P2.2 DEVELOPMENT OF NOR'EASTERS DURING EL NIÑO YEARS

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1. BACKGROUND

The El Niño Southern Oscillation (ENSO) phenomenon is the coupling of atmospheric and oceanic events over the tropical Pacific. El Niño refers to the anomalous warming of the eastern side of the Pacific every three to five years. This warming induces high pressures over the western Pacific and low pressures over the southeastern Pacific, a reversal of normal sea level pressure patterns over the tropical Pacific. The Southern Oscillation produces temperature variations that not only accounts for surface temperature changes, but for weather pattern changes as well. There is no specific definition for the Southern Oscillation but it involves changes in temperatures of both the atmosphere and sea surface and it is the cause for interesting weather phenomena. Large scale motion in the tropics corresponds to direct thermal circulations, and these circulations are set off by the Southern Oscillation (Philander, 1990). During a "mature El Niño", an atmospheric episode occurs when an anticyclonic couplet develops in the upper troposphere of the central Pacific, where anomalous heating of the atmosphere is at a maximum. This strengthens the Hadley Circulation and causes the subtropical jet stream to intensify and move equatorward (Philander, 1990). The El Niño even causes a more southerly movement of the extratropical cyclones as they track across the United States (Smith and Ledridge, 1999). This southern migration tends to increase the temperature differential between air mass and surface causing a more intense cyclone to form. An example of an intense winter extratropical cyclone that develops over coastal areas or western ocean basins can be considered a Nor'easter. Such storms are unique in that they can develop very rapidly and become very intense (Davis and Dolan, 1993). The most intense of these storms are called 'bombs', characterized by a central pressure drop exceeding 1mb/hr over a 24-hour period (Sanders and Gyakum, 1980).

Nor'easters are significant marine cyclones along the East Coast. These storms occur when cold air from the continent interacts with warm air and water just offshore, associated with the Gulf Stream. This paper investigates whether El Niño events have any influence on the development of such storms. This paper looks at tracks of winter storms during the 1983-84, 1997-98, and 2004-05 El Niño events. The number of extratropical cyclones, intensity of these cyclones and the central and minimum pressures of the cyclones were gathered. By comparing these data, conclusions are made regarding the generation and movement of Nor'easter storms. The storms during El Niño events were pushed further south due to the jet stream dipping southward. The frequency of storms increased during strong El Niño years (e.g., 1983-'84 or 1997-'98). Although the ability to predict when or where these storms will occur is difficult at best, this study provides clues to better understand the effect of El Niño on these extratropical marine cyclones.

The purpose of this paper is to examine a relationship, if there is one, between development of Nor'easters and the El Niño event. Due to the teleconnections between the Pacific and mid-Atlantic, there are differences in climatic properties that would both increase the frequency and intensity of Nor'easters. The first goal is to study and track storms that occur during known El Niño events. The second is to study the frequency and intensity of these storms.

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2. METHODOLOGY

In particular this study concentrates on storms commonly referred to as Nor'easters. Often such storms develop along cold fronts that track across the continental U.S. or the Gulf of Mexico and then stall between the Appalachians and the western Atlantic Ocean. These storms rapidly intensify and some may develop into marine cyclones. This paper examines coastal cyclones for the months of December to March for the following winters: 1982-83, 1997-98, and 2004-05.

Several NOAA websites were used to collect data on extratropical cyclones. The NOAA Climate Analysis Center's website (http://www.hpc.ncep.noaa.gov/dailywxmap/ pdffiles.html) was used to study the development and movement of storms. For the 1982-83 winter, weather maps from an online archive of the NOAA Central Library were used. By gathering these maps, tracks of storms across the U.S. for this year are plotted. All of these maps are daily (1200 UTC) snapshots of the pressure systems. For the recent El Niño events data from the NOAA Daily Weather Map Series (http://docs.lib.noaa.gov/rescue/dwm/ data_rescue_daily_weather_maps.html) were used.

