

EVALUATION OF THE MODIFIED ECFL LURCS RIP CURRENT
FORECASTING SCALE AND CONDITIONS OF SELECTED
RIP CURRENT EVENTS IN FLORIDA

By

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by

Matthew Schrader

This document is dedicated to my parents and brothers.

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I would like to thank my family for their support and advice during my past two-and-a-half years at UF. I always loved to go home.

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Abstract of Thesis Presented to the Graduate School
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By

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Sea state parameters and meteorological conditions associated with rip current events were evaluated for sites in Volusia County, Florida, and counties in the Florida Panhandle. Data from a two-week period in Volusia County were used to make an unbiased evaluation of the Modified ECFL LURCS rip current forecasting scale. Rip current rescues performed by county lifeguards during this time were used as markers for rip current occurrences. The Modified ECFL LURCS scale was used to hindcast the rip current threat at these times. An evaluation of the scale was made by comparing the calculated threat of occurrence to actual rip rescue occurrences. The scale predicted rip currents for the majority of days containing rescues and did not predict rips on days without rescues. A further study of rip current occurrences along the Florida Panhandle revealed some similarities in wave characteristics and meteorological events that may create sea conditions which force rip currents. Some conditions, however, are dissimilar and suggest that specific locations have their own range of key parameters, and a specific

range of parameters cannot be used to accurately predict rip current threat in different locales. Meteorological events at the time of rip occurrences were evaluated in an effort to study the effect of passing weather systems, which induce varying wave and wind directions and strongly alter the sea state.

CHAPTER 1 INTRODUCTION

As part of an ongoing study at the University of Florida, meteorological maps, photographs, wave and tide data were used in an attempt to characterize dangerous rip current events in various sites throughout Florida. The Modified ECFL LURCS, a rip current predictive index developed by Engle (2003), was used in the evaluation. This served as a blindfolded test of the index.

Rip currents, on average, result in more deaths in Florida than hurricanes, tropical storms, lightning and tornadoes combined (Lascody 1998). Beaches in Volusia County, on Florida's east coast, and in the counties of Florida's Panhandle, which border the Gulf of Mexico, have high numbers of rip current rescues and deaths compared with other Florida beaches. Volusia County averages more rip current rescues each year than all other Florida counties combined (Lascody 1998). Panhandle counties, including Escambia, Santa Rosa, Walton, and Bay County experienced a high number of rip current drownings and rescues during the summer of 2003.

In an effort to predict the formation of rip currents, Lushine (1991) developed the Lushine Rip Current Scale (LURCS), an empirical forecasting technique that utilizes wind direction and velocity, swell height, and the time of low tide to forecast rip current danger in South Florida (Engle 2003). The LURCS scale was modified for use in east central Florida (ECFL LURCS) by changing the tidal factor and including swell period Lascody (1998).

The ECFL LURCS was modified by Engle (2003) in order to reduce the amount of false alarms predicted by the scale. Two wind factors were removed from the scale and three parameters were added: 1) an improved tide factor, 2) a wave direction factor, and 3) a directional spreading factor. These modifications were based on directional wave data obtained for Volusia County for 1996 and improved the accuracy of the ECFL LURCS scale for that specific site.

In this study, with the intention of testing the Modified ECFL LURCS scale, a two-week data set from the Daytona Beach area was evaluated. This period corresponded to a field experiment which included the deployment of a directional wave gage. This study also had the added parameter of daily beach population which was used to normalize the number of daily rip current rescues.

It was thought that wave and sea characteristics that create rip currents in Volusia County may also create rips in other parts of Florida. To investigate this theory, wave characteristics and tidal stage at sites along the Florida Panhandle were evaluated on days marked by rip current drownings during the summer of 2003. An evaluation of the parameters favorable for rip current formation in Volusia also showed a positive correlation to rip formation in the Panhandle, although values and ranges of the parameters differed.

Large-scale meteorological events such as pressure systems may play a part in the creation of rip current producing conditions. Meteorological maps, time-lapse and still photos taken on days with high numbers of rip current rescues were evaluated to examine possible connections between rip currents and weather patterns. On days with high numbers of rescues and deaths, all available data, including wave and sea state

parameters, meteorological maps, photographs and beach population are presented in an attempt to describe as fully as possible all factors that may lead to events of rip current occurrence.

CHAPTER 2 RIP CURRENTS

Rip currents are relatively narrow currents, generated in the near shore, which move offshore through the surf zone. The word “rip” may be derived from the idea that the current rips through the sand and offshore bar, creating channels through which the current flows. The offshore velocity in rip currents can exceed 2 m/s (4.5 mi/hr), and they contribute to the death toll at beaches by carrying unwary swimmers directly offshore into deep water (Dean and Dalrymple 2002). They can form along beaches with varying topography, or flat beaches with sandbars, as well as near structures such as piers and jetties.

Tidal stage, wave height, period, wave direction, and directional spreading have been correlated to rip current formation. Shepard et al. (1941) noted the relation between larger waves and stronger rip currents as well as a connection with tidal stage. In 1958, McKenzie correlated wave direction with the orientation of rip currents, stating that rips commonly turn diagonally across the surf zone into the direction of approaching waves. Engle’s (2003) research in Volusia County, Florida indicated an especially strong correlation of rip current rescues with both wave direction and directional spreading. Sonu (1972) and Lushine (1991) also found positive correlations between shore-normal wave angles and rip current occurrence. Lushine specifically referred to winds of sustained onshore direction, which would imply that the wave direction was most likely

also onshore. According to anecdotal evidence from the Panhandle, rip current accidents are more likely to occur after a period of sustained onshore wind.

Surf-zone topography has also been found to have a strong influence on rip current formation and strength. Rip currents are associated with longshore variations of bottom contours in the nearshore, where rip currents occur in the deeper regions and shoreward transport occurs over the shallower regions. This topography includes beach cusped features as well as deeper channels occurring periodically in the offshore bar. Beaches along Volusia County are straight, and longshore-alternating bars and rip channels are reasonably common. The beaches are fairly two-dimensional, but when rip currents are present, low relief cusped features and feeder channels can be seen in the swash zone.

Sonu (1972) related rip currents to surf-zone undulations. His study area was Seagrave Beach, in the Florida Panhandle, in the vicinity of data collected for this study. Beaches here tend to be more three-dimensional than those of Volusia County. Beach cusped features, and the nearshore circulation they induce (where waves tend to break on the cusp horns, then run out of the embayments), may form more permanent channels for rip current action. It is possible that tidal stage is not as important here as in Volusia County, where the more two-dimensional beach profile may require certain sea conditions for rip channels to open, and lower water levels for the rip cells to strongly develop. However, at Seagrave Beach, Sonu (1972) positively correlated increasing rip current velocities to lower tide levels. It was thought that low tide caused stronger breaking on the bar, increasing set-up and radiation stress which would strengthen rip current intensity. For a more in depth discussion of the general characteristics and causes of rip currents, the reader is referred to Engle (2003).

The difficulty with using rescue data as a marker for rip current occurrence is that people must be in the water for rescues to occur. Rip currents are probably occurring during conditions that include long period, large onshore waves (and probably onshore wind). However, due to the fact that no swimmers are in the water when conditions are rough, a lack of rescue data does not verify this.

Lushine observed that rip currents would sometimes continue to occur once the wind turned clockwise after a several day period of moderate to strong onshore wind. He also noted that rip currents generated by swells, especially when these swells are decreasing, can be particularly hazardous, because local winds may be light, and bathers may be deceived into thinking surf conditions are safe (Lushine 1991). It appears that rip rescues begin to occur with a drop in wave height, decreasing (or more offshore) winds, and a general improvement in the weather. An increase in rescues during such “improving” conditions was noted by both Lushine (1991) and Engle (2003). Often, this type of improving weather and sea state is a characteristic of a passing frontal system in Florida.

the Panhandle recorded an unprecedented amount of rescues and deaths. There have been, “upwards of 40 drowning deaths since Jan. 1, 2000,” in the Panhandle counties of Gulf, Bay, Walton, Okaloosa, Santa Rosa and Escambia (Hauserman, 2003).

In 1991 Lushine noted that little had been published about the number of drownings caused by rip currents or about attempts to operationally forecast their occurrence. He then developed the LURCS scale to predict rip current threat.

The scale works by assigning values to specific ranges of parameters. Those ranges that correlate to the highest incidence of rip rescues are assigned the highest values. The sum of all parameter values is the “scale” of the rip current threat, and warnings are issued to the public depending on this scale exceeding a certain threshold value.

Subsequent modifications to Lushine’s scale by Lascody (1998) and Engle (2003) seem to indicate that parameters (and their ranges) affecting rip current development are site specific. The parameters included in Lushine’s scale were wind direction, wind speed, swell height, time of low tide, and a persistence factor relating to previous days’ conditions. Lascody’s modifications included the addition of a wave period parameter and a miscellaneous factor to account for higher astronomical tides. Engle removed the wind parameters and introduced a directional spreading parameter and a more detailed tide parameter, among other modifications. Each researcher’s modifications to an existing scale lead to the notion of parameters being site specific. For instance, the effect of tidal stage, may be more important at one site than another. Similarly, the range of tide that correlates to the strongest rips may also differ between sites.

It is because of this that quite possibly one rip current forecasting scale cannot adequately predict rip currents for a large expanse of coastline, such as east central Florida. It is possible that a scale needs to be developed for each region, based on certain parameters and ranges.

For instance, on June 8, 2002, Walton County beaches in the Panhandle recorded eight rip current deaths. Data describing the primary forcing parameters are comparable to days in Volusia County with large numbers of rescues: relatively shore normal wave direction, and decreasing wave height. However, tidal fluctuation on June 8th, in Walton County, was the smallest of the month. The Modified ECFL LURCS, developed for east central Florida, could not be directly applied to beaches in Walton County even though some of the forcing signatures are similar. A new scale would have to be developed including parameter ranges most influential to that region.

An improvement that might be made to prediction efforts, and could very likely be applicable to sites throughout, and outside of, Florida, is accounting for large-scale meteorological events. This study found a correlation between the occurrence of rip currents and the presence of pressure and frontal systems. Storms usually accompany these systems, bringing strong winds and larger waves with long periods.

It is the purpose of this study to predict rip currents, not rip current rescues. Rip current rescue data, however, are used to mark the existence of rip currents in the belief that where there are rescues, there are currents. Rescue logs from Volusia County are very detailed and clearly indicate what type of rescue took place. Rip current rescues are always noted with the word "RIP" to distinguish them from other types of rescues such as "swimmer in distress," or "overturned jet ski." Logistical problems limit the opportunity

to measure rip currents directly since they are sporadic and not always located in the same place. Therefore rip rescue data, despite their shortcomings, represent the most available and credible evidence available.

CHAPTER 4
STUDY SITES AND DATA

Volusia County

Site Description

The coastline of Volusia County, including Daytona Beach, was the study site on Florida's east coast.

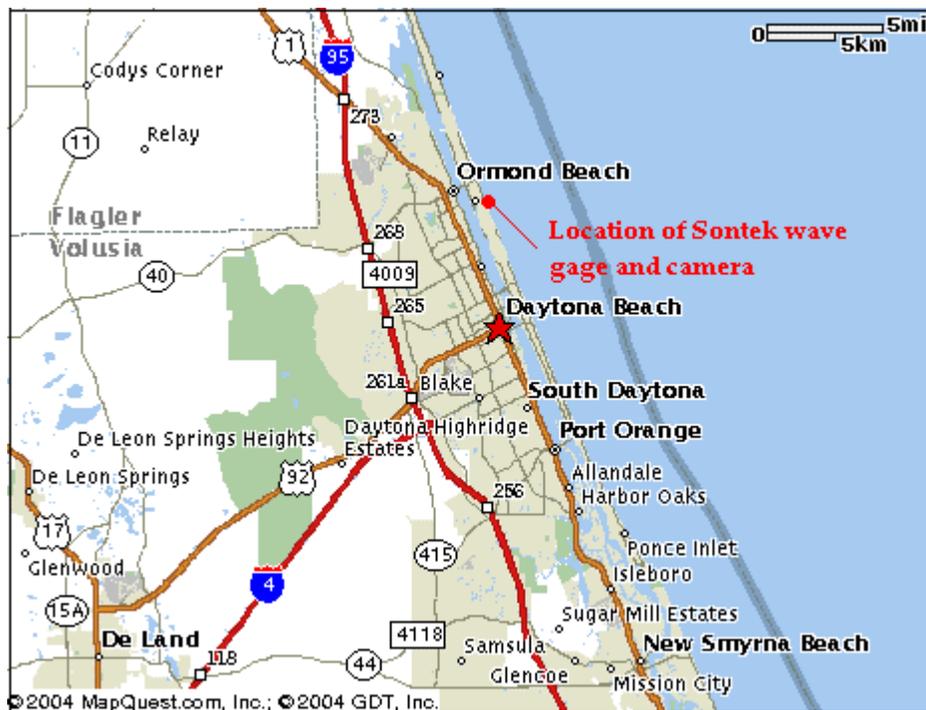


Figure 4.1: Map showing study site in Volusia County, Florida and the location of the Sontek wave gage and camera used for still and time-lapse photos

Beaches along this area are relatively straight and sandy, and periodically spaced rip channels occur fairly frequently in the offshore bar. The average beach slope from the upper beach face to the depth of closure is $1/45$, and the mean sediment diameter is 0.2mm at the shoreline (Charles et al. 1994). The continental shelf is 70km offshore, and

the bottom slopes mildly to this point. The beach and beach face are relatively two-dimensional, and offshore contours are relatively shore-parallel. Semidiurnal tides have an approximate maximum range of 2 meters. During the summer months (the time of this and Engle's (2003) study) wave directions are normally from the southeast. Northeasterly wave directions occur during most of the winter and are characteristic of offshore summer storms. The average deep water wave height for 1996, according to Engle's study (2002), was 0.7 meters. The average wave height during this study was 0.86 meters.

Rip Current Rescue Data

Rescue data were made available by the Volusia County Beach Patrol. Rescue logs are kept for each of 103 lifeguard towers along Volusia's beaches. The logs list: type of rescue, time of rescue, tower number, and number of victims. Rip rescue data from all towers in Volusia County were used in this study. However, only rip rescues from the hours of 10 a.m. to 5 p.m. were considered since these are the hours during which the beach is most populated. This procedure hopefully reduces the likelihood of a rip current event not being "recognized" due to a lack of swimmers

Wave Data

Directional wave data were collected by a Sontek wave gage. The gage was deployed roughly $\frac{1}{4}$ miles from shore in 4 meters of water off Ormond Beach in Volusia County (see Figure 4.1). This site was chosen for its proximity to where bathymetric data was being collected in the hopes of mapping rip channels. The gage uses one pressure sensor and three velocity beams, which measure water velocities in the x (east- positive), y (north- positive), and z (up- positive) directions. An internal compass records velocities relative to magnetic north. The package samples at a rate of 2 Hz, and

recorded data in hourly bursts. Each of 322 bursts for the period contained 4200 samples. Spikes in the time series were replaced by linearly interpolated values.

Available data covered a two-week period from May 7th through May 20th, 2002. The pressure/velocity data were analyzed by a suite of Matlab programs, titled DIWASP (Directional Wave Spectra Toolbox for Matlab). DIWASP used the IMLM (Iterative Maximum Likelihood Method) of spectral estimation in order to compute wave height, period, and direction for the two-week period. The directional spectra were then created from this output. Frequency resolution for the directional spectra was 0.01 Hz, and directional resolution was 1 degree. Wave direction used in this study corresponds to the dominant direction (Dp) output from DIWASP. This is the direction with the highest energy integrated over all frequencies. Directional spreading was calculated using Matlab code written and used by Engle (2003) for his study.

Statistics were derived from the directional energy density spectra, $S(f, \theta)$, as follows. The k^{th} moment of the spectral density function, denoted m_k , is defined as:

$$m_k = \iint f^k S(f, \theta) d\theta df$$

The k^{th} angular moment of the spectral density function, denoted dm_k , is defined as:

$$dm_k = \iint \theta^k S(f, \theta) df d\theta$$

Engle (2003) computed directional spreading as:

$$dspr = \sqrt{\frac{dm_2}{dm_0}}$$

However, he did not remove the mean direction from all directions when calculating the second angular moment to input into the calculation for directional spreading. If the peak of the directional spectrum was around zero (in which case the mean would be close to

zero), failure to remove the mean would not create a significant difference in the calculation. However, if the peak is not centered close to zero, removing the mean becomes important. The following additions were made to his code:

$$\text{mean direction (D)} = \frac{dm_1}{dm_0}$$

$$\theta_{new} = \theta - D$$

$$dm_2 = \iint \theta_{new}^2 S(f, \theta_{new}) df d\theta_{new}$$

In order to verify the DIWASP output, the same pressure/velocity data was run through another suite of Matlab programs created by Nortek, titled ‘WDS’ (Wave Directional Spectrum). Output from this suite includes wave height, period, direction, and directional spreading.

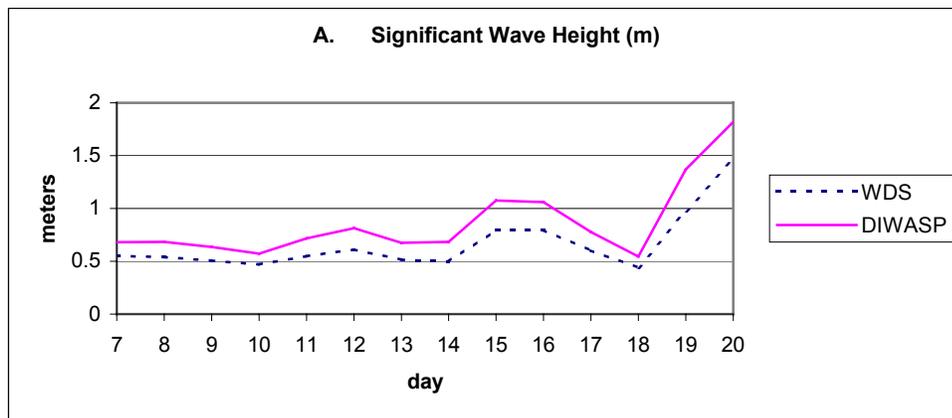


Figure 4.2: Output comparison between WDS and DIWASP. A) significant wave height, B) peak period, C) peak wave direction, and D) directional spreading. Zero degrees corresponds to shore-normal. Counter-clockwise from shore-normal is the positive direction.

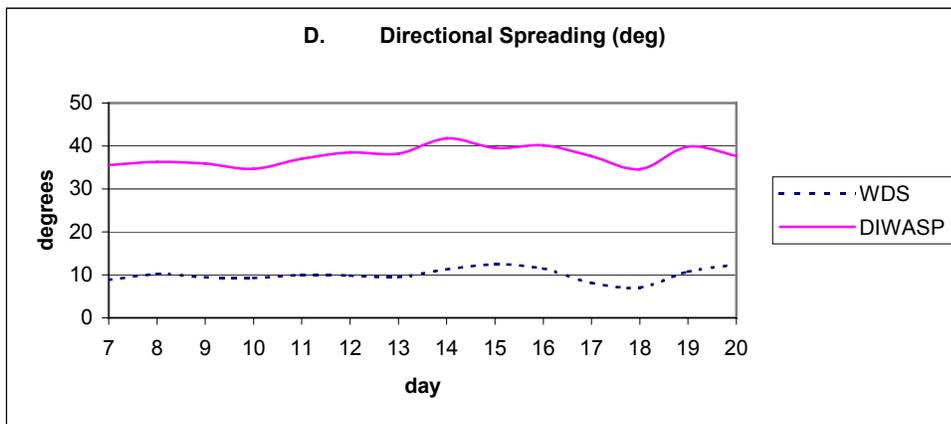
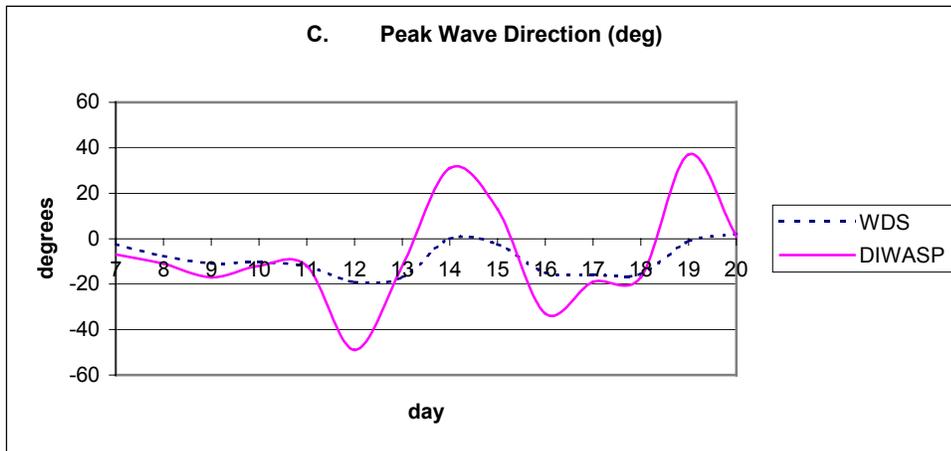
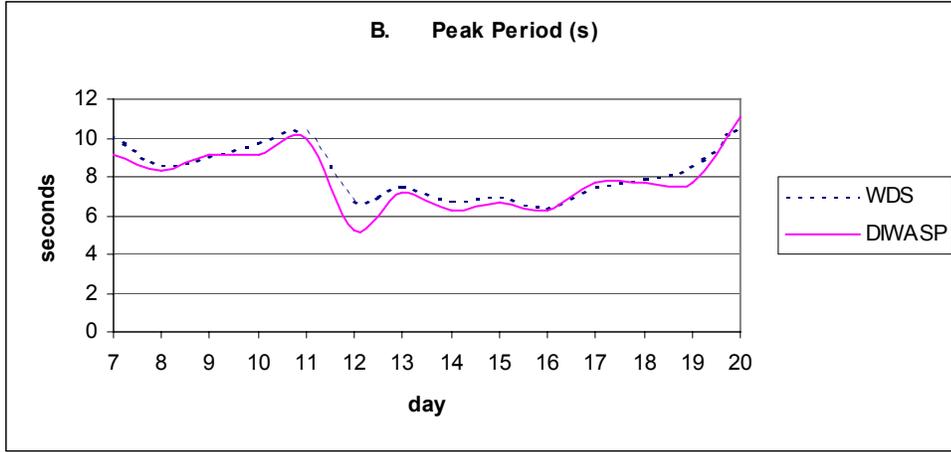


Figure 4.2. Continued

Figure 4.2 shows that wave heights and periods between the two suites agreed well. Wave directions given by WDS were consistently more shore normal than DIWASP, however the general directions (northeasterly or southeasterly) agreed. Engle used DIWASP in his study, and the DIWASP data were used in this study for a few reasons. The first reason is that the DIWASP wave directions showed better agreement with photographic evidence showing a pronounced shift in wave direction from southeast to northeast on May 14th and 19th. WDS does not show such a marked change in direction. It is also important that DIWASP computes a dominant wave direction (D_p) as well as a peak wave direction (WDS only calculates peak wave direction; therefore, that is the only period comparison shown in Figure 4.1). Engle (2003) computes directional spreading related to the dominant direction (D_p), which is the direction with the highest energy integrated over all frequencies. WDS computes directional spreading for the peak direction integrated over the peak frequency. This difference is the main reason why directional spreading results from WDS were smaller than those from DIWASP. In order to stay consistent with Engle (2003), the dominant wave period from DIWASP and Engle's program for directional spreading were used in this study.

