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Proceeding Paper

Variability of the North Atlantic Subtropical High in the year's wet season and its relationship with the tropical cyclonic activity †

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Abstract: The variability of North Atlantic Subtropical High and its inlfuence on the behavior of tropical cyclogenesis are charactized and analized. The database of the Center for Environmental Prediction and the Center for Atmospheric Research was consulted, for the months of May to October between 1950-2019. The variables used were the central pressure to determine the position of the North Atlantic Subtropical High on surface, and the geopotential to obtain the position of the anticyclonic center at 850 hPa, as well as the geopotential at 500 and 200 hPa over the región of the anticyclone on surface. This system weakens at surface level and intensifies at other tropospheric levels. The relationship with tropical cyclone activity in the Atlantic basin was assured and updated. Low levels playa n important role in tropical cyclogenesis, the position and extension of the anticyclonic ridge at this level, the parameters with highest coincidence, and in the present century the anticyclone parameters in the months of June and July have increased their significance.

Keywords: North Atlantic Subtropical High,Tropical Cyclone Activity Seasonal Forecast; Climate Variability

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1. Introduction.

In Cuba, the state of the weather is conditioned by North Atlantic Subtropical High (NASH) geographical location in the tropical zone and by his seasonal changes in the position and intensity. Several authors suggest the increase in the influence anticyclonic over Cuba, which has contributed to the increase of the subsidence over the region and to inhibit the mechanisms that produce precipitation, mainly during the rainy season, when vast regions of the country are affected by drought processes.

Cuba is one of the countries hardest hit in the Caribbean by tropical cyclones that form in the Atlantic basin every year. In this sense [1, 2],have show that the behavior of the NASH in the moths preceddings the hurricane season influences the number of Hurricanes that originate and intensify in the Caribbean Sea.

It is necessary to update the study by [2] because it don't work because the changes in the general circulation of the atmosphere. In addition, it does necessary include other months to have the significance of months closest to the hurricane season forecast update.

2. Materials and Methods

2.1. Selection of the Study Area

The selected area includes a large part of the North Atlantic Ocean between 10-60°N and 10-110°W because it allows observe the North Atlantic Subtropical Anticyclone in its entirety and the extensión of its dorsal. This domain also covers areas of the Gulf of Mexico and the Caribbean Sea due to that 67% of the tropical cyclones that affect Cuba in the period 1890-1991 were develop in the Caribbean Sea and the rest comes mostly from the Atlantic Ocean[1].

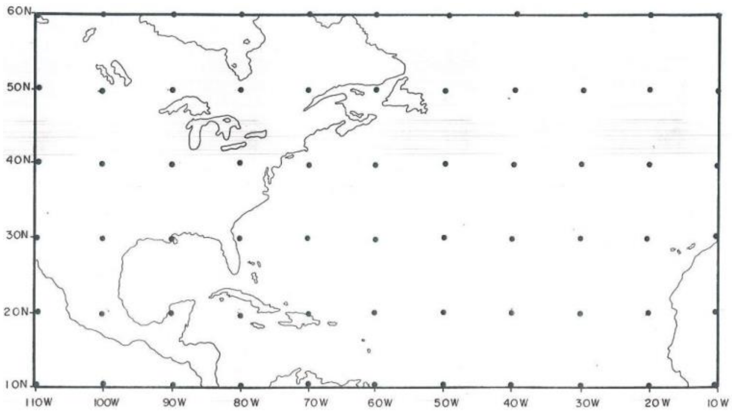


Figure 1. Region of study.

2.2. Data Collection in the Study Area

The monthly database of the National Center for Environmental Prediction and National Center for Atmospheric Research (NCEP/NCAR) was consulted on the website http://www.psl.noaa.gov/ (accessed on June 21, 2022) for the period between the months of May to October, between the years 1950-2019 (70 years) with a resolution of 2.5 degrees. The rainy season of the year was selected for this study because, in addition to the preparation of the hurricane season forecast update in the Atlantic basin issued by the Institute of Meteorology of the Republic of Cuba, the conditions are taken into account of the atmospheric and oceanic circulation prior to the period of maximum activity and are used for the seasonal prediction of cyclonic activity in the North Atlantic. The study period covers 1950-2019 [3]. The data of the tropical cyclones used were extracted from the Atlantic Hurricane Database known as HURDAT2. It was also consulted in parallel the official chronology of the Cuban Institute of Meteorology www.insmet.cu. The data used in the research were manually estimated.

