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THE MISS/HIT RATIO - AN ESTIMATE OF RELIABILITY FOR TROPICAL CYCLONE TRACK PREDICTIONS

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THE MISS/HIT RATIO - AN ESTIMATE OF RELIABILITY FOR TROPICAL CYCLONE TRACK PREDICTIONS

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ABSTRACT. Populations along the United States Gulf and Atlantic coasts have increased rapidly during the past two decades. During the same period, landfall of strong hurricanes in densely populated areas has been infrequent. This situation has led to low hurricane experience levels for millions of coastal residents. Such low experience levels greatly increase the potential for the loss of many lives if a strong hurricane should strike. Recent efforts to increase awareness of the hurricane threat encouraged development of detailed preparedness and evacuation plans. An important factor in proper design and response to such plans is an awareness of the reliability of predicted storm tracks.

Strike probabilities routinely provide estimates of the chance that the center of a tropical cyclone will pass within a specified distance of selected points of interest. These estimates are based on a current official forecast track and historical errors of official forecast tracks. This study derives miss/hit ratios from strike probabilities that were computed for typical threat situations at six coastal locations. Given that a storm is predicted to hit a point of interest, a miss/hit ratio estimates, from past performance, the number of times that storm is expected to miss for each observed hit. Thus, the miss/hit ratio is a general estimate of reliability of track predictions. Miss/hit ratios were related to storm intensity through estimations of areal extents of winds.

Quantitative estimates of reliability presented in this study reflect earlier findings regarding official forecast errors. In general, highest reliabilities are expected for shorter forecast periods and lower-latitude coastal locations.

1. INTRODUCTION

Populations along the United States Gulf and Atlantic coasts have increased rapidly during the past two decades. At the same time, there has been infrequent landfall of strong hurricanes in these areas. As a result, millions of coastal residents have low hurricane experience levels (Hebert and Taylor, 1975).

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Such inexperience has greatly increased the potential for loss of many lives in the event that a severe hurricane should strike. Recent efforts to substitute hurricane awareness education for hurricane experience have spawned development of detailed preparedness and evacuation plans. The density of coastal populations necessitates plans for actions to be taken as much as 3 days before the arrival of dangerous winds and storm surges.

Because of uncertainty in predictions of tropical cyclone tracks, these early preparations will be taken at times when a storm does not significantly affect a particular location. Even though early actions are necessary for successful completion of evacuations or preparations, actions taken in areas not directly affected by a storm may lead to complacency or resentment toward future requests for actions. This is a major concern of both hurricane forecasters and preparedness officials.

Implementation of preparedness actions outlined by detailed plans will be based on the estimated threat to each location. One quantitative estimate of the threat is a "strike probability". A strike probability results from statistical consideration of historical errors in official forecasts of storm motion issued by the National Hurricane Center (NHC) for storms in the Atlantic basin. This report uses such strike probabilities to derive general statements of expected reliability in tracks of tropical cyclones that are predicted to hit various coastal locations. Representative threat situations were formulated for six coastal points, and associated strike probabilities were computed. These probabilities were used to produce miss/hit ratios. These miss/hit ratios express the number of times storms can be expected to miss each location for each expected hit during similar situations in the future.

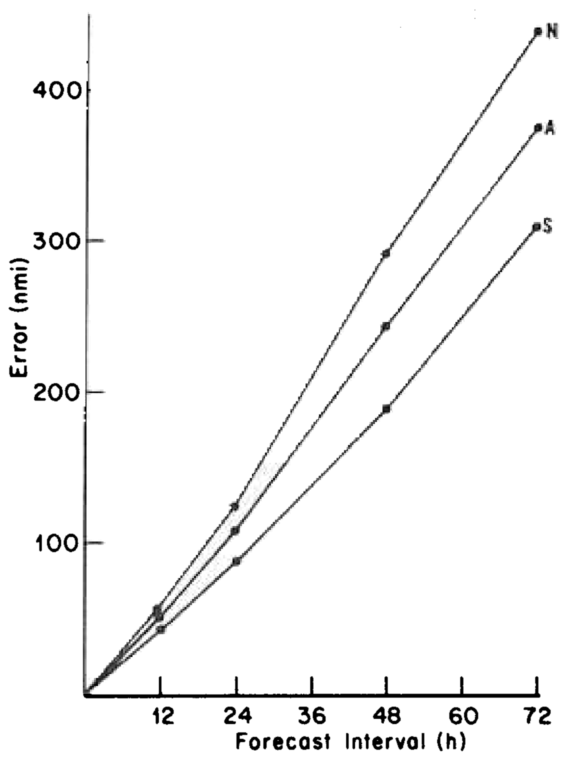

Figure 1. Mean forecast errors(nmi) for all official tropical cyclone forecasts issued by the National Hurricane Center during 1970-1979 (from Neumann and Pelissier, 1981). Values are shown for all cases (A), cases north of 24.5°N (N), and cases at or south of 24.5°N (S).