Tidal Data

Tidal data were retrieved from a web-based tide predictor "<http://tbone.biol.sc.edu/tide/index.html>". Comparison with tidal data from 1996 used by Engle indicated a constant difference of +0.53m due to the use of a different tidal datum (the predictor uses mean lower low water). Therefore, this factor was subtracted from all 2002 predicted tidal data in an effort to keep parameters used in this study and Engle's as similar as possible.

Photographic Data

Photographs of the beach and ocean near the field site in Ormond Beach, Volusia County, Florida were taken using an automated camera situated on the roof of a beach-front condominium approximately 1 mile south of the site (see Figure 4.1).

The camera location was chosen because it is 1) in Volusia County, just north of Daytona Beach, 2) shoreward of where the Sontek wave gage was deployed, and 3) the site of bathymetric surveys.

For the two-week study period in 2002, a snapshot was taken at the start of every hour, and then a 3-minute time-lapse photo was taken. Unfortunately, not many time-lapse photos exist. Due to technical difficulties, the time-lapse photos were often only taken as snapshots.

Meteorological Data

Weather maps were retrieved from the website “http://weather.unisys.com/archive/sfc_map/”. Composite surface maps contain the following analyses: radar summary, surface data plot, frontal locations and pressure contours. Surface data is reported hourly from places like airports and automated observing platforms. These data are updated hourly at around 30 minutes past the hour. Frontal data are only available every 3 hours, so fronts may not exactly match the weather conditions.

Beach Population Data

Beach attendance was estimated from entrance ramps along Volusia County beaches. These ramps are controlled by Republic Parking, and records are kept of the number of cars entering the beach each day. This gives a rough estimate of the number of people on the beach when rip rescues occur but not necessarily the number of people

in the water. However, it is a reasonable conclusion that on days when there are many cars at the beach, there will be more people in the water compared to days with few cars.

Panhandle Counties

Site Description

During the summer of 2003 rip current deaths were recorded in four different counties including Bay, Escambia, Santa Rosa, and Walton along the Florida Panhandle (see study area in Figure 4.3).

A basic analysis of wave data, tide conditions and meteorological conditions was conducted for this time period. It was the goal of this study to make a preliminary investigation into rip current forcing parameters in the Panhandle and to evaluate if they were comparable to those found in Volusia County.

Beaches in the Panhandle study area are sandy with very common cusped features on the beach face and surf zone undulations. Sonu (1972) noted that the surf zone is relatively shallow with 1 meter or less depth over the inner bar. Outside the inner bar, the bottom drops steeply to about 5 meters, and then rises to about 4 meters at the outer bar, approximately 200 meters offshore. The offshore topography is smooth. Semidiurnal tides in this area have an approximate maximum range of 0.7 meters. The average deep water wave height during the days studied in 2003 was approximately 1.2 meters at the offshore buoy.

Rip Current Death Data

The beaches along Florida's Panhandle are not monitored as densely as those of Volusia County. For this reason, and due to a lack of record keeping, there is not much data available regarding rip current rescues. Rip current deaths, however, were well documented by periodicals during the summer of 2003. Through this source, the day and

area where drownings occurred are known. However, the approximate time that the victim was caught in the rip current is not known.

Wave Data

Wave height, period, and wave directional data were taken from NOAA National Data Buoy Center buoys: #40239 for Bay and Walton Counties, and #42040 for Escambia County.



Figure 4.3: Study area and location of NDBC buoys #42040, located 64 nm south of Dauphin Island, AL at water depth 237m, and #42039, located 115 nautical miles east-southeast of Pensacola, FL at water depth 284m.

Wave heights and directions were then shoaled and refracted, using linear wave theory, to 10m water depth. Waves with periods of 7 through 9 seconds would travel from buoy #42039 to the coast in approximately 4 through 5.5 hours and from buoy #42040 to the coast in approximately 2.5 through 3 hours. Dropouts occur in the shoaled/refracted data where wave directions at the 10m mark were calculated to be coming from a direction greater than 90 degrees (0 degrees corresponds to south) or less than -90 degrees. These wave directions would correspond to waves not coming to

shore. Tidal data was retrieved from the same tide predictor as noted above for Volusia County data, and the same web-based weather map provider used for Volusia County was used for the Panhandle.

CHAPTER 5 STATISTICAL ANALYSIS

Volusia County

Rip Current Rescue Statistics

It is the purpose of this study to predict the occurrence of rip currents most dangerous to beach goers and not rip current rescues or drownings. Like lightning injuries due to a thunderstorm, rip current rescues are influenced by both meteorological and human factors. Weather forecasters do not predict how many people will be struck by lightning during a certain storm because it is unpredictable how many people will go out in bad weather, or will go to a place where a lightning strike is likely to occur. It is the same case with rip currents. There are far too many anthropogenic factors involved, such as whether people will be in the water, or whether they will go near rip channels when rip currents are occurring. Like severe weather prediction, it is more practical to warn people of dangerous conditions, then depend on them to heed the warning.

Due to factors such as cold temperatures or very large waves (both of which tend to keep people out of the water), rip currents may be occurring on many days, but there will likely be no rescues to “mark” them. This is a shortcoming with the use of rescue data in place of actual rip current measurements. However, Lushine (1991) Lascody (1998) and Engle (2003) used rescue statistics and found that the benefits of rescues as a long term, dense record of rip current events outweighed the drawbacks, and thus considered them as a valid source of data for creating their predictive scales.

The logistics of placing and maintaining instruments in the field to measure rip currents are complex and can present many obstacles. This is due to the constantly shifting nature of beaches (like those in Volusia Co. and the Panhandle) with a sandy bed as well as the migratory nature of rip channels. Instances of instrument burial were fairly common when *in situ* measurements were attempted. Some structures, such as rock jetties, have permanent rip channels nearby where measurements would be far easier, but these are not the naturally occurring sandbar rip channels that lead to most rescues and deaths.

An analysis of rescues and wave data is limited by the length of the data set. This study's analysis from Volusia County constituted a period of only two weeks, which severely limited the number of rescues that were analyzed. This had a large effect on the accuracy of the Modified ECFL LURCS due to the fact that the number of rescue days was small. Therefore, if one is missed, it has a greater negative effect on the scale's accuracy than if there were a longer time series with a larger amount of predicted rescue days.

Beach population data bolsters the reliability of rescue data in marking days of high rip current occurrence. Total daily rescues can be normalized by daily beach population. Hence, days with many rescues and few people on the beach would represent a higher rip threat than days with many rescues and many people on the beach. Normalization of rip rescues per hour was accomplished by dividing by the total number of cars that entered the beach that day (beach ramp data was only available on a daily, not hourly, basis). This number was multiplied by 10,000 for ease of use. This can be visualized by comparing May 10th and 12th in Figure 5.1. The 10th had fewer rescues than the 12th.

However, since population was also low on the 10th, the relative risk, reflected by normalized rescues, is actually higher than that of the 12th. As an extreme case, consider the days of May 7th and 20th, which both had one rescue. Beach attendance on the 7th was relatively normal, so the normalized rescues are slightly higher than the raw rescues. However, on the 20th, there was a very low population which gives a great deal of weight to the one rescue and results in a spike in the normalized rescues. However, with only one rescue to use as a marker, the extrapolation to a dramatically greater risk is somewhat tenuous. At any rate, the comparison demonstrates the value of beach population data.

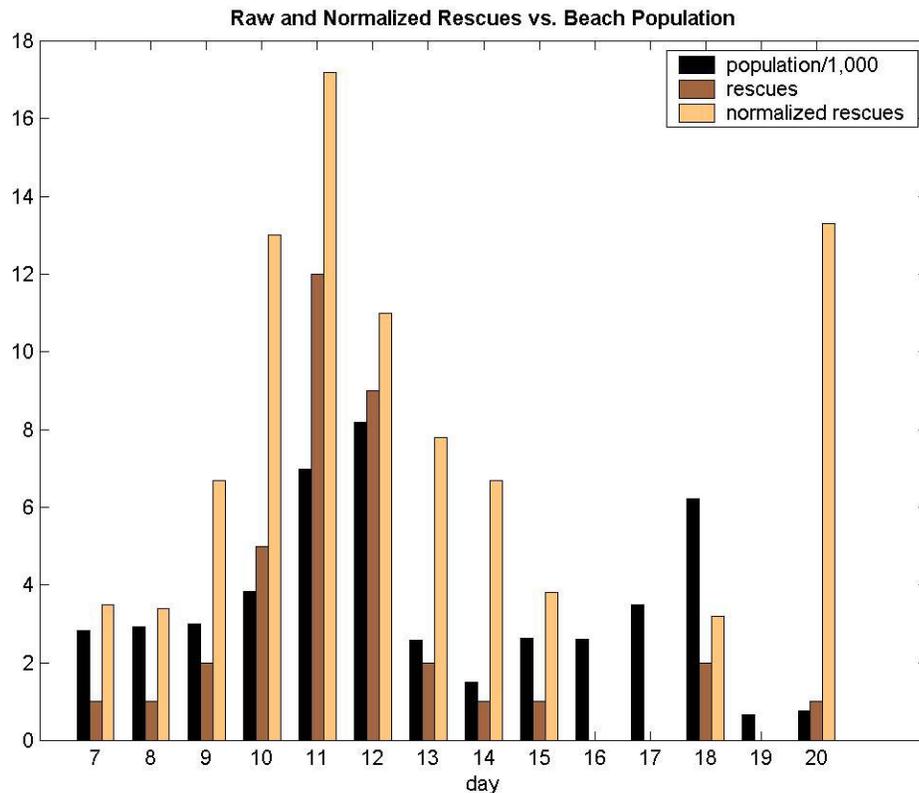


Figure 5.1: Daily beach population compared to daily rescues and daily normalized rescues for May 7th through 20th, 2002. Normalized rescues are daily rescues divided by the daily population multiplied by 10,000.

By observation, the times of greatest attendance at the beach are the hours between 10 a.m. and 5 p.m. In order to evaluate parameters during the time of highest attendance,

and highest number of rescues, only rescues between these hours were considered. The time of the study (May 7th through May 20th, 2002) is also a time of high beach attendance and includes a major beach holiday. Because of this, the study was not adversely affected by a seasonal low beach attendance.

Wave and Tide Statistics

Four wave parameters including deep water wave height, wave period, deep water wave direction, and directional spreading along with tidal stage are compared to normalized rip current rescues in this section. Each parameter is individually related to normalized rescues using a double bar histogram. In each histogram, light colored bars represent parameter frequencies for the entire period (May 7th through 20th, from 10:00am to 5:00pm each day). The number of observations in each bin range was normalized by the total number of observations. The dark colored bars represent the frequency of normalized rip current rescues within specified parameter ranges. For instance, the deep water wave height histogram (Figure 5.2(A)) shows how often wave heights of 0.5m, 1m, 1.5m, etc. occurred during the entire period, compared to how often rip rescues occurred when waves were at those heights. Therefore, if wave heights of 0.9m had a small frequency, while rip rescues at that height had a high frequency, there would be a strong positive correlation between that wave height and rip current occurrence. The relative magnitude of the normalized rip rescue probability compared to the overall probability within each bin of the double histogram is effectively a measure of the risk.

The parameters and rip rescues were recorded on an hourly basis, therefore the values of tidal stage, wave height, period, direction, and spreading are fairly precise for each rescue. If four rescues occurred between 12 p.m. and 1 p.m. during a day, then the parameters for that hour were recorded four times.

The sum of the squared difference (SSD) between the light and dark bars is given on each plot. A higher SSD means a high correlation (positive or negative) between rip occurrence and that parameter. For example, there might be a high positive correlation between 0.9m wave height and rips and a high negative correlation between 1.6m wave height and rips. These combined would give the same SSD as having a high positive correlation for both. A higher SSD simply says there is a correlation, not whether the correlation is positive or negative.

Wave height and direction were shoaled and refracted to deep water (consistent with the approach of Engle (2003)) for use in the Modified ECFL LURCS scale.

Figure 5.2(A) shows that 82% of rescues occur at wave heights between 0.7m and 1.3m. The highest correlation is at 0.9m with 34% of rescues happening while wave heights only reach this height 14% of the time. These values are higher than those found by Engle (2003). He found that 63% of all rescues occurred with wave heights between 0.45 and 0.85 meters. A possible outlier in this study occurs at 2.4m. This high wave height only occurred 3% of the time, but rescues at this height occurred 12% of the time. It must be remembered that only two weeks of data were used for this study which included a relatively small amount of rescues (37 rescues). The event in question occurred on May 20th. There was one rescue on that day but a low beach population of 754 cars. Since the rescues were normalized by population, a great amount of weight was given to this one rescue.

Wave periods between 8 and 9 seconds have the strongest positive correlation with rescues. This agrees well with Engle (2002), Lushine (1991) and Lascody (1998) who

found strong correlations between rip current rescues/drownings and longer period waves.

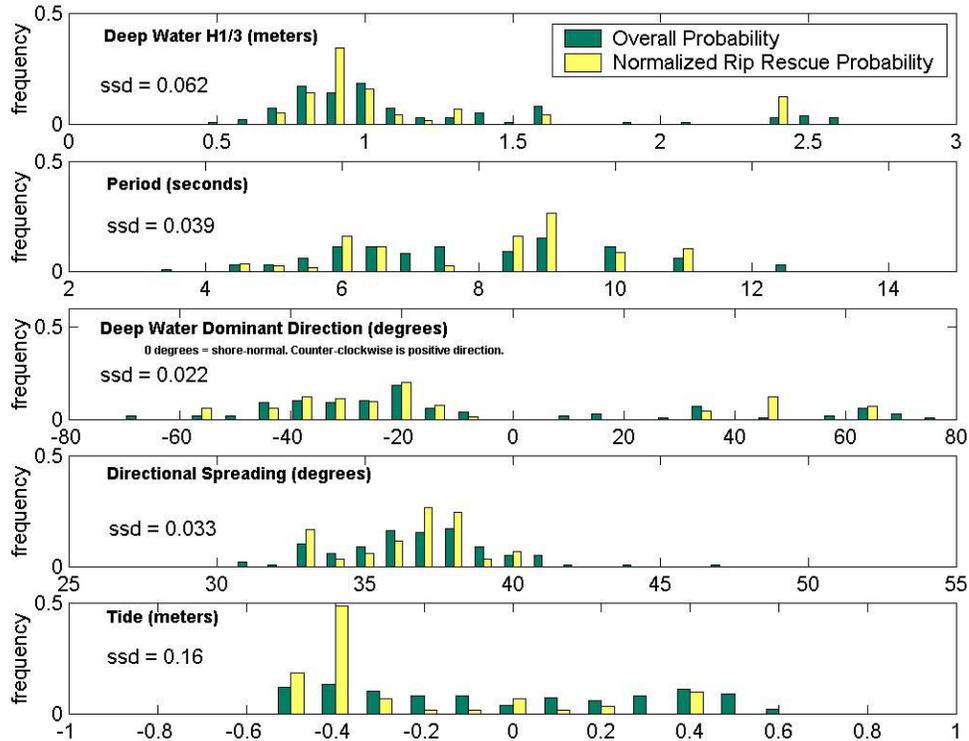


Figure 5.2: Frequency distributions of A) deep water significant wave height, B) wave period, C) deep water dominant direction D) directional spreading, and E) tidal stage. May 7th through 20th, 2002, 10:00am through 5:00pm. Rip rescue data is normalized by beach population.

Rescues had the best correlation with deep water wave directions of -20 degrees to -39 degrees (Figure 5.2(C)). Engle found the best correlation between 20 to -35 degrees. During the summer, most waves come from the southeast (negative angles). It must be remembered that data for this study was from a relatively short time period, compared to Engle's, and few days had waves from positive angles. The high correlation that Engle found between directly onshore (0 degrees) waves and high rip rescue occurrence was not apparent in this data set.

Directional spreading showed a weaker correlation than in Engle's study. This study found directional spreading of less than 39 degrees occurred 75% of the time and accounted for 91% of rescues. Engle (2003) found that directional spreading less than 35 degrees accounted for 75% of rescues while waves occurred in that range just 37% of the time. However, in this study, the SSD was the lowest of all parameters.

Tidal stage (Figure 5.2(E)) had the strongest positive correlation with rip rescues in this study. This is reflected in an SSD of 0.16, the highest of all parameters. The greatest positive correlation is with tides in the -0.5 to -0.4 meter range. This range accounts for 68% of rescues while occurring only 25% of the time. Engle found the range from -0.75m to -0.45m accounted for 62% of rescues while occurring 42% of the time. During this study, the tide never dropped below -0.5m (between 10:00am and 5:00pm) as it did in Engle's study. It is thought that more rescues occur at lower tide levels because there is stronger breaking on the bar which increases set up. Lower water levels also force water flow through the more hydrodynamically efficient rip channels instead of over the shallow bar.

Comparison plots of the entire two-week period were useful in further evaluation of parameters with a high SSD. These plots include parameter values from all hours during the two-week period but only the rescues (not normalized) that occurred between 10:00am and 5:00pm.

Figure 5.3 demonstrates that the majority of rescues occur during decreasing wave height. This relation was also noted by Engle (2003), Lushine (1991), and Lascody (1998). The clusters of rescues occurring during wave heights under 1.25m also lead to the conclusion that lower wave heights can pose more of a threat to beach goers; not

because there are no rips with higher waves, but because bathers do not perceive the danger when waves are smaller.

