Relationship Between Geopotential Height Anomalies Over North America and Europe and the USA Landfall Atlantic Hurricanes Activity

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Abstract: The present paper investigates the relationship between geopotential height anomalies at level of 500 hpa over North America and Europe, and the USA landfall Atlantic hurricanes activity. The decadal data of the number of hurricanes by category which stroked the mainland USA for each decade through the period (1851-2006) are used through the present study. The daily NCEP/NCAR reanalysis data composites for geopotential height at 500 hpa level over North America and Europe for the period of (1949-2006) are used too. Hurricane datasets and anomalies in geopotential height are analyzed and correlated together. The results revealed that there are significant positive correlations between the anomalies in geopotential height over North America and East Europe simultaneously, and existence of Atlantic hurricanes of category 3 that strike USA. In addition to that, significant positive correlations between the anomalies in geopotential height over North America and existence of major hurricanes (category 3, 4 and 5) that landfall USA is found too. However, significant negative correlations between the anomalies in geopotential height over North Atlantic and existence of all USA Landfall Atlantic Hurricane categories are existed else category 1. In general one can conclude that anomalies in geopotential height at 500 hpa level over North America and Europe are control the USA landfall Atlantic hurricanes activity.

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1. Introduction

The USA landfall Atlantic hurricanes activity and its causes had been challenged in several scientific literatures (e.g., Elsner et al., 1999; Gray 2001; Goldenberg, et al., 2001, Landsea 2005; Mann and Emanuel 2006; Elsner 2006 and 2008; Asbury et al., 2006; Trenberth and Shea 2006; Vecchi and Knutson 2008 and Hafez 2008). However, increases in key measures of Atlantic hurricane activity over recent decades were believed to reflect, in large part, contemporaneous increases in tropical Atlantic warmth (e.g., Emanuel, 2005). Some studies (e.g., Goldenberg et al., 2001) had attributed these increases to a natural climate cycle termed the Atlantic Multidecadal Oscillation (AMO); while other studies suggest that climate change may instead be playing the dominant role (Emanuel, 2005; and Webster et al., 2005). Also, the global warming arguments had been given much attention by many media references to recent papers claiming to show such a linkage. Despite the global warming of the sea surface that has taken place over the last three decades, the global numbers of hurricanes and their intensity have not shown increases in recent years except for the Atlantic, Klotzbach (2006). In addition to that, processes affecting hurricane development over the North Atlantic like the El Nino Southern Oscillation (ENSO), the stratospheric Quasi-Biennial Oscillation (QBO) and Sea Surface Temperatures (SSTs) were discussed. Global coupled climate model simulations cannot answer directly the question on enhancement of hurricane activities (or its absence) under increased greenhouse gas concentrations because of their too coarse resolution. Therefore large-scale quantities that affect hurricane formation were investigated in a future warmer climate. However, more frequent or more intense hurricanes were expected from an increase in the local SST, from more latent heat flux from the ocean to the atmosphere, from more westerly winds in the tropical stratosphere that reduces the occurrence of strong easterly phases of the QBO and from a more moist-unstable stratification of the atmosphere. However, a stronger vertical wind shear similar to the difference between El Nino and La Nina events suggested fewer hurricanes in the northern Atlantic. Also a more dry-stable atmosphere would lead to fewer hurricanes (Gray 1984; and Arpe and Leroy 2008). Meanwhile, the USA landfall of major hurricanes Dennis, Katrina, Rita and Wilma in 2005 and the four Southeast landfall hurricanes of 2004 (Charley, Frances, Ivan and Jeanne) raised questions about the possible role that global warming played in these two unusually destructive seasons (Klotzbach and Gray 2008). In fact, Hafez (2008) found that blocking systems over the Northern Hemisphere played a great role in USA landfall of strongest hurricanes Katrina, Rita and Wilma in 2005 season and also in the activity of hurricane Andrew 1992. Hafez (2009) gets a model for extratropical cyclone Klaus that developed over the North Atlantic Ocean and invade southern France and northern Spain on January 2009. He found that, Azores high played a great role in developing of cyclone Klaus. However, recently, Klotzbach (2010) found that the large-scale equatorial circulation which known as the Madden–Julian Oscillation (MJO) impacts on tropical cyclone activity in several basins around the globe. Large differences in frequency and intensity of tropical cyclone activity were seen; both in the tropical Atlantic as well as in the northwest Caribbean and Gulf of Mexico depended on the MJO phase. Coherent changes in upper- and lower-level winds and relative humidity are likely responsible for these differences. In the present work, author will try to uncover the key for answer the following question, what is the actual response that controlling of USA landfall Atlantic hurricanes activity.