2. BACKGROUND

Official advisories concerning Atlantic tropical cyclones are issued by the NHC. Information in these advisories varies depending on the primary user. For example, military needs require predicted positions for 12, 24, 48, and 72 hours into the future. These positions are a framework of a predicted storm track. Each predicted position is likely to be in error, and as the length of the forecast period lengthens, the size of the error tends to increase. Neumann and Pelissier (1981) presented a detailed discussion of prediction errors that occurred during 1970-1979 in the Atlantic basin. These errors are further analyzed by Crutcher. Neumann, and Pelissier (1982).

As seen in Figure 1, greatest variations in errors correspond to increases in the length of the forecast period. Neumann and Pelissier (1981) also found geographical variations in the mean prediction errors. Predictions made for storm cases south of 24.5°N resulted in smaller mean errors than cases north of 24.5°N. This latitude corresponds to the mean location of the subtropical ridge. Therefore, storms to the south are generally under the influences of easterly winds, while those to the north are generally under the influences of westerly winds.

Increasing mean errors reflect increasing uncertainty in the future position of the storm. As an extension of these concepts a statistical technique is used operationally at the NHC to estimate probabilities that storms will pass within specified distances of various locations along the coastline of the Atlantic tropical cyclone basin. The original procedure for computation of these strike probabilities in the Atlantic basin was developed for the U. S. Navy (Jarrell, 1981), and it has been recently adapted for use by the NHC. Probabilities are based on tracks that were predicted in military advisories issued by the NHC and on historical records of errors in such predictions. Basically, this procedure formulates bivariate normal probability distributions from historical errors and computes the probability contained within a specified area around each point of interest. This procedure is described in detail by Jarrell (1978).

3. STRIKE PROBABILITIES

Instantaneous (for a given time) and cumulative (for a given time period) strike probabilities were computed for cases in which a storm is 72, 48, 24, and 12 hours away from each point of interest. Representative tracks shown in Figure 2 provide a predicted storm track that threatens each location listed

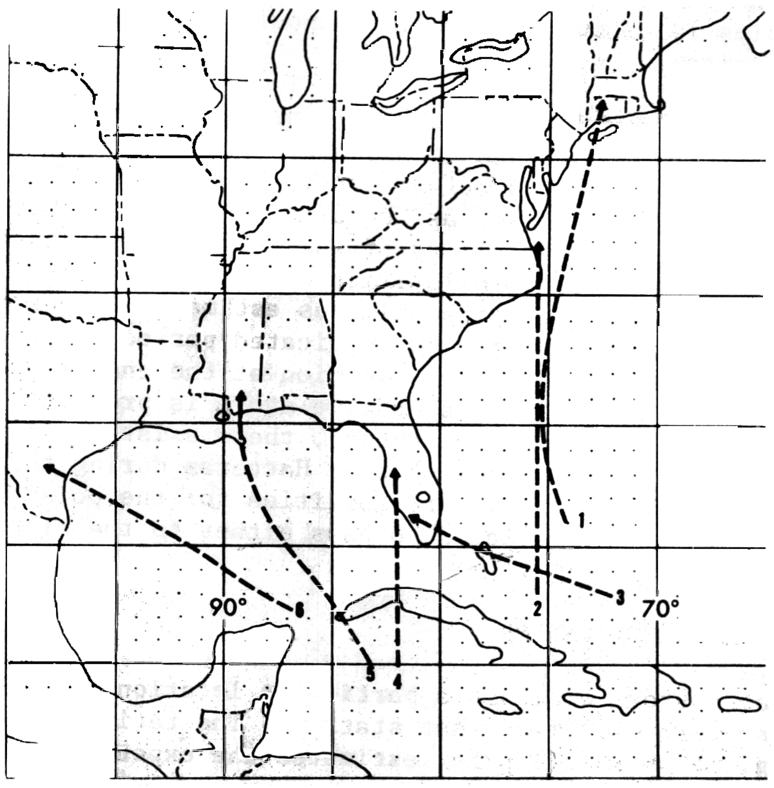

Figure 2. Storm tracks posing representative threats to six coastal locations. Numbers correspond to those listed in Table 1.