2.3. Data Processing

Pressure and mean monthly position of the NASH at surface level(Prs): The mean monthly pressure was determined from the mean sea level taking into account the pressure value of the closest closed isobar to the center that coincides with the highest pressure value in the oceanic area of the Atlantic. The mean position was also considered as the latitude and longitude at which the center of this system was found.

Geopotential (gth850) and position of the anticyclonic center at 850 hPa (Lat8 and Lon8): Reasoning equivalent to that used to determine the geopotential height and the position of the anticyclonic center on the surface was used. *Position of the anticyclonic ridge at 850 hPa (LatRid8 and LonRid8)* ridge is considered as a reference up to the value of the length of the closed isohypse of 1560 mgP in the wet season [4].

Subtropical high's central intensity (SHCI): The geographical area in which the strength is determined, unlike the zone used by [5] in the rainy season restricts it as the zone framed by 30-38 °N and 28- 45 °W, position consistent with the mean position of the North Atlantic Subtropical High during the months of May to October in the eastern Atlantic .

Geopotential at 500 and 200 hPa over the central region of the NASH: The mean position of the North Atlantic Subtropical Anticyclone on the surface was taken during the rainy period of the year. Subsequently, the geopotential height values at 500 and 200 hPa were extracted. *The Belt of high subtropical pressures in 500 hPa (La5) in* the approximate latitude over which the subtropical high pressure belt extended was determined, the high pressure strip was located. The difference between the latitude of the belt at 500 hPa and the latitude of the NASH in surface is also used (LaP).

To characterize the cyclonic activity was selected Number of tropical cyclones formed over the oceanic area of the Atlantic and the Caribbean Sea

2.4. Information Processing

After grouping the data, the statistical processing of the same was carried out, through the use of descriptive statistics in search of elements that characterized the sample. Position and dispersion measures such as the average, maximum value, minimum value and standard deviation were used.

2.4.1. Time Series Trend Analysis

The Mann-Kendall statistical test was applied to the data to determine the trend.

$$KM = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign(x_j - x_k) \quad (1)$$

Where x_1, $x_2, \dots x_n$ are the data points and j the data point at the time of KM calculation. If $x_j - x_k$is positive then KM=1 , otherwise Km=-1. The null hypothesis of no trend is rejected at the significance level a_0, if $a_1 < a_0$. Positive (negative) values of the statistician subjectively indicate an increasing (decreasing) trend in the series. For the verification of the hypotheses, a significance level $\alpha = 0.05$ was preset and they were developed using the program WinStat.exe (1997) [6].

2.4.2. Principal Components Analysis.

After the correlation, those variables of the North Atlantic Subtropical Anticyclone that presented the highest correlations with the tropical cyclonic activity were selected and was applied a Principal Components Analysis. This makes it possible to reduce the size of the number of original variables that have been considered in the analysis, losing the least amount of information possible.

3. Results.

3.1. Behavior of the Nash in the Period 1950–2019

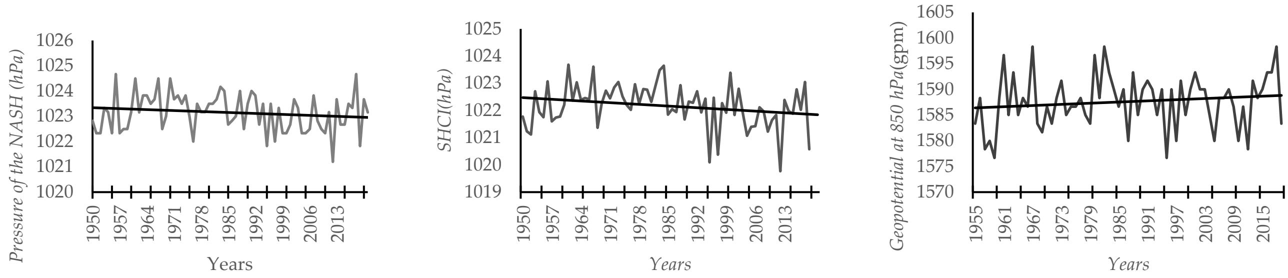
3.1.1. Pressure of the NASH at Surface Level, Geopotential of the Anticyclonic Center at 850 hPa and SHCI