2. Data and Methods

The decadal data of number of hurricanes by category which stroked the mainland USA for each decade through the period (1851-2006), Updated from Blake et al., 2005, are used through the present study. The daily NCEP/NCAR reanalysis data for geopotential height at 500 hpa level over North America, North Atlantic Ocean and Europe for the period of (1949-2006) (Kalnay et al., 1996) are used too. This data set obtained from the NOAA - CIRES, Climate Diagnostics Centre (CDC) through the Web Site (http://www.cdc.noaa.gov). For the purpose of the present study, it is liable to divide the area of study to four zones. First zone, zone A, is the North America (100° W- 20° W) latitudes and (60° N – 30° N) longitudes. Second zone, zone B, is the North Atlantic Ocean (20° W – 00° E) latitudes and (60° N – 30° N) longitudes. Third zone, zone C, is the West Europe (00° E – 40° E) latitudes and (60° N – 30° N) longitudes. The last one, zone D, is the East Europe (40° E – 60° E) latitudes and (60° N – 30° N) longitudes. In the present work, these datasets are analyzed using of anomalies methodology and linear correlation coefficient techniques, Spiegel (1961).

3. Results

3.1 Analysis of geopotential height over 500 hpa over North America and Europe in the period (1948-2006)

Through the present study, time series analysis of datasets of geopotential height of 500 hpa level for the period (1948-2006) for four distinct zones over North America and Europe is done. For the purpose of study these zones are (zone A, zone B, zone C, and zone D). The results revealed that for zone A, (North America), geopotential height varies from year to year with minimum value (5627 m) in year 1976 and maximum value (5675 m) in year 2005. Maximum values of geopotential height are existed through the period (2001-2005). Figure 1a illustrates these variations. for zone B, (North Atlantic Ocean), geopotential height values varies rabidly from year to year with minimum value (5635 m) in year 1960 and maximum value (5730 m) in year 1978. Figure 1b shows these variations. Zone C, (West Europe), characterized by dramatically increases in geopotential height values through the period (1981-2006) rather than the period (1948-1980) with maximum value (5710 m) in year 2005. Figure 1c shows this dramatically variation. In addition to that, through zone D (East Europe) two maxima and two minima of geopotential height are existed. The two maxima are (5718 and 5722 m) for years of 1952 and 2005 respectively. Meanwhile two minima (5638 m) for years 1956 and 1973, see Figure 1d.

3.2 Analysis of geopotential height anomalies over 500 hpa over North America and Europe through period (1948-2006)

In this section, geopotential height anomalies over 500 hpa over North America, North Atlantic Ocean, West Europe and East Europe through (1948-2006) period are analyzed. For zone A, it is clear that geopotential height anomaly values vary from year to year around its mean value (5649 m). With maximum value (+27 m) existed on year 2005. Meanwhile, the minimum value (-20 m) recorded on year 1976 through the study period as it is shown in Figure 2a. There is a positive anomaly trend exist from year 1964 until 2005. See the black straight line in Figure 2a. In addition to that, for zone B, the geopotential height anomaly values vary dramatically from year to year around its mean value (5685 m). Maximum anomaly value (+35 m) existed on year 1978. The minimum value (-50 m) observed on year 1960 through the study period as it is illustrate in Figure 2b. It is clear that, through the first half period of study, from year 1948 to 1980, there is a negative anomaly trend. Meanwhile, there is a positive anomaly trend exist for the second half of the study period from1981 to 2005 year. The trend is shown by black straight line in Figure 2b.The Analysis for zone C revealed that the mean value is (5678 m) for this zone. The maximum anomaly value (+32 m) is observed on year 2005 and the minimum value (-30 m) occurred on year 1965 as it is clear in Figure 2c. Positive trend occurred from year 1969 to 2005. As clear from black straight line trend in Figure 2c. For the last zone D, it is record the highest maximum anomaly value for all zones (+ 50 m) on year 2005. Meanwhile (-36 m) is the minimum value on 1973. However, the mean value is (5673 m) for this zone, see Figure 2d. Positive trend is observed from year 1960 to 2005 as it is clear from black line shown in Figure 2d. The results of the analysis of geopotential height anomaly through the period (1948-2005) for four zones revealed that there exist positive trends in anomaly values almost of the study period with highest maximum values on year 2005 except for North Atlantic Ocean, zone B.