Table 1. Coastal points of interest and their geographical locations. (Numbers for each storm correspond to tracks in Figure 2)

Storm Track	Point of Interest	Location	
1	Long Island, New York	41.0°N	73.2°W
2	Cape Hatteras, North Carolina	35.3°N	75.6°W
3	Miami, Florida	25.8°N	80.3°W
4	Sanibel, Florida	26.4°N	82.3°W
5	Mississippi Delta, Louisiana	29.4°N	89.1°W
6	Corpus Christi, Texas	27.8°N	97.5°W

in Table 1. Use of the same track to produce a series of forecasts simulates having a predicted path that does not change with time. A maximum sustained wind of 100 knots was assumed for each case. Although probabilities are weighted during the computation procedure according to direction and speed of storm motion and maximum sustained winds, tests showed these effects to be small compared with effects of the closeness of the predicted track to each point of interest. Because no bias is assumed in predicted positions, maximum probabilities occur along the projected track.

Figure 3 displays graphs of cumulative probabilities for various times and radii about each selected point. In each case, probabilities rise slowly from 72 hours until approximately 42 hours before predicted arrival, then rise more rapidly as the storm approaches. Also, as the size of the radius about the point of interest increases, the probability of the storm passing through that area increases for a given period. Similarities of the curves for different locations are apparent. These cumulative probabilities estimate chances of the storm directly affecting each location within the indicated period, given that the storm is predicted to be directly over that location at the end of each forecast period. As an example, when a representative storm is predicted to be at Cape Hatteras (Figure 3) 24 hours in the future, there exists a 44 percent chance that the storm will pass within 75 nmi of Cape Hatteras during the next 24 hours. For the same period, lower strike probabilities for the point of interest will result if the storm is predicted to pass either to the right or left.

4. MISS/HIT RATIOS

A probability, p, that a storm will hit a particular location implies a probability, 1-p, that a storm will miss that station. The ratio, R, of these two probabilities, given by $R = (1-p)/p$, estimates the expected number of misses for each hit.

