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ATLANTIC HURRICANE STRIKE PROBABILITY PROGRAM (STRIKPA).(U)
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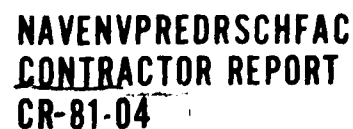
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ATLANTIC HURRICANE STRIKE PROBABILITY PROGRAM (STRIKPA)

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1.0 INTRODUCTION

The Atlantic Hurricane Strike Probability (STRIKPA) model is an interim step in the development of the Atlantic Wind Probability (WINDP-ATL) model. The concepts are for the most part identical to the western Pacific and eastern Pacific models. The exceptions are the way forecast difficulty is treated and the number and listing of stations for which strike probabilities are routinely computed.

2.0 MODEL DESCRIPTION

2.1 Basis for Forecast Difficulty Estimation

The basis for forecast difficulty estimation follows Crutcher (1980)¹. Using a clustering model (NORMIX) Crutcher identified three discrete bivariate normal populations of 24-hour forecast errors in the Atlantic Basin for the years 1970-1979. These are illustrated by 50% probability ellipses in figure 1.

Some modifications to Crutcher's work was necessary. The errors he used were adjusted for warning position error (WPE), but since this cannot be specified operationally it was necessary to replace this adjustment. An implicit assumption here is that the reintroduction of the WPE does not change the clustering. For any position on figure 1 (any 24-hour forecast error) there is a unique set of three probabilities whose sum is unity which is associated with the

¹Crutcher, H.L., 1980: Tropical Storm Forecast Error and the Bivariate Normal Distribution. 13th Tec. Conference on Hurricanes and Tropical Meteorology. AMS, Miami, FL, 1-5 Dec 1980.

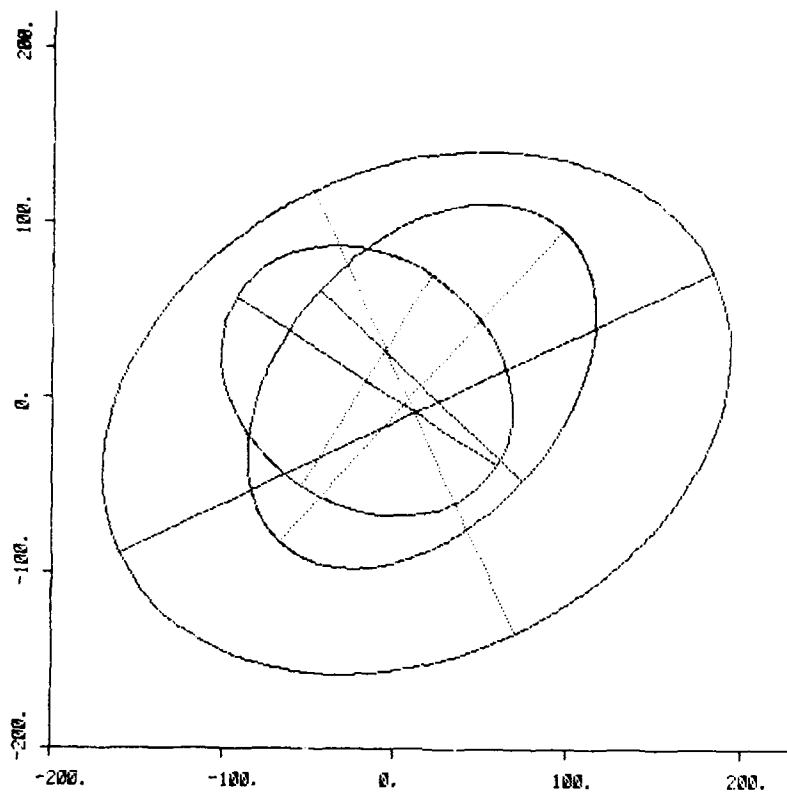


Figure 1. Fifty percent probability ellipses of 24-hour forecast errors for difficulty class ONE, TWO and THREE forecasts. The size of the ellipses increase with increasing class number. Units are n mi.

three populations. Three population probabilities were determined for each case with the WPE removed. The WPEs were then reintroduced and the population statistics were recomputed. Table 1 compares statistics for the three populations with the WPE removed (provided by Crutcher for years 1970-1979) to those with the WPE (1970-1978; 1979 was withheld for testing).

	POPULATION ONE		TWO		THREE	
	WPE	No WPE	WPE	No WPE	WPE	No WPE
W-E Mean	-16.9	-16.0	14.9	13.1	11.0	8.6
S-N Mean	9.7	5.1	6.9	1.8	-8.2	-14.3
W-E St Dev	72.3	69.6	86.0	90.0	154.7	167.4
S-N St Dev	65.4	62.6	88.8	85.3	127.1	132.2
CORR COEF	-.206	-.212	.391	.452	.237	.259
(W-E error to S-N error)						

Table 1. Comparison of bivariate normal parameters with and without warning position error (WPE). The 'WPE' column was based on 24-hour forecasts for years 1970-1978, while those in the 'No WPE' column, not only have been adjusted for WPE, but also include one additional year, 1979. Units are nmi.

Some of the differences in Table 1 are attributable to the withholding of 1979 from the data set, but most are clearly related to the reintroduction of the WPE. In any case the differences do not appear to be of the magnitude that would influence the clustering measurably.

CLASS	ONE			TWO			THREE		
	NA	WP	EP	NA	WP	EP	NA	WP	EP
24 h	81	99	94	99	130	97	160	148	132
48 h	200	204	176	236	251	188	325	286	254
72 h	362	324	275	394	378	297	477	407	393

Table 2. Average forecast errors (n mi) for difficulty classes ONE, TWO and THREE as defined for the northwestern Pacific (WP), northeastern Pacific (EP) and the North Atlantic (NA) ocean basins.