3.3 Analysis of the decadal timeseries for USA landfall Atlantic hurricanes activity

Through this section, data of the decadal number of Atlantic hurricanes by category that stroke the mainland USA through the period (1851-2006) were analyzed using of timeseries analysis. The category of Atlantic hurricanes obtained according to the Saffir- Simpson scale of hurricanes. The Saffir-Simpson hurricane Scale is a 1-5 rating based on the hurricane's present intensity, Zebrowski and Judith (2005). The results revealed that, hurricanes for category 1 varies from decade to decade with maximum number of 10 hurricanes occurred through the two decades (1901-1910) and (1911-1920). Meanwhile, with minimum number 3 hurricanes existed two times on (1961-1970) and (1991-2000). The average number of category 1 is 7.1 h/d (hurricane/decade) see Table 1 and Figure 3a. In addition to that, the trend of Atlantic hurricanes of category 1 that stroke USA is a negative trend through the period of (1851-2006), Figure 3a (red line). For category 2, it is found that the maximum number recorded is 9 h/d on (1881-1890) and minimum number is 1 h/d for decade of (1951-1960). The average number of category 2 is 4.7 h/d with negative trend, Figure 3b. The same numbers, like category 2, occurred for category 3 but for the decades (1941-1950) and (1861-1870) respectively but with average number is 4.8 h/d, see Table 1 and Figure 3c. The trend of category 3 variation with time is a positive trend through the period of study, Figure 3c (red line). It is noticed that, for category 4 there are several decades without any existence of episode of hurricanes. The maximum number is 4h/d occurred on the two decades of (1891-1900) and (1951-1960). See Table 1 and Figure 3d. The average number of category 4 is 1.2 h/d, with a very little negative trend, see Figure 3d (red line). The existence of category 5 hurricanes is very little, whereas the maximum number is 1 h/d during the period of study. It is occurred only three times for (1931-1940), (1961-1970) and (1991-2000) decades. Its average number is 0.2 h/d, as it is clear from Table 1 and Figure 3e. In general there exist a positive trend of category 5, see Figure 3e (red line). For all categories (1, 2, 3, 4 and 5), analysis shows that, maximum number is 24 h/d while minimum number is 12 h/d for the two decades (1941-1950) and (1971-1980) respectively, within average value is 17.9 h/d and negative trend through the period of study, see Table 1 and Figure 3f (red line). Major hurricanes of categories (3, 4 and 5) has 10 h/d as a maximum number and 1 h/d is a minimum number occurred on (1941-1950) and (1861-1870) decades respectively. The average number of it is 6.2 h/d with a slightly positive trend through the study period, as shown in Table 1 and Figure 4.

3.4 Relationship between geopotential height anomalies over North America and Europe and the USA landfall Atlantic hurricanes activity

Decadal data of geopotential height anomalies over North America and Europe and the USA landfall Atlantic hurricanes activity through the period of (1951-2006) has been correlated through this section. Table 2 illustrates the location for four distinct zones over North America and Europe. Table 3 shows the values of correlation coefficient between geopotential height anomalies over North America and Europe and the USA landfall Atlantic hurricanes activity. The correlation coefficient analysis revealed that there are significant positive correlations between the anomalies in geopotential height over northern America and Eastern Europe simultaneously and existence of Atlantic hurricanes of category 3. There are significant positive correlations between the anomalies in geopotential height over northern America and the existence of major hurricanes (3, 4, and 5) that strike USA. In addition to that, there are significant negative correlations between anomalies in geopotential height over northern Atlantic and existence of major and all Atlantic hurricane categories that strike USA except category 1.

4. Discussions

Almost of the previous studies of Atlantic hurricanes activity is referred it to global worming or to increase of SST in tropical region of the Atlantic Ocean, or ENSO conditions. The results of the present study uncovered that the anomalies in geopotential height values at 500 hpa over North America, North Atlantic, West and East Europe are controlling the activity of Atlantic hurricanes that landfall USA. Whereas, there are significant relationship between the existence of positive anomalies over North America and east Europe simultaneously and occurrence of category 3 hurricanes. In addition to that there are outstanding negative relationship between Atlantic hurricane of all categories that strike USA except category 1 and anomalies in geopotential height at 500 hpa levels which existed over the North Atlantic Ocean zone.

