A CLIMATOLOGY OF WINTER CYCLOGENESIS INTENSITY IN THE NORTHWEST GULF OF MEXICO

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Abstract

Extratropical cyclones which form over the northwest Gulf of Mexico have produced strong winds, high waves, and significant flooding damage along the coastal areas of the region. Because previous cyclone climatologies have not included detailed intensity information (minimum central pressure), this study provides a long-term climatology of the intensity values of winter cyclones forming over the northwest Gulf of Mexico. Extratropical cyclones which formed over the northwest Gulf of Mexico during the winters of 1966-67 to 1995-96 are classified as having either a weak or strong intensity, based on their minimum central pressure. The frequencies of the weak and strong intensity cyclones are calculated for each of the thirty winter seasons. The influence of El Niño and La Niña events on the winter season totals of weak and strong cyclones is also investigated. Statistical tests reveal that the frequency of strong extratropical cyclones forming over the northwest Gulf is significantly higher during El Niño winters. Although not statistically significant, there is also a tendency for very few strong cyclones to occur during La Niña winters.

1. Introduction

Extratropical cyclones which form over the northwest Gulf of Mexico can produce strong sustained winds and, therefore, are important producers of flooding along the coastal areas of the region. An excellent example of the flooding caused by these storms is provided by a cyclone which intensified over the northwest Gulf on 19-20 January 1983. Winds associated with the cyclone helped produce above normal tides from southeastern Louisiana to the western part of the Florida panhandle. Because of the high tides, many businesses, homes, and automobiles in the New Orleans area were flooded, resulting in damage totals of $6.3 million in Orleans Parish and $5 million in St. Bernard Parish (Johnson et al. 1984). The strong winds and high waves associated with northwest Gulf cyclones also cause beach erosion and pose a threat to the regions' shipping interests and offshore oil platforms (Hsu 1993).

Given the significant impact of extratropical cyclone winds on the coastal areas of the northwest Gulf, a detailed climatology of the intensity of Gulf cyclones would be of interest to meteorologists forecasting the coastal conditions as well as to the region's residents and shipping and oil interests. However, only one of the previous Gulf of Mexico cyclone climatologies (Saucier 1949; Johnson et al. 1984) has provided any data on cyclone intensity. Johnson et al. (1984) examined the frequency of Gulf cyclones during the winters 1972-73 to 1982-83 and included a category for those lows which attained a central pressure at or below 1010 mb. Out of the ten cyclones which develop over the Gulf of Mexico during an average winter (Saucier 1949; Johnson et al. 1984), approximately five cyclones per year had a minimum central pressure at or below 1010 mb during the winters 1972-73 to 1982-83 (Johnson et al. 1984).

To show more detailed information on the intensity (e.g., minimum central pressure) of Gulf cyclones, the authors of this paper provide a long-term climatology of the intensity values of winter cyclones forming over the northwest Gulf of Mexico. The influence of the El Niño/Southern Oscillation (ENSO) on the year to year changes in the frequency and intensity of northwest Gulf cyclones is also examined. Previous research indicates that winter cyclone activity in the Gulf of Mexico is influenced by ENSO (Johnson et al. 1984; Manty 1993). During El Niño winters, the upper-air westerlies are strengthened over the eastern North Pacific and the Gulf of Mexico (Yarnal 1985; Aceituno 1989; Cavazos and Hastenrath 1990). With a strengthened jet stream interacting with the strong sea surface temperature gradient usually present along the northwest Gulf during winter (Hsu 1992), the Gulf may experience an unusually high number of strong intensity winter cyclones during El Niño events. This was the case during the El Niño winter of 1982-83, when several Gulf cyclones attained a central pressure at or below 1010 mb (Johnson et al. 1984). The influence of La Niña events on the intensity of northwest Gulf cyclones is also examined. Manty (1993) found, for the years 1960 to 1989, that the number of Gulf cyclones forming during La Niña winters was significantly lower

than during non-La Niña winters. However, the intensity values of the Gulf cyclones during those La Niña winters were not studied (Manty 1993).

2. Data and Methods

a. Identification of cyclogenesis events

Cyclogenesis over the northwest Gulf of Mexico is examined for thirty winter (November to May) seasons from 1966-67 to 1995-96. The study region is defined as the area bounded by 90° W to 100° W longitude and 25° N to 30° N latitude (Fig. 1). The northwest Gulf was chosen as the region of study because: 1) it includes the majority of winter season cyclogenesis events in the Gulf (Saucier 1949; Johnson et al. 1984); and 2) the region's residents and shipping and oil interests are impacted by the extratropical cyclone winds. Winter cyclones forming in the Gulf of Mexico can also produce significant property damage and erosion along the eastern seaboard of the United States (Mather et al. 1964; Davis et al. 1993). However, the intensity values of Gulf cyclones along the east coast are not included in this study, because Davis et al. (1993) has already examined them.

