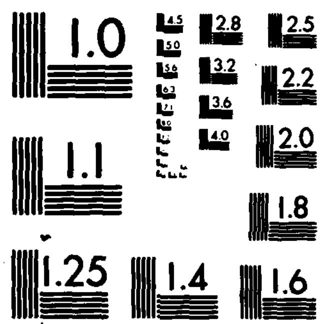
AD-A091 841 SCIENCE APPLICATIONS INC MONTEREY CA F/G 4/2
THE EASTERN PACIFIC TROPICAL CYCLONE STRIKE PROBABILITY PROGRAM--ETC(U)
AUG 80 J D JARRELL N62271-79-M-1679
UNCLASSIFIED NEPRF-CR-80-03 NL

END
DATE
FILMED
81-1
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

NAVENVPREDRSCHFAC
CONTRACTOR REPORT
CR 80-03

NAVENVPREDRSCHFAC CR 80-03

THE EASTERN PACIFIC TROPICAL CYCLONE STRIKE PROBABILITY PROGRAM

Prepared By:

Jerry D. Jarrell
Science Applications, Inc., Monterey, CA 93940

Contract No. N62271-79-M-1679

AUGUST 1980

Prepared For:
NAVAL ENVIRONMENTAL PREDICTION RESEARCH FACILITY
MONTEREY, CALIFORNIA 93940

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NAVENVPREDRSCHFAC Contractor Report CR-80-03 (14)

2. GOVT ACCESSION NO.: AD-A091 841

3. RECIPIENT'S CATALOG NUMBER: (18) NEPRF

4. TITLE (and Subtitle): (6) The Eastern Pacific Tropical Cyclone Strike Probability Program (EPSTRKP).

5. TYPE OF REPORT & PERIOD COVERED: (9) Final rept.,

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): (10) Jerry D. Jarrell

8. CONTRACT OR GRANT NUMBER(s): (15) N62271-79-M-1679

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
Science Applications, Inc.
2999 Monterey-Salinas Highway
Monterey, CA 93940

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:
PE 63207N PN W0513
NEPRF WU 6.3-14 (16)

11. CONTROLLING OFFICE NAME AND ADDRESS:
Naval Air Systems Command
Department of the Navy
Washington, DC 20361

12. REPORT DATE: (11) Aug[redacted]80

13. NUMBER OF PAGES: 30 (12) 31

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
Naval Environmental Prediction Research Facility
Monterey, CA 93940

15. SECURITY CLASS. (of this report): UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release;
distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Original manuscript received in June 1980.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Tropical cyclones
Strike probabilities
Hurricanes

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A system to infer the probability of an eastern Pacific tropical cyclone's striking within an area, given a tropical cyclone forecast, is described. The probabilities are based on an analysis of tropical cyclone forecast errors in the eastern North Pacific.

TABLE OF CONTENTS

Introduction

The Eastern Pacific Hurricane Strike Probability Program (EPSTRKP) is nearly identical in concept to the comparable Western Pacific Strike Probability Program (STRIKP) (Jarrell, 1978)[1]. There are, however, some differences in detail. An earlier study on eastern Pacific tropical cyclones was conducted by W.J. Thompson and R.L. Elsberry (1979)[2]. Thompson and Elsberry subsequently expanded the study to cover the central Pacific (140°W to 180°) and included augmented tracks of those cyclones which recurved over North America. This latter step was considered to be necessary because the earlier geographical distribution of errors appeared to be unrealistically low along the coast. This was attributed to the absence of both forecast positions (since overland dissipation was forecast) and verification positions (actual dissipation) overland, thus only correctly forecast overwater tracks were verifiable. The augmentation of recurvature tracks provided an increase in verifying positions, but made little or no change in the geographical error distribution.

Original Study

Thompson and Elsberry's original study was based on the official forecasts issued by the Weather Service Forecast Office, San Francisco for the years 1971 to 1977. It included only those forecasts in the San Francisco area of responsibility, which represents over 80% of the eastern

---

[1] Jarrell, Jerry D., Tropical Cyclone Strike Probability Forecasting. NAVENVPREDRSCHFAC Contractor Report CR78-01. December 1978.

[2] Thompson, W.J., and R.L. Elsberry, A statistical analysis of eastern Pacific tropical cyclone forecast errors. Twelfth Technical Con. on Hurricanes and Tropical Meteorology, New Orleans, April 1979.

Pacific tropical cyclones. After the forecasts for the year 1978 were added there were 2036 verifiable 24-hour forecasts.

Thompson and Elsberry also performed discriminant analyses on forecast error. Some of the results of those analyses will be presented in Appendix A.

Augmented Study

Thompson and Elsberry's 1971-78 data base was augmented by extending the postanalysis tracks of hurricanes over North America as far as possible. This was done with the aid of twice per day surface weather charts and satellite mosaics. The former were of limited use because the rough terrain of western Mexico makes interpretation of surface reports in the vicinity of a hurricane exceedingly difficult. The satellite mosaics were the most usable information source except, of course, there is little precision in locating a cyclone center when it has degenerated into a cloud mass over rough terrain. Nevertheless the tracks of those that were extended were reasonably certain.

The original data base was also augmented by adding those forecasts for the central Pacific issued by the Central Pacific Hurricane Center located at the Weather Service Forecast Office, Honolulu.

Statistics for the study before and after track extension and central Pacific augmentation are shown in Table 1.

The extension of overland tracks increased the number of verifiable forecasts from 1% at 24 hours to 6% by

