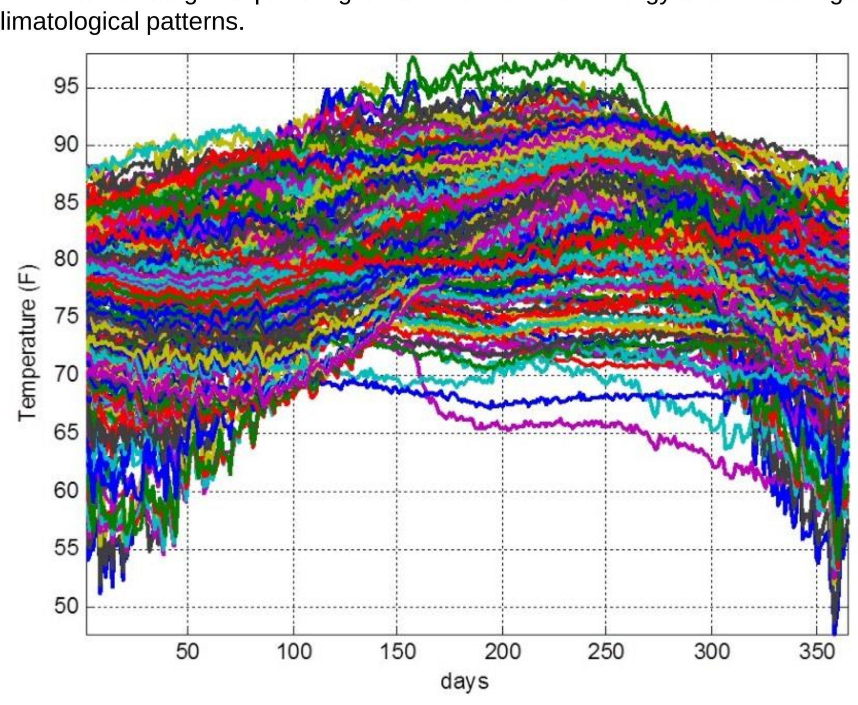


Figure 1. Climatology of HI for each Caribbean grid (1980-2010). The geographical region is (0-30 N, and 60-100 W) and includes 13x18=234 grids

The Caribbean exhibits five typical patterns of HI climatology as was mentioned before and the behavior of each regions can be characterized by computing the variables of central tendency, and variables of dispersion. Zone 1 that includes 48 grid shows a bimodal pattern

Zone	Sample size	HI Average (F)	HI Standard Deviation (F)	HI Median (F)	HI Maximum (F)	HI Minimum (F)	HI Range (F)
1	48	86.59	3.66	86.75	97.63	75.90	21.72
2	60	81.34	2.79	81.05	90.51	72.76	17.75
3	40	77.27	9.02	76.04	95.42	47.67	47.75
4	60	82.73	5.73	82.29	98.00	66.00	31.99
5	26	74.18	4.08	74.24	83.59	58.19	25.39

Table 1. Statistical description of the HI index climatological zones

The colors given in Figures 2 and 3 correspond to the same homogenous zone. For instance the hard blue color represents the zone 3 and located in the North of the Caribbean in Figure 2 and the hard blue unimodal pattern with the largest variability in Figure 3.