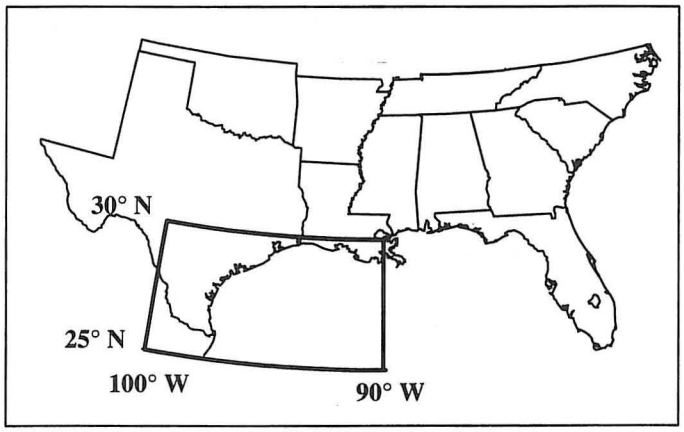

Fig. 1. Northwest Gulf of Mexico cyclogenesis study region.

The *Daily Weather Maps* (DWM) (National Oceanic and Atmospheric Administration 1966-1996) series is used to identify each cyclone which formed over the study region. Each cyclone that formed over the study area and existed for at least 24 hours (present on two consecutive weather maps) is included in this study. It is important to note that although a cyclone must be present on two consecutive maps, it does not have to remain located over the study area on both maps. The cyclones are divided into "strong" and "weak" categories. The "strong" cyclone category includes all cyclones that attained a minimum central pressure less than or equal to 1012 mb while over the study region. The "weak" cyclone category includes those cyclones whose minimum central pressure was greater than 1012 mb while over the study region.

The primary weakness of the DWM series is that there is only one map every 24 hours at 1200 UTC. This presents two problems for the development of a climatology of cyclone intensities. First, the minimum central pressure value that a cyclone reaches over the study area may not occur at 1200 UTC. Second, cyclones which form after 1200 UTC and move east of the study area by the next map will not have a measured central pressure value over the region. These cyclones that develop and move out of the region in between maps are included in the weak cyclone category, if they existed for at least 24 hours. Although the DWM does not always give the minimum central pressure reached by a cyclone over the study area, the DWM's long period of record makes it an excellent source for the development of a long-term cyclone climatology.

Table 1. Intensity Categories for Strong Cyclones (modified from Hsu 1993)

Cyclogenesis Category	Minimum Pressure (x)	Maximum Wind Speed (V_{max})
Class 1	$1006 < x \leq 1012$ mb	$11 \leq V_{max} < 15$ m/s
Class 2	$1000 < x \leq 1006$ mb	$15 \leq V_{max} < 18$ m/s
Class 3	$990 < x \leq 1000$ mb	$18 \leq V_{max} < 22$ m/s
Class 4	$980 < x \leq 990$ mb	$22 \leq V_{max} < 25$ m/s
Near Hurricane	$x \leq 980$ mb	25 m/s $\leq V_{max}$

Because the stronger storms produce higher wind speeds and are more likely to produce higher waves and water levels, the strong cyclogenesis events are further subdivided (Table 1) to get a better idea of the frequencies of the more intense storms. For each strong cyclone forming over the study area, its intensity category is determined from its minimum central pressure value that is reached while over the northwest Gulf. Although maximum wind speeds are not used to determine cyclone intensity in this study, Table 1 can be used to get an idea of the wind speeds associated with the intensity categories of the strong cyclones. For the derivation of the maximum wind speeds associated with the cyclogenesis categories, see Hsu (1993).

b. Analysis of cyclogenesis totals

After completing the analysis of the daily weather maps and identifying the intensity category of each storm, the thirty-season total and the individual season frequencies are calculated for the weak cyclones, the strong cyclones, and the subclasses of the strong storms. The influence of ENSO on winter-season cyclogenesis in the northwest Gulf of Mexico is evaluated through a comparison of the frequency and intensity of Gulf cyclones during El Niño, La Niña, and Non ENSO (neither El Niño nor La Niña) winters. Six El Niño events (1969-70, 1972-73, 1976-77, 1982-83, 1986-87 and 1990-95) and four La Niña events (1970-71, 1973-74, 1975-76 and 1988-89) occurred during the thirty-year study period (Kiladis and Diaz 1989; Trenberth and Hoar 1996).