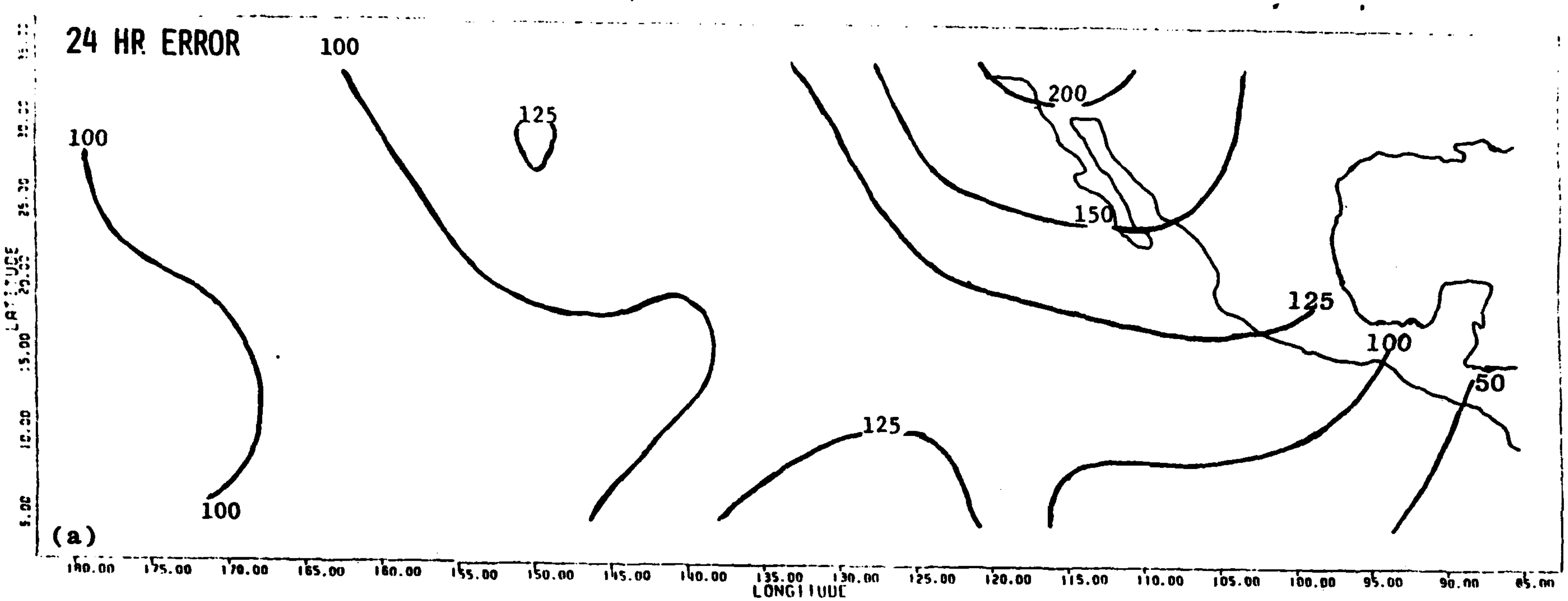
72 hours. This had the net effect of increasing average forecast errors as was expected.

Figure 1 shows average official 24-hour movement forecast errors on a geographical plot. Figure 1b shows the errors for the earlier study forecasts while figure 1a shows the same information after augmentation by extension of over-land verification tracks and the inclusion of central Pacific forecasts. Except for the obvious westward continuation of contours, the two figures are virtually identical.

	24 Hour			48 Hour			72 Hour		
	A	B	C	A	B	C	A	B	C
S-N Error									
Mean	-7	-8	-5	-12	-16	-10	-15	-25	-16
Std. Dev.	87	87	86	154	155	154	213	219	217
W-E Error									
Mean	-6	-7	-8	- 2	- 9	-15	- 6	-30	-33
Std.Dev.	104	104	102	197	200	194	295	310	303
Vector Error									
Mean	115	115	112	215	218	212	312	326	318
Std. Dev.	74	74	73	128	129	130	188	198	198
Corr Coef									
S-N vs W-E	.05	.05	.09	.08	.08	.16	.18	.18	.24
Cases	2036	2058	2327	1276	1309	1541	924	976	1163

Table 1. Evolution of error statistics from 1971-78. Means and standard deviations are in n mi.

A Eastern Pacific
B Eastern Pacific with overland track extensions
C Eastern and central Pacific with overland track extensions.



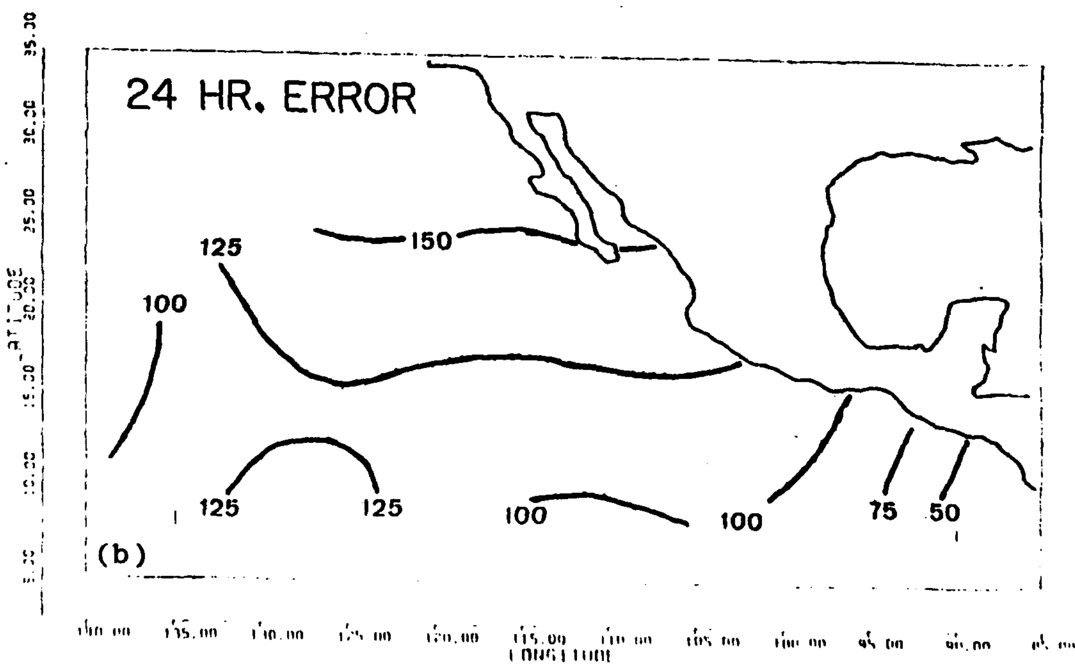


Figure 1. (a) Map of Central and Eastern Pacific average 24 hour forecast errors after extension of verifying tracks over North America.

(b) Same as (a) but before the addition of the Central Pacific cases and before the extension of North American tracks.

The addition of central Pacific forecasts increased the number of verifiable forecasts by 13, 18 and 19% at 24, 48 and 72 hours respectively. The average vector error decreased with the addition of these forecasts, although the bias (component mean errors) remained about the same in magnitude but its orientation became more westerly.

Operational Products

Two distinct strike probability products will be available under operational evaluation during the 1980 hurricane season for the eastern North Pacific.

Product 1. Tropical cyclone strike probabilities for preselected points. This can be disseminated automatically to a distribution list by Fleet Numerical Oceanographic Center (FNOC) via AUTODIN initially and possibly later via the Automated Weather Network (AWN). Included in this product will be a forecast class specification for confidence estimates for the Naval Western Oceanography Center (NWOC) Pearl Harbor (refer to figure 3 of Appendix A).

Product 2. Individual user requests for tropical cyclone strike probabilities via the Automated Product Request (APR) system (AUTODIN only).

Product 1 could be generated routinely by FNOC upon receipt of the NWOC Pearl Harbor tropical cyclone warning every six hours. Product 1 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 nine preselected points of interest. Although subject to change the points currently listed within the program are: Acapulco, Mazatlan, Puerto Vallarta, La Paz, San Diego, Hilo, Honolulu, Johnston Island and Midway Island. 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.

Product 2 would be run only upon request. 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 in product 1 (i.e., instantaneous and time integrated strike probabilities at 12-hour intervals after warning time).