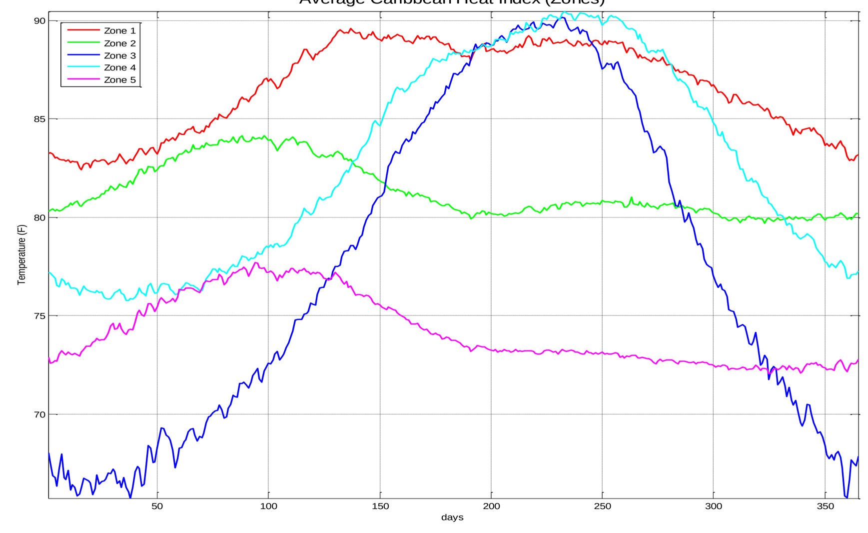


Figure 2. Five climatological patterns of Daily HI over the Caribbean (1980-2010).

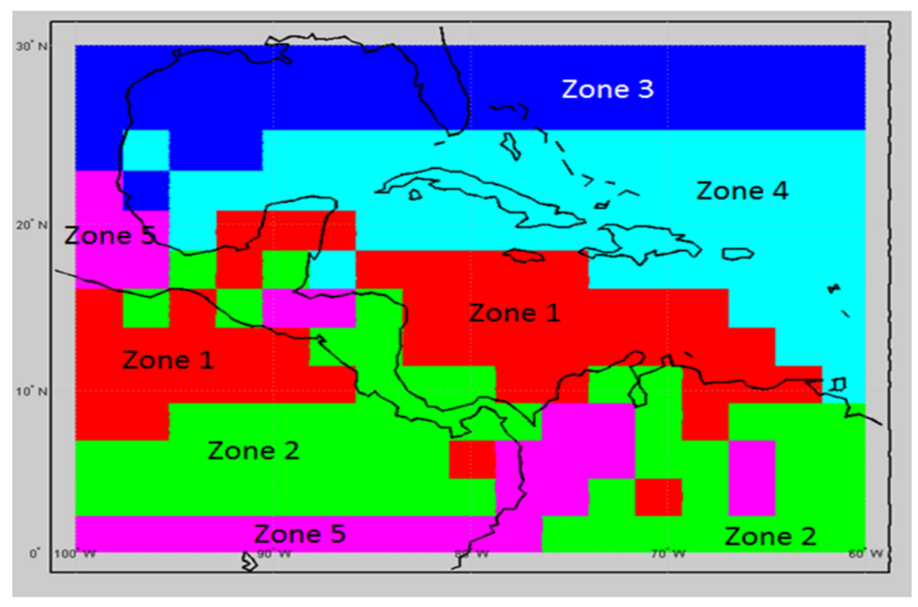


Figure 3. Homogenous zones based on HI climatology (1980-2010).