For comparison purposes the estimated average forecast errors for the three Atlantic hurricane forecast populations have been compared with difficulty classes ONE, TWO and THREE in the northwest and northeast Pacific ocean basins (Table 2). In the Pacific, the method of separation was quite different not only from the Atlantic, but for the two Pacific basins. Nonetheless, Class ONE in each case represents the easier forecasts and class THREE the more difficult. Class TWO appears to be less related in the different basins, resembling more class THREE in the western Pacific and Class ONE in the eastern Pacific. In the Atlantic, class TWO appears to retain a separate character.

One can see evidence of a variety of distinctions between conditions in the three ocean basins. For example, positioning, with combinations of satellite, land radar and aircraft is far superior in the Atlantic. This shows up best in the short range (Class ONE) easiest forecast. Forecast errors are in general less in the eastern Pacific for several reasons, but major among these are the rapid demise (hence non verification) of recurving cyclones and the dominance of highly persistent westward tracks. Long range (72-hour) forecasts are much better in the western Pacific

than in the Atlantic while short range forecasts are generally better in the Atlantic. These differences are no doubt related to (a) more abundant reconnaissance in the Atlantic (improves short range forecasts); (b) emphasis on long range forecasts in the military oriented western Pacific forecasts, versus the short range public warning forecast, and (c) a greater frequency of low latitude (and hence easier long range forecast) cyclones in the western Pacific.

Figure 2 shows the three populations for the Atlantic as sets of nested 50% ellipses at 0, 12, 24, 48 and 72 hours. It is apparent that although clustering was performed on 24-hour forecasts, contrast between populations is present at all time intervals.

Several methods were tried in the current work to identify conditions attendant with forecasts in each of the three groups. To set the stage for this investigation one can think of a particular forecast error as a point on figure 1. Points near the origin could likely have come from any of the three populations while points far removed are much more likely to have come from the large error population (population THREE). Thus we can never specify with certainty from which population a particular forecast came even after we can verify its error. It is even more difficult to establish before hand, into which population an error will fall.

After the fact, we can establish the relative probability that an error came from each of the populations. This is based on the probability density (height of the probability surface) at the error point (i.e., on figure 1) under each of the three bivariate normal distributions. The

Figure 2. Nested fifty percent probability ellipses for 0,12, 24,48 and 72 hours. Difficulty classes ONE, TWO and THREE are top to bottom, figures 2a, 2b and 2c, respectively. Units are in n mi.

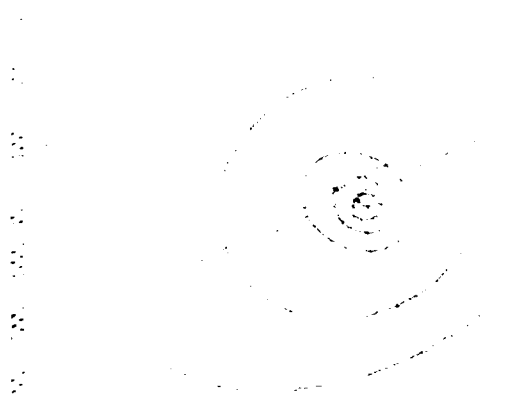


Figure 2a.

0 100 200 300 400 500 600 700

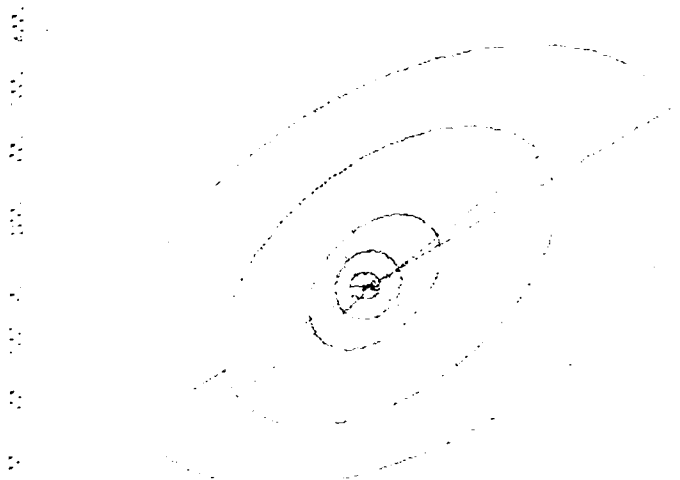


Figure 2b.

0 100 200 300 400 500 600 700

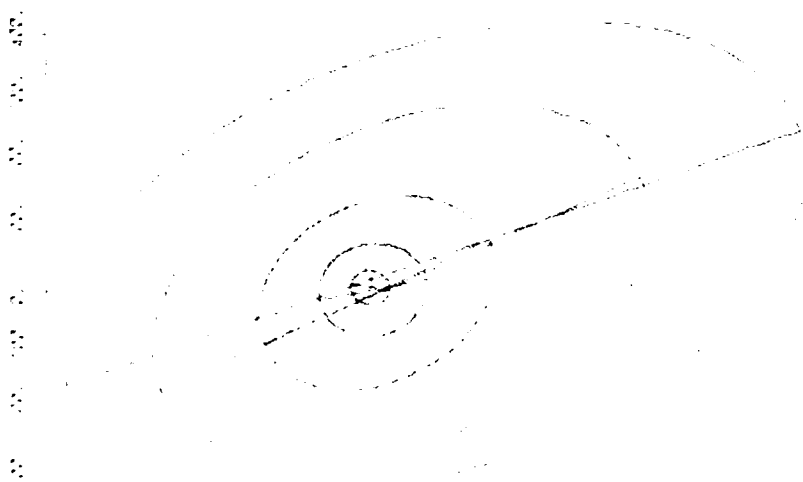


Figure 2c.