Major hurricanes have been strongly correlated to positive anomalies in geopotential height over North America simultaneously with negative anomalies over north Atlantic region. In particular, in year 2005.

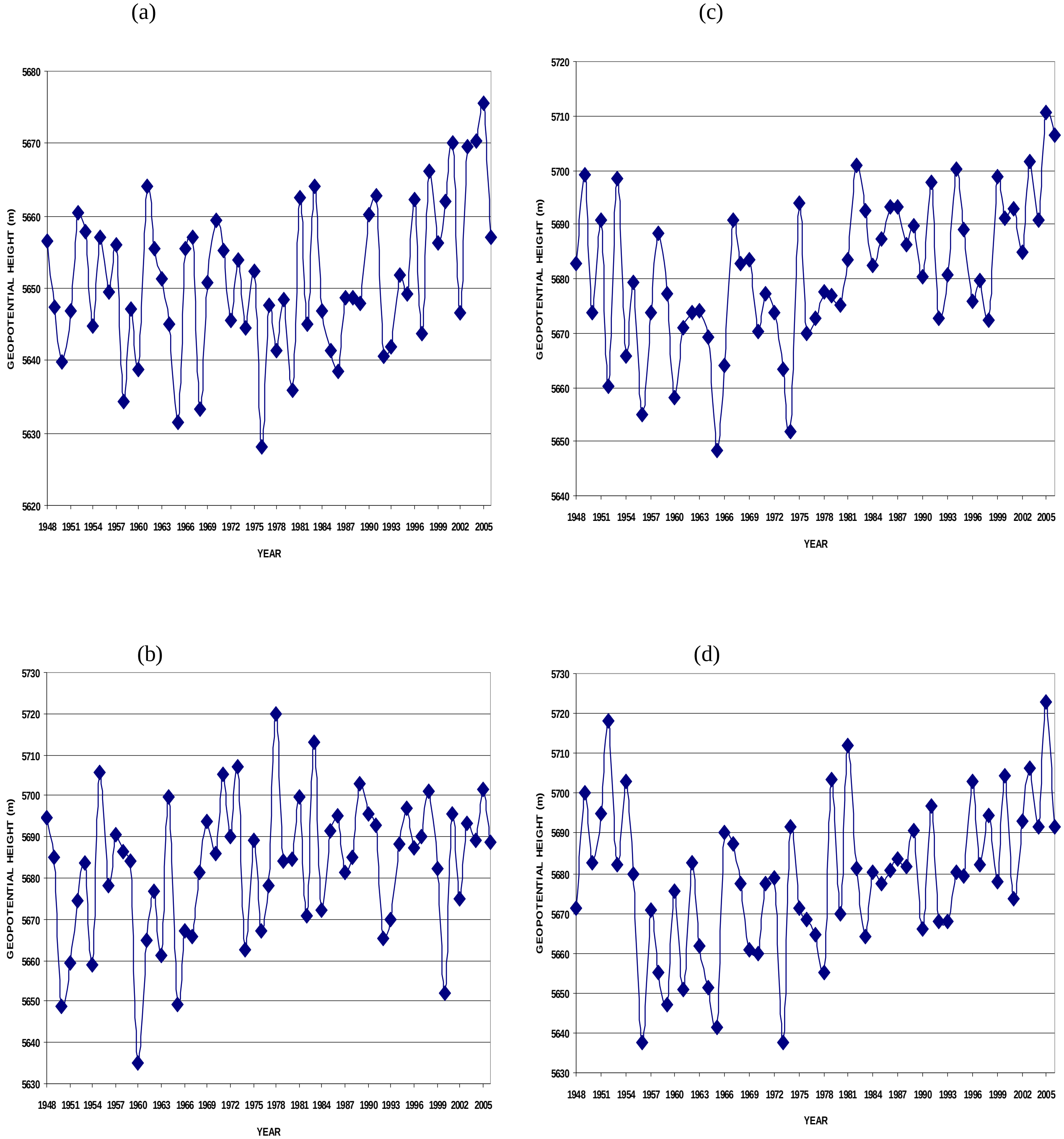

Figure 1. Time series of geopotential height at 500 hpa level for North America , North Atlantic, West Europe, and East Europe, four zones A, B, C and D respectively, through the period (1949-2006).