An example follows to show the user how the output will appear. The example is Tropical Storm ANDRES at 1800 GMT 2 June 1979. At this time ANDRES was 175 n mi south of Acapulco, Mexico with 35 kt winds. It was expected to move northwest at 8 kts for the first 12 hours becoming westerly and finally westsouthwest during June 5th (GMT). Its intensity was expected to increase over the 3-day period to 55 kts.

Two Eastern Pacific Strike Probability Program (EPSTRKP) runs for ANDRES are discussed below.

Run 1 is a FNOC originated run (Product 1) at 02/1800 GMT.

Run 2 is in response to a hypothetical user also at 02/1800 GMT specifying an area within 100 n mi of a point (15°N, 102°W). His request would have gone to FNOC via AUTODIN message as an APR formatted message (see Table 2). Required input is at least one Area of Concern (lat/long) and radii to the left and right of that point (relative to forecast motion).

Tables 3 and 4 illustrate the output from Runs 1 and 2, respectively. These tables also contain some descriptive information.

```
BT
UNCLAS//NO3160//
TROPICAL CYCLONE STRIKE PROBABILITY REQUEST, EASTERN PACIFIC
Q92X0001
/APR,AP(EPSTRKP),(other entries on this line as required)
/STM,NM(ANDRES),NR(EP02), DH(7906021800)/
/AOC,LA(150N),LO(1020W),RL(100),RR(100)/
.
.
.  (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 EP = Eastern Pacific

DH: Effective Date/time of warning. (Day 02 hour 1800 GMT) DH(7906021800) = 021800Z June 1979

/AOC: Area of concern line

LA: Latitude of point of concern. LA(150N)=15.0° north.

LO: Longitude of point of concern. LO(1020W)=102.0° west.

RL: Radius of area of concern to left of storms track.

RR: Radius of area of concern to right of storms track.

Usually RL is greater than RR. Default values of 75/50 nm will be used if both RL and RR are zero or blank.

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

Table 2. Sample Automated Product Request (APR) System Message.

Run 1 Output (Product 1)