3. Results

a. Thirty-season totals

Of the 166 cyclones which developed over the northwestern Gulf during the thirty winters studied: 83 had a minimum central pressure > 1012 mb and 83 had a min-

Table 2. Cyclogenesis Totals by Intensity Category (minimum central pressure ≤ 1012 mb)

Cyclogenesis Category	1966-1996 Total	Percentage
Class 1	65	78.31%
Class 2	11	13.25%
Class 3	7	8.44%

imum central pressure ≤ 1012 mb. A typical winter season (based upon median values) is characterized by three weak cyclones and two to three strong storms (median = 2.5) forming over the northwestern Gulf of Mexico. A breakdown of the more intense cyclones (Table 2) reveals that the majority of the strong cyclones only reach the class 1 intensity level while over the northwest Gulf.

Winter frequencies of the weak cyclones and the strong cyclones were also plotted and compared to their overall median values. Winter frequencies of the weak cyclones are: generally lower than the median from the mid 1960s to the mid 1970s, generally at or above the median from the mid 1970s to the mid 1980s, and more variable since the mid 1980s (Fig. 2a). The most distinctive features of the strong cyclone frequency chart (Fig. 2b) are the two high frequency winters during the 1980s (1982-83 and 1986-87) and the cluster of high frequency winters during the 1990s.