0 100 200 300 400 500 600 700

problem is first to forecast these population probabilities, or the position on figure 1. Once they are forecast, one must either select one population or use a combination. For probability purposes it is more reasonable to use a combination for two important reasons.

1. The relative probability of an error coming from any one population is rarely large (i.e., >60%). Thus, there is usually a sizable risk that the wrong population will be used.
2. Any predictive scheme which selects one population will be sensitive to changes in its predictors. There will be times when a small, perhaps meaningless, change in one predictor will alter the population selection and cause a large swing in the resulting strike or wind probabilities. This is undesirable since it undermines user confidence particularly if the probabilities oscillate at critical times.

2.1.1 Predicting the Population Probabilities. The most obvious method of discriminating between populations is on the basis of geography. Population ONE tends to be associated with low latitude tropical cyclones in the easterlies. Population THREE is associated with high latitude and recurving or post-recurvature cyclones. Speed of motion and direction of motion seems also to be important. Slow moving storms and westward moving storms are more often population ONE where fast moving and north or northeast tracks are predominately population THREE. Population TWO doesn't appear to be readily identified with usually recognized difficulty factors and may rather be a hybrid group which are otherwise population ONE or THREE recognized incorrectly

by the forecaster, or they may be unusual forecasts (closer to tallers, etc.).

Figure 3 shows the behavior of probabilities of populations ONE, TWO and THREE averaged over small increments of latitude. Notice that the probabilities are high (0.5) for population ONE at low latitudes and drop off with increasing latitude. The opposite is true for population THREE. Linear correlations are high, average probability of Population ONE, TWO and THREE correlated to latitude gives coefficients of -0.83, 0.03 and 0.77. Certainly the first and last are high enough so that latitude should be an excellent predictor for the average case. In individual forecasts, however, those correlation coefficients drop sharply to -0.29 and 0.27, respectively. Since the present interest is in individual cases the high composite correlation is useless.

Simply using average values on a geographic grid (e.g., 5° lat-lon Marsden squares) provides little variability in the population probabilities. Prior screening on direction/speed increases the variability, but the further stratification reduces the case numbers falling within 5° squares to the extent that considerable smoothing is necessary. Such smoothing has the effect of destroying the contrast created by prior screening.

A set of typical difficulty predictors was created and matched with the population probabilities. The means, standard deviations and the correlation matrix are given in Table 3. As can be seen from Table 3, the probabilities (P_1 , P_2 and P_3) are not well correlated with any of the parameters usually related to forecasting difficulty.