```
STRIKE PROBABILITY FORECASTS
ANDRES  021800Z
ACAPULCO     00ININ*120815 240418 360218 480119 600119 720119
MAZATLAN     00ININ 12ININ 24ININ 36ININ 48ININ 60IN01 72IN02
P VALLRTA    00ININ 12ININ 24ININ 360101 480104 600106 720107
LA PAZ       00ININ 12ININ 24ININ 36ININ 48ININ 60ININ 72IN01
SAN DIEGO    THREAT NIL*
HILO         THREAT NIL
HONOLULU     THREAT NIL
JOHNSTN I    THREAT NIL
MIDWAY I     THREAT NIL
FOR NWOC PEARL..CLASS = THREE
PROBABILITIES BASED ON FOLLOWING FORECAST
001400989035 121481004040 241501020045 481421049050 721321070055
```

FORECASTS: Time 12 hr Latitude 14.8N Longitude 100.4W Max Wind 40 kt

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

---

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

Table 3. Output from Run (1).

Run 2 Output (Product 2)

STRIKE PROBABILITIES FOR TROPICAL CYCLONE ANDRES

FROM 021800Z BASED ON FOLLOWING FORECAST

001400989035 121481004040 241501020045 481421049050 721321070055

STRIKE IS BEING WITHIN 100NM RIGHT AND 100NM LEFT OF 15.0N 102.0W

STRIKE PROBS 000202 123840 243143 361443 480743 600443 720343

TIME

PROB(%) that ANDRES will be in area at 051800 (Warning time + 72 hours) was 3%

PROB that ANDRES will be in area some time between 021800Z and 051800Z (72 hour period) was 43%.

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 ***

TABLE 4. OUTPUT FROM RUN (2).

APPENDIX A

Discriminant Analysis

The discriminant analyses routine of the UCLA BIOMED (Dixon, 1975)[1] series was run on the data to develop functions to discriminate on forecast error. Predictands were forecast error group numbers 1, 2 and 3. The groups were determined by using in turn the 24-, 48- and 72-hour forecast errors to split the forecasts into three equal groups according to error magnitude; group 1 had the smallest errors and group 3 the largest. Table A-1 shows average forecast errors for the three error classes, where the classes were imperfectly discriminated by applying functions developed on each of the predictands. If discrimination were perfect, the groups and classes would be identical.

Applied to:	24 hr errors			48 hr errors			72 hr errors		
Class:	1	2	3	1	2	3	1	2	3
Used for Split:									
24-hour errors	88	107	138	185	214	252	280	335	371
48-hour errors	95	98	132	174	194	265	266	301	402
72-hour errors	95	94	128	176	187	255	265	288	393

Table A-1. Average movement forecast errors for 24, 48 and 72 hours classed by discriminant functions. The functions were derived on forecasts of one time length, but applied to the other lengths.

Based on the difference in group means, the discrimination provided by the functions developed on 48 hour errors (underlined) is superior to the other two. There is generally poor discrimination between classes 1 and 2 as evidenced by the closeness of their means. Class three, the difficult forecast, appears to be well separated from the other two classes.

Eight predictors were selected from 23 candidates. Table A-2 defines the eight predictors, gives their means, standard

[1] Dixon, W. J., BMDP biomedical computer programs. University of California Press, Berkeley, 1975.

	Predictor	means Class 1	2	3	std dev 1	2	3		Function 1 Coef	Function 2 Coef
1	DIRECTION	280.0	277.0	282.0	47.6	55.4	57.9		-.005	.007
2	LATITUDE	15.3	15.2	15.8	2.72	2.63	2.77		-.104	.105
3	MAX WIND	65.9	67.4	61.9	23.8	25.2	21.4		.015	-.021
4	ADJ DIR	179.0	180.0	188.0	22.4	27.1	31.6		-.015	.012
5	FIX ACCY	25.1	26.1	28.3	8.01	8.73	9.91		-.058	-.008
6	$(JD-\overline{JD})^2/100$	11.0	13.5	14.9	13.7	16.3	17.4		-.020	-.021
7	ADJ LONG	14.4	11.6	10.6	11.0	9.3	8.3		.043	.070
8	N. COMP	1.95	2.07	2.46	1.47	1.49	1.73		-.314	.092
								Const	6.719	-4.950

Table A-2. Discriminant function predictors. Class means and standard deviation of each are given. Also shown are the coefficients for each predictor which define the two functions.

Predictor definitions:
1 Direction of cyclone 12 hour predicted motion in degrees clockwise from north
2 Latitude in degrees north of the equator
3 Maximum wind reported in the forecast in knots (nowcast wind)
4 Direction-110 or if Direction is <110, direction + 250. Places 0-360 discontinuity at 110°T
5 An average initial warning position error based on fix basis in n mi
6 Square of deviation of Julian Date from mean (227), scaled x 0.01
7 Absolute deviation of longitude from mean (119°W)