The North Atlantic Subtropical High had an average central pressure of 1023.16 hPa and presented a standard deviation of ±0.82 hPa. The maximum and minimum values of the series were 1024.67 hPa in 1956 and 2018, 1021.2 hPa in 2012 (Figure 2a). In recent years, mainly in the last decade of the study period, the North Atlantic Subtropical Anticyclone experienced a decrease in the value of the central pressure, in general it is a non-significant decrease (Table 1.).

The mean value of *SHCI* was 1022.17 hPa with a standard deviation of ± 2.50 hPa. The maximum value reached corresponds to the year 1961 with 1023.68 hPa and the minimum was in 2012 with 1019.77 hPa, the latter coinciding with the year when the minimum value was obtained from the central pressure of the anticyclone at surface level (Figure 2b). The trend in the time series was decreasing but insignificant (Table 1.).

The average geopotential height over the North Atlantic Subtropical High region at the 850 hPa isobaric surface was 1587.24 mgP, a value higher than that obtained by [3] with a standard deviation of ± 21.09 mgP. The maximum value of this variable was 1598.33

mgP in the years 1967, 1982 and 2018 and the minimum of 1576.67 mgP was found in the years 1959 and 1995 (Figure 2c). The trend in the time series was increasing and significant



(a) (b) (c)

Figure 2. Average central pressure of the North Atlantic Subtropical Anticyclone at mean sea level **(a)**, SHCI **(b)** and geopotential of the anticyclonic center at 850 hPa **(c)** between the months of May to October between the years 1950-2019 (black line indicates the trend).

Table 1. Value of the Mann test statistician (KM) for the above variables.

Parameters	KM	alpha
Pressure of NASH	-1.43	0.15
SHCI	-1.67	0.09
geopotential at 850 hPa	2.20	0.02

3.1.2. Mean Monthly Position of the NASH at Surface Level and Position of the Anticyclonic Center at 850 hPa

The North Atlantic Subtropical High was located on average at 34.47 °N and 34.66 °W. The northernmost latitude was 38 °N in 1995, meanwhile, its lowest latitude was observed at 32.58 °N during the year 1997. On the other hand, its westernmost longitude was 44.41 °W in 2003, while its easternmost position was 29.3 °W in 1998. There is no significant trend for latitude and it is slightly considerable for longitude in the period 1950-2019. The Mann-Kendall test showed a tendency to increase in longitude, which makes it located more to the west and in latitude of the North Atlantic Subtropical Anticyclone, but with insignificant results.

The anticyclonic center at 850 hPa was located approximately between 32.09 °N and 42.45 °W, with a standard deviation of ±1.32 °N and ±2.88 °W. The northernmost position in the displacement of the anticyclonic center was at 35.16 °N in 2018, while in 1997, it was the southernmost displacement at 27.75 °N. Regarding the longitude to the west that it was found, it was 48.91 °W in 1959 and its southernmost displacement was 36.25 °W in 1981 (Figure 2c and Figure 2d). Latitude presented a decreasing trend, which is not significant. The length shows a decreasing trend, therefore, it has moved further east, a result that they also obtained by [3](Table 2).