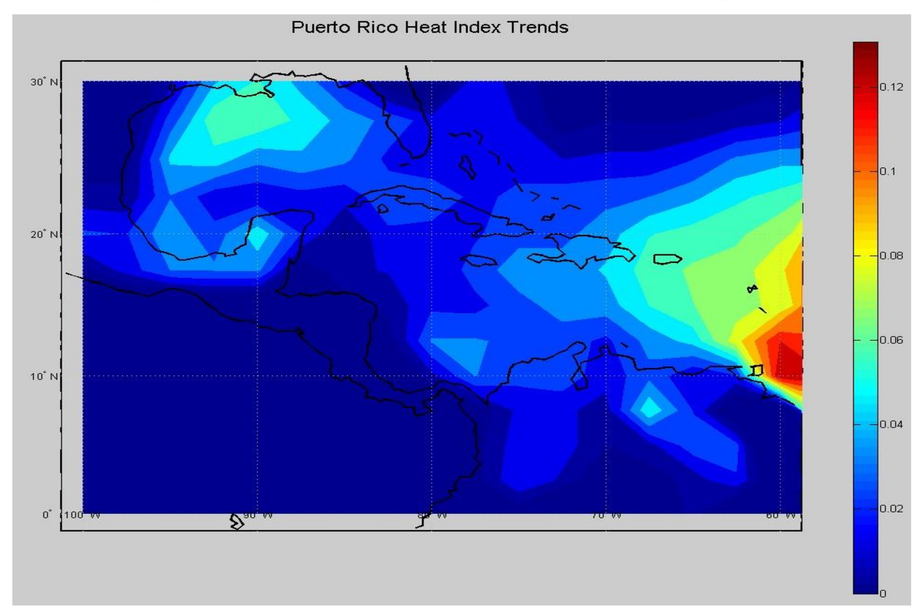


Figure 4. Trend of heat index

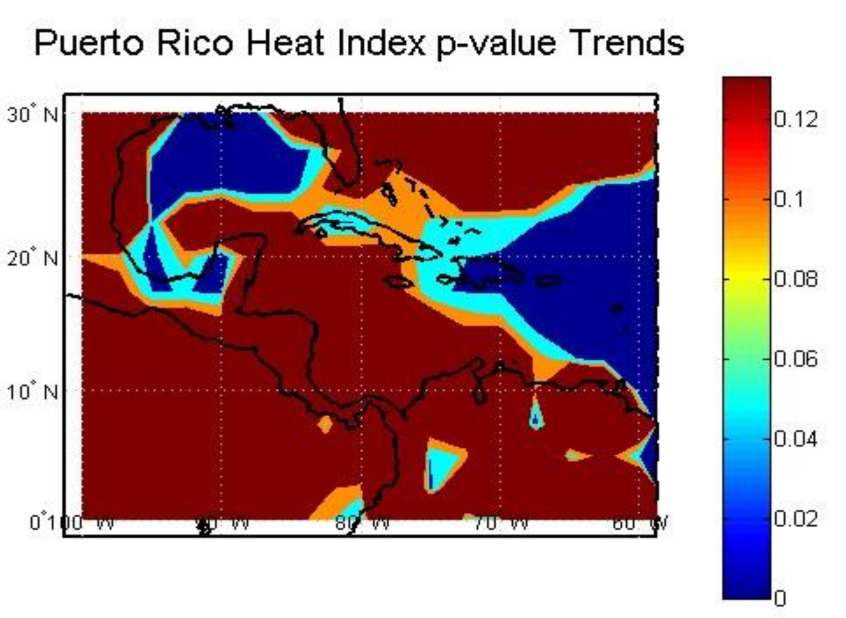
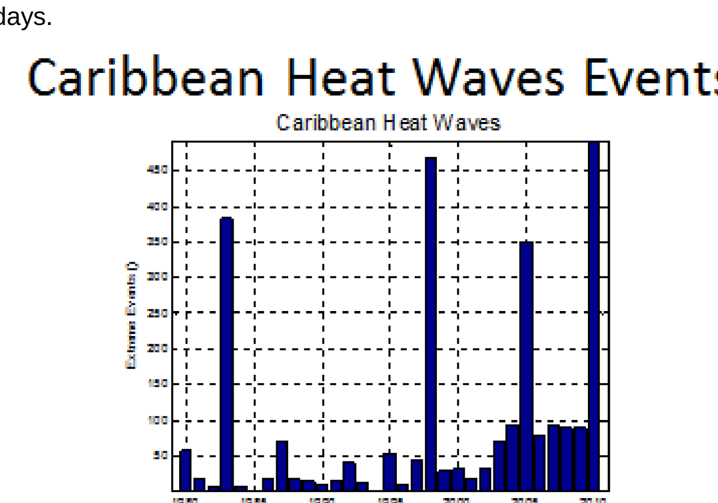


Figure 5. Significance of the trends

A heat wave is a prolonged period of excessively hot weather, which may be accompanied by high humidity, especially in oceanic climate countries. The term is applied both to routine weather variations and to extraordinary spells of heat which may occur only once a century. Severe heat waves have caused catastrophic crop failures, thousands of deaths from hyperthermia, and widespread power outages due to increased use of air conditioning. Pointed out that in the last decade major heat waves have seriously impacted several places around the world . In addition to their economic impacts, these severe events had extraordinary consequences on agriculture and human health. Thus, it is natural to ask whether heat waves during the last three decades over the Caribbean have increased in frequency, intensity, or duration.

There are several definitions of heat waves, but all include some notion of persistent extremely high temperatures. The heat wave in this work was defined as extreme hot event with HI equal or greater than the 99.5 percentile, and this extreme hot event persists for more than two consecutive days.