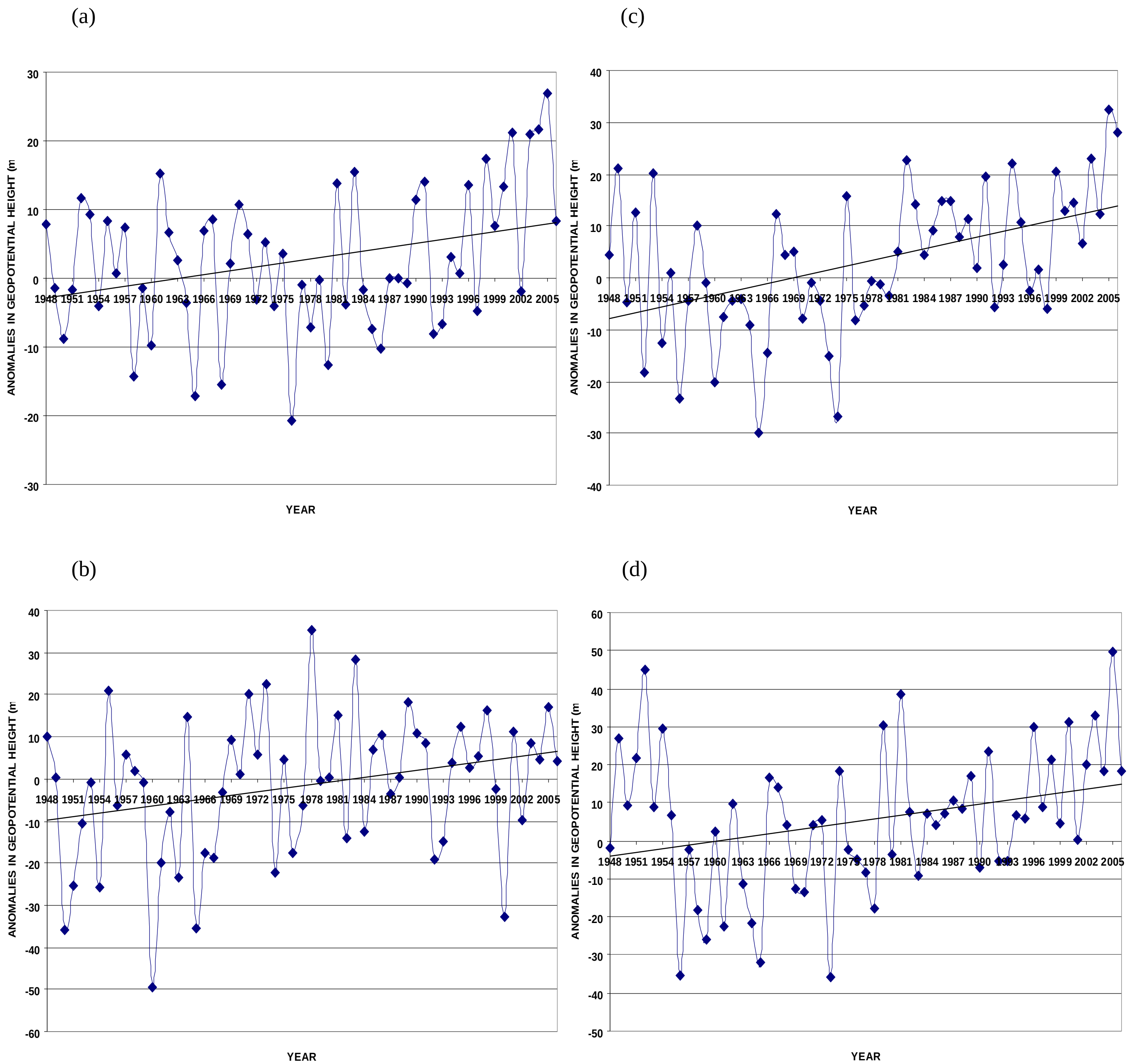

Figure 2. Time series analysis for anomalies in geopotential height at 500 hpa level and its trend for North America , North Atlantic, West Europe, and East Europe , four zones A, B, C and D respectively, through the period (1949-2006).