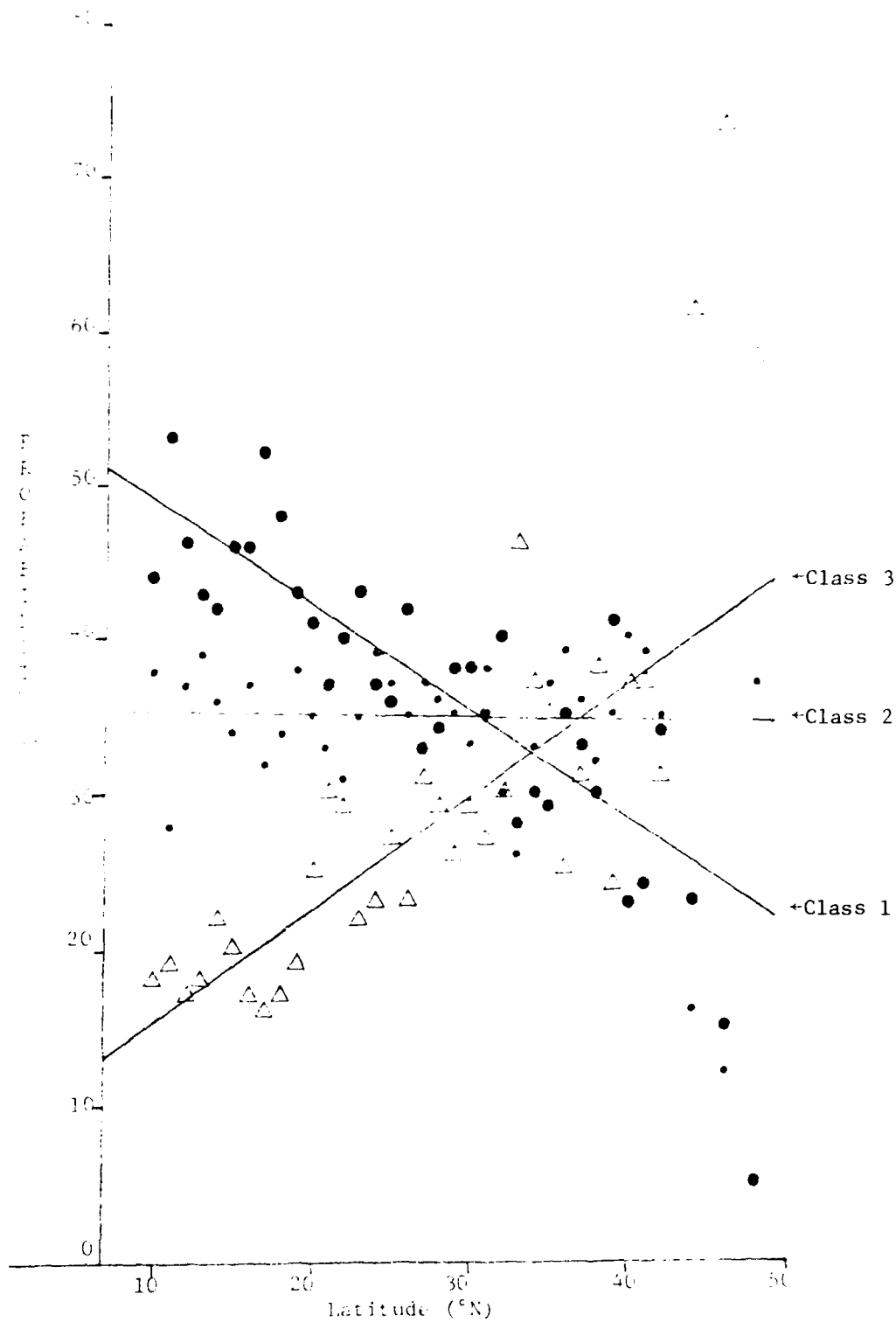


Figure 3. Scatter diagram of probabilities of a forecast being class ONE (●), TWO (•) or THREE (Δ) averaged over 1° latitude bands. Lines are least squares fit to the average probabilities.

However, the larger correlations (≈ 0.14) are significant (assuming about one-fourth of the 822 cases (200) are independent). Stepwise linear regression equations were fit to the data. The equations are also given in Table 3. These equations were tested on 1979 forecasts as independent data, and the correlation between the observed and predicted probabilities was .36 for P_1 and .32 for P_3 . P_2 was negatively correlated with its predicted value so it will be treated as a slack variable ($P_2 = 1 - P_1 - P_3$).

Once the probabilities are predicted, they are adjusted in two ways.

- (1) Each of the probabilities is constrained to be $0 \leq P_i \leq 1$.
- (2) As mentioned above probability P_2 is set equal to $1 - P_1 - P_3$.

2.1.2 Using the Predicted Population Probabilities in the Model. The strike probability code generates three runs: each run using the bivariate parameters from a different population. The final probabilities are a sum weighted by the predicted population probabilities. Symbolically this is

$$P(\epsilon) = \sum_{i=1}^3 P(\epsilon | k=i) P(k=i) ,$$

where $P(\epsilon)$ is the probability of some event ϵ , $P(\epsilon | k=i)$ is the probability of event ϵ given that we have a population i forecast, and $P(k=i)$ is the probability that the current forecast is indeed from population i .

	P_1	P_2	P_3	LAT	Lon	V_m	U	V
Mean	0.375	0.351	0.274	26.9	66.0	1.1	-0.18	0.1
Std. Dev.	0.195	0.129	0.211	8.1	10.2	1.0	0.1	0.1
Units	None	None	None	deg	deg	ft	ft	ft
Corr With								
P_1	1.0							
P_2	-.432	1.0						
P_3	-.800	-.205	1.0					
LAT	-.289	-.011	.274	1.0				
Lon	.189	.059	-.211	-.331	1.0			
V_m	-.009	-.009	.014	.246	-.069	1.0		
U	-.334	-.010	.316	.715	-.261	.149	1.0	
V	-.148	-.089	.192	.266	-.049	.060	.311	1.0

REGRESSION EQUATIONS

$$P_1 = 0.3176 - .0020LAT + .0012LON + .0006V_m - .0049U - .0018V$$

$$P_2 = 0.3283 + .0005LON .0023U + .0005V$$

$$P_3 = 0.3628 + .0004LAT - .0017LON + .0003V_m + .0200U - .0064V$$

(This equation was
not used. See
section 2.1.1)

Table 3. Statistics relating class probabilities P_1 , P_2 and P_3 to several predictors. Regression equations relating the probabilities to the predictors are shown across the bottom. This is based on forecasts from years 1970-78.

3.0 OPERATIONAL PRODUCTS

The strike probability product will be available under operational evaluation during the 1981 hurricane season for the North Atlantic.

Product Tropical cyclone strike probabilities for preselected points. This can be disseminated automatically to a distribution list by Fleet Numerical Oceanography Center (FNOC) via AUTODIN initially and possibly later via the Automated Weather Network (AWN). Included in this product will be a table of forecast confidence estimates for the Naval Eastern Oceanography Center (NEOC) Norfolk, VA.

This product could be generated routinely by FNOC upon receipt of the NEOC Norfolk retransmission of NHC Miami's tropical warning every six hours. The message would give the probabilities of a particular tropical cyclone being within 75 n mi (left) or 50 n mi (right), relative to forecast track, of twelve preselected points of Navy interest and seventeen points of Air Force interest. Although subject to change the points currently listed within the program are:

Navy Points

Roosevelt Roads, PR
Guantanamo, Cuba
Key West, FL
Pensacola, FL
New Orleans, LA
Corpus Christi, TX
Mayport, FL
Charleston, SC
Morehead City, NC
Norfolk, VA
New London, CT
Bermuda, BWI

Air Force Points

Howard AFB, Panama
MacDill AFB, FL
Tyndall AFB, FL
Eglin AFB, FL
Keesler AFB, MS
Ellington AFB, TX
Bergstrom AFB, TX
San Antonio Basin, TX
Homestead AFB, FL
Patrick AFB, FL
Hunter AAF, GA
Myrtle Beach, SC
Andrews AFB, MD
Dover AFB, DE
Atlantic City, NJ
McGuire AFB, NJ
Pease AFB, NH

The strike probabilities, computed upon receipt of each 6-hourly warning and given at 12-hour intervals after warning time, are presented in two forms. The first is the instantaneous probability, valid at a single instant of time only. The second is a time integrated probability -- the probability that a strike will occur at some time between the effective time of the warning and multiples of 12 hours thereafter. Similarly probabilities of 30 and 50 kt winds are expected to be added to this message at a later date.