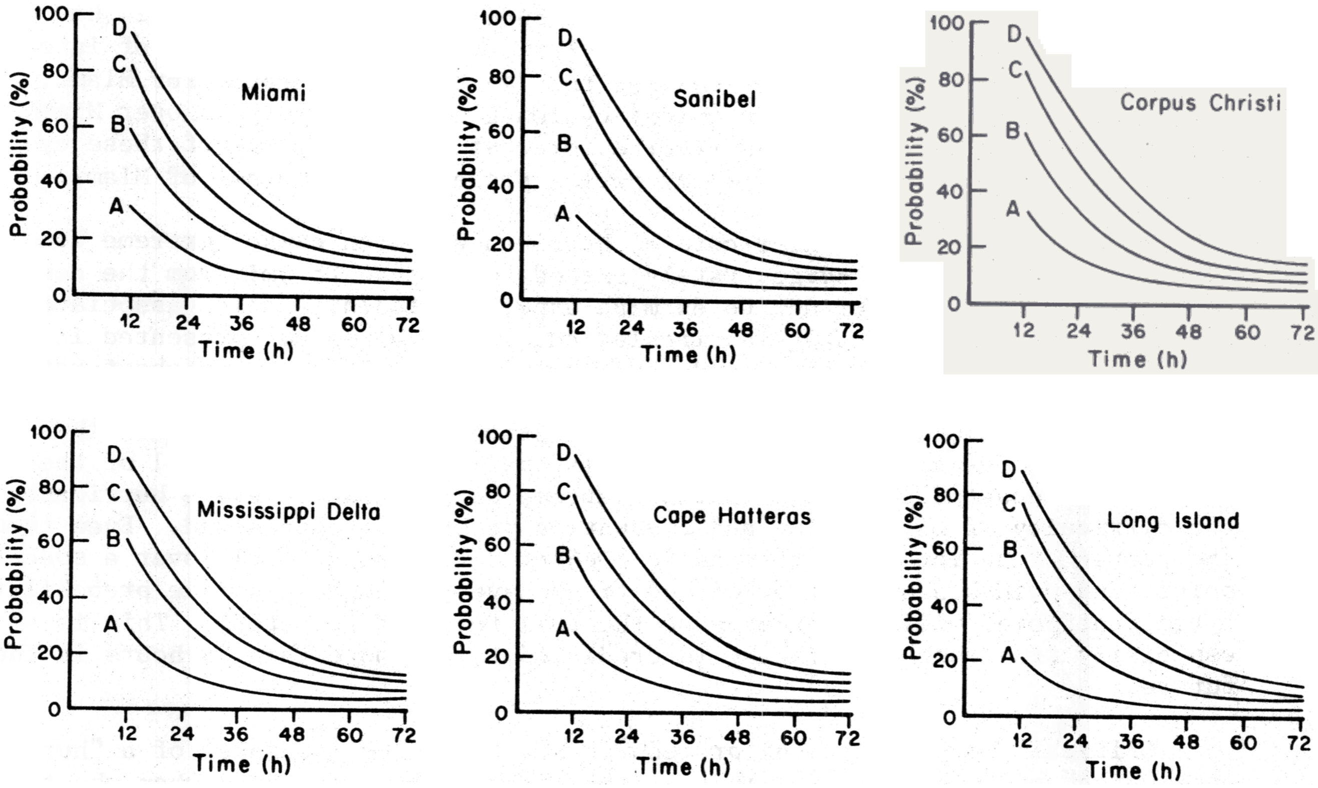

Figure 3. Cumulative strike probabilities computed from representative storm tracks for six coastal locations. A, B, C and D denote curves for radii about each point of interest of 25, 50, 75 and 100 nmi, respectively.

Figure 4 contains graphs of miss/hit ratios computed for a 50 nmi radius and various periods for the six coastal locations. Periods of 12 hours were used, with the exception of the period from 12 to 24 hours, which was further divided into 6-hour periods. Probabilities used in computations of miss/hit ratios were taken from corresponding graphs in Figure 3 as a mean probability for each time period. Ratio values are shown as rounded to the next lower whole number. Graphs for Miami, Sanibel, and Corpus Christi are the same. Long Island has the highest ratios for all periods other than 12 to 24 hours, but the ratio for this period is 1 for all stations. As an example of interpretation of a miss/hit ratio, consider the 24- to 36-hour ratio for Miami, a value of 3. For every four tropical cyclones predicted to pass over Miami sometime between 24 to 36 hours after a forecast is issued, one of these cyclones will be expected to verify as having passed within 50 nmi of Miami.

Because the intense inner core of hurricanes, which causes extreme conditions of wind and storm surge, rarely extends more than 25 nmi from the center of the storm, it is important to examine expected miss/hit ratios associated with this region of the storm's circulation. Such values are presented in Figure 5. Lowest ratios are found for Miami and Sanibel, while highest ratios are found for Long Island. Interpretations of values are similar to those expressed for values in Figure 4. For all stations, ratios are higher than those for the 50-nmi radius. Because this smaller region is typical of the size of the coastal zone experiencing extreme damage from a severe hurricane, the difficulty of the warning and evacuation problem is emphasized. Even though the center of an intense hurricane is predicted to pass directly over a specific point, and points along the predicted track have the highest strike probability, often that point will not experience the full force of the storm. This is especially true when a hurricane is predicted to hit more than 24 hours in the future.

Critical times in warning procedures are those for issuances of a "hurricane watch" or "hurricane warning". A hurricane watch is issued when the threat of hurricane conditions (winds of 64 knots or higher and/or dangerously high water) exists in that area, usually between 24 and 36 hours in the future. A hurricane warning is issued when hurricane conditions are expected in a specified coastal area in 24 hours or less. An example of the expected miss/hit ratios that correspond to these announcements can be seen in the 24 to 36 hour period for a hurricane watch. For a 50-nmi radius, which approximates the extent of hurricane-force winds, miss/hit ratios are generally 3 to 1, except 4 to 1 for the Long Island point. If the inner core of the storm (25 nmi radius) is used, ratios range from 7 to 1 at Miami and Corpus Christi and up to 12 to 1 on Long Island. In addition, the 18- to 24-hour period corresponds to the issuance of a hurricane warning. In all locations the miss/hit ratio is 1 to 1 for a 50-nmi radius. For the 25-nmi radius, values are 4 to 1 everywhere, except Long Island, where the value is 7 to 1.

These results are consistent with an implied increased threat to areas for which a hurricane watch or warning has been issued. Even at the issuance of a hurricane warning, uncertainty remains as to the precise section of the coastline that will experience the intense inner core of the hurricane. Currently, these factors are incorporated into hurricane watches and warnings according to the extent of the coastline that is designated as threatened.