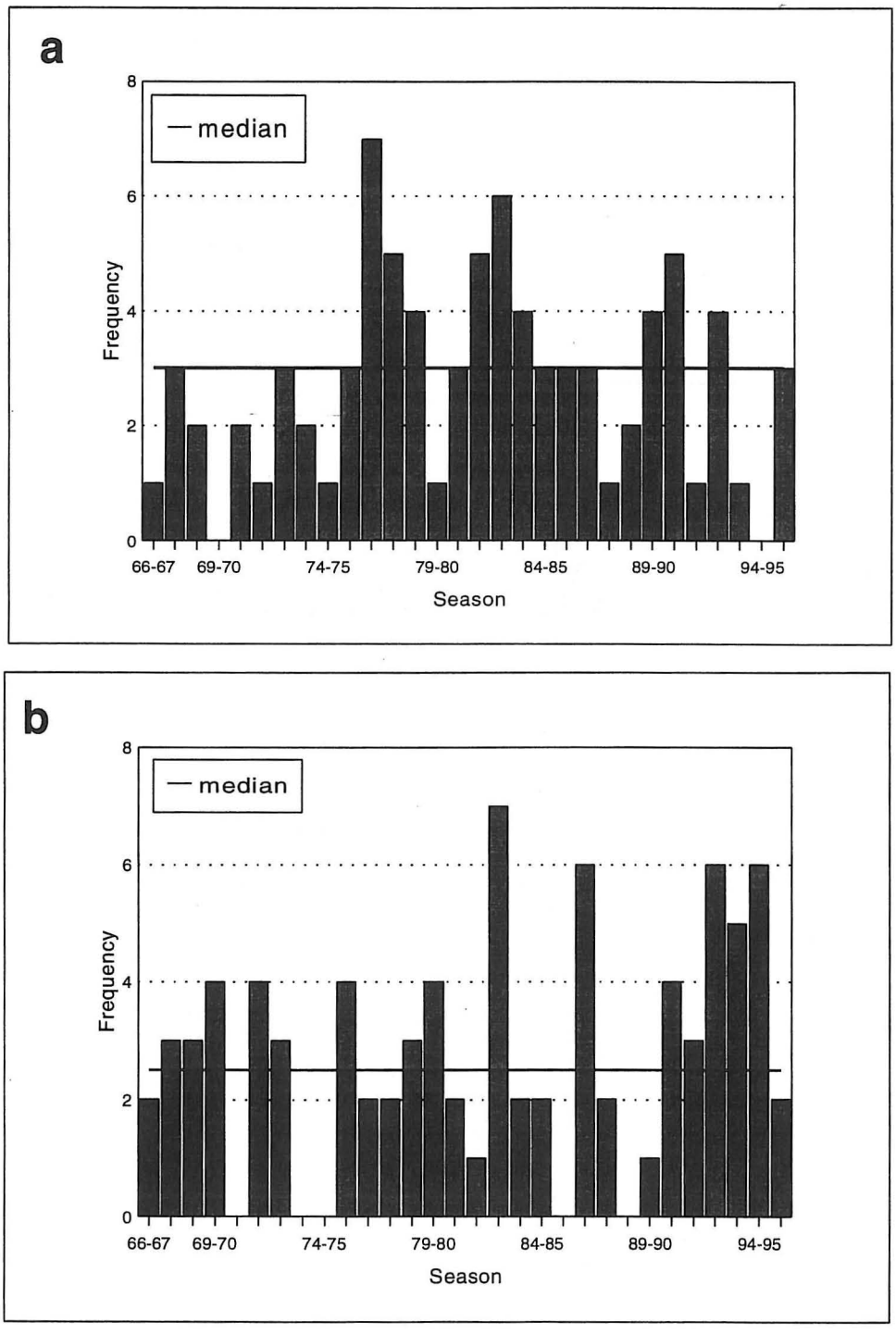

Fig. 2. Cyclogenesis frequencies in the northwest Gulf for the winter seasons 1966-67 to 1995-96: a. Weak (central pressure > 1012 mb), b. Strong (central pressure ≤ 1012 mb).

When cyclone totals are examined by decade, it is interesting to note that the first decade (1966-67 to 1975-76) only had 41 cyclones, while the middle (1976-77 to 1985-86) and final (1986-87 to 1995-96) decades had 66 and 59 cyclones respectively. The much higher cyclone totals in the second and third decades could be partly attributed to an increase in the amount of data available for the Gulf. Deepwater buoys 42001, 42002, and 42003 were put into operation in the mid 1970s and several Coastal Marine Automated Network (CMAN) stations were added in the mid 1980s. However, there were three La Niña events in the first decade, which may have contributed to the lower cyclone totals.

b. Influence of the El Niño-Southern Oscillation (ENSO)

There does not appear to be a clear El Niño influence on the winter frequencies of weak cyclones, even though the two highest frequency winters (Fig. 2a) are during El Niño events (1976-77 and 1982-83). Out of the ten El Niño years, the frequencies of weak cyclones are above the median during four winters, below the median during four winters, and equal to the median for the winters of 1972-73 and 1986-87 (Fig. 3a). There is some indication of fewer weak cyclones during La Niña winters. For the four La Niña years,