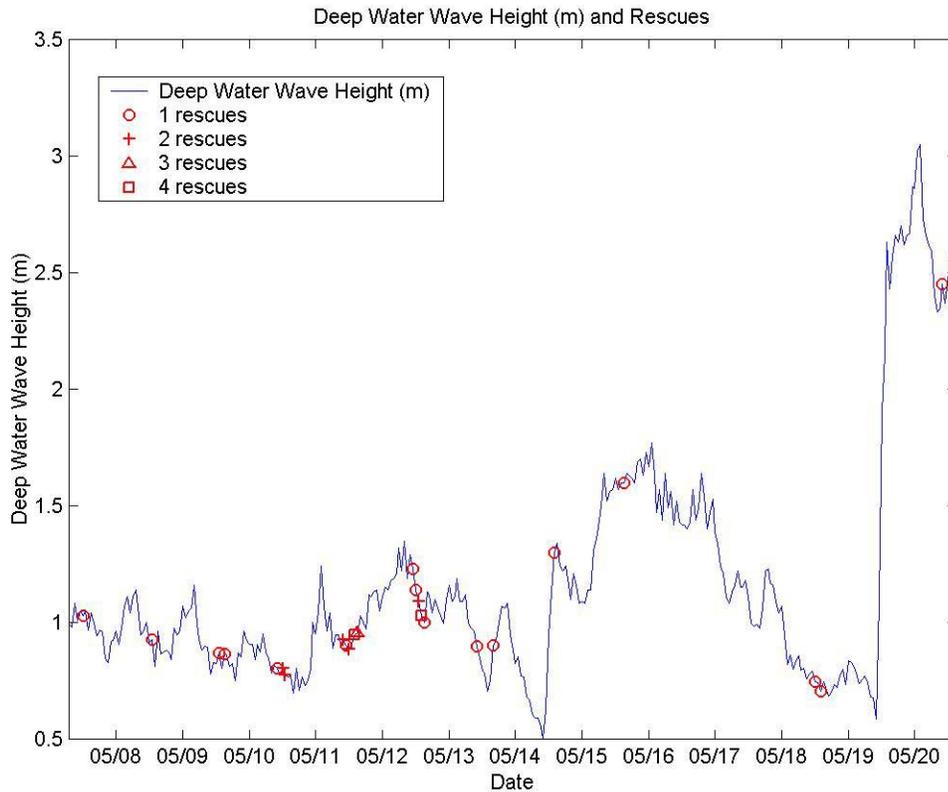


Figure 5.3: Entire record of deep water wave heights for Volusia County, FL and 10:00am through 5:00pm rescues. May 7 – May 20, 2003.

Figure 5.4 demonstrates that most rescues were grouped in the first week when wave directions were more consistent. During the second week, wave direction fluctuates widely, possibly due to local wind waves moving at different directions from a longer period swell. Only 5 rescues occur during this confused sea state. This supports the conclusion that consistent, normally directed wave angles are more conducive to rip current occurrence.

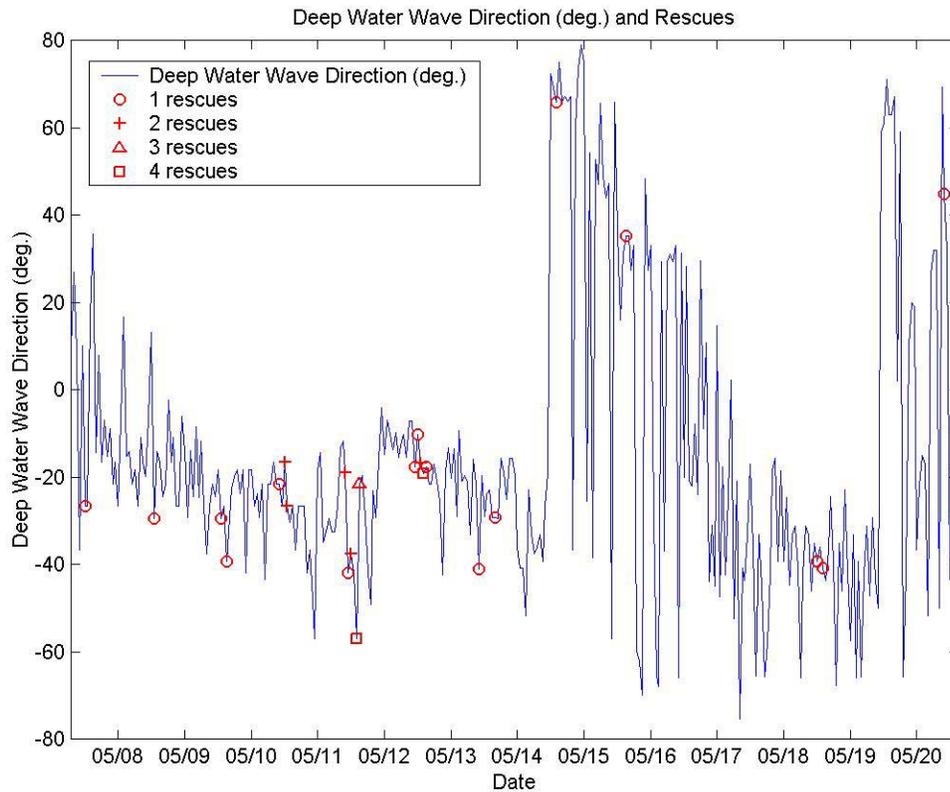


Figure 5.4: Entire record of deep water wave directions for Volusia County, FL and 10:00am through 5:00pm rescues. May 7 – May 20, 2003.

The relation between lower tide levels and rescues is very evident in Figure 5.5. During the first week, there is at least one rescue at every other low tide (this would be the daylight low tide when the beach was populated). Only three rescues occurred near high tide during the entire period. Also of note is the amount of rescues occurring on a falling tide. Six out of seven rescues that occurred in the mid-tide range (between -0.2 and 0.2 meters) of the first week occurred during a falling tide.

Engle (2003) referred to anecdotal evidence from beach patrol staff suggesting that rip current related rescues may occur more frequently during outgoing tide. However, he found no correlation between ebbing tide and rescues. Sonu (1972) noted that rip current intensity increased with a falling tide due to increased breaker activity on the bar.

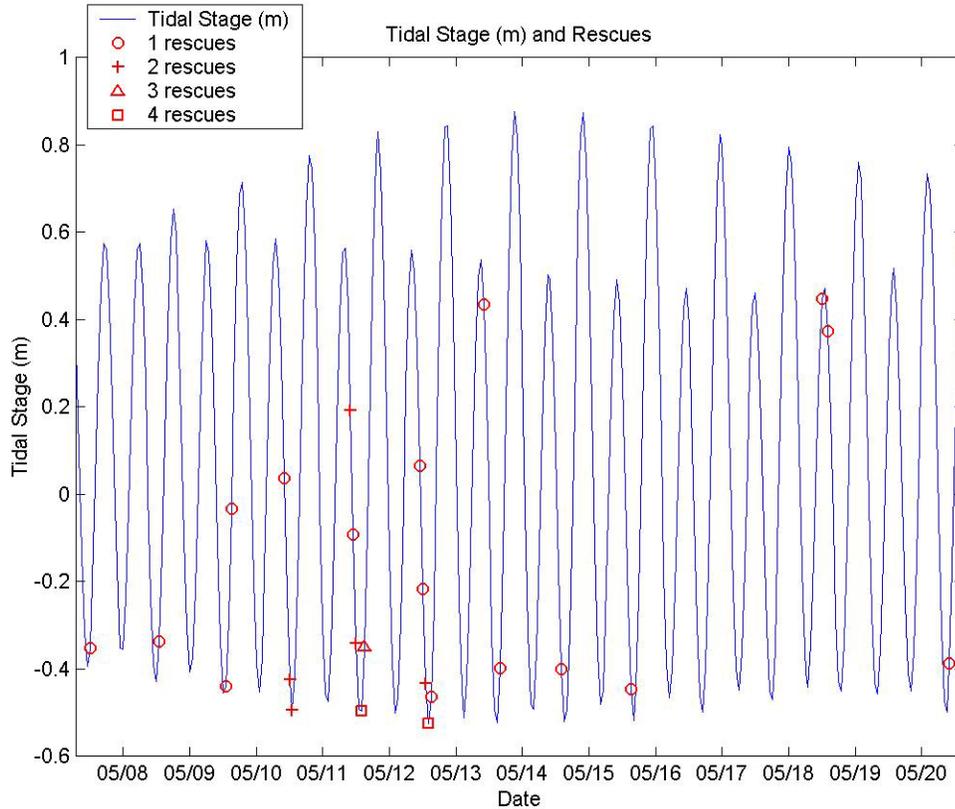


Figure 5.5: Entire record of tidal stage for Volusia County, FL and 10:00am through 5:00pm rescues. May 7 – May 20, 2003.

Panhandle Counties

Rip Current Drowning Statistics

The same anthropogenic factors that arise when relating rip current rescues to rip current occurrence also arise with rip current drowning statistics. A further complication is that drownings (thankfully) are much less commonplace than rescues. Also, only the day (and not the time) of drowning is known. So, conditions at the exact time a victim was caught in a rip are unknown. Since rescue data is unavailable from the Panhandle counties, only those few days with records of rip current drownings were evaluated in this study. A summary of the days follows.

Table 5.1: Rip current related deaths in Florida Panhandle counties during the summer of 2003.

Date (2003)	Number of Deaths	Site	County
18-Mar	1	Panama City	Bay
27-Mar	1	Pensacola	Escambia
7-Apr	1	Pensacola	Escambia
9-May	1	Perdido Key	Escambia
10-May	1	Navarre Beach	Escambia
11-May	1	Pensacola	Escambia
8-Jun	8	various	Walton
9-Jun	1	Pensacola	Escambia
2-Jul	2	various	Bay
13-Jul	1	Panama City	Bay
31-Aug	4	Pensacola	Escambia

Wave and Tide Statistics

It is possible that there are certain signatures of rip current outbreaks in Florida. These signatures include relatively long period swells, small directional wave angles to shore, low directional spreading, and declining wave energy. These are characteristics noted by Engle (2003) and others, including this study, for the east coast of Florida. In an attempt to find similarities with these signatures in the Panhandle, wave and tide statistics were analyzed on days with rip related drownings. As can be seen in Table 5.1, June 8th, July 2nd, and August 31st were the days with the greatest number of documented rip current drownings. These three days will be the focus of this section.

Figure 5.6 shows wave conditions in Walton County on the biggest rip current drowning day of the summer. Hour zero is 12:00am on June 7th. During the probable hours the drownings took place (from around 10:00am through 6:00pm), there is a noticeable decline in wave height while the wave period stays fairly long. These conditions could fool beachgoers into thinking that conditions are safe since the waves have calmed down. However, the energy within the waves is still reasonably high.

Lascody (1998) refers to a sequence of events where moderate/strong onshore winds generate choppy surf and strong rip currents, but people stay out of the water due to the waves. Then, as winds subside and conditions improve, people go into the surf, and long period swells result in the formation of rip currents and large numbers of rescues.

Lushine (1991) also states that rip currents generated by decreasing swells can be particularly dangerous since local winds may be light, and bathers may be deceived into thinking surf conditions are safe.

Also notable in Figure 5.6 is the crossing of wave directions through zero, showing that wave directions were more shore normal before the rip current outbreak. This change in direction may be the result of a passing frontal system. The wave direction before and during the probable hours of drowning were fairly shore normal at 20 degrees.

Tidal stage has been found to be an important factor for rip current threat in Volusia County, as well as in southeast Florida. Sonu (1972) also found a correlation between higher rip current velocities and a falling tide at Seagrove, in the Florida Panhandle. However, on June 8th, tide data from Panama City Beach, Florida indicates that the tidal difference was very small during the probable hours of drowning. A low tide at 9:26am was 0.26m and a high tide at 2:06pm was 0.29m. The next tide was at 11:09pm and was 0.12m. These tides are relatively average for this area. The average sea level for the months of June, July and August, 2003 was 0.25m. The lowest and highest tides of June took place a week later and were -0.16m and 0.62m, respectively. The small tidal difference during this rip current outbreak leads to the notion that tidal stage may not be as important at this site as it is in Volusia County. This may be attributed to the existence of beach cusps prevalent at Panhandle sites which act as

catalysts for rip channel formation. A lower tide may be necessary in the relatively 2-D bathymetry of Volusia County in order for rip channels to form and function.

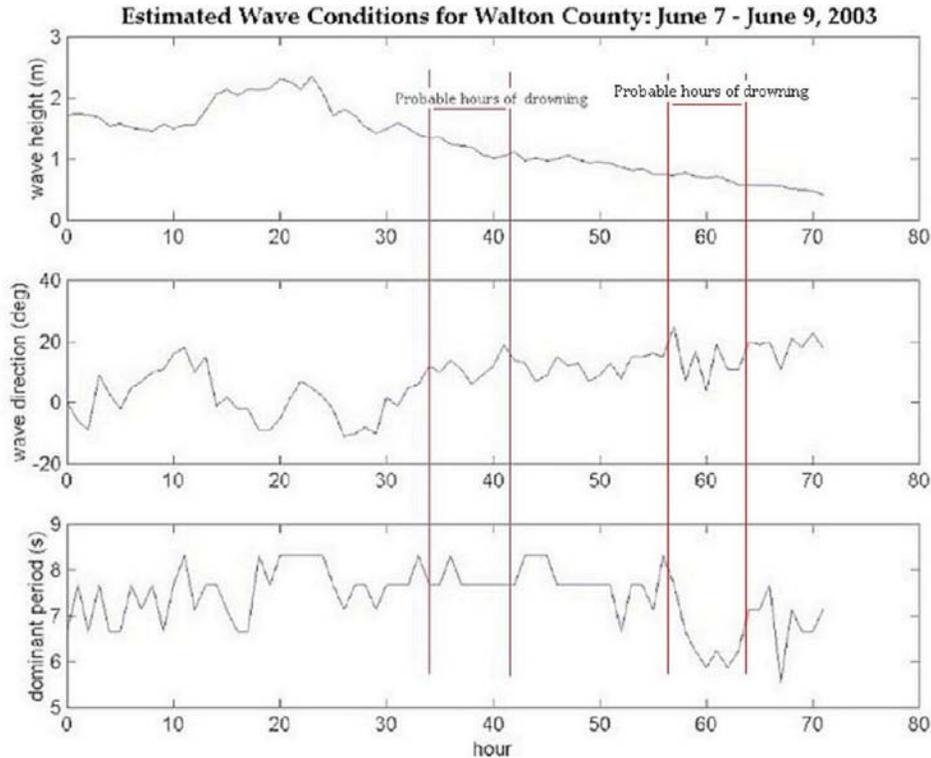


Figure 5.6: Wave conditions at Walton County, estimated from NDBC buoy #42039. Eight drownings occurred on June 8, 2003, most likely between 10:00am and 6:00pm (the first “probable hours of drowning” section). One drowning occurred on June 9th, most likely during the second “probable hours of drowning” section.

Conditions for July 1st-3rd in Figure 5.7 also show declining wave height, relatively high period (for the Panhandle), and wave direction crossing through zero before the rip current drownings occurred. The tidal difference was 0.56m at 10:00am to 0.09m at 5:00pm.

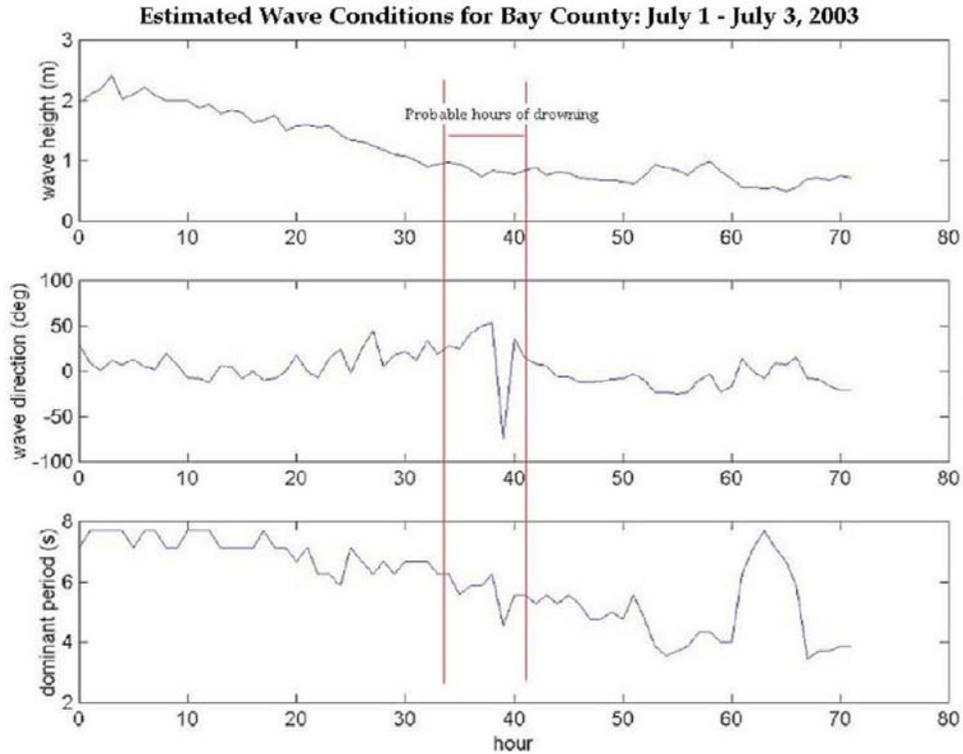


Figure 5.7: Wave conditions at Bay County, estimated from NDBC buoy #42039. Two drownings occurred on July 2, 2003.

Conditions for the period August 30th through September 1st are shown in Figure 5.8. There is a relatively constant wave height combined with wave direction crossing through zero before the drownings. Wave period is high before the drownings and then relatively constant at around 6 seconds. Tidal stage at 10:00am was 0.296m and was 0.303m at 5:00pm. Again there was a very small tidal difference during the hours of probable drowning and no tides lower than average.

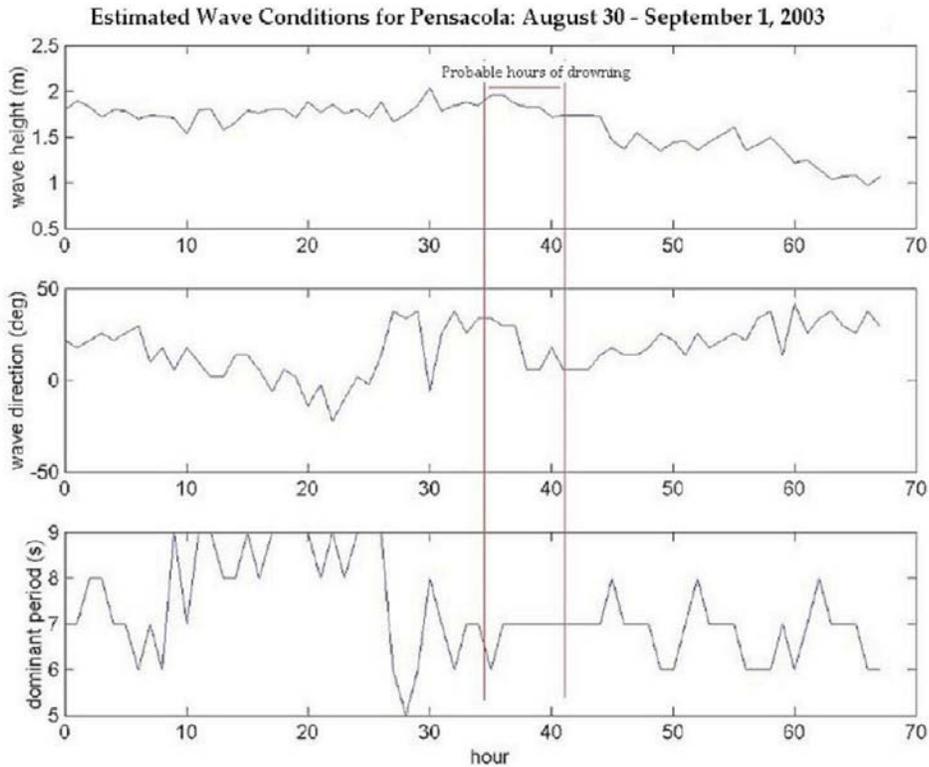


Figure 5.8: Wave conditions at Pensacola estimated from NDBC buoy #42040. Four drownings occurred on August 31 (Sunday, Labor Day weekend), 2003.

Value of Wind Statistics

Wind statistics were not included in this study. As stated earlier, two objectives of this study were to further evaluate Engle's (2003) findings in Volusia County and to compare these findings with rip current outbreaks in the Panhandle. After statistical research on Volusia County sites, Engle opted to remove wind direction and wind speed from the Modified ECFL LURCS scale. In keeping with Engle's research, neither of these parameters were used during this study to evaluate rip currents in either Volusia County or the Panhandle. However, Engle's Modified ECFL LURCS scale was created with data specifically from Volusia County. If a rip current predictive index is created

for sites in the Panhandle, wind parameters should not necessarily be rejected on the basis of Engle's or this study.

Wind speed and direction are parameters in both the LURCS scale and the ECFL LURCS scale. The LURCS scale was created with data specifically from southeastern Florida, and the ECFL LURCS scale was created with data from east-central Florida. The ECFL LURCS scale was then modified by Engle (2003) based on directional wave data from Volusia County. This brings out the point that parameters will have varying importance depending on the site. Therefore one scale can not necessarily be used for an entire region, east-central Florida for example, but may need to be modified to fit conditions for a smaller area.

CHAPTER 6 METEOROLOGICAL ANALYSIS

Wind, Pressure, and Frontal Systems

Since waves and wind have been found to have a great effect on rip currents, it is evident that the large-scale weather patterns which create such forces may be a key in the prediction of rip occurrence. Lascody (1998) pointed out that although rip currents are an oceanographic phenomena, meteorological factors influence their development. He found that some rip current outbreaks followed passing frontal systems and made note of the effect of pressure differences affecting wind. He stated that the analysis of wind/wave reports showed that specific synoptic weather patterns were usually identifiable on days with large numbers of rip current rescues or drownings. Lushine (1991) also refers to long-term weather patterns being associated with a 10-year cycle in rip current drownings.