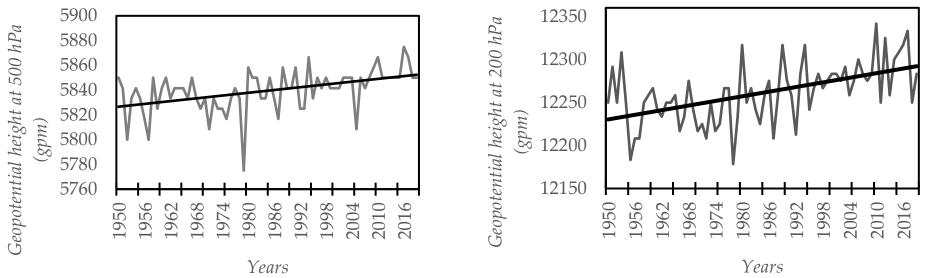
Table 2. Value of the Mann test statistician (KM) for the above variables.

DATA	Parameters	KM	alpha
NASH	Latitude	0.14	0.88
	Longitude	0.09	0.92
Anticyclonic center at 850 hPa	Latitude	-1.61	0.11
	Longitude	-0.92	0.35

3.1.3. Geopotential height in the central region of the NASH at 500 hPa and 200 hPa

The average geopotential height over the NASH region at the 500 hPa isobaric surface was 5839.40 mgP, a value that is higher than that obtained by [3], and with a standard deviation of ± 49.05 mgP. The maximum value of this variable was 5866.67 mgP in the years 1994, 2010 and 2016, while the minimum was 5783.33 mgP found in the year 1979 (Figure 3a).

The geopotential analysis in the North Atlantic Subtropical High region at 200 hPa was 12261.18 mgP with a standard deviation of ±100.40 mgP. The maximum value was 12345.83 mgP in the year 2010, while the minimum value was 12178.33 mgP in the year 1978 (Figure 3b). The both parameters of the NASH show a significant increasing trend for the time series. (Table 3.)



(a) (b)

Figure 3. Behavior of the geopotential over the central region of the North Atlantic Subtropical Anticyclone at 500 hPa **(a)** and 200 hPa **(b)**, during the months of May to October between the years 1950 and 2019 (black line indicates the trend).

Table 3. Value of the Mann test statistician (KM) for the above variables.

Parameters	KM	alpha
Geopotential height in the region of the NASH at 500 hPa	4.38	0
Geopotential height in the region of the NASH at 200 hPa.	4.72	0

3.2. Relationship of the North Atlantic Subtropical High to Tropical Cyclone Originated in the Atlantic Ocean and the Caribbean Sea

Parameters such as the strength of the surface anticyclone, the longitudinal displacement of the center of high geopotential in May and the length of the ridge at 850 hPa. In addition, the correlation with the high pressure range appears at 500 hPa. In this century there is a greater correlation with those parameters related to the position of both the surface anticyclone and the high geopotential cell at 850 hPa in the months of June and July.

Both in the global series and from 2000, the Principal Components Analysis yielded three factors, each representing 66 and 75% of the variability of tropical cyclones originating in the North Atlantic Ocean, respectively. In the case of tropical cyclones originating in the Caribbean Sea, the Principal Component Analysis yielded three and one factors each, which represent 72 and 60% of the variability of tropical cyclones originating in the Caribbean Sea, respectively.

The 850 hPa level continues to play a fundamental role in the prediction of tropical cyclogenesis in the North Atlantic basin, which in turn reaffirms what was collected in the method of [1] . The SHCI shows a high correlation with cyclonic activity, showing a similar behavior to the central pressure and allowing to describe some cyclogenesis parameters where the central pressure of the anticyclone on the surface was not present.

Cyclonic activity in the Atlantic oceanic area is perfectly described by the parameters of the North Atlantic Subtropical High in the month of May and those related to its latitudinal and longitudinal position in the months of May and July. Greater cyclogenesis is expected in the Caribbean if the North Atlantic Subtropical High on the surface moves to the eastern half of the Gulf of Mexico ,[6] , that is, if the NASH moves further west. of its average position; although it was also found that the extension of the ridge at 850 hPa can also contribute to this, coinciding with. It is necessary to highlight the increase in significance reached by the parameters of the North Atlantic Subtropical Anticyclone in the month of July during this century, an aspect that had not been reflected in previously related studies on the subject.