Additionally the program could be run upon special request although the implementing software is not now in place. The user would make his request to FNOC via AUTODIN. He would include information sufficient to identify the tropical cyclone, the point of concern (latitude/longitude), and the radii about that point describing the area considered to constitute a strike. The output would be in the same form as the above product (i.e., instantaneous and time integrated strike probabilities at 12-hour intervals after warning time).

An example for hurricane David at 0400 GMT 3 and 4 Sep 1979 follows to illustrate the input and output. At 0400 GMT 3 Sep David was about 80 n mi ESE of Miami with 90 kt maximum winds. He was expected to skirt the length of the Florida east coast and thereafter go inland in the Carolinas on a recurving track up the Atlantic seaboard. Since David was still on a northwest track, either a continuation of that track into the Gulf of Mexico or the forecast recurvature track was possible; thus stations along the east coast as well as those in the Gulf of Mexico were under some threat.

Two Atlantic Strike Probability Programs (STRIKPA) runs for David are discussed below.

Run 1 is a standard FNOC originated run at 01/0400 GMT.

Run 2 is in response to a hypothetical user at 03/0400 GMT specifying an area within 50 n mi of Cape Kennedy (28.4N, 80.6W). His request would have gone to FNOC via AUTODIN message in APR format (Table 4 gives a probable APR format when and if individual user runs are provided). Required input would be at least one Area of Concern (lat/long) and radii to the left and right of that point (relative to forecast motion).

Tables 5 and 6 illustrate the output from Runs 1 and 2, respectively. These tables also contain some descriptive information. It should be noted that a users manual will be distributed to operational users of STRIKPA prior to the dissemination of this product.

BT

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TROPICAL CYCLONE STRIKE PROBABILITY REQUEST, ATLANTIC
Q92X0001

/APR,AP(STRIKPA), (other entries on this line as required)

/STM,NM(DAVID),NR(NA04),DH(7909030400)/

/AOC,LA(284N),L)(806W),RL(50),RR(50)/

.

.

. (as many AOC lines as needed)

.

.

.

/AAD,

etc. (as needed)

/PARA,

/ERK/ (required end)

BT

/STM: Storm line

NM: Name of cyclone

NR: Cyclone number, Ocean Basin NA=North Atlantic

DH: Effective Dat/time of warning. DH(7909030400) =
030400Z Sep 1979

(Day 03 hour 0400 GMT)

/AOC: Are of concern line

LA: Latitude of point of concern. LA(284N)=28.4° north

LO: Longitude of point of concern. LO9806W=80.6° west.

RL: Radius of area of concern to left of storm's track

RR: Radius of area of concern to right of storm's track.
Usually RL is greater than RR. Default values of 75/50
n mi will be used if both RL and RR are zero or blank.

Note: One input record will be rewritten for each /AOC (including storm information). Request message in accordance with FLENUMWEACEN, 1977: ASWOCAS Request Procedures Manual, Vol. 2.

Table 4. Sample Automated Product Request (APR) System Message.
This information is tentative since software to accept this request is not currently in place.

Run 1 Output (Product 1)

STRIKE PROBABILITY FORECASTS

DAVID 040400Z

ROOSEROADS THREAT NIL*

GUANTANAMO THREAT NIL

KEY WEST THREAT NIL

PENSACOLA 00ININ*12ININ 24ININ 36ININ 48IN01 60IN01 72IN02

NEWORLEANS 00ININ 12ININ 24ININ 36ININ 48ININ 60ININ 72IN01

CORPUR CHR THREAT NIL

MAYPORT 00ININ 124250 240451 360251 480151 600151 72IN51

CHARLESTON 00ININ 12ININ 242333 360833 480333 600233 720133

MOREHD CTY 00ININ 12ININ 240304 360714 480417 600218 720118

NORFOLK 00ININ 12ININ 24ININ 360306 480411 600313 720214

NEW LONDON 00ININ 12ININ 24ININ 36ININ 48IN01 600104 720207

BERMUDA 00ININ 12ININ 24ININ 36ININ 48ININ 60ININ 72IN01

FOR NEOC NORVA: FORECAST CONFIDENCE TABLE

TIME	PROB	DIST	PROB	DIST	PROB
12HR	50	50	26	75	24
24HR	48	100	25	150	27
48HR	33	200	25	300	42
72HR	28	300	24	450	48

DIST are radii of circles about forecast positions. PROB are probabilities that verifying position will be within inner circle, between circles or outside outer circle respectively. For example, probability that 24-hr forecast error is less than 100 nm is 48%; between 100-150 nm is 25%; and greater than 150 nm is 27%.

PROBABILITIES BASED ON FOLLOWING FORECAST

002810803080 123000805080 243250797085 483500770070 723800760065

FORECASTS: Time 12 hr Latitude 30.0N Longitude 80.5W Max Wind 80 Kts

LAT/LONG of preselected points are stored within program.
Strike is predefined to occur if tropical cyclone passes within 75 nm radius (left) or 50 nm radius (right) of track of tropical cyclone.

*THREAT NIL means all probabilities for this station were <0.5%.
IN means insignificant (<0.5%).

Table 5. Output from Run (1).