Cold fronts often move over the Florida peninsula from the northwest, pressure differences affect wind flow, and low pressure systems create strong surf. A combination of these weather patterns seems to be strongly related to rip rescues and drownings. Cold fronts, for example, can be characterized by 1) sharp temperature changes over a relatively short distance, 2) shifts in wind direction, 3) pressure changes, 4) clouds and precipitation patterns, and 5) changes in the air's moisture content (Ahrens 1994).

Shifts in wind direction may be of particular importance to rip current occurrence. Often, winds are onshore as a front approaches, building swell with higher period waves. Then, as the front passes, the wind rotates offshore and the weather improves. Offshore

wind, smoothing the sea surface, combined with decreasing swell height and clearing skies make surf conditions more attractive. Swimmers may enter the water although wave energy is still high and rip currents are present.

Volusia County 1996

Volusia County beaches are affected by northwest cold fronts as well as low pressure systems in the Atlantic. In the open ocean, areas of low pressure create large, high period swell that impacts the coast. Often, lows move from west to east over the Florida peninsula. As the low moves offshore and the fetch increases, wave heights can often decrease as period increases, creating a signature of rip current outbreaks.

Precipitation and clouds are also associated with the low which keep bathers off the beach. Once the low has passed however, weather improves and bathers enter the water although dangerous rips still exist.

A weather pattern such as this may have influenced a rip current outbreak during the dates researched by Engle (2003). On Friday, June 28th, 1996 there were 23 rip current rescues, around 5 rescues on Saturday, 32 rescues on Sunday, and 30 rescues on Monday, July 1st. Conditions for the high rescue days are summarized below.

Table 6.1: Conditions for high rescue (>15) days during a rip current outbreak in Volusia County during June/July 1996.

Date	Day	# of Rip Rescues	Wave Ht. (m)	Wave Per. (s)	Wave Dir. (deg)	Spreading (deg)	Time of Low Tide	Level of Low Tide (m)
6/28	Fri	23	0.83	6.9	20	37	11am	-0.6
6/30	Sun	32	0.86	6.3	-5	29	1pm	-0.8
7/1	Mon	30	0.64	8.5	-3	31	2pm	-1.0

A low pressure system was in the Atlantic while another low crossed the state from the Gulf of Mexico on the 27th and 28th. Figure 6.1 shows weather surface maps at two times (7:00am and 7:00pm) per day in sequential order.

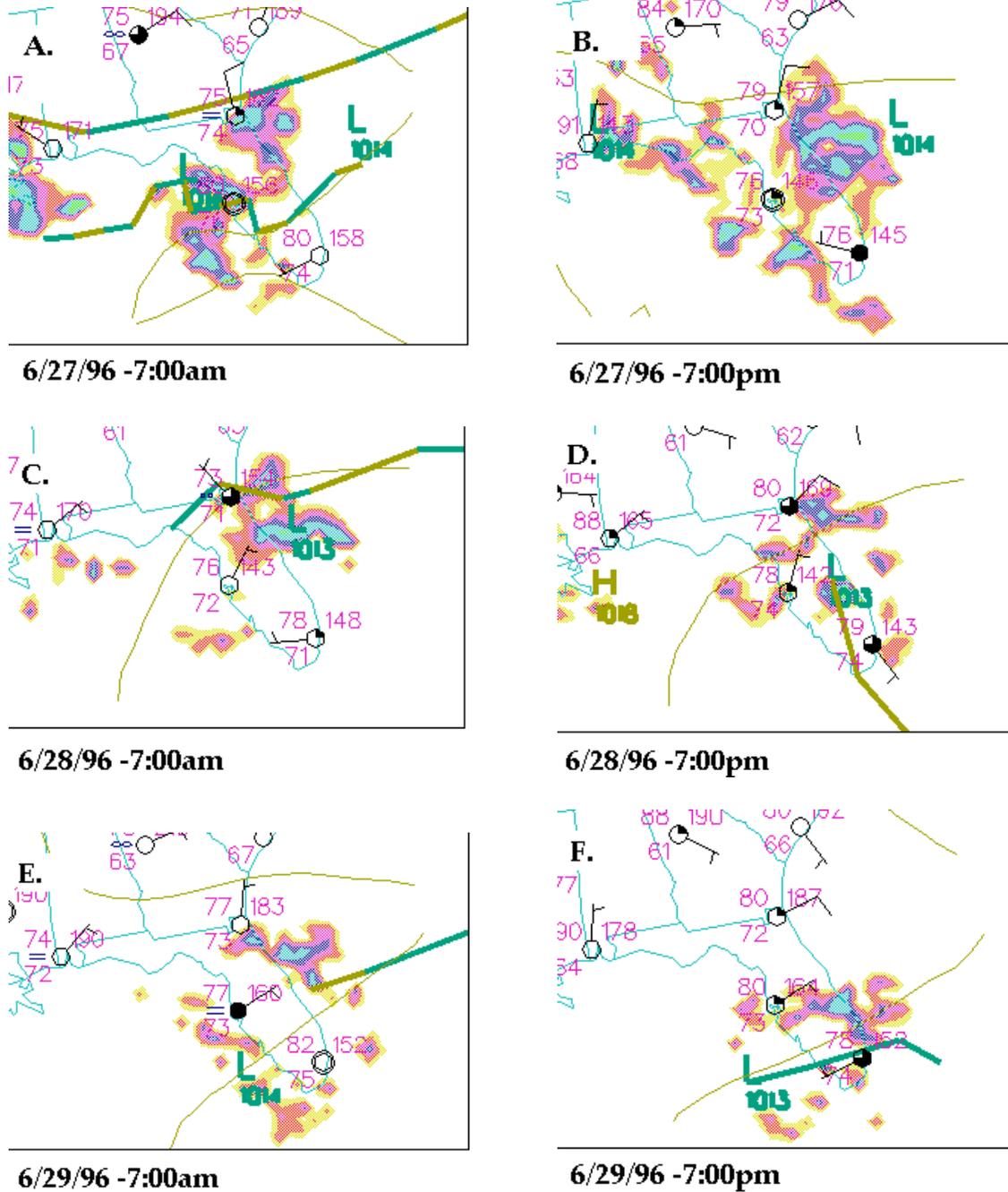


Figure 6.1: Surface weather maps for A) June 27th, 1996 at 7:00am EST through J) July 1st, 1996 at 7:00pm EST. The pressure given is the last three digits of the actual pressure (987=998.7mb, 024=1002.4mb).

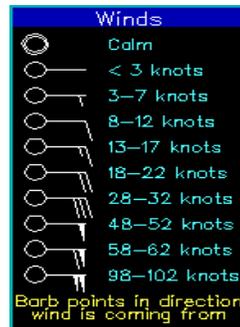
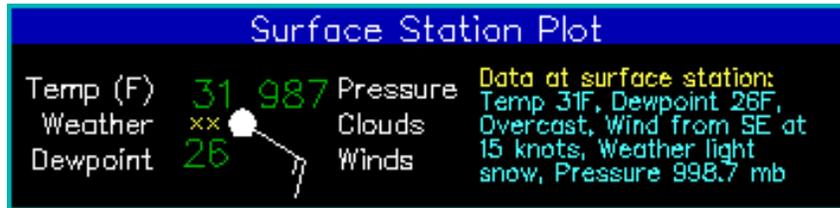
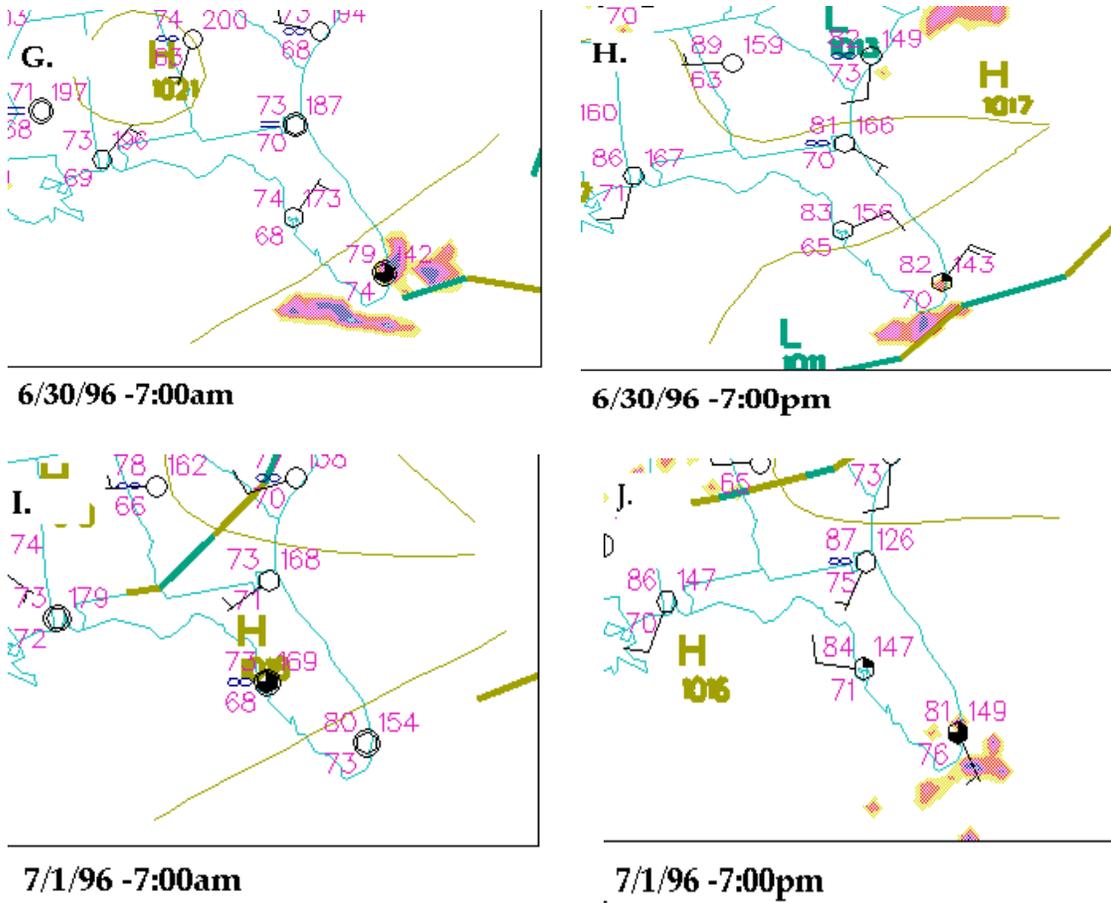


Figure 6.1. Continued

On June 27th, two low pressure areas can be seen around the Florida peninsula. The offshore low would have created storm swell which impacted Volusia County.

The front became stationary during the morning of the 29th, and there were relatively few rescues although it was a Saturday. Possibly, this is due to afternoon rain showers or the north wind creating a longshore current. Wave height increased by the 30th. Wind and wave directions crossed through zero and began arriving just south of shore normal.

By Monday the period had increased while wave heights dropped. Skies were clear. Morning and afternoon winds were offshore, flowing from high to low pressure areas across the state. These conditions resulted in 30 rescues.

Engle (2003) referred to five other rip current outbreaks in Volusia Co. during 1996. The wave conditions for these days are listed in Table 6.2.

Table 6.2: Wave conditions for five rip current outbreaks in Volusia County, 1996.

Date	Day	# of Rip Rescues	Wave Ht. (m)	Wave Per. (s)	Wave Dir. (deg)	Spreading (deg)	Time of Low Tide	Level of Low Tide
6/5/96	Wed	31	0.56	8.8	-9.00	32	5pm	-0.7
6/19/96	Wed	30	0.62	7.9	-8.00	30	5pm	-0.6
7/13/96	Sat	45	0.74	8.2	-23.00	n.a.	1pm	-0.6
7/16/96	Tue	22	0.74	5.7	-32.00	n.a.	3pm	-0.7
8/10/96	Sat	23	0.48	8.7	-18.00	n.a.	12pm	-0.6

Of these days, only June 19th and August 10th seem to be strongly associated with local weather patterns. As can be seen in Figure 6.2, on the 19th a high pressure area was positioned in the Gulf of Mexico. Easterly winds on the Atlantic coast of Florida during the night of the 18th became calm by morning. When rescues occurred on the afternoon of the 19th, winds were likely from the southeast and pressure had increased (Figure 6.2 (C)).

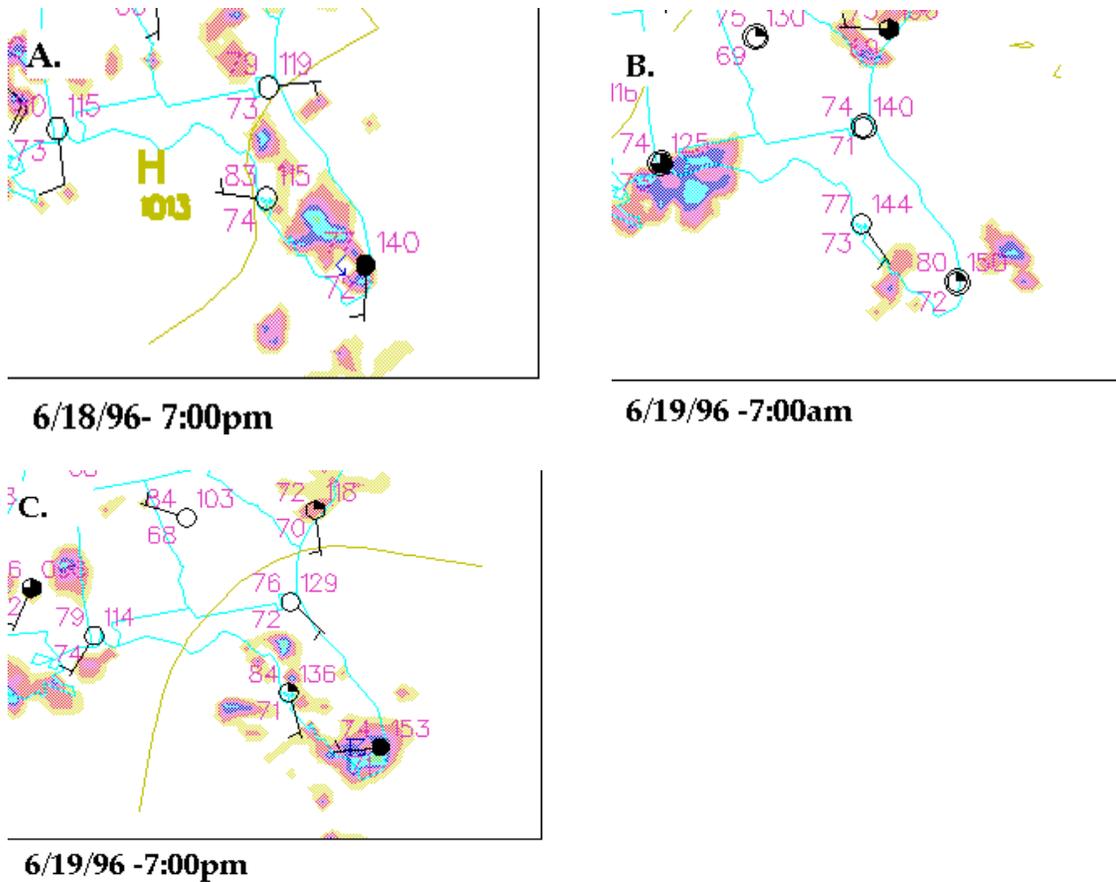
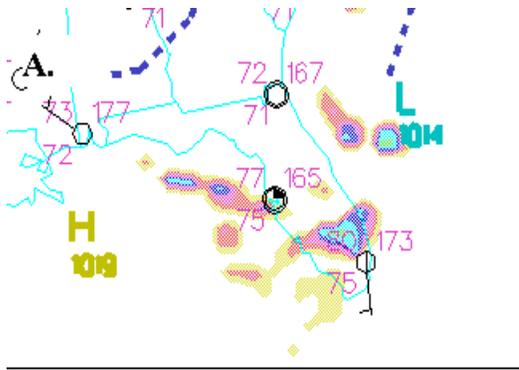


Figure 6.2: Surface weather maps for A) June 18, 1996 at 7:00pm EST through C) June 19, 1996 at 7:00pm EST.

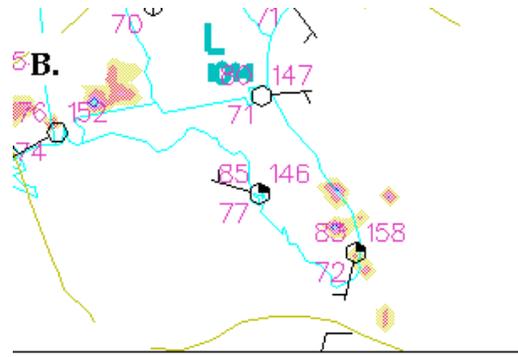
The outbreak on August 10th also had an associated low as can be seen in Figure 6.3. Offshore low pressure generating east winds on the 9th probably caused the long period swell seen on August 10th. The low moves across Florida during the early morning of the 10th. Morning winds were calm.

Weather conditions for the June 5th outbreak (Figure 6.4) were composed of high pressure in the Gulf of Mexico and offshore winds in the morning. Winds were onshore by early evening, two hours after low tide (5:00pm).

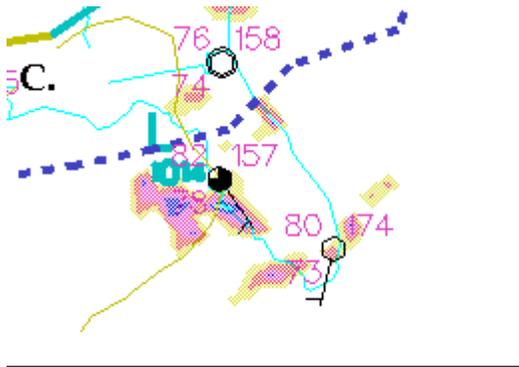
The July 13th outbreak had clear skies, and a high pressure area over Florida causing a south wind to flow toward lower pressure (Figure 6.5).



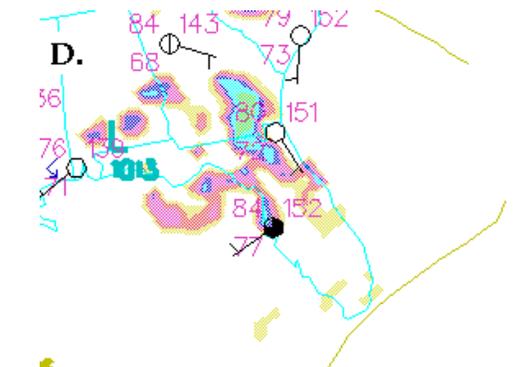
8/9/96 - 7:00am



8/9/96 - 7:00pm

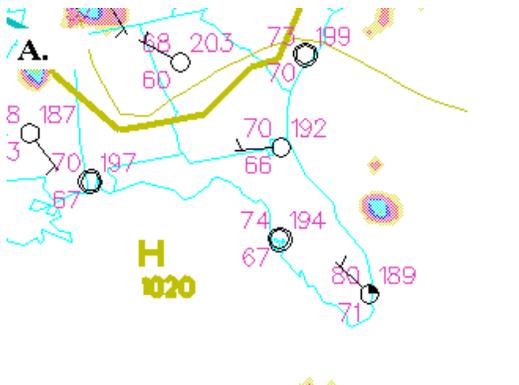


8/10/96 - 7:00am

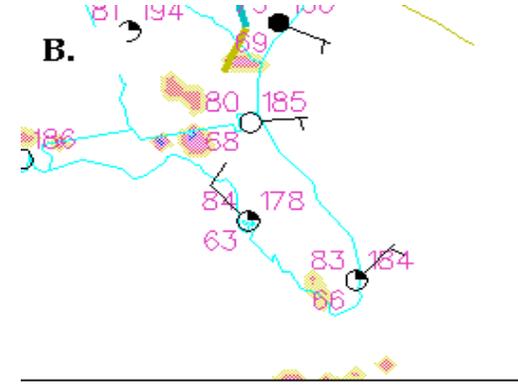


8/10/96 - 7:00pm

Figure 6.3: Surface weather maps for A) August 9, 1996 at 7:00am EST through D) August 10, 1996, 7:00pm EST.



6/5/96 - 7:00am



6/5/96 - 7:00pm

Figure 6.4: Surface weather map for June 5, 1996 at A) 7:00am EST and B) 7:00pm EST.