Extreme Year	Total Events
2010	492
1998	461
1983	383
2005	351

Figure 6: Caribbean heat waves events

With the five zones delimited on the Caribbean further studies where developed to study the heat index and heat waves behavior, in the figure 6 the number of annual heat waves per zone will be observed:

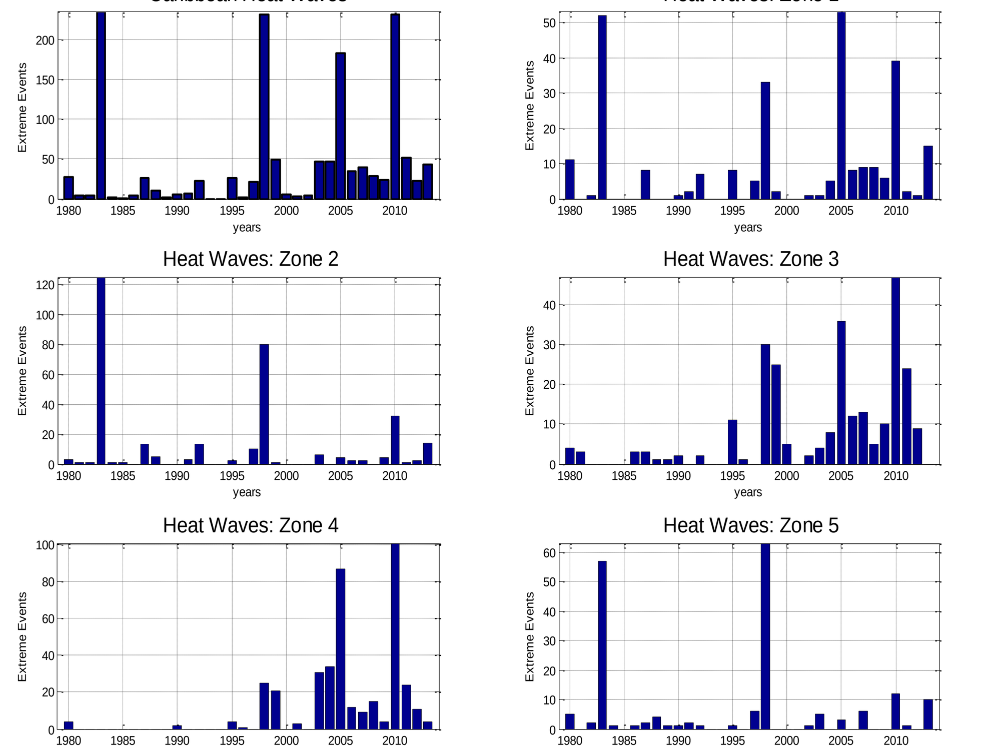


Figure 7: Heat waves per zone

Data from some specific stations over the caribbean area, presented in figure 8 and table 2, were extracted and divided in groups, heat wave events were calculated and a brief sumary of the results are presented on table 2:

Groups	Country	Station	95% Percentile Maximum Temperature	95% Percentile Heat Index	95% Percentile Maximum Temperature at least 2 or more days	Duration Average	Heat Wave Events	Duration Average
1	St Kitts and Nevis	Robert L. Bradshaw	88	106	2271	5.3	397	2.9
1	Antigua & Barbuda	V.C. Bird	89	105	405	3.6	370	3.9
1	Guadeloupe	Le Raizet	90	107	1838	3.9	456	2.9
1	Martinique	Le Lamentin	90	107	743	3.6	346	3
1	St. Vincent	E.T. Joshua	88	106	2380	4.8	320	2.9
2	Puerto Rico	San Juan Intl	91	108	507	2.9	394	3.2
2	Dominican Republic	Cibao Intl	93	109	587	3.5	300	2.9
2	Jamaica	Sangster Intl	90	112	1865	4.5	518	3.8
2	Haiti	Toussaint Louverture Intl	95	112	764	3.4	288	3.5
2	Honduras	Goloson Intl.	90	109	1173	3.4	474	3
2	Cuba	Jose Marti	91	109	920	3.3	413	3.1
2	United States	Miami Intl	92	108	462	3.4	442	3.2
3	Venezuela	La Chinita Intl.	97	120	598	2.9	237	2.6
3	Colombia	Ernesto Cortissoz	94	118	257	2.6	324	2.8
3	Mexico	Valladolid	95	120	516	3.3	449	4.3
	Group 1	Lesser Antilles	89	106	7637	4.2	1889	3.1
	Group 2	Greater Antilles	92	110	6278	3.5	2829	3.2
	Group 3	Continental	95	119	1371	2.9	1010	3.2

Extreme HI	Extreme Duration 95 Percentile
125	7
111	6.6
116	7
130	7

Extreme HI	Extreme Duration 99.5 Percentile
132	15.5
116	14.8
119	14.1
134	18.9

Table 2: station names and important results.