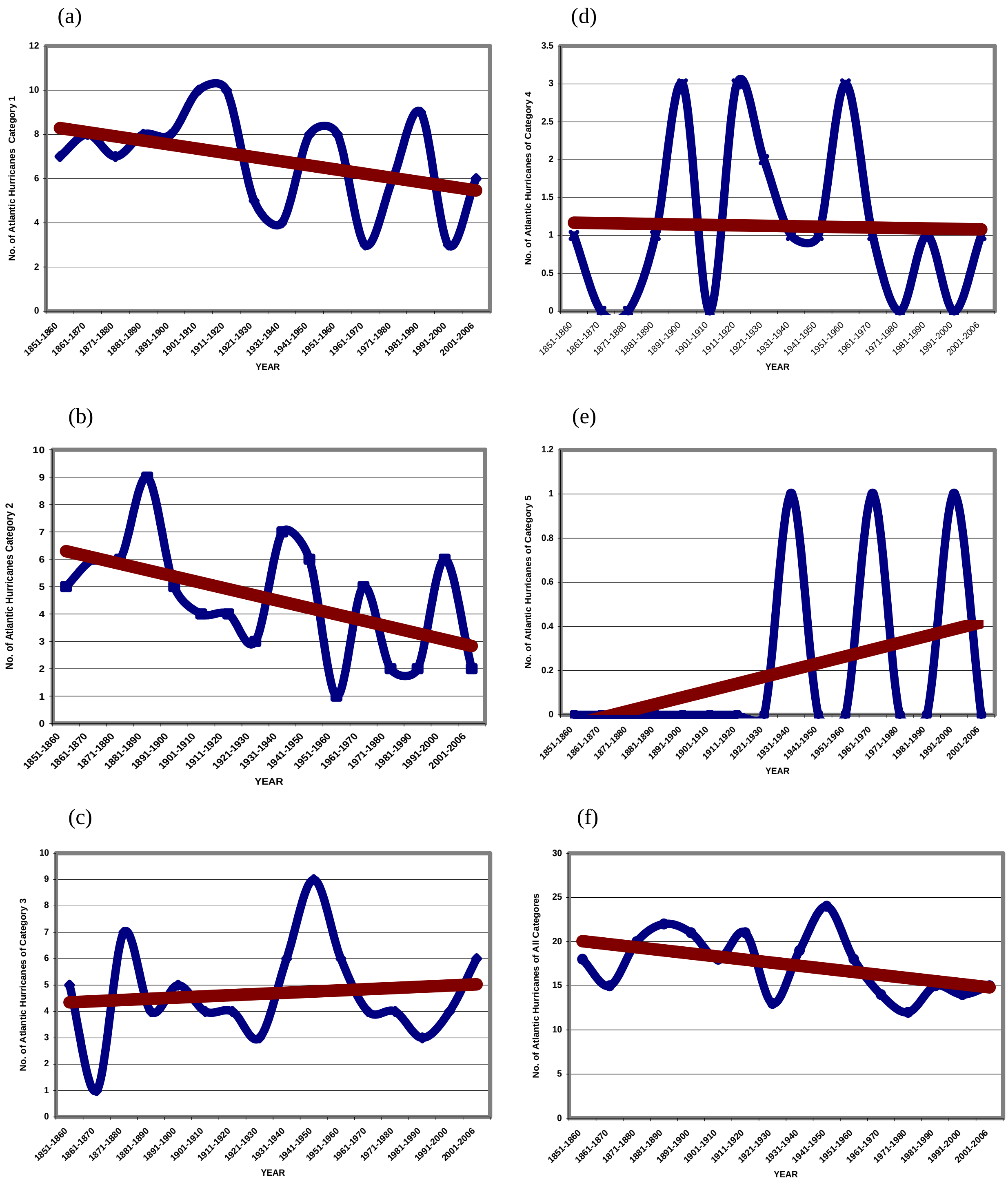

Figure 3. Represents the decadal timeseries for USA landfall Atlantic hurricanes by category and its trend for the period of (1851-2006). Whereas, Figure 3a for category 1, Figure 3b for category 2, Figure 3c for category 3, Figure 3d for category 4, Figure 3e for category 5, and Figure 3f for all categories.