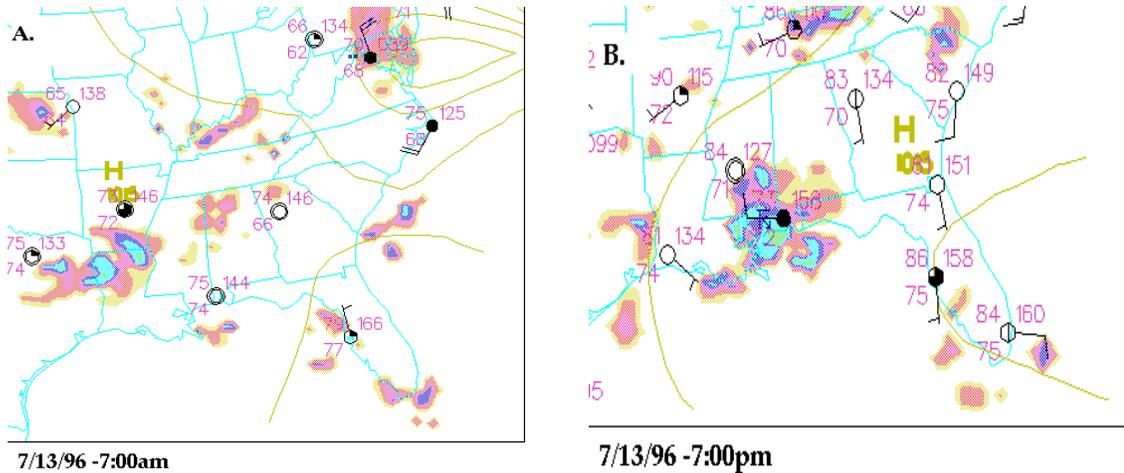


Figure 6.5: Surface weather maps for July 13, 1996 at A) 7:00am EST and B) 7:00pm EST.

On the morning of the 16th (Figure 6.6) rain was present, winds were calm, and a stationary front was present in the northern southeast U.S. High pressure over north Florida caused a southeasterly wind by early evening.

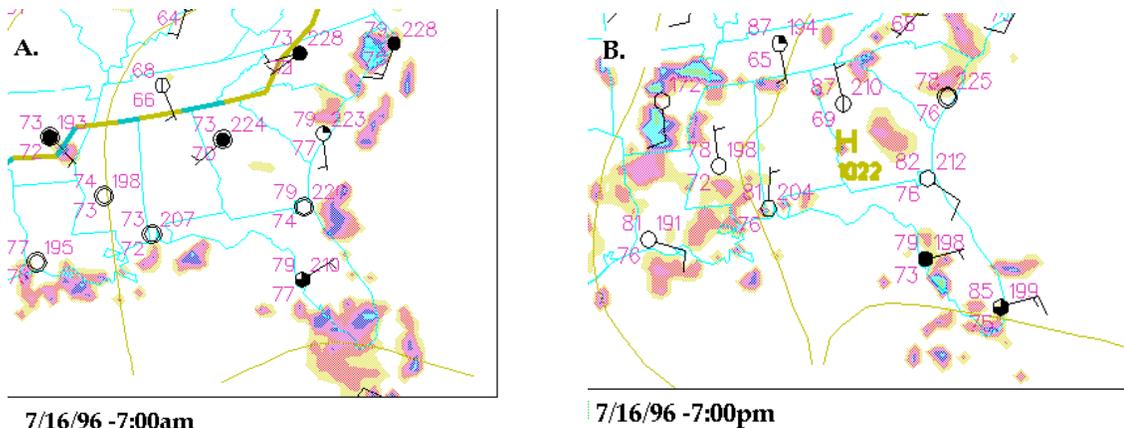


Figure 6.6: Surface weather maps for July 16, 1996 at A) 7:00am EST and B) 7:00pm EST.

Volusia County 2002

During the 2002 study, the period with the most rescues was from May 9th through May 13th, 2002. Conditions for these days are in Table 6.3.

Table 6.3: DIWASP’s estimated conditions (from Sontek wave gage) from 10:00am through 5:00pm for May 7th – May 20th, 2002 on Volusia County beaches. Wave height and direction are deep water values, shoaled and refracted from the Sontek wave gage. The tidal elevation given is the lowest tide during daylight hours (not necessarily between 10:00am and 5:00pm).

Day	# of Rip Rescues	Beach Population	Wave Ht. (m)	Wave Dir. Deg.	Wave Period (s)	Dspr Deg.	Time of	Low Tide
							Low Tide	Level
07 Tues.	1	2836	1.01	-14.50	9.88	34.96	11:39	-0.40
08 Wed.	1	2938	0.91	-16.66	8.82	35.41	12:17	-0.43
09 Thurs.	2	2996	0.83	-26.73	9.15	33.79	12:53	-0.47
10 Fri.	5	3842	0.76	-26.67	10.15	33.17	13:28	-0.5
11 Sat.	12	6980	0.93	-37.50	8.31	36.89	14:02	-0.51
12 Sun.	9	8197	1.12	-17.65	5.69	38.04	14:36	-0.53
13 Mon.	2	2576	0.81	-29.09	7.97	36.54	15:11	-0.53
14 Tues.	1	1488	1.00	39.00	5.73	40.87	15:49	-0.53
15 Wed.	1	2625	1.58	35.16	6.42	39.39	16:30	-0.52
16 Thurs.	0	2602	1.45	-20.00	5.69	41.07	17:16	-0.50
17 Fri.	0	3500	1.05	-35.97	7.32	36.61	18:09	-0.48
18 Sat.	2	6216	0.74	-39.34	7.05	34.49	19:10	-0.46
19 Sun.	0	654	1.89	63.00	7.67	37.16	8:12	-0.46
20 Mon.	1	754	2.48	-13.00	10.22	37.96	9:11	-0.51

Weather maps from the 9th through the 13th (Figure 6.7) show a cold front approaching Florida from the north, which stalls and never pushes through the state.

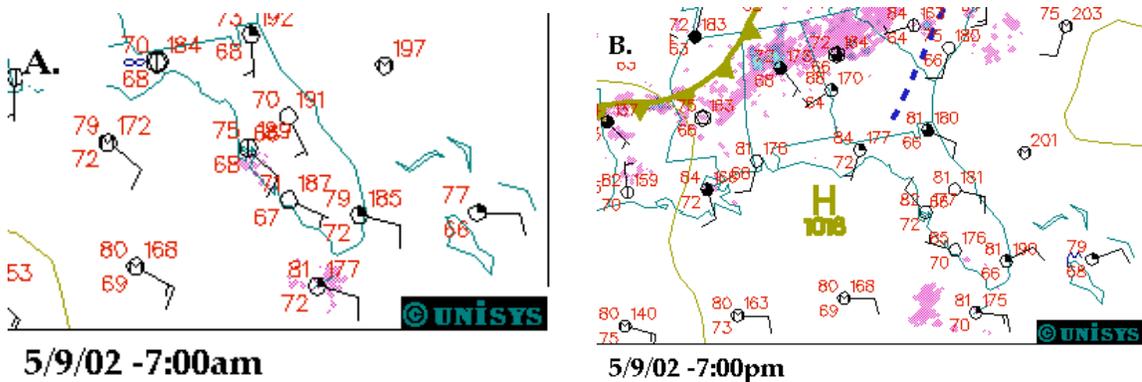
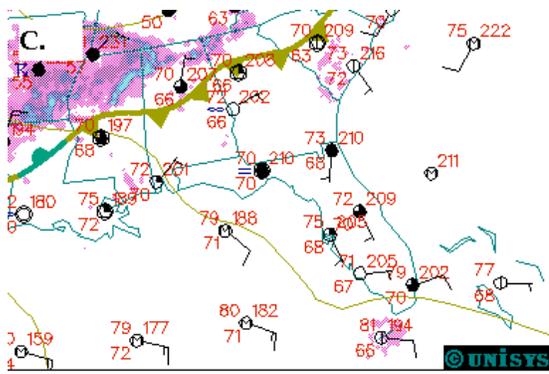
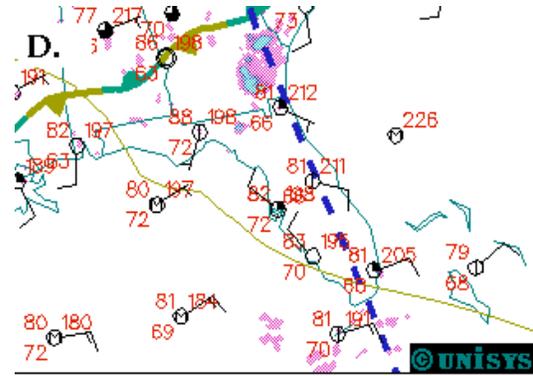


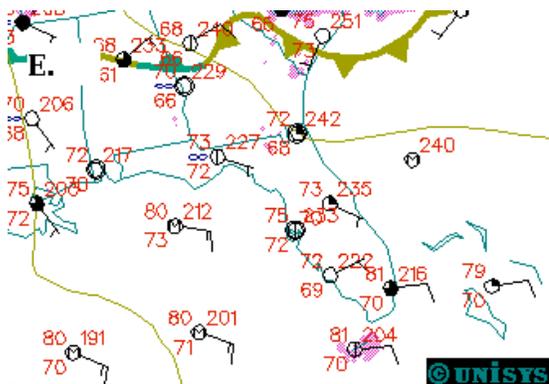
Figure 6.7: Surface weather maps for A) May 9, 2002 at 7:00am EST through J) May 13, 2002, 7:00pm EST.



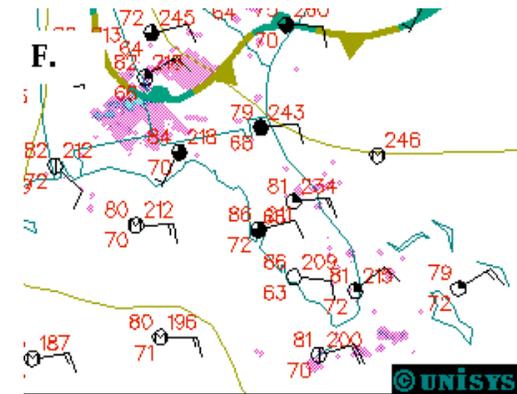
5/10/02 -7:00am



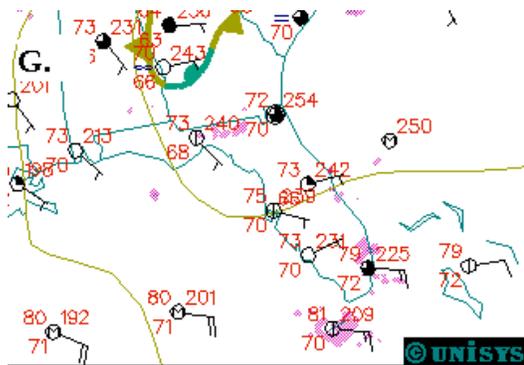
5/10/02 -7:00pm



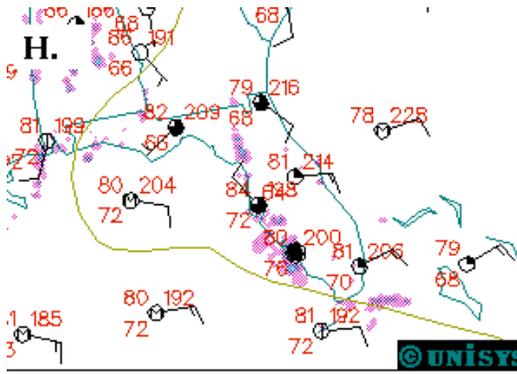
5/11/02 -7:00am



5/11/02 -7:00pm



5/12/02 -7:00am



5/12/02 -7:00pm

Figure 6.7. Continued

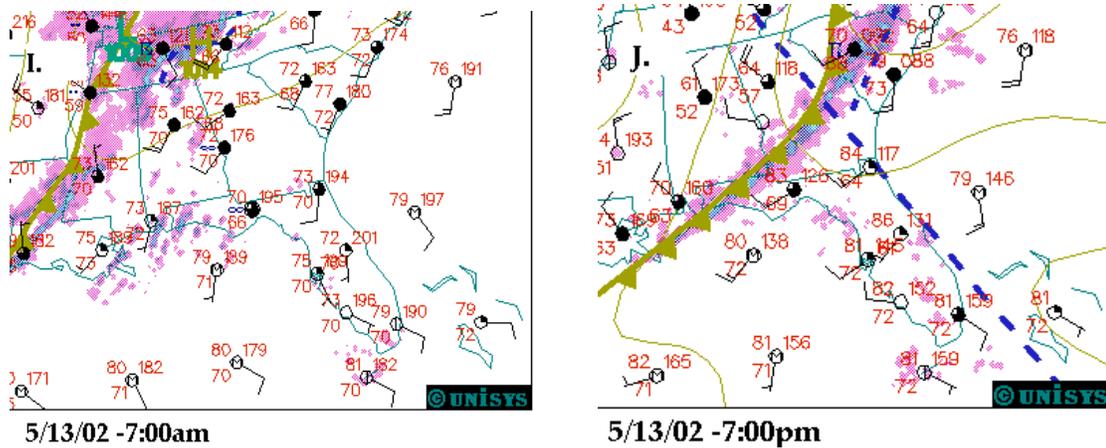


Figure 6.7. Continued

Winds feed into the front throughout the period. They switch from calm, or from the south, during the mornings to a more onshore direction by early evening. These winds created a southeasterly wave field as can be seen in Table 6.3. Skies were partly cloudy with calm morning winds turning onshore by the early evenings of the highest rescues days (the 11th and 12th).

Figure 6.8 shows time-lapse photos of the 11th and 12th. On both days, some rip channel formation can be seen along the outer bar, especially to the north (top) of the photo. Channels seem to be more defined on the 11th, which had more rescues and a lower population (see Table 6.3).



Figure 6.8: Time-lapse photographs of Ormond Beach, Volusia Co. on May 11th, 2002 at A) 10:31am and B) 11:01am and May 12th at C) 11:33am and D) 1:33pm.

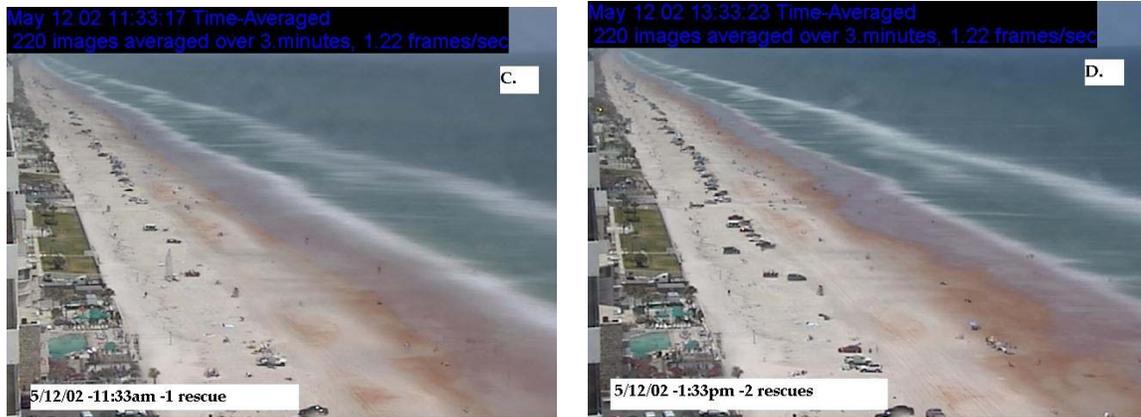


Figure 6.8. Continued

Two rescues on the 18th of May seem to have occurred during weather conditions similar to those of the 9th through the 13th.

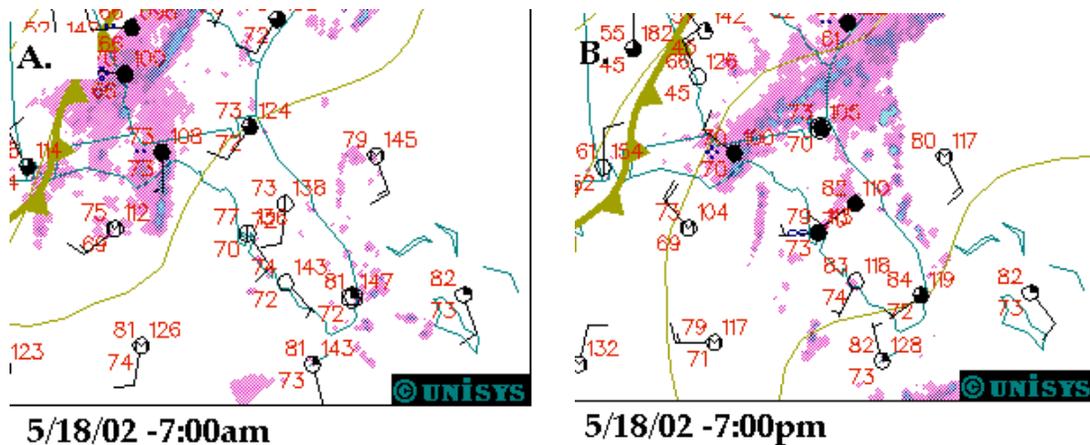


Figure 6.9: Surface weather maps for A) May 18, 2002 at 7:00am EST through B) May 18, 2002, 7:00pm EST.

A northwestern front sits above Florida (Figure 6.9), but does not move southward through the state. This causes a southeasterly wind and -39 degree wave direction. Wave height had decreased from the day before to the smallest height of the study period, 0.74 meters, and the average period was 7 seconds. By the early evening winds were calm. Population was relatively high, and from the snapshots in Figure 6.10, afternoon skies were clear and sea conditions appeared mild.

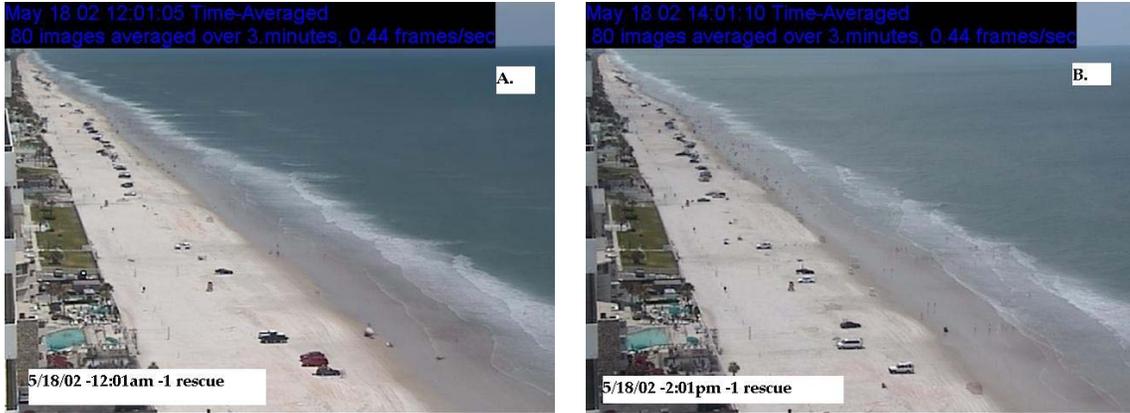


Figure 6.10: Snapshots of Ormond Beach, Volusia Co. on May 18th, 2002 at A) 12:01pm and B) 2:01pm. One rescue occurred around each of these times.

Every other day with rescues during the 2002 study is associated with a cold front moving across the state. Rescues on May 7th and 8th occur in the wake of a cold front moving through during the early morning of the 7th. Just the tail of the front can be seen in the lower right of Figure 6.11(A).

After the front, winds on the morning of the 7th were calm. Wind speeds at the offshore buoy were calm while onshore winds picked up during the afternoons of both days. These days had wave directions under -20 degrees (Table 6.3).

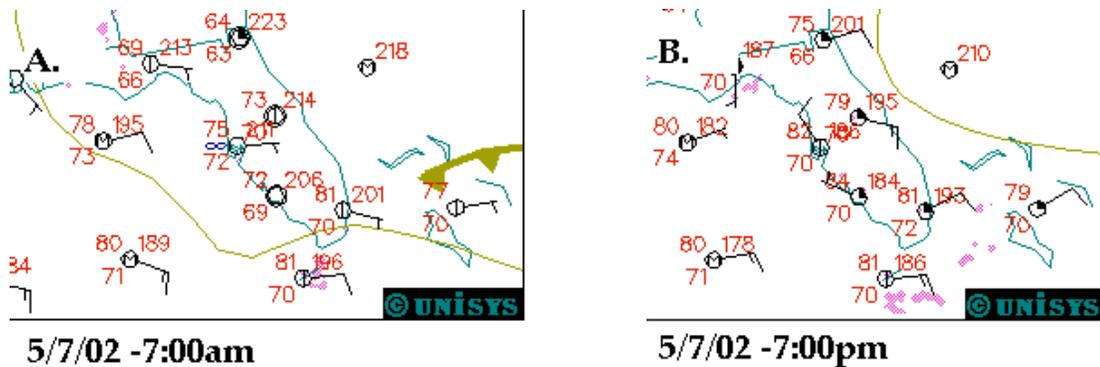


Figure 6.11: Surface weather maps for A) May 7, 2002 at 7:00am EST through D) May 8, 2002, 7:00pm EST.