After the tracks were found, the storms that were actually Nor'easters, and even more specifically "bombs", were identified for study. To determine which storms constituted a Nor'easter or a "bomb", certain factors were identified. If the storm stalled in the area near the Gulf of Mexico, off the southeast coast of the U.S., or over the Appalachian Mountains, or if the storm developed rapidly with the intensity reaching that of "bomb" criteria (Sanders and Gyakum, 1980), or if it tracked across the U.S. and came up the East Coast hitting the northeast of the United States, the storm may become a "bomb". Most of all, the central pressure of the cyclone and the rate of intensification were used to determine its status as a Nor'easter or a "bomb".

The final step was to compare tracks of storms and examine if the intensities and frequencies indicated a relationship between El Niño and the explosive development of these cyclones. If there were a relationship, then because the jet stream was moved poleward during El Niño events, temperature differential would increase between the air and the sea causing an extratropical cyclone to intensify.

3. RESULTS

During known El Niño years, data show a southerly movement of storm tracks in the winter.

Fig. 1 The position of the jet stream is relatively high in normal winters compared to the more southern movement of the trough during the El Niño winters. This graphic shows the jet stream taking a more northerly track consistent with a normal winter scenario. (Taken from [http://ww2010.atmos.uiuc.edu/ (Gh)/ guides/mtr/cyc/upa/jet.rxml on 28MAR05](http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/cyc/upa/jet.rxml)).

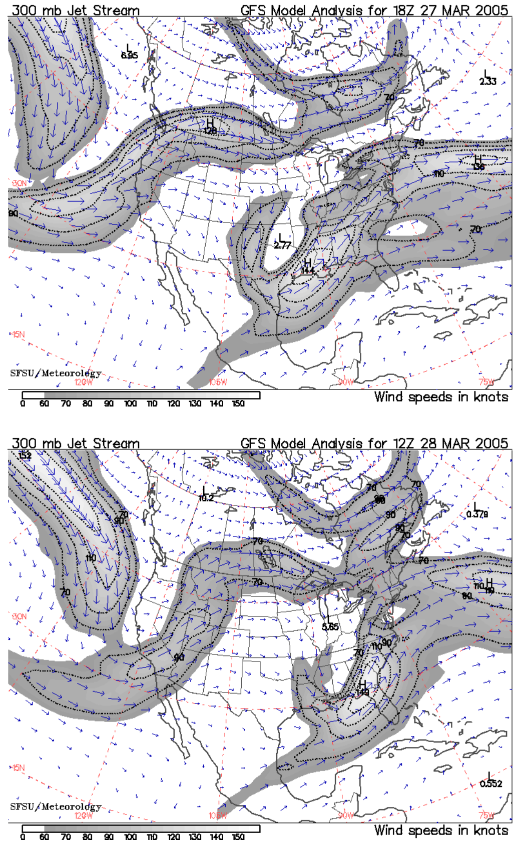

Fig. 2 These two charts show how the position of the jet stream is forced equatorward during an El Niño event. They show two days (27 and 28 MAR 2005) of the jet stream. The trough is pushed south of Florida into the Gulf of Mexico. Taken from [http://squall.sfsu.edu/crws/jetstream.html on 28MAR05](http://squall.sfsu.edu/crws/jetstream.html).

Fig 3a. provides a depiction of the "normal tracks" of winter extratropical cyclones, which will serve as a standard for comparison. The tracks for the monthly breakdown of the 1982-83 storms are in Fig. 3b and the tracks for the monthly breakdown of the 1997-98 storms are in Fig. 3c. The general trend for cyclones in the winters of 1982-83 and 1997-98 is that they develop over the southern states, in the Gulf of Mexico, or off the eastern coast of Florida in the Atlantic Ocean. The storm tracks (represented by the thick black lines) for both of these El Niño years clearly have a more southerly route than the "normal" tracks of the cyclones (Fig. 3a). The tracks of the storms (2004-05) shown in Fig. 3d did not show such a dramatic southward movement and they do not seem to fit the pattern for a normal El Niño event. Because the storms were not tracking southward, it may provide evidence that this indeed was not a strong El Niño event.