Run 2 Output (Product 2)

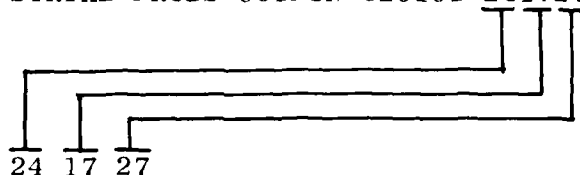
STRIKE PROBABILITIES FOR TROPICAL CYCLONE DAVID

FROM 030400Z BASED ON FOLLOWING FORECAST

002430776090 122610803100 242800810065 483200815035 723600790025

STRIKE IS BEING WITHIN 50NM RIGHT AND 50NM LEFT OF 28.4N 80.6W

STRIKE PROBS** COININ 120101 241727 360428 480128 600128 72IN28



24 Time 24 hours after synoptic time 030000GMT

17 The probability of a "strike" at 040000Z
(030000 + 24 hr) is 17%

27 The probability of a "strike" between 030000Z and
040000Z (24 hour period) is 27%

ABBREVIATIONS:

Number 01-99; strike probability in %

IN = insignificant; $p < 0.5\%$ Prevents representation
of 0% and 100% which
occur only as an
approximation.

The input forecast data is error checked only in that the tropical cyclone forecast motion is computed between forecast points. If vector motion deviates substantially from the climatological mean, the following warning message will appear in all products:

UNUSUAL MOTION -- PLEASE RECHECK WARNING DATA

**Note that although the forecast warning time is 040400Z, the 00ININ reflects an extrapolation of minus four hours to 040000Z, whereby the program is initialized. All subsequent time intervals are from 040000Z initialization. This minus four hour extrapolation is an internal program adjustment. The 00 position in the "PROBABILITIES BASED ON FOLLOWING FORECAST" section of the output message is also an extrapolated position.

Table 6. Output from Run (2).

4.0 TESTING

The 1979 Atlantic tropical cyclone forecasts were withheld from the developmental data as a test set. This set consisted of 245 nowcasts and 214 12-hour forecasts, 195 24-hour forecasts, 112 48-hour forecasts and 99 72-hour forecasts which could be verified.

The testing consisted of running strike probability forecasts off Atlantic hurricane (and lesser tropical cyclone) forecasts for 12 Navy points of current interest and an additional 24 points scattered throughout the open water areas of the North Atlantic and Gulf of Mexico. The Navy points are listed in section 3.0.

Tables 7 and 8 compare the expected to observed number of "strikes". Predictions were grouped into cells of increasing width, $<\frac{1}{2}\%$, $\frac{1}{2}$ to $1\frac{1}{2}\%$, $1\frac{1}{2}$ to $3\frac{1}{2}\%$, etc. and strikes observed based on best track. Time integrated probabilities over t hours were verified only if a continuous record of verifying positions was available for t hours. This prevents an obvious bias by excluding of necessity those that die before they reach a station but including those which strike within the first few hours. This is progressively less important in shorter range forecasts.

It is difficult to assess the significance of such information, but verification is obviously necessary. To illustrate the problem in establishing the significance of differences in expected vs observed, let's assume we want to use a test on whether the two are different. One such test assumes the number of successes (expected) in N Bernoulli trials is given by PxN where P is the probability of a single success. Our P is the forecast strike probability.

A < P < B	24 Hour			48 Hour			72 Hour		
	EXP	OBS	CASES	EXP	OBS	CASES	EXP	OBS	CASES
0 - $\frac{1}{2}\%$	0	0	6731	0	0	3627	0	0	2974
$\frac{1}{2}\%$ - $1\frac{1}{2}\%$	0	0	75	2	2	186	4	3	429
$1\frac{1}{2}\%$ - $3\frac{1}{2}\%$	2	2	56	5	6	147	3	7*	161
$3\frac{1}{2}\%$ - $7\frac{1}{2}\%$	4	1	59	3	5	72	0	0	0
$7\frac{1}{2}\%$ - $15\frac{1}{2}\%$	7	5	60	0	0	0	0	0	0
$15\frac{1}{2}\%$ - $31\frac{1}{2}\%$	13	10	39	0	0	0	0	0	0
$31\frac{1}{2}\%$ - $63\frac{1}{2}\%$	0	0	0	0	0	0	0	0	0
$63\frac{1}{2}\%$ - 100 %	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
	21	18	7020	10	15	4032	7	10	3564

Table 7. Comparison of expected to observed number of strikes based on an independent sample of 1979 Atlantic tropical cyclone forecasts. Strike probabilities were computed on 245 warnings and for 12 stations plus 24 other points in the open Atlantic. These are for instantaneous probabilities and a strike was considered to have occurred if the nowcast probability exceeded 50%.

*Differences are significant ($\alpha=0.05$)

A < P < B	24 Hour			48 Hour			72 Hour		
	EXP	OBS	CASES	EXP	OBS	CASES	EXP	OBS	CASES
0 - $\frac{1}{2}\%$	0	0	6554	0	0	3385	0	0	2542
$\frac{1}{2}\%$ - $1\frac{1}{2}\%$	0	1	53	2	0	170	3	1	226
$1\frac{1}{2}\%$ - $3\frac{1}{2}\%$	0	0	45	3	0	122	5	0*	213
$3\frac{1}{2}\%$ - $7\frac{1}{2}\%$	3	2	59	5	0*	93	12	1*	240
$7\frac{1}{2}\%$ - $15\frac{1}{2}\%$	5	5	50	14	15	124	23	29	210
$15\frac{1}{2}\%$ - $31\frac{1}{2}\%$	14	10	63	18	25	88	19	32*	91
$31\frac{1}{2}\%$ - $63\frac{1}{2}\%$	26	23	60	17	12	37	13	10	31
$63\frac{1}{2}\%$ - 100 %	<u>23</u>	<u>21</u>	<u>28</u>	<u>10</u>	<u>10</u>	<u>13</u>	<u>9</u>	<u>8</u>	<u>11</u>
	71	62	6912	69	62	4032	84	81	3564

Table 8. Same as Table 7 but time integrated probabilities are given.