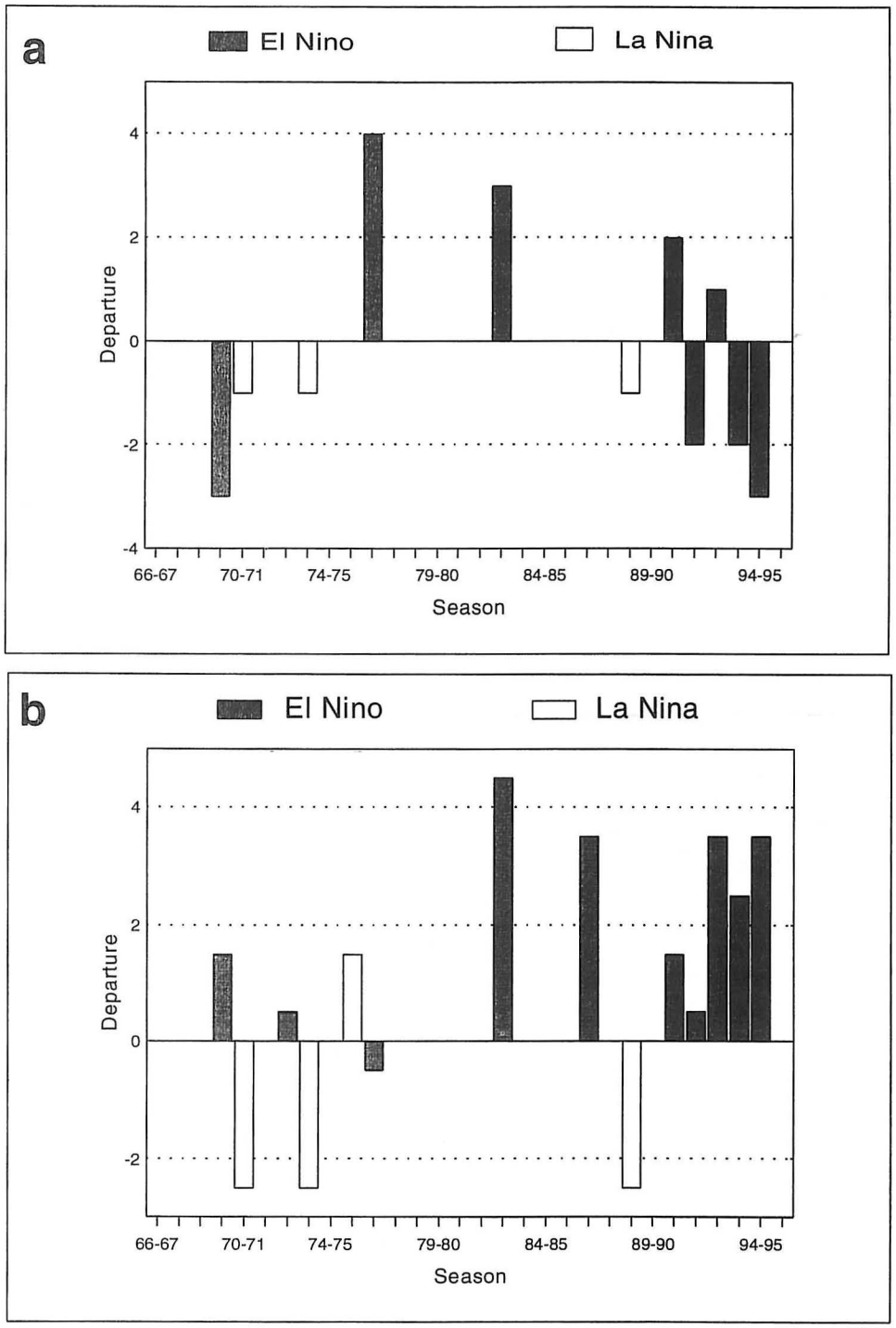

Fig. 3. El Niño and La Niña winter cyclogenesis frequency departures from the median: a. Weak (central pressure > 1012 mb), b. Strong (central pressure ≤ 1012 mb).

the frequency of weak cyclones are slightly below the median during three winters and equal to the median during the winter of 1975-76 (Fig. 3a).

For the strong cyclones, there appears to be a good relationship between high frequency winters and El Niño events. The five highest frequency winters (Fig. 2b) occur during El Niño events (1982-83, 1986-87 and 1990-95). Also, the frequencies of the strong cyclones are above the median during nine out of the ten El Niño winters (Fig. 3b). For the four La Niña winters, the strong cyclone frequencies are below the median and equal to zero during three winters and above the median during one winter (Fig. 3b).

To determine if northwest Gulf cyclone frequencies are significantly higher during El Niño winters and significantly lower during La Niña winters, the median test (Siegel and Castellan 1988, p. 124) is used. For both the weak cyclones and the strong cyclones, the median cyclone frequencies during El Niño, La Niña, and non ENSO winters (Table 3) are compared. The difference in the frequency of the weaker (> 1012 mb) cyclones during El Niño, La Niña, and non ENSO winters is not found to be statistically significant (Table 4). However, the frequency of the stronger (≤ 1012 mb) cyclones during El Niño winters is significantly higher than during non ENSO winters (Table 4). Although no strong cyclones formed over the northwest Gulf in three of the four La Niña winters, the frequency of strong cyclones during La Niña winters is not found to be significantly lower than the frequency of strong cyclones during El Niño winters or non ENSO winters (Table 4).

4. Conclusions

The frequency of weak and strong extratropical cyclones forming over the northwest Gulf of Mexico has been examined for thirty winter seasons. The winter totals of weak and strong cyclones were found to be highly variable, with some winters having no weak or no strong cyclones and other winters having as many as seven weak or seven strong cyclones. El Niño and La Niña events were investigated as possible contributors to cyclone variability in the northwest Gulf of Mexico. The frequency of weak cyclones during El Niño, La Niña, and non ENSO winters was not found to differ significantly. It is somewhat surprising that the frequency of strong cyclones during La Niña winters was not found to be significantly lower than during El Niño or non ENSO winters. The lack of statistical significance may be the result of having only four La Niña events, with one of the La Niña winters having a strong cyclone frequency above the median. The frequency of the stronger intensity cyclones in the northwest Gulf was found to be significantly higher during El Niño winters than during non ENSO winters. During El Niño winters, the presence of strengthened upper-air westerlies over the Gulf of Mexico is a likely contributor to the higher frequencies of strong cyclones.

Table 3. Median Number of Cyclones during El Niño, La Niña, and Non ENSO Winters

Season	> 1012 mb	≤ 1012 mb
El Niño	3	4.5
La Niña	2	0
Non ENSO	3	2

Table 4. MEDIAN TEST: Probabilities (significant in bold)

Cyclone Intensity	El Niño vs. La Niña	El Niño vs. Non ENSO	La Niña vs. Non ENSO
> 1012 mb	0.28	0.48	0.28
≤ 1012 mb	0.13	**0.005**	0.66

However, additional research is needed to identify the importance of the upper-level westerlies and other atmospheric circulation features for the formation of strong cyclones during El Niño winters. Another possible area of future research is the identification of the circulation features that inhibit the development of strong cyclones over the Gulf during certain winters especially during La Niña events.

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