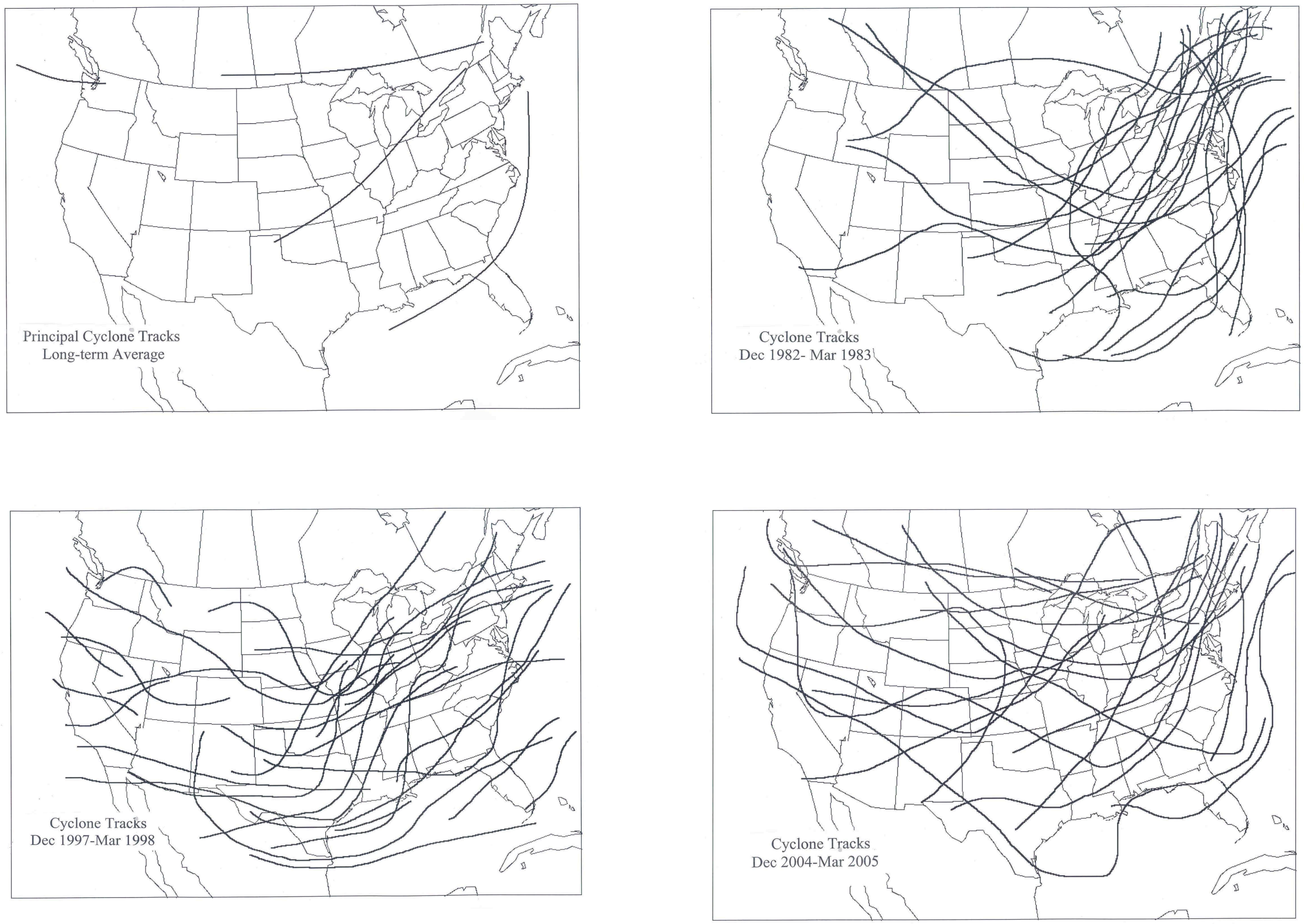

Fig 3. Tracks of extratropical cyclones over the continental United States: (a) long term average; (b) the winter of 1982-83; (c) the winter of 1997-98: and (d) the winter of 2004-05.

The intensity and frequency of the storms affecting the Northeast U.S. during these two known El Niño years are high. Fig. 4 provides a monthly breakdown of cyclone frequency for each winter. Clearly there are a large number of storms along the coast of the U.S. that flow across the U.S. into the northeast. These storms can also be seen as having greater pressure drops over the whole life of the storm and usually a greater rate of pressure drop over a short period of time.