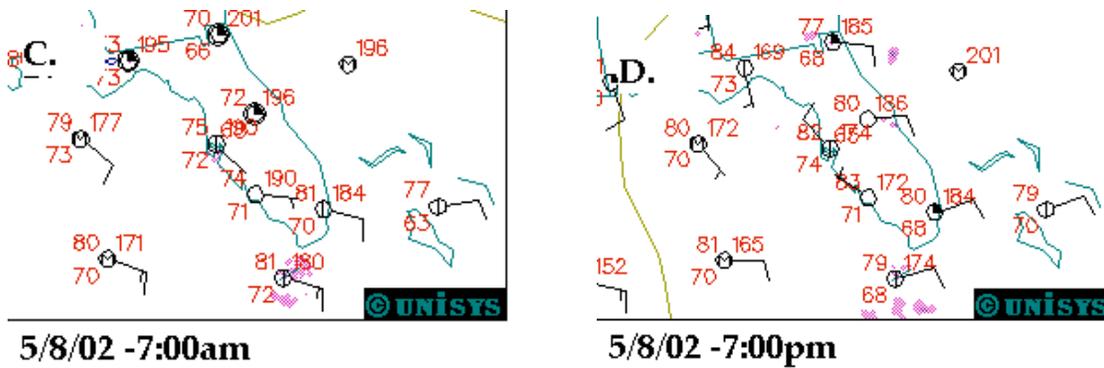


Figure 6.11. Continued

Rescues on May 14th, 15th, and 20th may be associated with the passage of northwest cold fronts passing all the way through Florida. Figure 6.12 shows weather conditions on the 14th and 15th. One rescue occurred just before low tide (see Table 6.3) on each day, one rescue around 2:30pm on the 14th and one around 3:00pm on the 15th. As the front approaches on the 14th, local winds turn offshore. Wave direction crosses through zero and begins coming from the northeast on the afternoon of the 14th, just after 12:00pm, in response to northeast winds behind the front.

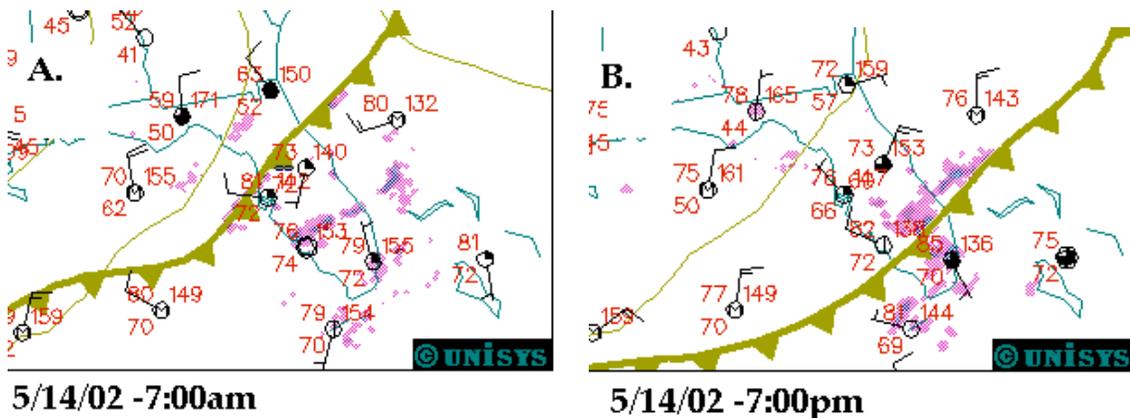


Figure 6.12: Surface weather maps for A) May 14, 2002 at 7:00am EST through D) May 15, 2002, 7:00pm EST.

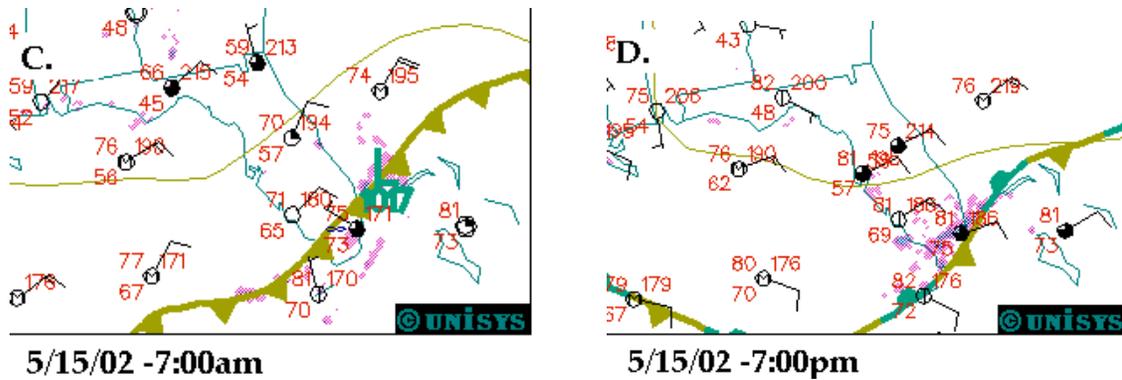


Figure 6.12. Continued

This northeast flow continues and wave heights build to 1.58 meters on the 15th.

Time-lapse photographs from around the times of the rescues can be seen in Figure 6.13.



Figure 6.13: Time-lapse photos of Ormond Beach, Volusia Co. on A) May 14th, 2002 at 2:31pm and B) May 15th at 3:09pm. One rescue occurred around each of these times.

The time-lapse photos show breaking on the bar, but not any well defined rip channels through the bar. However, some areas show signs of channel development. It must be remembered that the rescues happened in one spot along the entire coastline of Volusia County and not necessarily exactly at this site in Ormond Beach where this camera is located.

A fast-moving cold front swept through Florida on the 20th of May, 2002 (Figure 6.14). Beach population was very low and one rip rescue occurred.

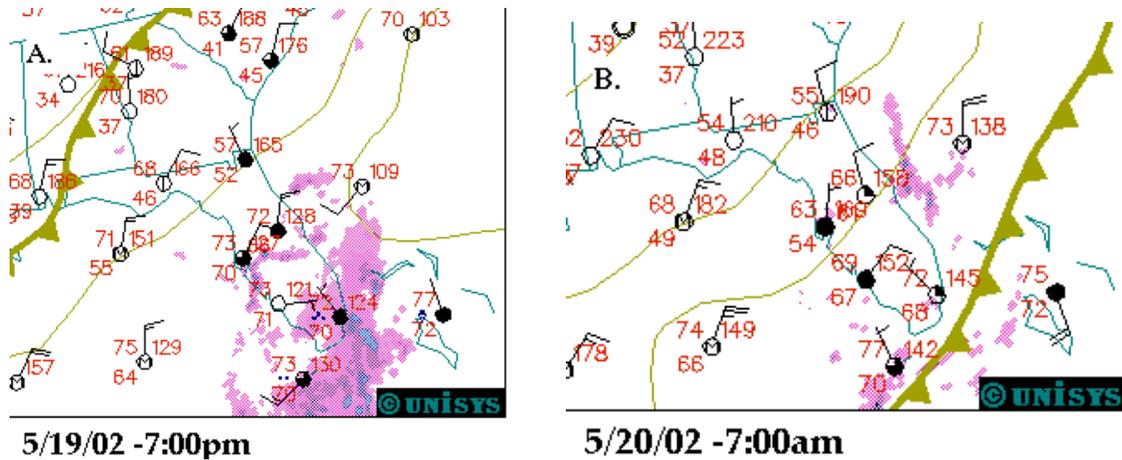


Figure 6.14: Surface weather maps for A) May 19, 2002 at 7:00pm EST and B) May 20, 2002 at 7:00am EST.

By the morning of the 20th, winds at the offshore buoy were 18-22 knots from the north (which would be side-onshore at Volusia County beaches). Wave heights on this day were the highest of the period at 2.5 meters with an average period of 10 seconds.

The analysis of weather conditions during rip current outbreaks in Volusia County seem to enforce the conclusion reached by Engle (2003): The wind field is not well correlated to rip current outbreaks in this region. Cold fronts that do not cross the state have a calm or weak local wind field associated with them. Onshore winds are better linked to cold fronts that push through the state (May 14th – 15th). Rip currents appear linked to low pressure systems which cross the state from west to east. Decreasing swell height and increasing period result as the systems move farther into the Atlantic.

Florida Panhandle 2003

Low pressure and frontal systems also seem to have a great influence on rip current occurrence in the Panhandle. This region of Florida is not impacted by long period ground swell like the east coast due to the relative small size and shallow depth of the

Gulf of Mexico. Instead, onshore wave direction caused by onshore winds may be the most significant signature of rip currents in this area.

Every day evaluated in this study, where rip current outbreaks occurred in the Panhandle, had some form of low pressure system associated with it. Most of these systems were close in proximity to the Panhandle. However, on July 13th (1 drowning) and August 31st (4 drownings), rain and wind over the Panhandle seem to be associated with distant lows across the upper southeastern states.

The outbreak in Escambia County, from May 9th through 11th (3 deaths), seems to be associated with a strong low in the mid-eastern U.S. which created a strong northerly wind flow across the Gulf, leading to onshore wind (and waves) along the Panhandle.

Figure 6.15 shows estimated wave conditions for this period.

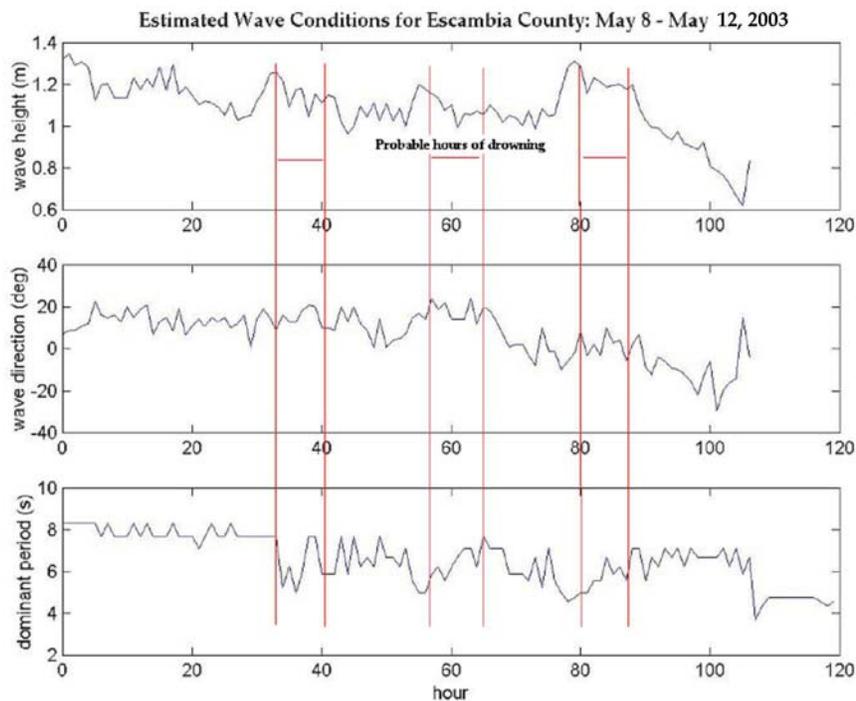


Figure 6.15: Wave conditions estimated from NDBC buoy #42040. One drowning occurred on each day from May 9th – May 11th, 2003.

Wave data were shoaled and refracted, using linear wave theory, from deep water offshore buoys to 10m water depth. Probable hours of drowning are from around 10:00am through 6:00pm each day.

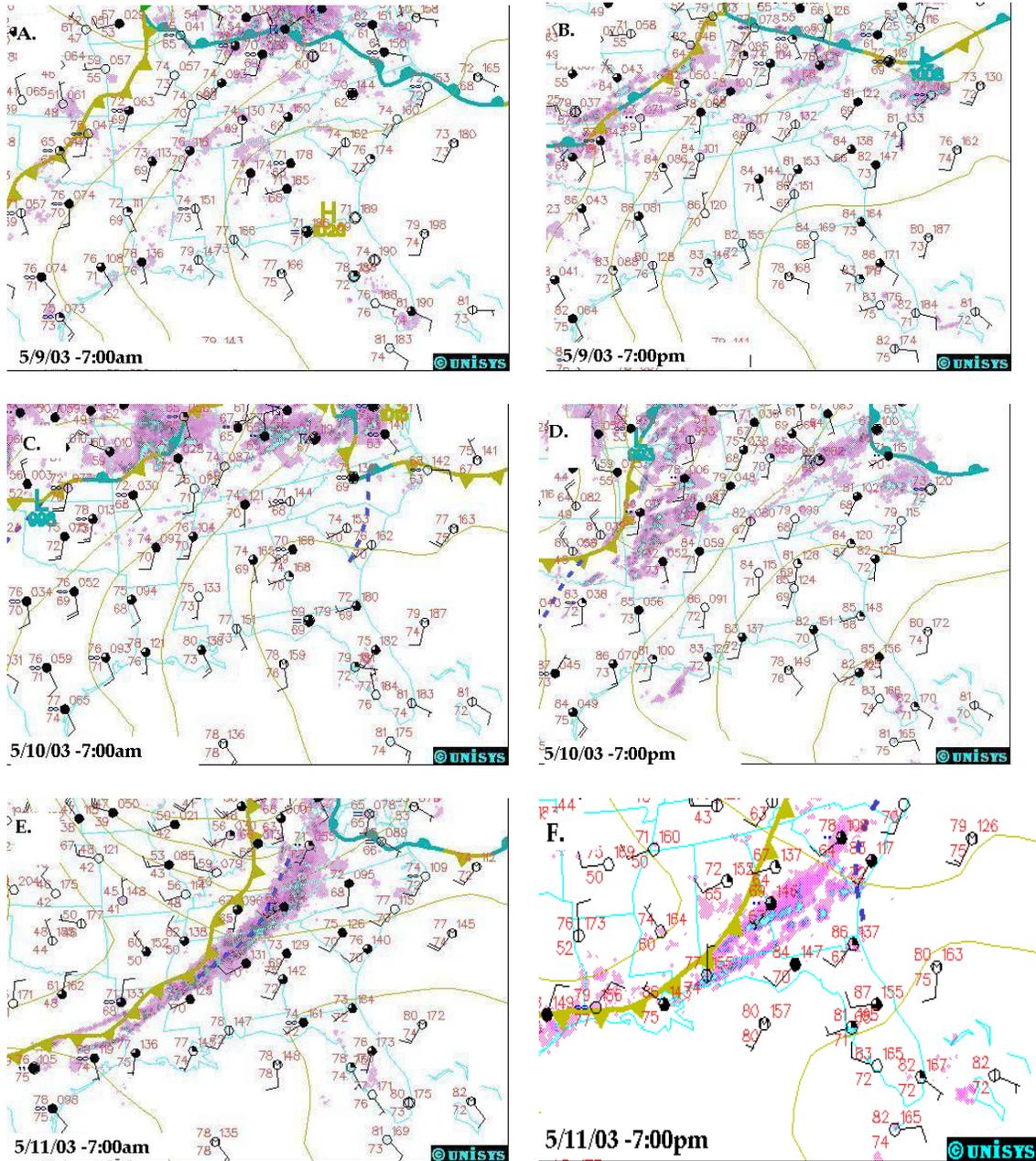


Figure 6.16: Surface weather maps for A) May 9th, 2003 at 7:00am EST through F) May 11th, 2003 at 7:00pm EST.

On May 8th, wind direction was from the south at 8-12 knots. Figure 6.16 shows weather conditions during the following three days when one drowning occurred on each day. Wind velocity at an offshore buoy reaches 13-17 knots at 7:00am on May 9th (Figure 6.16(A)). The onshore wind flow continues feeding into the approaching low pressure system at around 8-12 knots during the rest of the outbreak. This continuous onshore wind created a shore normal wave field as can be seen in Figure 6.15. Wave directions reach zero before each drowning and cross zero before the drowning on May 9th. The drownings begin after a decline in fairly high, long period waves. Each drowning probably occurred during decreasing wave height.

A strong northerly wind flow during June 7th fed into an approaching cold front. Eight drownings occurred the next day in Walton County, and one drowning occurred on the 9th in Pensacola. Figure 6.17 shows estimated wave conditions during this outbreak.

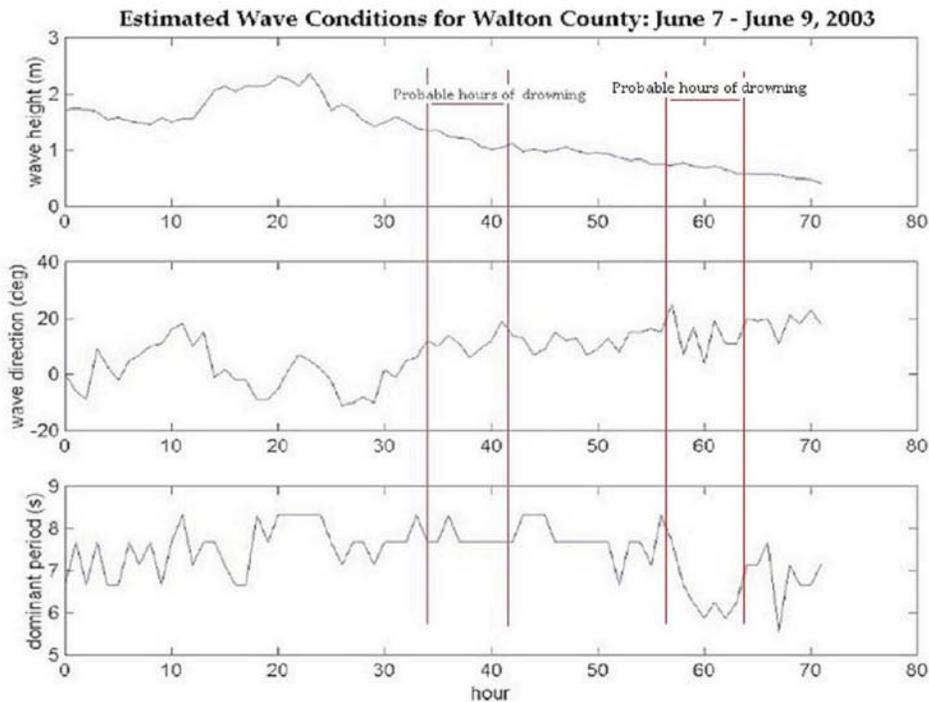


Figure 6.17: Wave conditions estimated from NDBC buoy #42039. Eight drownings occurred on June 8th and one occurred on June 9th.

The onshore wind flow continued on the 8th and 9th as can be seen in Figure 6.18.

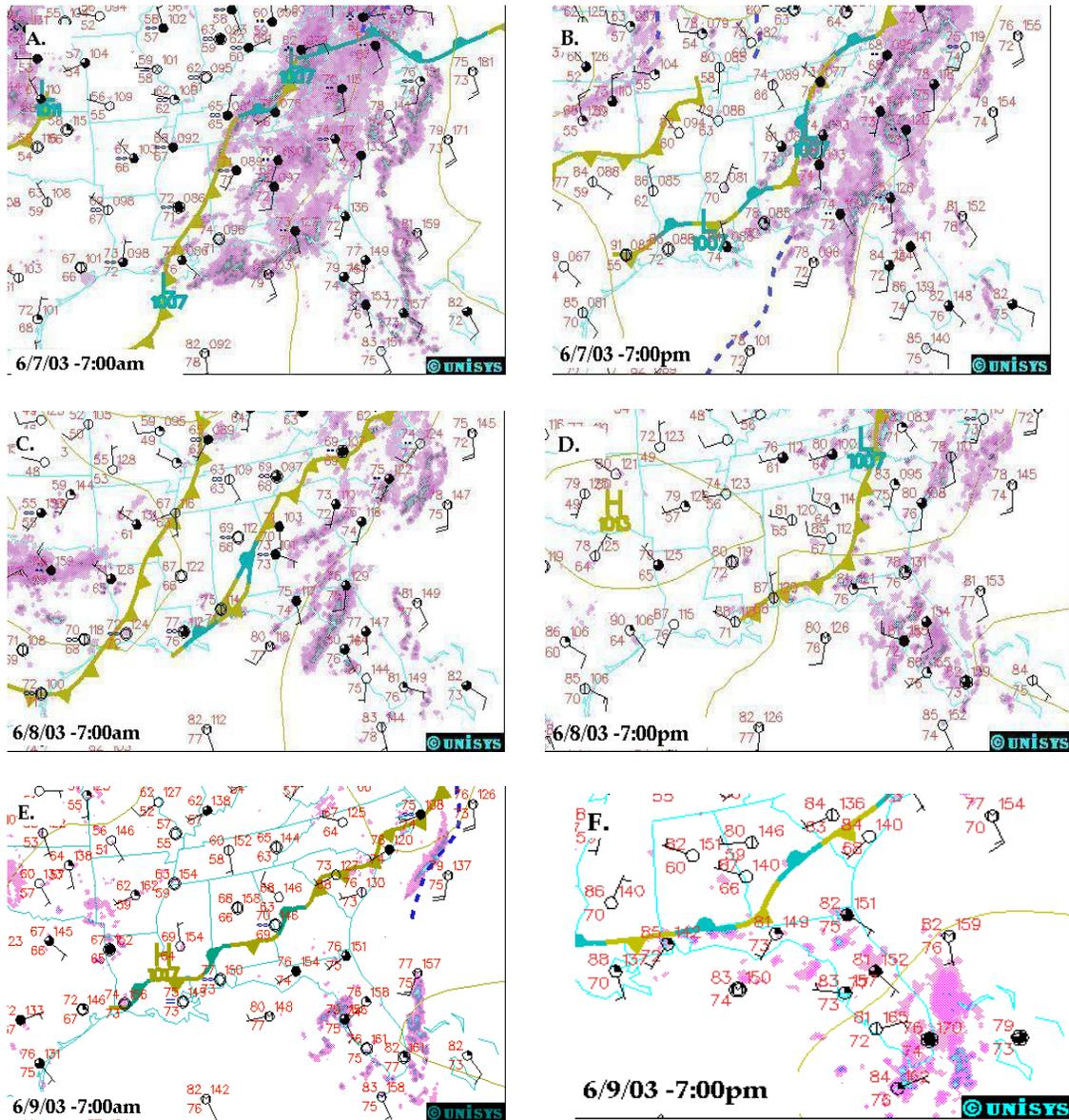


Figure 6.18: Surface weather maps for A) June 7th at 7:00am EST through F) June 9th, 2003 at 7:00pm EST.