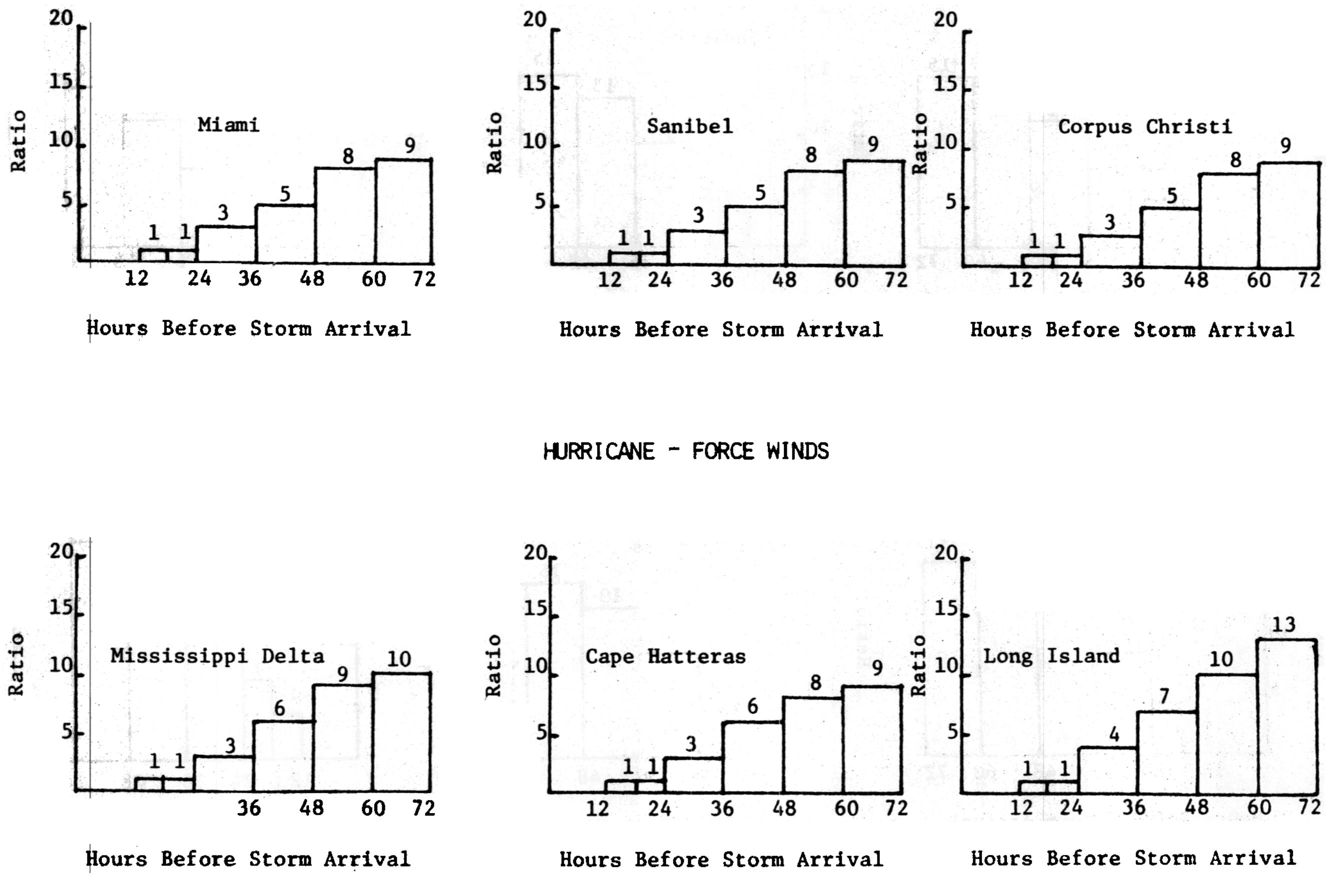

Figure 4. Miss/hit ratios for each coastal location for indicated time periods before storm landfall. Values are based on an area of 50 nmi radius about each point.