8 Absolute deviation of northward component of motion (see 1) from mean (3 kts)

deviations and the coefficients that define the discriminating functions. A close examination of Table A-2 suggests less than optimum conditions for discriminant analysis. Some of the predictors are clearly not normally distributed, (i.e., direction is strongly bimodal), some are closely related (direction and adjusted direction). These are not serious since the worst offender, direction, is one of the least significant predictors (see diagram at the origin of figure A-1 where length of the vector relates to predictor contribution to error discrimination). Other aspects of the discriminant analysis that might appear questionable are the small differences in predictor means. Sample size was 2327 cases so each class has on the order of seven hundred cases. Differences in means of 1.96St.Dev./$\sqrt{N}$ are significant at the 5% level, which means differences greater than 0.07S are significant. For example, the standard deviation for variable #8 is about 1.5 kts, therefore differences in the mean of .11 kts would be significant. The actual differences are .12 kts and .51 kts between the class 1 mean and the other two and .39 kts between classes 2 and 3, all are significant. Of course not all the differences in the means are significant at the 5% level, but most are.

One comparable way to look at the differences in standard deviations is to perform the same test on the means as above, but use each of the class standard deviations. Intuitively, if there is no difference in the outcome, the difference in the standard deviations is not important. There are very few comparisons where the outcome depends on which of the three standard deviations is used.

Figure A-1 shows an x-y space with function 1 on the x-axis and function 2 the y-axis. The values of these functions

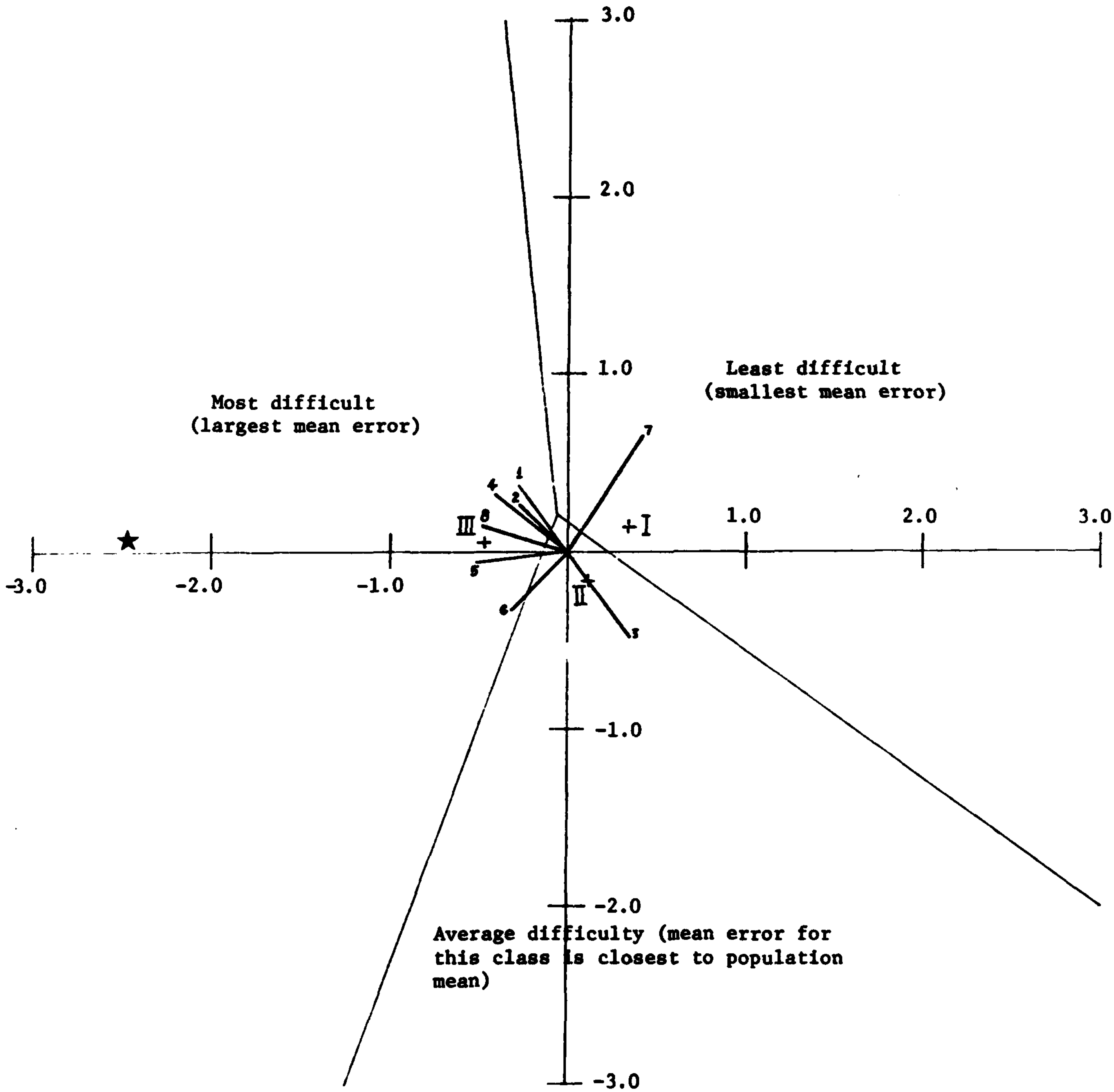


Figure A-1. Function 1 vs Function 2 in x-y space. +'s show location of intersection of functions evaluated at the three class means. The space is partitioned according to class. The diagram at the origin depicts the effect of an increase of one standard deviation in each of the eight predictors. Star refers to Tropical Storm ANDRES on 2 June 1979 at 1800 GMT. (See sample output, Table 3 of text.)

have been evaluated at the group mean for each predictor (see Table A-2). These mean points are plotted, and the space is divided into three areas whose member points would be nearest to the included mean point. Since there is little difference in class 1 and 2, the far left of the diagram is the difficult area, with the right and center the average forecasts. The origin represents the two functions evaluated at the population mean, versus class mean, of each predictor.

The diagram at the origin represents the effect of one predictor alone being increased by one standard deviation. This provides some insight into the causes of forecast difficulty in EASTPAC. See for example the effect of a deviation of predictor 5, Fix Accuracy. This is actually the mean warning position error for all warnings based on combinations of methods used to locate the center (aircraft, satellite, radar, etc.). While the mean error is around 25 n mi, the worst method, extrapolation alone, has a 50 n mi average error, which is about 3 standard deviations away from the mean. Notice in figure A-1, three lengths of the small vector labeled 5 moves a forecast from the average into the difficult (class three area) forecast region by a large margin.

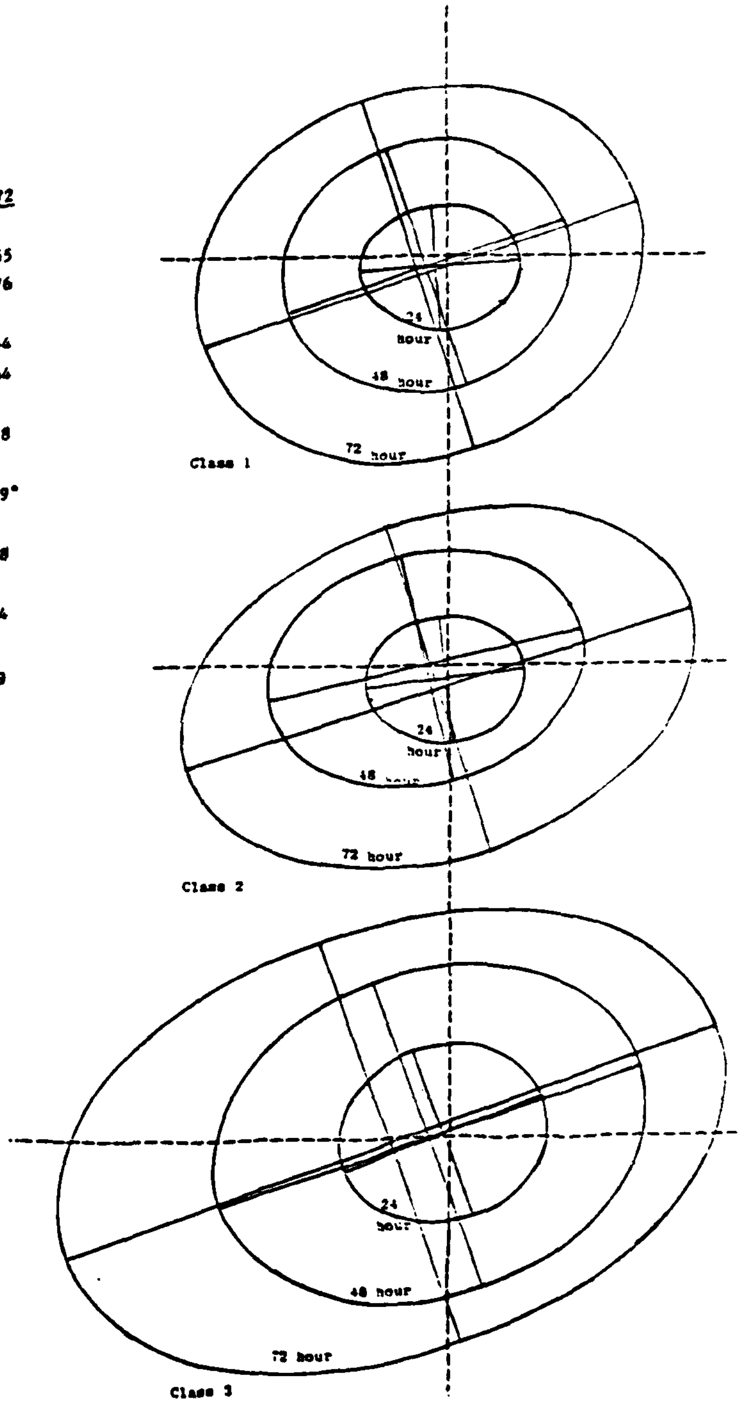
The star in figure A-1 represents an actual computation of Function 1 (x=-2.47) and Function 2 (y=0.60) for tropical storm ANDRES on 2 June 1979. (ANDRES was discussed as the output example in the operational products section of this report). We expect this is a difficult forecast and will likely have a large error. The discriminant analysis predictors and basic variable are given below as are the terms of Function 1 (x) and Function 2 (y).

	Basic Variable		Predictor	Function 1	Function 2
1	Direction	NW=315°	315°	-1.58	2.21
2	Latitude	14°N	14°	-1.46	1.47
3	Max wind	35 kt	35 kt	0.53	-0.74
4	Adj dir	315-110	205°	-3.08	2.46
5	Fix acy	Sat/Extrap	43.5 n mi	-2.52	-0.35
6	Jul date	153	54.76	-1.10	-1.15
7	Adj Long	98.9°W	20.10°	0.86	1.41