Two cold fronts approach the Panhandle on the 7th. South winds at the offshore buoy are 18-22 knots and decrease to 8-12 knots on the 8th. Local winds are lighter. Offshore buoy winds clock to the west by the morning of the 9th and are calm by early evening.

Two rip current drownings on July 2nd in Bay County may have been associated with the passage of a cold front that skims across the upper Gulf of Mexico as it moves in an easterly-northeasterly direction. South winds feed into the passing system as seen in Figure 6.19.

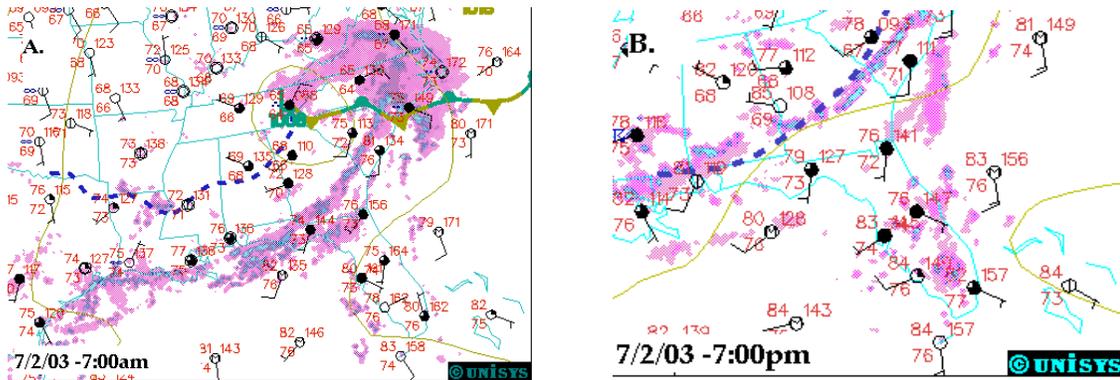


Figure 6.19: Surface weather maps for July 2nd at A) 7:00am EST and B) 7:00pm EST.

Figure 6.20 shows how estimated wave angles cross through zero as the low pressure system moves across the Panhandle. Wind directions never turn offshore since the low stays north of Florida. The constant onshore wind flow caused the onshore wave field seen in Figure 6.20. Wave heights decrease as the low moves north and wind velocities decrease.

August 31st had four rip related drownings in Pensacola. Figure 6.21 shows a stationary front present in the southeastern U.S. during this time. Low pressure and associated strong winds may have contributed to the drownings. August 30th saw strong south to east-southeast winds which continued into the 31st. These wind directions affected the wave field as can be seen in Figure 6.22. The general wave direction crosses through zero during the early morning of the 31st, before rescues occurred.

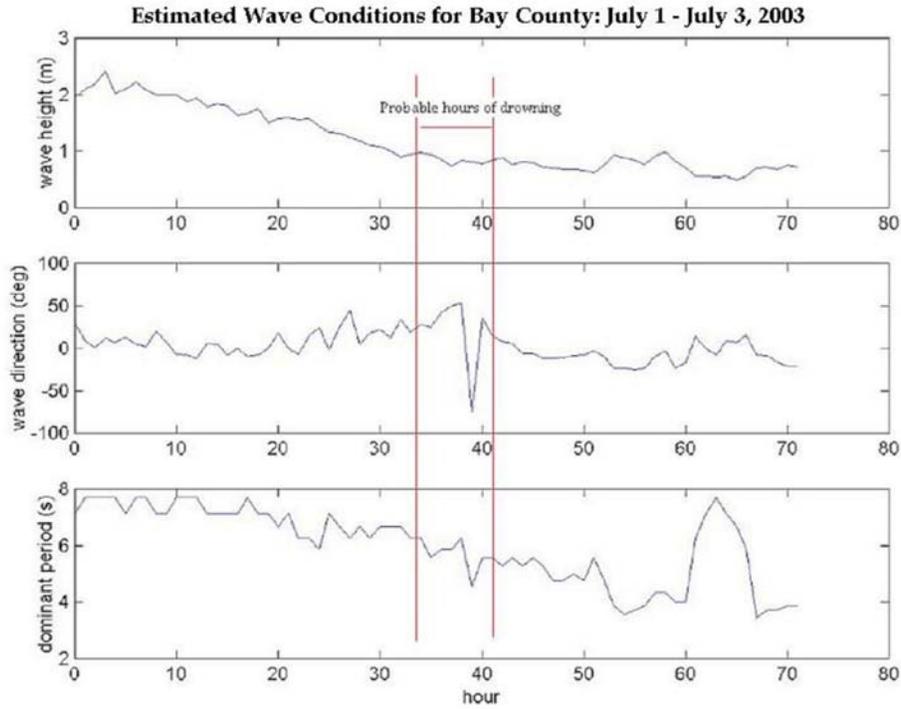


Figure 6.20: Wave conditions estimated from NDBC buoy #42039. Two drownings occurred on July 2nd.

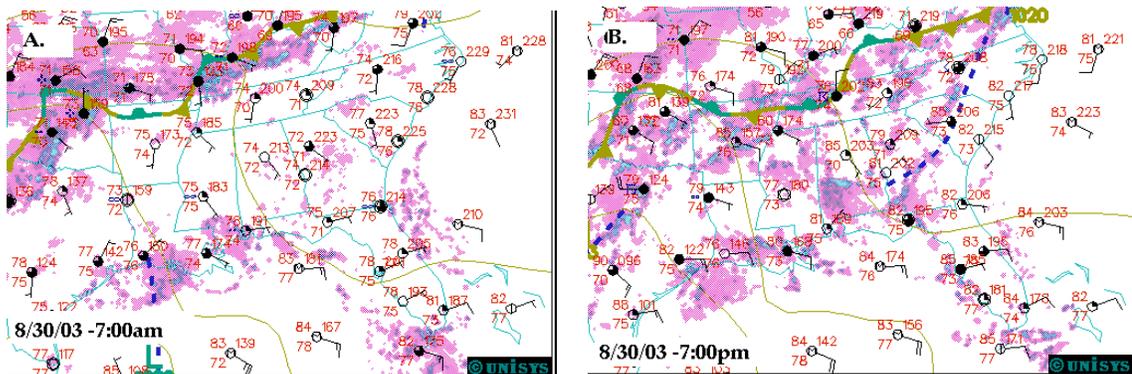


Figure 6.21: Surface weather maps for the period A) August 30th, 7:00am through D) August 31st, 7:00pm. Eastern standard time.

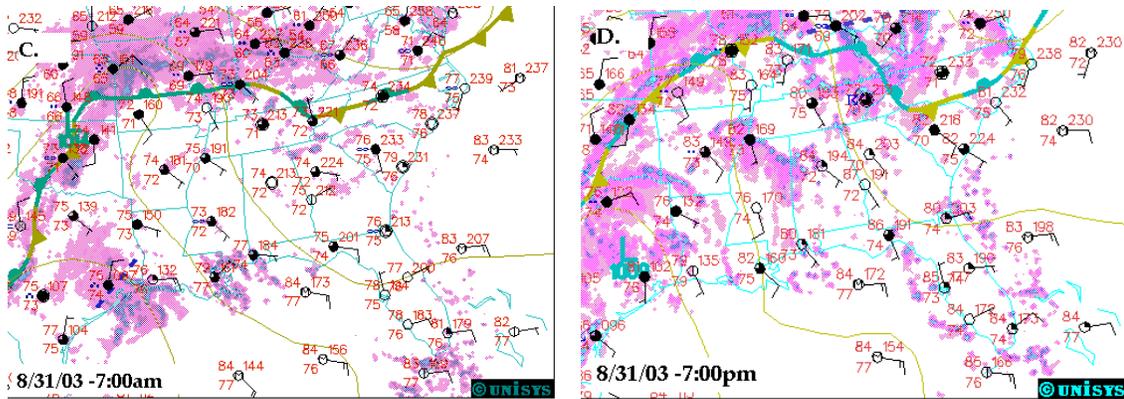


Figure 6.21. Continued

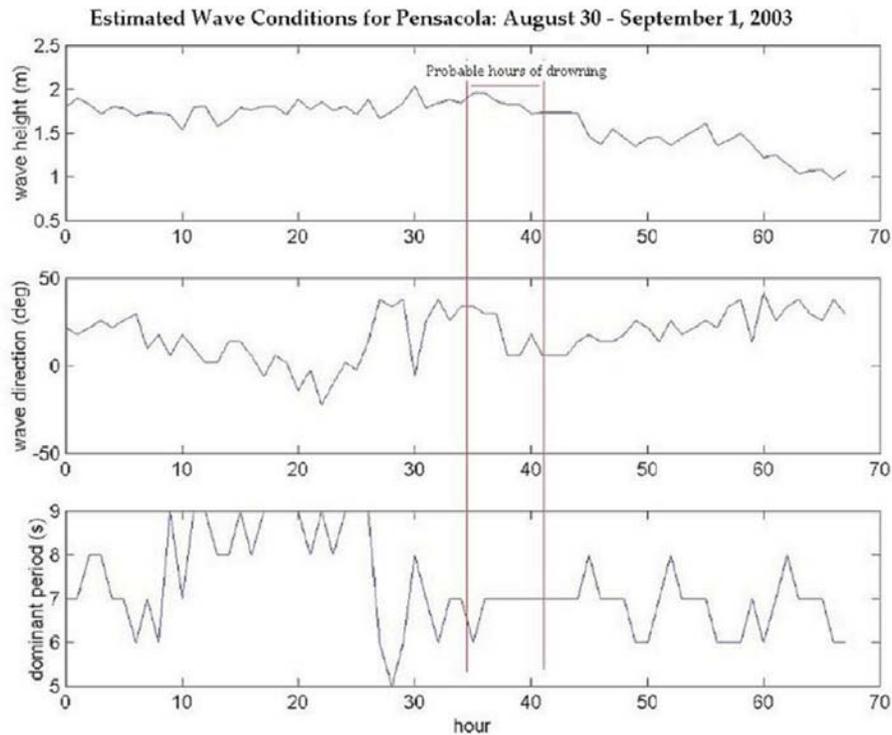


Figure 6.22: Wave conditions estimated from NDBC buoy #42040. Four drownings occurred on August 31st.

Summary

As Lascody (1998) noted, specific weather patterns seem to be associated with rip current outbreaks in Florida. These patterns are usually associated with low pressure systems and related winds. The pattern for outbreaks in Volusia County involves the

passage of low pressure systems and associated fronts as well as the presence of cold fronts to the north. Low pressure systems that move into the Gulf create long period swell which decreases in height as the low moves farther from shore. This signature is associated with rip current outbreaks. An onshore flow of wind is associated with cold fronts that push through the state. When fronts stay north of the state weak wind patterns do not appear well correlated with rip outbreaks.

Rip currents in the Panhandle are associated with cold fronts that often stay north of the state. The presence of a cold front to the north creates strong onshore winds and wave directions. Afternoon winds may lighten, but directions remain onshore instead of becoming calm or turning offshore as they do in Volusia. Onshore winds causing choppy ocean conditions may not be as great a deterrent for entering the water to Panhandle beachgoers as they are to bathers in the Atlantic. As stated earlier, the relative small size and shallow depth of the Gulf of Mexico keeps wave heights and periods lower than in the Atlantic. Swimmers may be more prone to go in the water during onshore wind waves in the Panhandle where clear water and waves breaking close to shore make conditions appear more benign than similar conditions on the Atlantic Coast.

CHAPTER 7 MODIFIED ECFL LURCS SCALE

Analysis

Further analysis of the Modified ECFL LURCS (Engle, 2003) scale was carried out in this study using data from Volusia County during the two-week period in May, 2002. The analysis was run as closely as possible to Engle's (2003) experiment in Volusia County. Wave heights and directions taken at the Sontek wave gauge were shoaled and refracted out to deep water. No modifications were made to the parameter ranges used by the Modified ECFL LURCS. Engle selected these ranges based on rescue statistics for the period of April 1996 through September 1996. This study, by using a new data set, is a blind test of the Modified ECFL LURCS scale.

Statistics used by the National Weather Service are employed in order to evaluate the performance of the scale. The POD (Probability of Detection) represents the accuracy of the scale. It equals the sum of rescues during a day that was forecast to have rip currents, normalized by the total number of rescues on all days. The FAR (False Alarm Ratio) is a measure of over-warning and equals the percentage of days that rips were predicted but had no rescues. As in Engle's (2003) study, an Alarm Ratio (AR) was also computed. This is the percentage of days that the scale predicted rip currents.

A representative value for each parameter was computed for each day. An average daily value for deep water wave height, wave period and directional spreading was used. The median value for wave direction and the minimum tide level were used. An inherent

problem with using median and average values is that if patterns vary significantly throughout the day, the median or average may not be relevant to conditions at the time rescues occurred. However, Engle (2003) found that analyzing data for periods shorter than a day (hourly, for example) was difficult due to rescue data being too noisy on that scale.

The Modified ECFL LURCS assigns an index value greater than zero to specific ranges of each parameter. Figure 7.1 is an example computation of the Modified ECFL LURCS checklist.

Wave Period	
Period, T (s)	Factor
T < 6	0
6 ≤ T < 9	0.5
9 ≤ T < 11	1
11 ≤ T < 12	2
T ≥ 12	3
Wave Period Factor =	0.5

Wave Direction	
Direction, θ (deg)	Factor
θ < -35 or θ > 20	0
-35 ≤ θ < -30 or 20 ≤ θ < 15	1
-30 ≤ θ < -25 or 15 ≤ θ < 10	2
-25 ≤ θ < -15 or 10 ≤ θ < 5	3
-15 ≤ θ ≤ 5	4
Wave Direction Factor =	4

Wave Height	
Height, Ho (ft)	Factor
Ho < 1	0
1 ≤ Ho < 2	0.5
2 ≤ Ho < 3	1
3 ≤ Ho < 5	2
5 ≤ Ho < 8	3
Ho ≥ 8	4
Wave Height Factor =	1

Tide	
Tide, h (m)	Factor
h > -0.2	0
-0.5 < h ≤ -0.2	1
-0.75 < h ≤ -0.5	2
h ≤ -0.75	1
Tidal Factor =	1

Directional Spreading	
Dspr, (θ°)	Factor
θ > 35	0
30 < θ ≤ 35	3
θ < 30	4
Dspr Factor =	3

Sum the factors: The Modified ECFL LURCS rip current threat =	9.5
--	------------

Figure 7.1: Example computation of the Modified ECFL LURCS checklist.

Ranges with higher positive correlation to rip current rescues are given higher index values. Index values are added for each parameter, and the sum is the rip current threat. A rip current warning is issued if the threat is greater than five. A “very high threat” warning would be issued for a value of nine or greater.

Figure 7.2 depicts the Modified ECFL results for the two-week period in May, 2002. The dark bars represent the rip current threat. Light bars represent the amount of daily rescues. Ideally, if there are rescues on a particular day, the threat index value should be above the threshold value of five. This indicates that a rip current threat warning would be issued.

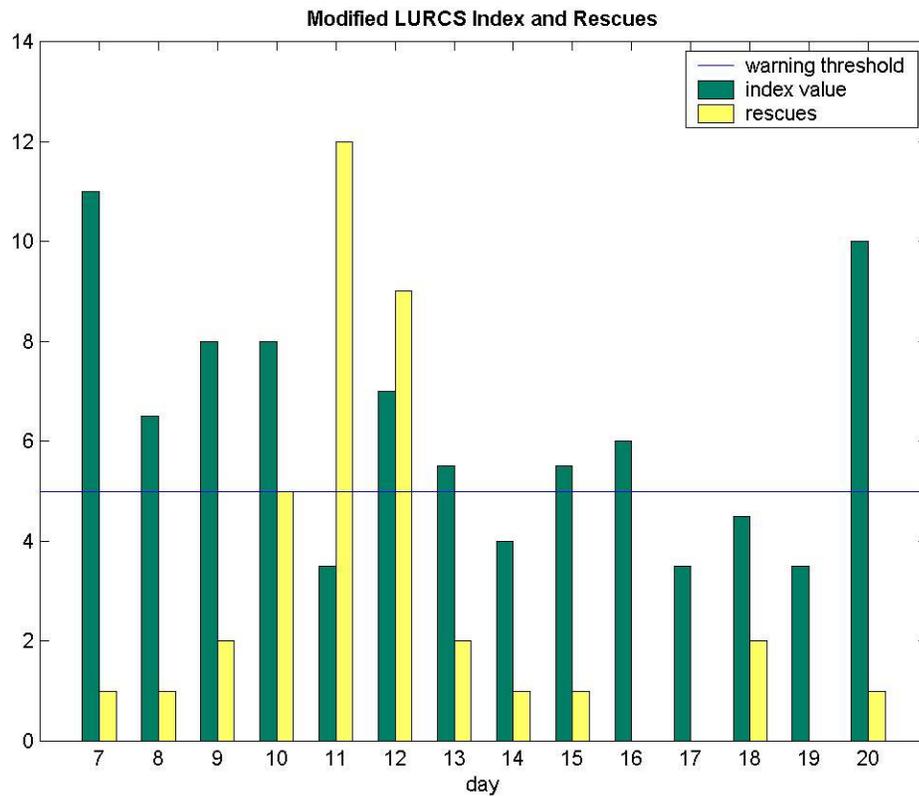


Figure 7.2: Modified LURCS rip current predictive scale results for May 7th-20th, 2002, Volusia County, FL.

A POD of 0.595 was computed for the period. This means that over 50% of the rescues were predicted. An AR of 0.643 relays that the scale predicted rip currents on 9 out of 14 days, and a FAR of 0.111 means the scale predicted rips on one day that had no rescues. Both the AR and FAR are low which is important for the applicability of the scale. A scale that falsely predicts rip currents on many days is of no use to beach rescue staff. These low values are comparable to those from Engle's (2003) study. However, the large rip current events (from May 27th through July 5th) were better predicted in his study which resulted in a POD of 0.971. The relatively low POD of this study is the result of the Modified ECFL LURCS not predicting the large rescue day on the 11th. If this day had been predicted, the POD would jump up to 0.919.

Table 7.1: Parameter values for hours 10:00am through 5:00pm used by the Modified ECFL LURCS. Wave height and direction are deep water values shoaled and refracted from the Sontek wave gage for May 7th-20th, 2002, Volusia County, FL.

Day	# of Rip Rescues	Beach Pop.	Wave Ht. (m)	Wave Dir. Deg.	Wave Period (s)	Dspr Deg.	Low Tide Level (m)	Threat Index Value	Warning Issued?
07 Tues.	1	2836	3.33	-14.50	9.88	35	-0.40	11	yes
08 Wed.	1	2938	3.00	-16.66	8.82	35.4	-0.43	6.5	yes
09 Thurs.	2	2996	2.71	-26.73	9.15	33.8	-0.46	8	yes
10 Fri.	5	3842	2.51	-26.67	10.15	33.2	-0.49	8	yes
11 Sat.	12	6980	3.05	-37.50	8.31	36.9	-0.50	3.5	no
12 Sun.	9	8197	3.67	-17.65	5.69	38	-0.53	7	yes
13 Mon.	2	2576	2.64	-29.09	7.97	36.5	-0.52	5.5	yes
14 Tues.	1	1488	3.30	39.00	5.73	40.9	-0.52	4	no
15 Wed.	1	2625	5.20	35.16	6.42	39.4	-0.52	5.5	yes
16 Thurs.	0	2602	4.74	-20.00	5.69	41.1	-0.46	6	yes
17 Fri.	0	3500	3.43	-35.97	7.32	36.6	-0.31	3.5	no
18 Sat.	2	6216	2.43	-39.34	7.05	34.5	-0.06	4.5	no
19 Sun.	0	654	6.22	63.00	7.67	37.2	-0.15	3.5	no
20 Mon.	1	754	8.14	-13.00	10.22	38	-0.39	10	yes

The actual POD increases to 0.686 when rescues are normalized by population (Figure 7.3). As stated earlier, dividing daily rescues by daily population reduces the effect that population has on the number of rescues each day. Normalized rescues are a

better representation of rip current risk than un-normalized rescues. Days with low population and a high amount of rescues may have more “risk” associated with them than days with high population and a high number of rescues.