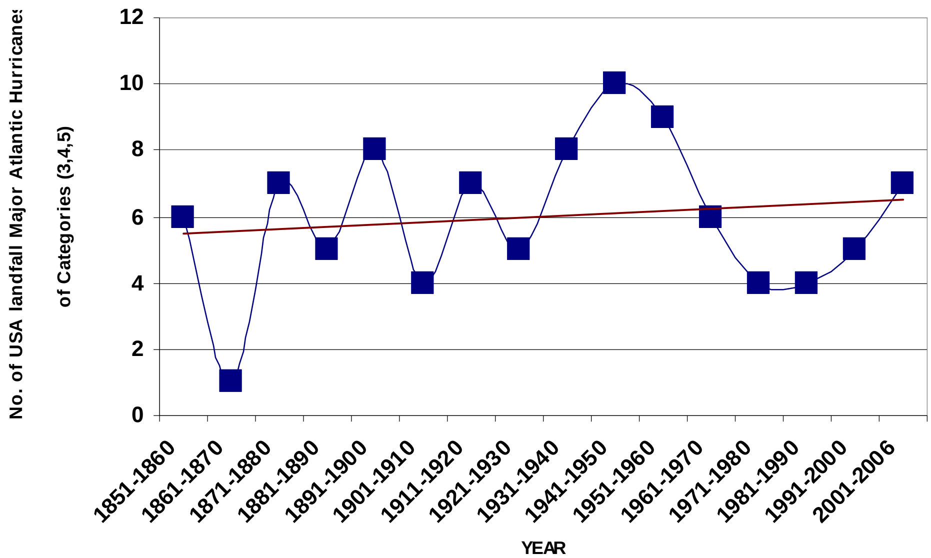

Figure 4. Represents the decadal timeseries for USA landfall major Atlantic hurricanes of categories (3, 4, and 5), and its trend for the period of (1851-2006).

Table 1. The decadal number of hurricanes by category that stroke the mainland USA through the period (1851-2006). (Updated from Blake et al., 2005 and 2007). Note: Only the highest category to affect the U.S. has been used.

DECADE	CATEGORY					ALL	MAJOR
	1	2	3	4	5	1,2,3,4,5	3,4,5
1851-1860	7	5	5	1	0	18	6
1861-1870	8	6	1	0	0	15	1
1871-1880	7	6	7	0	0	20	7
1881-1890	8	9	4	1	0	22	5
1891-1900	8	5	5	3	0	21	8
1901-1910	10	4	4	0	0	18	4
1911-1920	10	4	4	3	0	21	7
1921-1930	5	3	3	2	0	13	5
1931-1940	4	7	6	1	1	19	8
1941-1950	8	6	9	1	0	24	10
1951-1960	8	1	6	3	0	18	9
1961-1970	3	5	4	1	1	14	6
1971-1980	6	2	4	0	0	12	4
1981-1990	9	2	3	1	0	15	4
1991-2000	3	6	4	0	1	14	5
2001-2006	6	2	6	1	0	15	7
1851-2006	110	73	75	18	3	279	96
Average per decade	7.1	4.7	4.8	1.2	0.2	17.9	6.2

Table 2. The location for four distinct zones over North America and Europe.

ZONES	LATITUDES	LONGITUDES
Zone A (North America)	100° W- 20° W	60° N – 30° N
Zone B (North Atlantic)	20° W – 00° E	60° N – 30° N
Zone C (West Europe)	00° E – 40° E	60° N – 30° N
Zone D (East Europe)	40° E – 60° E	60° N – 30° N

Table 3. Shows the values of correlation coefficient between decadal of geopotential height anomalies over North America and Europe and the USA landfall Atlantic hurricanes activity through the period (1951-2006).

Hurricane activity / Correlation coefficient	Category of USA landfall Atlantic hurricanes activity						
Anomalies in geopotential height at:	**1**	**2**	**3**	**4**	**5**	**All (1,2,3,4,5)**	**Major (3,4,5)**
Zone (A)	-0.121	0.039	0.511	-0.011	-0.034	0.189	0.306
Zone (B)	0.389	-0.329	-0.216	-0.499	-0.548	-0.400	-0.564
Zone (C)	0.178	-0.062	0.149	-0.172	-0.220	0.101	-0.061
Zone (D)	0.170	-0.132	0.384	-0.072	-0.279	0.206	0.127

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