8	North mvmt	5.66 kts	2.66 kt	-0.84	0.24
			Constant	6.72	-4.95
				-2.47	0.60

Generally the terms which are contributing to the forecast difficulty are those where Function 1 is negative (direction, both terms, and fix accuracy) and to a lesser extent those negative terms in Function 2 which are not of consequence here.

Figure A-2 shows plots of 24-, 48- and 72-hour unit probability ellipses. A point on a unit ellipse is one standard deviation away (±) from the mean in one coordinate when the other is at the mean. A unit probability ellipse is equivalent to a 39% probability ellipse.

	Class 1			Class 2			Class 3		
Forecast (hours)	24	48	72	24	48	72	24	48	72
W-E error									
mean	-12	-22	-30	-4	2	-9	-8	-24	-65
std dev	88	157	247	92	177	284	116	237	376
S-N error									
mean	-13	-13	-16	-16	-24	-28	6	7	-4
std dev	70	132	191	71	134	198	102	186	264
W-E and S-N									
Correlation	.03	.12	.18	.06	.14	.26	.13	.20	.28
Orientation of									
Major Axis	4°	17°	17°	6°	13°	17°	21°	19°	19°
Length of									
Major Axis	38	159	253	92	179	292	119	243	388
Lengh of									
Minor Axis	70	130	183	71	131	187	99	177	244
Area									
(10^4 nmi^2)	1.9	6.5	14.6	2.0	7.4	17.1	3.7	13.5	29.9



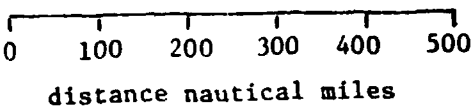


Figure A-2. Unit probability ellipses of forecasting errors from three forecast difficulty classes at 24, 48 and 72 hours. The class parameters are given in the inset table. The origin is the forecast position.

The three nested sets represent the three classes of errors. The nested ellipses represent in increasing size the 24-, 48- and 72-hour forecast. The class 2 ellipses are larger than those of class 1 but the difference is small. In general the class 3 ellipses are similar in shape and orientation to those of classes 1 and 2 but corresponding ellipses are roughly twice as large (in area). The inset table summarizes the ellipse parameters.

The discrimination can be contrasted to that reported by Nicklin (1977)[2] for the western Pacific. In that case the 24-hour errors were far better discriminated, but the 72-hour errors were not discriminated as well. It can be seen from Table A-1 that if the 24-hour error had been used as the basis for discrimination (as it was in the western Pacific) the effect would have been to make the results more similar. The 48-hour discrimination is about the same in both ocean basins. One difference is that in the western Pacific the less difficult third of the forecasts were well separated from the remainder whereas in the eastern Pacific the most difficult third of the forecasts are more easily isolated. Overall, the discrimination appears slightly better in the eastern Pacific, perhaps because of the inclusion of information relative to initial position accuracy (see variable 5, Table A-2).

Forecast confidence estimates can be inferred for each forecast class. These can either be expressed as a percentage of occasions when the actual forecast error will

---

[2] Nicklin, Donald S., A Statistical Analysis of Western Pacific Tropical Cyclone Forecast Errors, M.S. Thesis, U.S. Naval Postgraduate School, Monterey, CA, June 1977.

lie between zero and some set distance (i.e., the probability the error is less than 100 n mi) or as a distance which will exceed the actual error with a set probability (the radius of a 75% probability circle). Figure A-3 presents this probability information for 24-, 48- and 72-hour forecasts (curves left to right) and for classes 1, 2 and 3 (top to bottom). For example 200 n mi represents the radius of 95%, 57% and 30% probability circles for class 1 24-, 48- and 72-hour forecasts respectively. Similarly the 80% confidence limit on class 2 forecast errors is 153, 296 and 465 n mi at 24, 48 and 72 hours respectively.

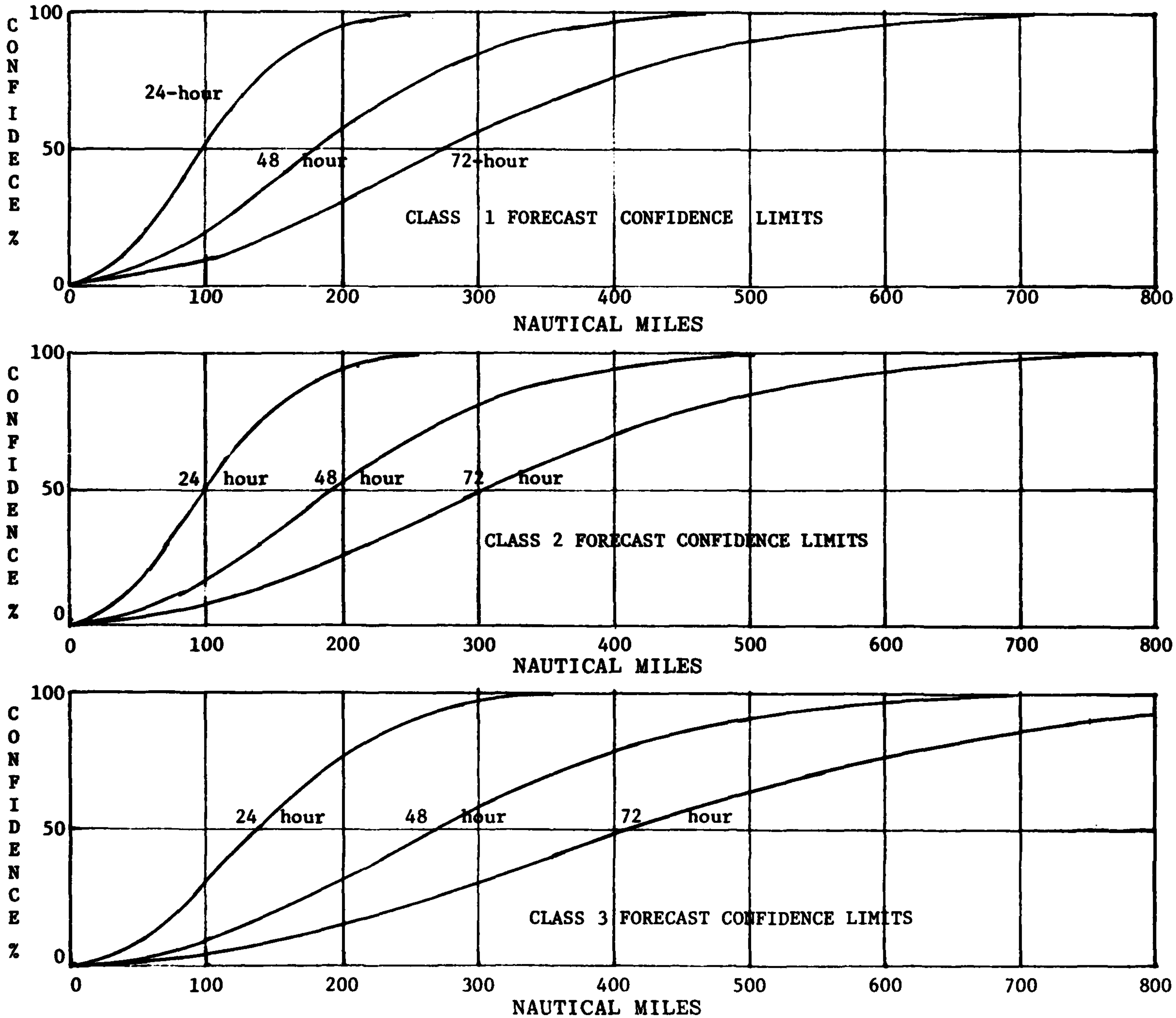


Figure A-3. Confidence limits on eastern Pacific hurricane forecast accuracy by class top to bottom.

Distribution List

COMMANDER IN CHIEF
U.S. PACIFIC FLEET
PEARL HARBOR, HI 96860

COMMANDER
THIRD FLEET
PEARL HARBOR, HI 96860

COMMANDER
SEVENTH FLEET (N30W)
ATTN: FLEET METEOROLOGIST
FPO SAN FRANCISCO 96601

COMMANDER
U.S. NAVAL FORCES, PHILIPPINES
BOX 30/N3
FPO SAN FRANCISCO 96651

COMMANDER NAVAL AIR FORCE
U.S. PACIFIC FLEET
NAVAL AIR STATION, NORTH ISLAND
SAN DIEGO, CA 92135

COMMANDER NAVAL SURFACE FORCE