*Indicates differences are significant ($\alpha=0.05$)

We can use a binomial distribution to see if our observed "strikes" is close enough to the expected. In Table 7, the worst comparison was 3 expected vs 7 observed with 161 cases (72-hour instantaneous). The number three was arrived at by noting the average strike probability in that cell ($1\frac{1}{2}$ to $3\frac{1}{2}\%$) was 2%, and 2% of 161 is rounded to 3. The standard deviation on the 2% is 1.1% using 161 independent cases. Five percent of the time we expect the "observed" to fall more than 1.96 standard deviations away from the mean or outside the interval 0 to 4.2%. Since we observed 4.35% ($7/161$), we might be alarmed, this represents 2.14 standard deviations away from 2.00 which is significant. The problem of interdependence can be seen by noting there are only 195 24-hour forecasts, yet there are (from Table 7) 7020 24-hour strike probability forecasts. These are obviously interrelated. To correct for this we usually assume one-fourth of the cases are independent. When we do that none of the differences in Tables 7 and 8 are significantly different. With or without this assumption, the agreement between observed and expected is excellent.

To provide more insight into the behavior of the STRIKP's as a hurricane threatens, a summary of the STRIKP's for the 72 hours prior to the six 1979 strikes on the Navy test points is provided as Tables 9 and 10. Those probabilities which were counted as having verified as a strike are underlined. Some which verified were not counted because they were not observable during the entire verification period. Notice that some of the small (under 2%) probabilities actually verified. With Frederick, even a 12-hour 1% forecast resulted in a strike on Guantanamo. That was a case of an ill-defined depression whose track was, and still is, in doubt.

HURRICANE BOB .. NEW ORLEANS 11 JULY 1979 1600GMT

BOB	101600Z	NEWORLEANS	00ININ	12ININ	<u>241825</u>	360727	480228
BOB	102200Z	NEWORLEANS	00ININ	120202	<u>242039</u>	360439	480139
BOB	110400Z	NEWORLEANS	00ININ	121921	<u>241647</u>	360347	480147
BOB	111000Z	NEWORLEANS	00ININ	124378	<u>240178</u>		
BOB	111600Z	NEWORLEANS	<u>008484</u>	120192	<u>241N92</u>		

TROPICAL STORM CLAUDETTE .. ROOSEVELT ROADS, P.R. 18 JULY 1979 1000GMT

CLAUDETTE	161600Z	ROOSEROADS	THREAT	NIL			
CLAUDETTE	162200Z	ROOSEROADS	THREAT	NIL			
CLAUDETTE	170400Z	ROOSEROADS	00ININ	12ININ	<u>240406</u>		
CLAUDETTE	171000Z	ROOSEROADS	00ININ	12ININ	<u>241827</u>		
CLAUDETTE	171600Z	ROOSEROADS	00ININ	122931	<u>240457</u>	<u>361N57</u>	<u>481N57</u>
CLAUDETTE	172200Z	ROOSEROADS	00ININ	122859	<u>241N61</u>	<u>361N61</u>	<u>481N61</u>
CLAUDETTE	180400Z	ROOSEROADS	000707	120283	<u>241N83</u>	<u>361N83</u>	<u>481N83</u>
CLAUDETTE	181000Z	ROOSEROADS	<u>006767</u>	121N68	<u>241N68</u>	<u>361N68</u>	<u>481N68</u>

HURRICANE DAVID .. MAYPORT, FLORIDA 4 SEPT 1979 1600GMT

DAVID	011600Z	MAYPORT	00ININ	12ININ	<u>241NIN</u>	<u>361NIN</u>	<u>480204</u>
DAVID	012200Z	MAYPORT	00ININ	12ININ	<u>241NIN</u>	<u>360101</u>	<u>480307</u>
DAVID	020400Z	MAYPORT	00ININ	12ININ	<u>241NIN</u>	<u>360101</u>	<u>480308</u>
DAVID	021000Z	MAYPORT	00ININ	12ININ	<u>241NIN</u>	<u>360204</u>	<u>480410</u>
DAVID	021600Z	MAYPORT	00ININ	12ININ	<u>241NIN</u>	<u>360408</u>	<u>480413</u>
DAVID	022200Z	MAYPORT	00ININ	12ININ	<u>240304</u>	<u>360917</u>	<u>480319</u>
DAVID	030400Z	MAYPORT	00ININ	12ININ	<u>240609</u>	<u>361020</u>	<u>480421</u>
DAVID	031000Z	MAYPORT	00ININ	12ININ	<u>240711</u>	<u>360819</u>	<u>480320</u>
DAVID	031600Z	MAYPORT	00ININ	120303	<u>242235</u>	<u>360535</u>	<u>480235</u>
DAVID	032200Z	MAYPORT	00ININ	122934	<u>242247</u>	<u>360548</u>	<u>480248</u>
DAVID	040400Z	MAYPORT	00ININ	124250	<u>240451</u>	<u>360251</u>	<u>480151</u>
DAVID	041000Z	MAYPORT	000404	123270	<u>240370</u>	<u>360170</u>	<u>480170</u>
DAVID	041600Z	MAYPORT	<u>002727</u>	120227	<u>241N27</u>	<u>361N27</u>	<u>481N27</u>

Table 9. Summary of strike probabilities prior to the closest point of approach (CPA) of Hurricane Bob to New Orleans, Tropical Storm Claudette to Roosevelt Roads, P.R. and Hurricane David to Mayport, Florida. Where forecasts were available strike probability estimates were computed 72 hours prior to CPA. Underlined probabilities verified in a "strike".