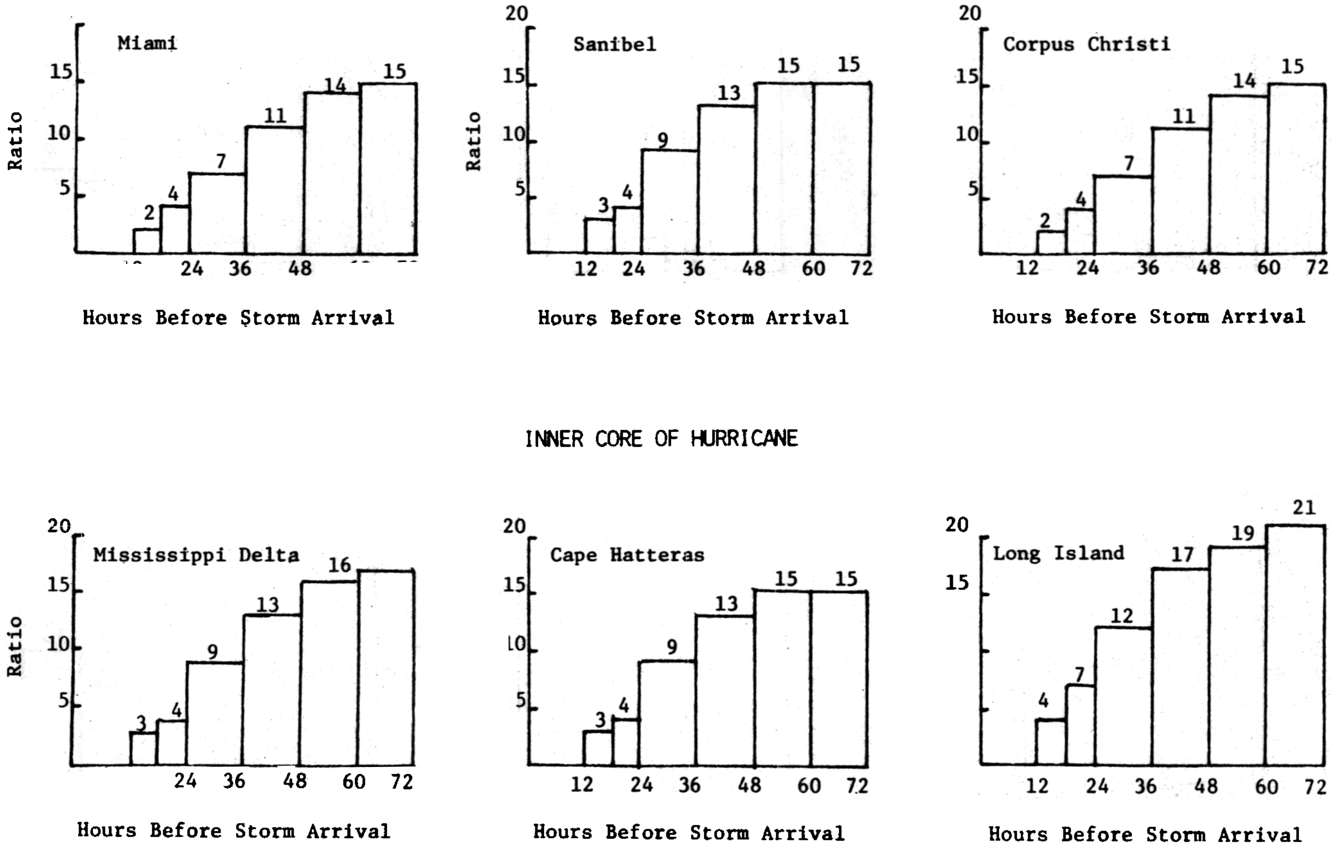

Figure 5. As in Figure 4, but for an area of 25 nmi radius about each point

5. SUMMARY AND COMMENTS

Increasing coastal populations have heightened the potential for great loss of life as the result of landfall of a severe hurricane. Persons who are asked to respond to warnings and/or evacuation requests often are not aware of the uncertainty associated with predicted storm tracks. This study expresses this uncertainty as the number of misses expected for each hit by representative storms at six selected locations.

Miss/hit ratios were computed as the ratio of probabilities obtained from an operational program currently in use at the National Hurricane Center. Values quantitatively reflect known prediction errors and uncertainties incorporated into hurricane watch and warning areas. Ratios decrease as the length of the forecast period shortens, indicating increased reliability in the shorter-term predictions.

Currently discussed miss/hit ratios are useful for planning, because they are estimates of reliability for predicted hurricane tracks in typical landfall cases. However, only one of several possible methods was used in computation of these miss/hit ratios, and values given are based on stated assumptions about the selected storms. Other methods may result in somewhat different values. Also, miss/hit ratios presented in this study do not estimate threats in individual situations. For these cases, strike probabilities computed with operational runs should be considered. Application of miss/hit ratios presented in this study to specific preparedness/evacuation problems is a topic for future study.

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