U.S. PACIFIC FLEET
CODE N331A
NAVAL AMPHIBIOUS BASE, CORONADO
SAN DIEGO, CA 92155

COMMANDER
AMPHIBIOUS GROUP 1
ATTN: METEOROLOGICAL OFFICER
FPO SAN FRANCISCO 96601

OFFICER IN CHARGE
OPERATIONAL TEST & EVALUATION
FORCE, SUNNYVALE
NAVAL AIR STATION
MOFFETT FIELD, CA 94035

COMMANDER NAVAL SURFACE GROUP MIDPAC
PEARL HARBOR, HI 96860

COMMANDER NAVAL SURFACE GROUP
WESTERN PACIFIC
FPO SAN FRANCISCO 96601

COMMANDING OFFICER
USS CONSTELLATION (CV-64)
ATTN: METEOROLOGICAL OFFICER
FPO SAN FRANCISCO 96635

COMMANDING OFFICER
USS CORAL SEA (CV-43)
ATTN: METEOROLOGICAL OFFICER
FPO SAN FRANCISCO 96632

COMMANDING OFFICER
USS ENTERPRISE (CVN-65)
ATTN: METEOROLOGICAL OFFICER
FPO SAN FRANCISCO 96636

COMMANDING OFFICER
USS KITTY HAWK (CV-63)
ATTN: METEOROLOGICAL OFFICER
FPO SAN FRANCISCO 96634

COMMANDING OFFICER
USS MIDWAY (CV-41)
ATTN: METEOROLOGICAL OFFICER
FPO SAN FRANCISCO 96631

COMMANDING OFFICER
USS RANGER (CV-61)
ATTN: METEOROLOGICAL OFFICER
FPO SAN FRANCISCO 96633

COMMANDING OFFICER
USS BLUE RIDGE (LCC-19)
ATTN: METEOROLOGICAL OFFICER
FPO SAN FRANCISCO 96628

COMMANDING OFFICER
USS NEW ORLEANS (LPH-11)
ATTN: METEOROLOGICAL OFFICER
FPO SAN FRANCISCO 96627

COMMANDING OFFICER
USS OKINAWA (LPH-3)
ATTN: METEOROLOGICAL OFFICER
FPO SAN FRANCISCO 96625

COMMANDING OFFICER
USS TRIPOLI (LPH-10)
ATTN: METEOROLGICAL OFFICER
FPO SAN FRANCISCO 96626

COMMANDING OFFICER
USS POINT LOMA (AGDS-2)
ATTN: METEOROLOGICAL OFFICER
FPO SAN FRANCISCO 96677

COMMANDING OFFICER
3RD MARINE AIRCRAFT WING
MARINE CORPS AIR STATION, EL TORO
SANTA ANA, CA 92709

COMMANDER IN CHIEF PACIFIC
BOX 28
CAMP SMITH, HI 96861

COMMANDER IN CHIEF PACIFIC
BOX 13
STAFF CINCPAC J37
CAMP SMITH, HI 96861

SPECIAL ASSISTANT TO THE ASSISTANT
SECRETARY OF THE NAVY (R&D)
ROOM 4E741
THE PENTAGON
WASHINGTON, DC 20350

CHIEF OF NAVAL OPERATIONS
(OP-952)
NAVY DEPARTMENT
WASHINGTON, DC 20350

DEPUTY DIRECTOR FOR OPERATIONS
(ENVIRONMENTAL SERVICES)
OJCS, ROOM 1B679
THE PENTAGON
WASHINGTON, DC 20301

NAVAL DEPUTY TO THE ADMINISTRATOR
NATIONAL OCEANIC & ATMOSPHERIC ADMIN.
ROOM 200, PAGE BLDG. #1
3300 WHITEHAVEN ST. NW
WASHINGTON, DC 20235

OFFICER IN CHARGE
NAVAL OCEANOGRAPHY COMMAND DET.
NAVAL AIR STATION
BARBERS PT, HI 96862

OFFICER IN CHARGE
U.S. NAVAL OCEANOGRAPHY COMMAND DET.
U.S. NAVAL AIR FACILITY, BOX 35
FPO SAN FRANCISCO 96614

OFFICER IN CHARGE
NAVAL OCEANOGRAPHY COMMAND DET.
NAVAL AIR STATION
MOFFETT FIELD, CA 94035

OFFICER IN CHARGE
NAVAL OCEANOGRAPHY COMMAND DET.
NAVAL AIR STATION
SAN DIEGO, CA 92145

COMMANDING OFFICER
OFFICE OF NAVAL RESEARCH
EASTERN/CENTRAL REGIONAL OFFICE
BLDG 114 SECT. D
666 SUMMER ST.
BOSTON, MA 02210

COMMANDING OFFICER
OFFICE OF NAVAL RESEARCH
1030 E. GREEN STREET
PASADENA, CA 91101

COMMANDER
OCEANOGRAPHIC SYSTEMS PACIFIC
BOX 1390
PEARL HARBOR, HI 96860

COMMANDER
NAVAL OCEANOGRAPHY COMMAND
NSTL STATION
BAY ST LOUIS, MS 39529

COMMANDING OFFICER
FLEET NUMERICAL OCEANOGRAPHY CENTER
MONTEREY, CA 93940

COMMANDING OFFICER
NAVAL WESTERN OCEANOGRAPHY CENTER
BOX 113
PEARL HARBOR, HI 96860

COMMANDING OFFICER
NAVAL EASTERN OCEANOGRAPHY CENTER
MCADIE BLDG. (U-117)
NAVAL AIR STATION
NORFOLK, VA 23511

COMMANDING OFFICER
U.S. NAVAL OCEANOGRAPHY COMMAND CENTER
BOX 12
COMNAVMARIANAS
FPO SAN FRANCISCO 96630

COMMANDING OFFICER
NAVAL OCEANOGRAPHY COMMAND FACILITY
NAVAL AIR STATION, NORTH ISLAND
SAN DIEGO, CA 92135

COMMANDER (2)
NAVAL AIR SYSTEMS COMMAND HEADQUARTERS
ATTN: LIBRARY (AIR-954)
WASHINGTON, DC 20361

COMMANDER
NAVAL AIR SYSTEMS COMMAND HDQ (AIR-370)
WASHINGTON, DC 20361

OFFICE OF NAVAL RESEARCH
SCRIPPS INSTITUTION OF OCEANOGRAPHY
LA JOLLA, CA 92037

COMMANDER NAVAL AIR SYSTEMS COMMAND
METEOROLOGICAL SYSTEMS DIV. (AIR-553)
WASHINGTON, DC 20360

COMMANDER
NAVAL SHIP RESEARCH & DEVELOPMENT CENTER
SURFACE SHIP DYNAMICS BRANCH
ATTN: S. BALES
BETHESDA, MD 20084

DEPARTMENT OF METEOROLOGY
NAVAL POSTGRADUATE SCHOOL
MONTEREY, CA 93940

COMMANDING OFFICER
FLEET NUMERICAL OCEANOGRAPHY CENTER
GEOPHYSICS TACTICAL READINESS LAB (GTRL)
MONTEREY, CA 93940

COMMANDER
AWS/DN
SCOTT AFB, IL 62225

USAFETAC/CBT
SCOTT AFB, IL 62225

3350TH TECHNICAL
TRAINING GROUP
TTGU-W/STOP 623
CHANUTE AFB, IL 61868

3 WW/DN
OFFUTT AFB, NE 68113

AFGL/LY
HANSCOM AFB, MA 01731

OFFICER IN CHARGE
SERVICE SCHOOL COMMAND, GREAT LAKES
DETACHMENT CHANUTE/STOP 62
CHANUTE AFB, IL 61868

1ST WEATHER WING (DON)
HICKAM AFB, HI 96853