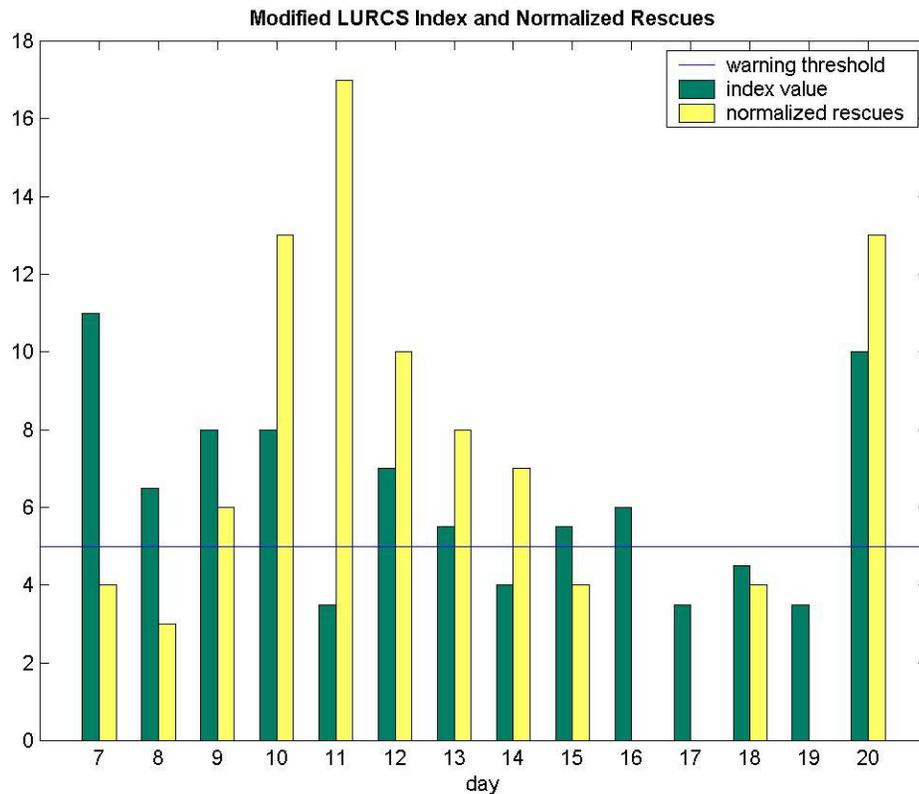


Figure 7.3: Modified LURCS rip current predictive scale results, using normalized rescues, for May 7th-20th, 2002, Volusia County, FL.

The reasons that the 11th was not predicted to have rescues are non-shore normal waves (-37.5 degrees) and directional spreading of 36.9 degrees, which is just outside the limit of 35 degrees. The day would have been predicted had the spreading been 2 degrees lower. Directional spreading for the hours of 10:00am through 5:00pm on the 11th was fairly constant, shifting from 35.8 to 37.8 degrees. Figure 5.4 depicts deep water wave directions for the entire period. Wave direction fluctuates widely on the 11th with a spike, due to one point, reaching -53 degrees.

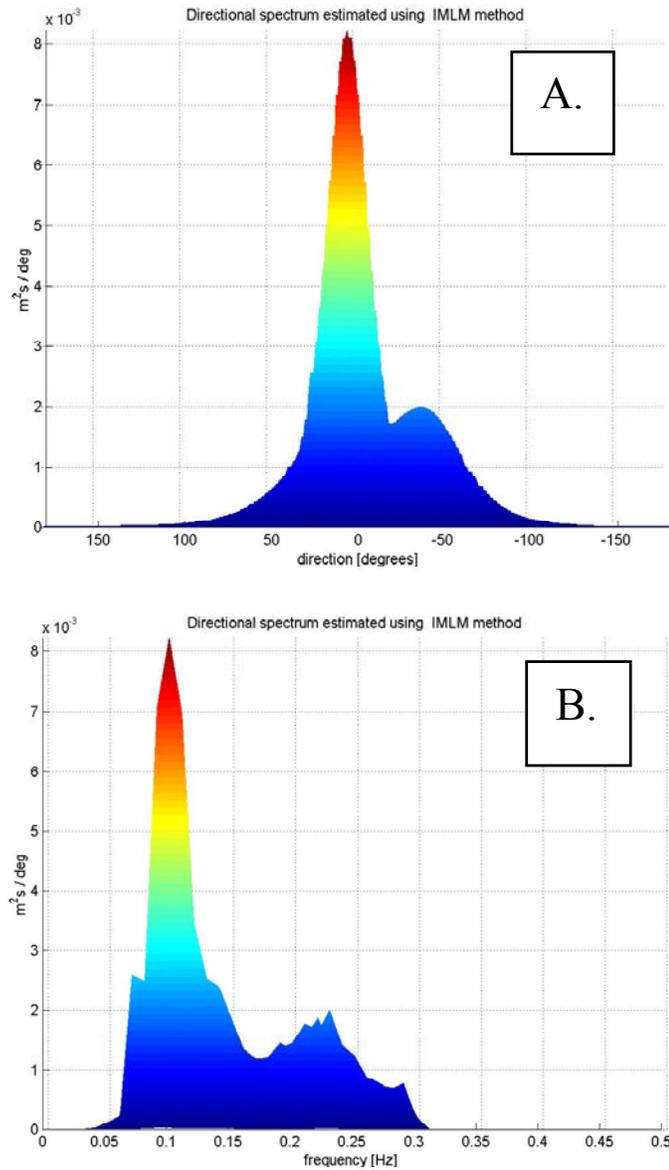


Figure 7.4: Spectra depicting A.) wave direction at 4m depth and B.) wave frequency for May 11th, 2002 in Volusia County, FL.

Figure 7.4 shows that the fluctuation may have been caused by a confused sea state where swell with a period of around 10 seconds was relatively shore normal, while higher frequency waves (possibly locally generated wind swell) of around 4-5 seconds came from the southeast.

From the figure, it is apparent that on the 11th the greatest amount of energy was from nearly shore normal waves of around 10 seconds, which would undoubtedly aid in the forcing of rip currents.

Large fluctuations in wave direction during the second week of the study period are also indicative of a confused sea state. Figure 7.4 shows hourly spectra from the 14th and 16th. From the figure, it is apparent that energy was coming from different directions.

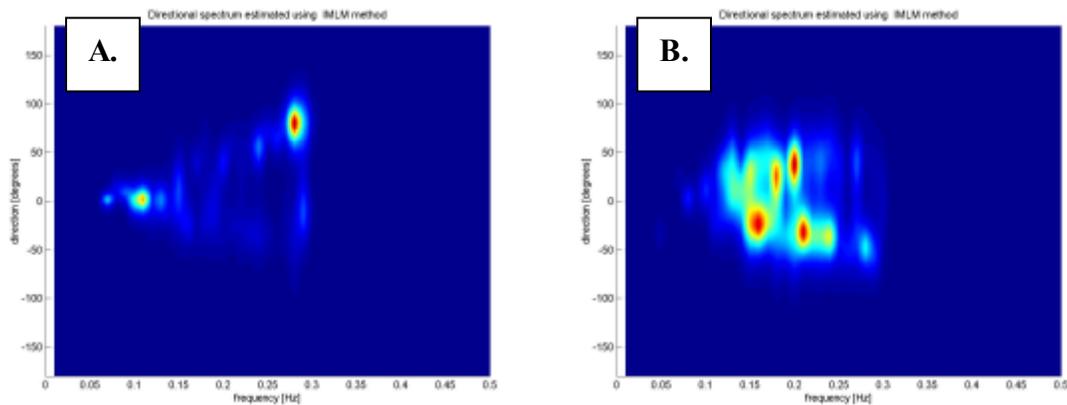


Figure 7.4: Spectra at 4m water depth depicting A.) May 14th, 2002, 11:00am and B.) May 16th, 2002, 12:00pm. Volusia County, FL.

Figure 7.4(A) shows some shore normal wave energy with a 10-second period and greater energy from around 75 degrees with a 3-4 second period. May 16th at 12:00pm saw strong energy from -50 to 50 degrees with periods of 4 through 9 seconds. These conditions of fluctuating wave direction would not be conducive to rip current development. This is supported by the lack of rescues during the second week even though the population was similar to the first week (with the exception of the 19th and 20th).

Also of note is that the only two days were designated with a very high threat (index value of 9 or greater), the 7th and the 20th. Only one rescue occurred on both of these days. Both days had shore normal wave directions under -15 degrees. This

combined with directional spreading just under 35 degrees were the main reasons the index produced such a high threat level on the 7th.

The average daily beach population during the period was 3,443 cars. The 7th (a Tuesday) had 2,836 cars (see Table 6.3) while the 20th (a Monday) had 754. No days with below average population had more than two rescues. It is possible that strong rip currents were present on the 7th and 20th, but due to low population, only one rescue occurred. Figure 7.5 shows mid-day conditions around the time of the rescue on the 7th, which occurred just after low tide. Rip channel formation is evident on the bar and supports the index's claim that there was a rip current threat on this day. Possibly the "high threat" wave conditions on this day were the beginnings of the event that reached its peak on the 11th.



Figure 7.5: Time-lapse photo of Ormond Beach, Volusia Co. May 7th, 2002 at 1:01pm. One rescue occurred between 12:00pm and 1:00pm.

Due to a high wave height, long average period, and shore normal wave directions, it is very likely that there were rip currents on the 20th. However, high precipitation kept the population very low and only one rescue occurred.

There was not such a marked relation between directional spreading and rescues in this study as there was in Engle's. He noted a peak in rescues whenever directional spreading values dropped below 30 degrees. However, there was not as wide a fluctuation in spreading during this study as in Engle's. Values during his study varied between 60 degrees to around 25 degrees. Directional spreading during this study generally fluctuated between 42 and 30 degrees.

Figure 7.6 shows the correlation between directional spreading and rescues. The large rescue events occur at and below 38 degrees, but rescues are not dominantly grouped at low points in the series as they were in Engle's study.

Conclusions

It should be emphasized that Engle created the Modified ECFL LURCS using data collected during summer months when waves generally come from the southeast. This is reflected in the weighting of the wave direction factor being biased toward negative (southerly) wave angles. In Figure 7.1, it can be seen that an index value greater than 0 is given to wave angles from -35 to 20 degrees. Since there are fewer bathers (and therefore rescues) in the winter months when wave directions are more northerly, this bias is valid as long as rescue data is being used in place of actual rip current data. However, the scale would have to be altered for analysis on *in situ* rip current measurements which may include data from any time during the year.

Overall, the Modified ECFL LURCS performed well on the short data set available. Two out of the three high rescue days (the 10th, 11th, and 12th) were issued a

rip current warning. Data from a longer period of time would obviously facilitate a better analysis of the scale. With a longer time series, errors (such as the scale not predicting one large rescue day) would not have such a great impact on the evaluation.

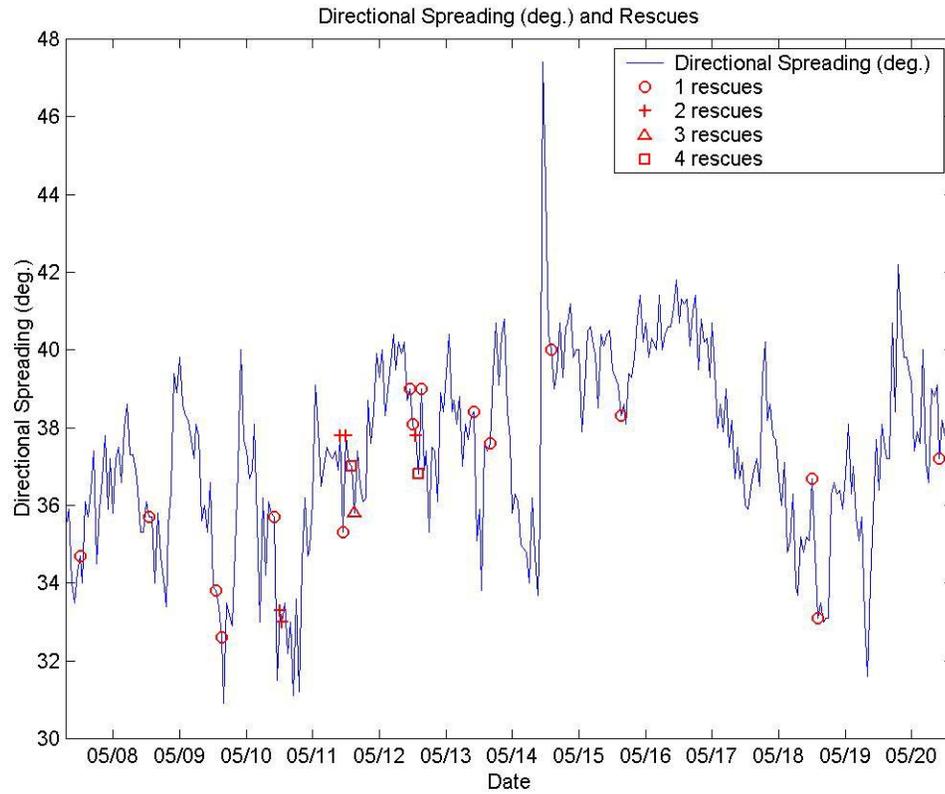


Figure 7.6: Entire record of directional spreading for Volusia County, FL and 10:00am through 5:00pm rescues. May 7 – May 20, 2003.

CHAPTER 8 SUMMARY AND CONCLUSIONS

Rip current outbreaks may have certain “signature” parameters that can be used to identify their occurrence. These signatures involve: wave height, wave period, wave direction, directional spreading, and tidal stage. Patterns involving these parameters are evident before outbreaks in Volusia County, Florida, and similar patterns are evident in the Panhandle of Florida. These patterns include: decreasing wave energy, shore normal wave direction, and low directional spreading. Tidal stage and surf-zone topography are also important factors.

Results from this study were similar to those found by Engle (2003). Outbreaks in both Volusia County and the Panhandle often occurred during times of decreasing wave height and relatively high wave period. In Volusia County a correlation was apparent between relatively onshore wave directions of -20 to -39 degrees. However, the high correlation that Engle found between shore normal (0 degrees) waves and high rip rescue occurrence was not found here. In the Panhandle wave direction often crossed through zero and remained shore normal before the outbreaks.

In the relatively two-dimensional topography of Volusia County beaches, low tide had a strong correlation with rescues. However, tidal stage may not play as important a role along Panhandle beaches where a more three-dimensional topography appears to aid in the forcing of rip currents. A strong correlation between directional spreading and rescues was not found in this study. However, Engle’s general conclusion was evident in the results: that rip currents occur at lower values of directional spreading.

Large-scale weather patterns such as pressure systems and associated frontal systems were usually found in the proximity of areas where rip current outbreaks occurred. These systems seemed to have the greatest effect on wind direction which would affect wave direction and, in the case of onshore winds, possibly augment (but not drive) mass transport of breaking waves, thereby increasing rip current strength. However, all the parameters mentioned that force rip currents could be affected by weather conditions. Rip current occurrence may be better understood with further study of such meteorological systems, and predictive indexes may be improved by including a factor indicating their approach or presence.

A new data set was used to further analyze the Modified ECFL LURCS. The ranges of parameters determined by Engle (2003) were effective in predicting rip currents given the fact that the two-week period of study was relatively short. The scale predicted most major rip current rescue days and predicted over half of all rescue days. Rip currents were predicted only 64% of the total period, and only one false alarm was given. These are important points for beach patrol staff; A predictive scale is of less use to lifeguards if it greatly overpredicts rip current days and gives a high number of false alarms.

With further analysis demonstrating its reliability, the Modified ECFL LURCS will become a practical tool for beach rescue staff. Such a tool would greatly aid in the preparation for rip current events, which would reduce the number of rip-related rescues and drownings. This would be accomplished by the index alerting beach rescue staff to the presence of conditions favorable for rip current occurrence, thereby allowing them to increase staff numbers, frequency of beach patrols, and other preventative measures. The

index would also allow government agencies to warn the public of unsafe conditions.

The ECFL LURCS is currently used by the National Weather Service (NWS) to forecast rip currents along the east coast of Florida in order to issue warnings through the media.

Future studies may further analyze how tidal stage affects rip currents at different sites. The correlation found between rescues and falling tide in this study may also be of importance. Wind velocity and direction may be important site-dependent parameters and should be given further consideration. As mentioned above, stronger correlations between rip currents and meteorological events may be drawn from additional study.

The next step involving the use of the Modified ECFL LURCS should incorporate *in-situ* directional wave data in order for real-time rip current threat predictions to be made and compared to actual rescue data.

LIST OF REFERENCES

- Ahrens, C. Donald, *Meteorology Today. An Introduction to Weather, Climate, and the Environment*, West Publishing Company, St. Paul, MN, 1994.
- Charles, L., R. Malakar, R.G. Dean, *Sediment Data for Florida's East Coast*, UFL/COEL-94/014, Coastal Engineering Department, University of Florida, 1994.
- Dean, Robert G., Dalrymple, Robert A., *Coastal Processes with Engineering Applications*, Cambridge University Press, Cambridge, UK, 2002.
- Engle, Jason A., *Formulation of a Rip Current Forecasting Technique through Statistical Analysis of Rip Current-Related Rescues*, Master of Science Thesis, University of Florida, 2003.
- Hauserman, Julie, *Currents Deadly for Fla. Tourists*, St. Petersburg Times, Sunday, July 20, 2003.
- Lascody, L.L., *East Central Florida Rip Current Program*, Natl. Wea. Dig., Vol.22, No.2, pp.25-30, 1998.
- Lushine, J.B., *A Study of Rip Current Drownings and Related Weather Factors*, Natl. Wea. Dig., Vol. 16, pp.15-30, 1991.
- McKenzie, P., *Rip Current Systems*, J. of Geology, 66(2), pp.103-113, 1958.
- National Data Buoy Center (NDBC), *Station 42039 Historical Data, 2003*, NOAA/NDBC, Available [On-Line] http://www.ndbc.noaa.gov/station_page.phtml?station=42039, January 10, 2004.
- National Data Buoy Center (NDBC), *Station 42040 Historical Data, 2003*, NOAA/NDBC, Available [On-Line] http://www.ndbc.noaa.gov/station_page.phtml?station=42040, January 11, 2004.
- Shepard, F.P., K.O. Emery, and E.C. LaFond, *Rip Currents: A Process of Geological Importance*, J. Geol., 49(4), 337-369, pp.337-369, 1941.
- Sonu, C.J., *Field Observations of Nearshore Circulation and Meandering Currents*, J. Geophys. Res., 77, 3232-3247, pp.244-258, 1972.
- Unisys Weather, *Archived Surface Weather Maps, 1996, 2002, 2003*, Unisys, Available [On-Line] <http://weather.unisys.com/archive/>, March 5, 2004.

Volusia County Council, *Volusia County, Florida Beach Patrol*, pamphlet, Orlando, FL, 2003.

WWW Tide and Current Predictor, *Tidal Data, 1996, 2002, 2003*, Available [On-Line] <http://tbone.biol.sc.edu/tide/index.html>, March 12, 2004.

BIOGRAPHICAL SKETCH

Matthew Schrader's earliest beach memory involves the smell of Coppertone suntan lotion as his mother smeared globs of it across his face while visiting his grandparents' condo in Boca Raton, Florida. He was only three or four years old at the time, with pale white skin (since his family had relocated from his 1975 birthplace of Falls Church, Virginia, to Sayre, Pennsylvania). So, his mother was right to slather him in an SPF overcoat. Once released from her grasp, he immediately tripped and, as he rolled across the beach, applied a thorough layer of gritty sand to the freshly applied lotion.

By the age of 13, his family was living in Tampa, Florida, where Matthew began skimboarding on west coast beaches and surfing whenever his parents would make the two-hour drive to the east coast. After graduating from high school in 1994, he began undergraduate studies at the University of South Florida in Tampa. He decided to study civil engineering because he liked to draw, and he liked to build. He specialized in environmental engineering, not yet understanding that this meant "wastewater engineering." He also enjoyed writing and took extra classes in order to minor in creative writing. At different times during his studies, he worked part time as a lifeguard, swimming instructor, outdoor educator (in Colorado), and as an engineering intern for the Southwest Florida Water Management District (SWiFtMuD).

It was while working for SWiFtMuD that he became interested in engineering applications for habitat restoration and creation. After graduating from USF, he

immediately began postbaccalaureate studies at the University of Florida in Gainesville with the environmental engineering and sciences program, studying ecological engineering. Under the direction of Dr. Mark Brown, he came to the conclusion that he wanted to apply ecological principles to the coastal zone. With the helpful advice of others, including his parents, Dr. Brown, and Jason Engle, Matthew decided to begin his Master of Science degree in the coastal and oceanographic engineering program at UF. His future will involve many more beach memories and the pungent smell of Coppertone, without the grit.