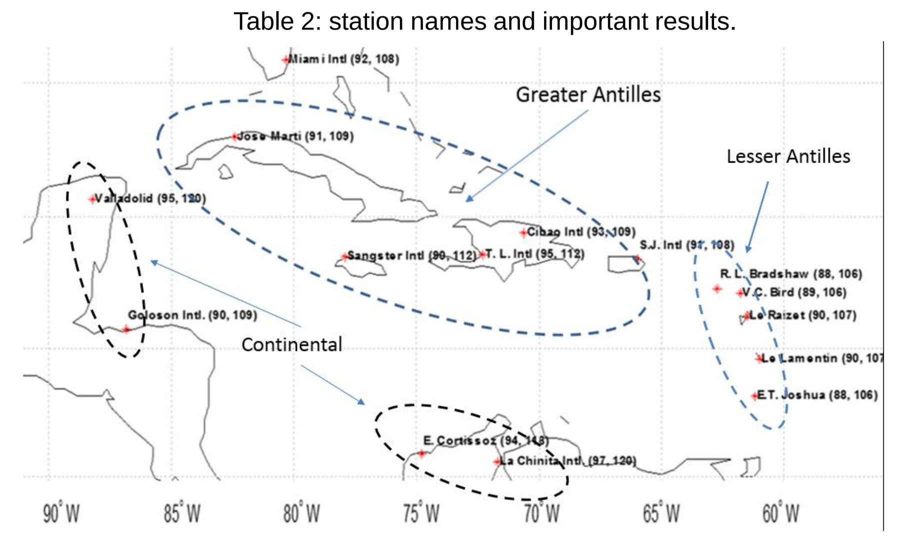
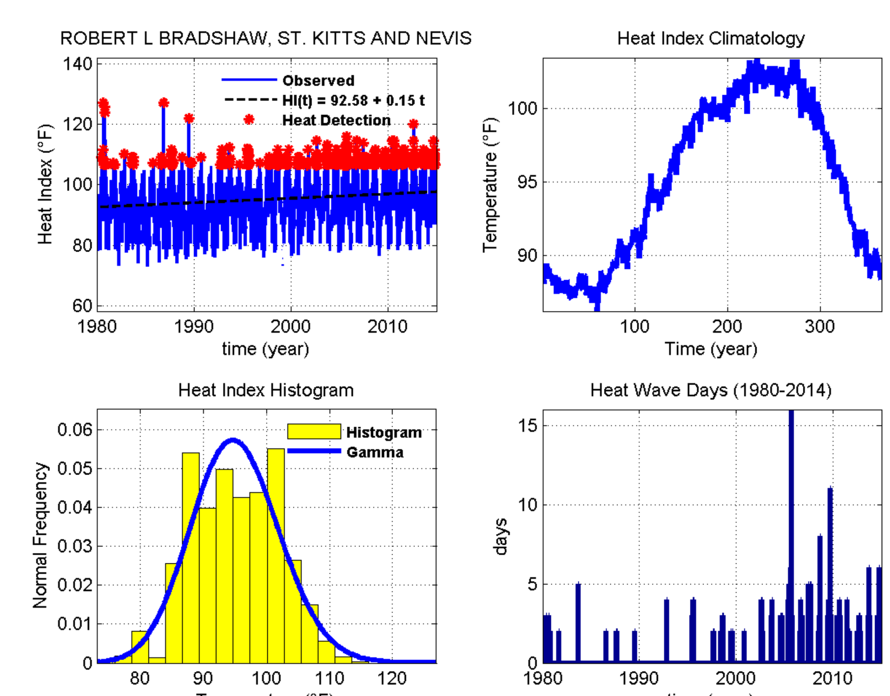
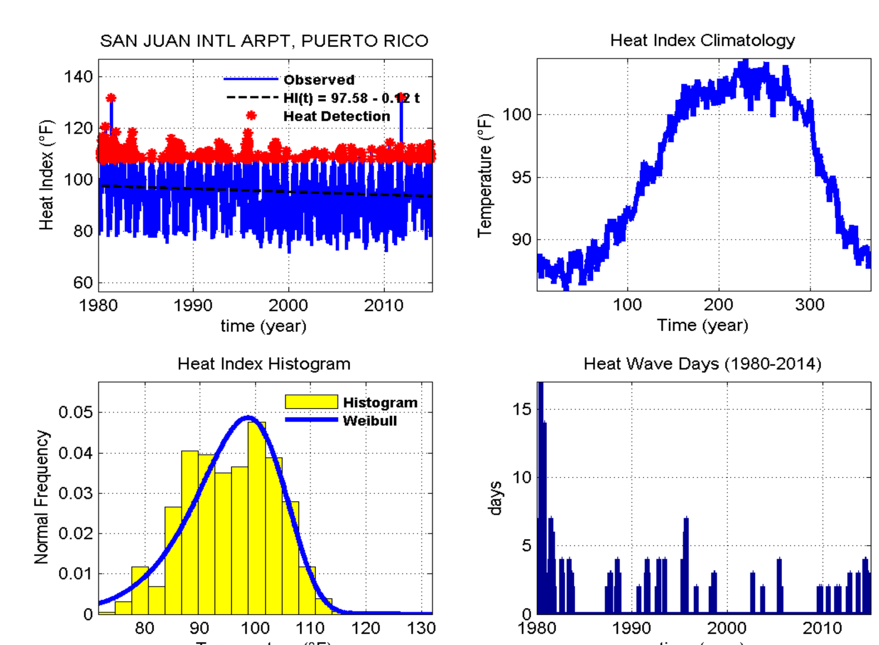
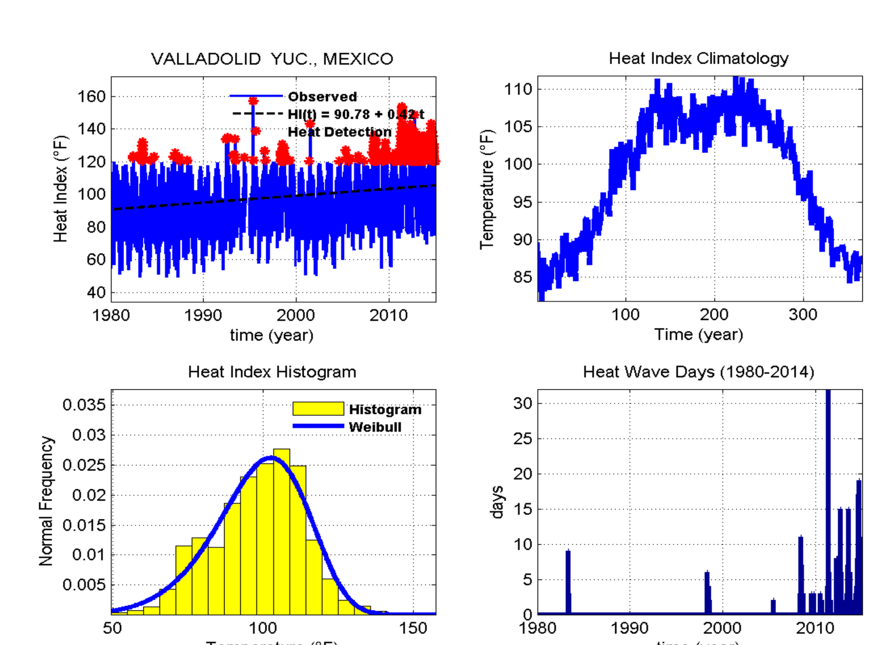


Figure 8. Threshold of air temperature, and heat index by station (95 percentile)

Information of heat index yearly distribution and climatology developed, considering the daily maximum temperature, for one specific station per group are presented in the following figures:







Literature review:

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•Peng, G., J. Li, Y. Chen, A.P. Norizan, L. Tay. High-resolution surface relative humidity computation using MODIS Image in Peninsular Malaysia. Chinese Geographical Science 2006 16(3) 260-264.
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