HURRICANE FREDERICK .. ROOSEVELT ROADS P.R. 4 SEPT 1979 1500GMT

FREDERICK	011000Z	ROOSEROADS	00ININ	12ININ	24ININ	36ININ	480101	600206	720307
FREDERICK	011600Z	ROOSEROADS	00ININ	12ININ	24ININ	36ININ	480207	600311	720412
FREDERICK	012200Z	ROOSEROADS	00ININ	12ININ	24ININ	36ININ	480408	600512	720513
FREDERICK	020400Z	ROOSEROADS	00ININ	12ININ	24ININ	36ININ	480512	600614	720615
FREDERICK	021000Z	ROOSEROADS	00ININ	12ININ	24ININ	36ININ	480612	600715	720716
FREDERICK	021600Z	ROOSEROADS	00ININ	12ININ	240206	360616	480615	600815	720816
FREDERICK	022200Z	ROOSEROADS	00ININ	12ININ	241018	360621	480621	600921	720921
FREDERICK	030400Z	ROOSEROADS	00ININ	12ININ	241018	360420	480621	600921	720921
FREDERICK	031000Z	ROOSEROADS	00ININ	120101	241726	360527	480627	600927	720927
FREDERICK	031600Z	ROOSEROADS	00ININ	121012	241834	360425	480625	600925	720925
FREDERICK	032200Z	ROOSEROADS	00ININ	123947	241148	360548	480642	600942	720942
FREDERICK	040400Z	ROOSEROADS	00ININ	122083	241N83	36IN83	48IN83	60IN83	72IN83
FREDERICK	041000Z	ROOSEROADS	005555	122080	240280	36IN80	48IN80	60IN80	72IN80
FREDERICK	041600Z	ROOSEROADS	005656	120358	241N58	36IN58	48IN58	60IN58	72IN58

HURRICANE FREDERICK .. GUANTANAMO CUBA 7 SEPTEMBER 1979 1600GMT

FREDERICK	041000Z	GUANTANAMO	00ININ	12ININ	24ININ	360206	480307	600311	720412
FREDERICK	041600Z	GUANTANAMO	00ININ	12ININ	24ININ	360407	480412	600314	720415
FREDERICK	042200Z	GUANTANAMO	00ININ	12ININ	240208	360713	480412	600314	720415
FREDERICK	050400Z	GUANTANAMO	00ININ	12ININ	24ININ	360408	480412	600314	720415
FREDERICK	051000Z	GUANTANAMO	00ININ	12ININ	240206	360511	480514	600315	720415
FREDERICK	051600Z	GUANTANAMO	00ININ	12ININ	240101	360408	480511	600315	720415
FREDERICK	052200Z	GUANTANAMO	00ININ	12ININ	240507	360817	480412	600220	720321
FREDERICK	060400Z	GUANTANAMO	00ININ	12ININ	240811	360919	480520	600221	720321
FREDERICK	061000Z	GUANTANAMO	00ININ	12ININ	240304	360511	480314	600215	720315
FREDERICK	061600Z	GUANTANAMO	00ININ	12ININ	240611	360515	480216	600117	720117
FREDERICK	062200Z	GUANTANAMO	00ININ	120101	240610	360414	480215	600115	720115
FREDERICK	070400Z	GUANTANAMO	00ININ	123946	241646				
FREDERICK	071000Z	GUANTANAMO	005454	120369	240169				

HURRICANE FREDERICK .. PENSACOLA FLORIDA 13 SEPT 1979 0400GMT

FREDERICK	100400Z	PENSACOLA	00ININ	12ININ	24ININ	36ININ	480101	600104	720105
FREDERICK	101000Z	PENSACOLA	00ININ	12ININ	24ININ	36ININ	480103	600207	720208
FREDERICK	101600Z	PENSACOLA	00ININ	12ININ	24ININ	36ININ	480205	600308	720310
FREDERICK	102200Z	PENSACOLA	00ININ	12ININ	24ININ	360101	480206	600308	720311
FREDERICK	110400Z	PENSACOLA	00ININ	12ININ	24ININ	360102	480308	600210	720212
FREDERICK	111000Z	PENSACOLA	00ININ	12ININ	24ININ	360407	480412	600214	720315
FREDERICK	111600Z	PENSACOLA	00ININ	12ININ	24ININ	360508	480413	600215	720316
FREDERICK	112200Z	PENSACOLA	00ININ	12ININ	240102	360612	480415	600216	720317
FREDERICK	120400Z	PENSACOLA	00ININ	12ININ	241622	360925	480326	600126	720128
FREDERICK	121000Z	PENSACOLA	00ININ	121416	241545	360345	480145	600145	720145
FREDERICK	121600Z	PENSACOLA	00ININ	122935	241446	360346	480146	600146	720146
FREDERICK	122200Z	PENSACOLA	00ININ	124958	240758	360158	48IN58	60IN58	72IN58
FREDERICK	130400Z	PENSACOLA	006262	121083	241N83	36IN83	48IN83	60IN83	72IN83

Note: Same as Table 7, but for Hurricane Frederick during his approach to Roosevelt Roads, P.R., Guantanamo, Cuba and Pensacola, Florida.

5.0 SUMMARY

The strike probability concepts have been thoroughly tested in operational use and with independent testing in the western Pacific. The extensions of those concepts to the Atlantic are based on sound statistical principles. The Atlantic model independent test results show excellent agreement between the observed and the expected. Barring a dramatic shift in forecast accuracy, these tests and Pacific operational experience with most of the important model aspects, suggest the model will perform reliably.

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