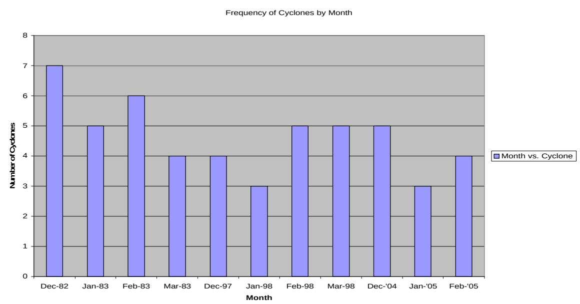

Fig. 4. A plot of monthly cyclone frequencies for three winters: (1982-83, 1997-98, 2004-05)

The relative intensities of the different storms can be compared by examples of a few parameters. Fig. 5 provides a plot of the minimum central pressures of each storm were taken from the daily weather maps over the duration of the storm. Since the storms are classified according to their month of occurrence, this enables a comparison of the storms by month from one event to the next. The data show the central pressures for the two known El Niño years to be higher in the month of December and gradually decreasing into February and March. The 1982-83 event shows its lowest pressures in March, while the 1997-98 event shows its lowest pressures in February. This observation agrees that an El Niño causes the winter storms to be more intense in the later months of winter. The 2004-05 event is a bit different in that it has its lowest pressures in December and January. More intense storms in these months are considered “normal” conditions compared to the delayed intensities of the El Niño years.

Another way to look into the intensities of the storms is to compare the rate of fall of central pressure of the storms during a 24-hour period (Fig. 6). The results of the rate of pressure fall for the events are a bit more inconclusive. In the 1982-83 event, the rate of pressure falls are not very large – with the exception of 9 January, very few storms achieved the “bomb” criteria. While several storms achieved low central values, especially in February and March, few developed explosively. Storms during the 1997-98 period demonstrated similar behavior. On the other hand, the storms during the winter of 2004-05 were more explosive in their development off the East Coast.

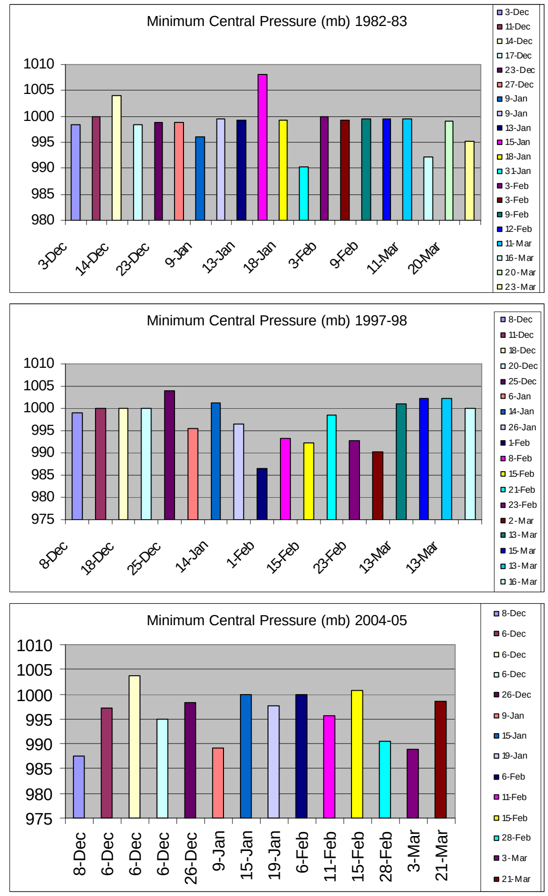

Fig. 5. Plots of minimal central pressures for cyclones during the winters of 1982-83, 1997-98, and 2004-05.