Table 4. Coordinated factors of the variables, based on the correlations obtained for the periods 1950-2019 and 2000-2019, referring to tropical cyclones originating in the Atlantic oceanic área (In red color the correlation coefficients appear for a significance level α<0.05).

1950-2019 period				**2000-2019 period**		
Parameters	**Factor 1**	**Factor 2**	**Factor 3**	**Parameters**	Factor 1	Factor 2
At	-0.492174	-0.636923	0.073758	At	-0.760387	-0.392238
SHCI (May)	0.123590	0.448531	0.580723	Lat (Jul)	-0.850983	0.247482
Lon8 (May)	0.265898	0.388637	0.598651	Lon (Jun)	-0.759703	-0.358299
LonRid8 (Jul)	0.158372	0.663428	0.320834	Lon(Jul)	-0.850052	0.183750
LatRid8 (Jul)	0.094338	0.423518	-0.668403	Lat8 (Jul)	-0.742565	0.402848
La5 (Jun)	-0.854525	0.267342	0.108354	Lon8 (May)	0.087394	0.936878
LaP (Jun)	-0.878148	0.203478	0.102277	Lon8 (Jul)	-0.798835	-0.307470

Table 5. Coordinated factors of the variables, based on the correlations obtained for the periods 1950-2019 and 2000-2019, referring to tropical cyclones originating in the Caibbean Sea (In red color the correlation coefficients appear for a significance level α<0.05.

1950-2019 period				**2000-2019 period**	
Parameters	**Factor 1**	**Factor 2**	**Factor 3**	Parameters	Factor 1
Car	-0.473135	-0.326093	0.195926	Car	-0.760387
Prs (May)	0.954604	-0.224474	-0.003035	Lat (Jul)	-0.850983
SHCI (May)	0.899088	-0.213953	0.061957	Lon (Jun)	0.759703
Gth850 (May)	0.819421	-0.259142	0.231832	Gth850 (Jun)	0.850052
Lat8 (May)	0.836651	-0.114311	-0.213328	Lat8 (Jul)	-0.742565
Lat8 (Jul)	-0.309918	-0.790566	-0.271513	Lon8 (Jun)	0.087394
Lon8 (Jul)	-0.440305	-0.528751	-0.537345	LonD8 (May)	-0.798835
La5 (Jun)	0.021272	-0.586060	0.395376		
LaP (May)	-0.429450	-0.221189	0.700308		

If the pressure value of the anticyclone on the surface increases, downward movements dominate in the region of the anticyclone, which decreases the convective mechanisms in this area. In addition, the same occurs with the longitudinal variation of the anticyclonic ridge at 850 hPa, as it extends to the west, it largely dominates the convergence in the Caribbean Sea, thus increasing the formation of tropical cyclones in this area, coinciding with a greater affectation of tropical ciclones in Cuba. If the anticyclonic ridge at 850 hPa retreats to the east, there is greater formation of tropical cyclones in the Atlantic área.

4. Conclusions

- The North Atlantic subtropical High,with an average central pressure of 1023.16 hPa and mean value of *SHCI* of 1022.17 hPa, has experienced a slight shift to the north in latitude and to the west longitudinally with respect to its mean position, with a slight decrease in its central pressure and strength at surface. The anticyclonic cell at 850 hPa, with average geopotential height 1587.24 mgP showed a shift to the south in latitude and to the east in longitude. The middle and upper troposphere were characterized by a northward expansion of the subtropical high pressure belt with the consequent increase in geopotential height with KM=4.38 and KM=4.72 and average geopotential of 5866.67 mgP and 12178.33 mgP.

- The low troposphere during the rainy period of the year continues to be a level that provides important elements in the prediction of tropical cyclogenesis in the North Atlantic basin, which is reaffirmed by [1-3], mainly the month of May in the entire study period and Juny and July months in the years after 2000 parameters like the pressure value, SHCI and the position of the anticyclone on the Surface and the high geopotential center at 850 hPa.

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