A further way of comparing the track data is to compare the frequencies of the number of storms that formed during a specific event. To compare numbers for the years, the total number of storms is divided by the four-month time frame to give an average monthly storm frequency. The average number of storms during the 1982-83 event was 5.5 storms, the 1997-98 event was 4.25 storms, and the 2004-05 event was 3.5 storms. Taking the differences between the yearly events, the data can be compared to the Multivariate ENSO Index (MEI) to show there is indeed a difference between the years and the El Niño intensity. The MEI shows the very strong El Niño events during the 1982-83 winter (MEI=3.164) and the 1997-98 winter (MEI=2.871). The MEI also shows a weak El Niño event (MEI=0.826) during the 2004-05 winter (htpp://www.cdc.noaa.gov). That coupled with a relatively less intense winter could lead to the conclusion that the 2004-05 event was indeed not a strong El Niño event.

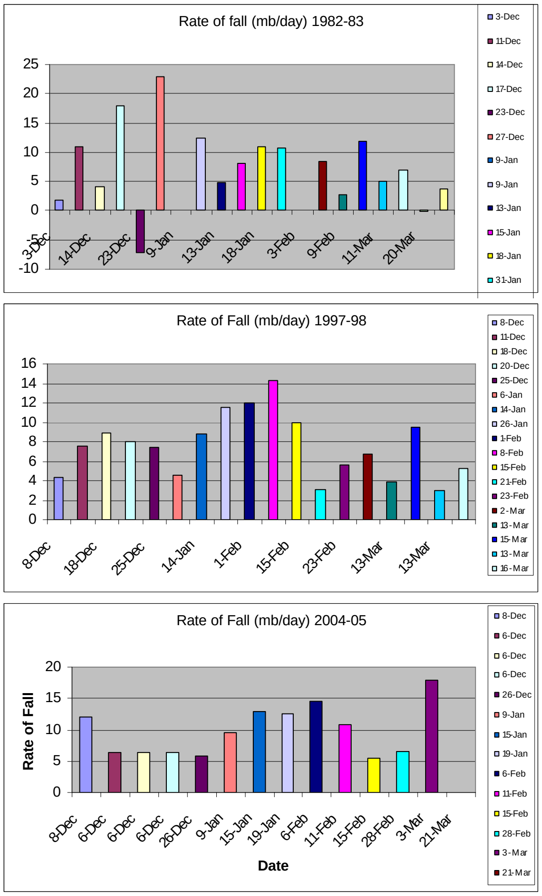

Fig. 6. Rate of pressure fall for cyclones during the winters of 1982-83, 1997-1998, and 2004-05.

4. DISCUSSION

Sanders and Gyakum (1980) found that the greatest number of "bombs" occurred during January, while in this study for three El Niño winters, there were more storms off the East Coast in the months of Feb. and Mar. This suggests that during El Niño winters, the jet stream was pushed further southward. Since the jet stream was in fact pushed further south in the years studied, the storms that developed were able to gain energy over the warmer water and land in the south and therefore intensify to bomb-type storms. Because of the southerly track of the storms due to El Niño, the storms would tend to encounter temperature differentials greater than that of more northerly tracking storms. The current year had fewer storms with relatively less frequency and intensity. That coupled with a relatively less intense winter could lead to the conclusion that the 2004-05 event was indeed not a strong El Niño event.

5. CONCLUSIONS

El Niño and the Southern Oscillation do indeed play a role in the intensification and frequency of the Nor'easters. The teleconnection that occurs between the Pacific and the North American atmosphere cause changes in the ability for storms to rapidly form during the winter months. The first two events studied (1982-83 and 1997-98) were two of the strongest in recent years. There was clearly a higher frequency of storms that followed a Nor'easter pattern in these El Niño years. Their intensities and strong El Niño patterns of storm formation shown by the data was substantiated by the MEI chart. The current year (2004-05) does not seem to be a strong El Niño year. It did not show signs of southern storm tracks and no storm ever formed into a "bomb". If anything, the 2004-05 year showed weak or moderate El Niño tendencies. This too was substantiated by MEI values.

For further research on this subject to show the effect of El Niño on the formation and intensity of Nor'easters, a few suggestions are made. If the study could examine the formation of the storms on a more frequent interval, such as every six hours, rather than every 24 hours, the storms could be better tracked. This may show the formation of a "bomb" within the 24-hr period that was previously unseen. By comparing more years in the study, a better correlation could be made. Comparing years that are also not strong El Nino years and even years that are strong La Nina years would aid in the development of a better connection.

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