DET 5 1WW/CC
APO SAN FRANCISCO 96274

DET 8, 30 WS
APO SAN FRANCISCO 96239

DET 17, 30 WS
APO SAN FRANCISCO 96328

DET 18, 30 WS
APO SAN FRANCISCO 96301

AFOSR/NC
BOLLING AFB
WASHINGTON, DC 20312

DIRECTOR (12)
DEFENSE TECHNICAL INFORMATION CENTER
CAMERON STATION
ALEXANDRIA, VA 22314

DIRECTOR OFFICE OF ENV. & LIFE SCIENCES
OFFICE OF THE UNDERSECRETARY OF DEFENSE FOR
RESEARCH AND ENGINEERING (E&LS)
ROOM 3D129
THE PENTAGON
WASHINGTON, DC 20301

DIRECTOR
TECHNICAL INFORMATION
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
1400 WILSON BLVD
ARLINGTON, VA 22209

DEVELOPMENT DIVISION
NATIONAL METEOROLOGICAL CENTER
NATIONAL WEATHER SERVICE, NOAA
WORLD WEATHER BLDG. W32, RM 204
WASHINGTON, DC 20233

FEDERAL COORDINATOR FOR METEOROLOGICAL
SERVICES & SUPPORTING RESEARCH
6010 EXECUTIVE BLVD
ROCKVILLE, MD 20852

DIRECTOR
OFFICE OF PROGRAMS RX3
NOAA RESEARCH LABORATORIES
BOULDER, CO 80302

DIRECTOR
NATIONAL HURRICANE CENTER, NOAA
UNIVERSITY OF MIAMI BRANCH
CORAL GABLES, FL 33124

NATIONAL WEATHER SERVICE, EASTERN REGION
ATTN; WFE3
585 STEWART AVENUE
GARDEN CITY, NY 11530

CHIEF, SCIENTIFIC SERVICES
NATIONAL WEATHER SERVICE, SOUTHERN REGION
NOAA, ROOM 10E09
819 TAYLOR STREET
FT. WORTH, TX 76102

CHIEF, SCIENTIFIC SERVICES
NATIONAL WEATHER SERVICE, WESTERN REGION
NOAA
P.O. BOX 11188, FEDERAL BLDG
SALT LAKE CITY, UT 84111

CHIEF, SCIENTIFIC SERVICES
NATIONAL WEATHER SERVICE, PACIFIC REGION
P.O. BOX 50027
HONOLULU, HI 96850

NOAA RESEARCH FACILITIES CENTER
P.O. BOX 520197
MIAMI, FL 33152

DIRECTOR
ATLANTIC OCEANOGRAPHIC & METEOR. LABS.
15 RICKENBACKER CAUSEWAY
VIRGINIA KEY
MIAMI, FL 33149

DIRECTOR
GEOPHYSICAL FLUID DYNAMICS LAB
NOAA, PRINCETON UNIVERSITY
P.O. BOX 308
PRINCETON, NJ 08540

NATIONAL MARINE FISHERIES SERVICE
OCEAN CLIMATOLOGY PROJECT
SOUTHWEST FISHERIES CENTER
P.O. BOX 271
LA JOLLA, CA 92037

METEOROLOGIST IN CHARGE
WEATHER SERVICE FORECAST OFFICE
NOAA
660 PRICE AVE.
REDWOOD CITY, CA 94063

METEOROLOGIST IN CHARGE
WEATHER SERVICE FORECAST OFFICE
NOAA
HONOLULU INTERNATIONAL AIRPORT
HONOLULU, HI 96819

DIRECTOR
DIVISION OF ATMOSPHERIC SCIENCES
NATIONAL SCIENCE FOUNDATION
ROOM 664
1800 G STREET, NW
WASHINGTON, DC 20550

DEPARTMENT OF ATMOSPHERIC SCIENCES
ATTN: LIBRARIAN
COLORADO STATE UNIVERSITY
FORT COLLINS, CO 80521

CHAIRMAN
DEPARTMENT OF METEOROLOGY
PENNSYLVANIA STATE UNIVERSITY
503 DEIKE BLDG
UNIVERSITY PARK, PA 16802

ATMOSPHERIC SCIENCES DEPT.
UNIVERSITY OF CHICAGO
1100 E. 57TH STREET
CHICAGO, IL 60637

ENVIRONMENTAL SCIENCES DEPT.
FLORIDA STATE UNIVERSITY
TALLAHASSEE, FL 32306

DEPARTMENT OF METEOROLOGY
UNIVERSITY OF HAWAII
2525 CORREA ROAD
HONOLULU, HI 96822

DIRECTOR
REMOTE SENSING LAB
P.O. BOX 248003
UNIVERSITY OF MIAMI
CORAL GABLES, FL 33124

ATMOSPHERIC SCIENCES DEPT.
OREGON STATE UNIVERSITY
CORVALLIS, OR 97331

DEAN OF THE COLLEGE OF SCIENCE
DREXEL INSTITUTE OF TECHNOLOGY
PHILADELPHIA, PA 19104

CHAIRMAN
DEPARTMENT OF METEOROLOGY
UNIVERSITY OF OKLAHOMA
NORMAN, OK 73069

LIBRARY
ATMOS. SCIENCES DEPT.
STATE UNIV. OF NEW YORK AT ALBANY
1400 WASHINGTON AVE.
ALBANY, NY 12222

DIRECTOR
CENTER FOR MARINE STUDIES
SAN DIEGO STATE UNIVERSITY
SAN DIEGO, CA 92182

HEAD, DEPT. OF ENVIRONMENTAL SCIENCES
UNIVERSITY OF VIRGINIA, CLARK HALL
ATTN: R. PIELKE
CHARLOTTESVILLE, VA 22903

METEOROLOGY DEPARTMENT
EASTERN AIR LINES, INC.
MIAMI INTERNATIONAL AIRPORT
MIAMI, FL 33148

RESEARCH LIBRARY
THE CENTER FOR THE ENVIRONMENT &
MAN, INC.
275 WINDSOR STREET
HARTFORD, CT 06120

METEOROLOGY RESEARCH INC.
464 W. WOODBURY RD
ALTADENA, CA 91001

LIBRARY
THE RAND CORPORATION
1700 MAIN STREET
SANTA MONICA, CA 90406

MANAGER
METEOROLOGICAL SERVICES
PAN AMERICAN WORLD AIRWAYS, HANGAR 14
JFK INTERNATIONAL AIRPORT
JAMAICA, NY 11430

METEOROLOGY DEPARTMENT
RESEARCH DIVISION
CONTROL DATA CORPORATION
2800 E. OLD SHAKOPEE RD., BOX 1249
MINNEAPOLIS, MN 55440

LABORATORY OF CLIMATOLOGY
ROUTE 1
CENTERTON
ELMER, NJ 08318
A B-4 C-1 D-2&3 E

DIRECTOR OF METEOROLOGY
TRANS WORLD AIRLINES INC.
HANGAR 12 - ROOM 235
J.F. KENNEDY INTERNATIONAL AIRPORT
JAMAICA, NY 11430

LIBRARY
GULF COAST RESEARCH LAB
OCEAN SPRINGS, MS 39564

SEA USE COUNCIL
1101 SEATTLE TOWER
SEATTLE, WA 98101

THE EXECUTIVE DIRECTOR
AMERICAN METEOROLOGICAL SOCIETY
45 BEACON STREET
BOSTON, MA 02108

AMERICAN MET. SOCIETY
METEOROLOGICAL & GEOASTROPHYSICAL ABSTRACTS
P.O. BOX 1736
WASHINGTON, DC 20013

DIRECTOR, JTWC
BOX 17
FPO SAN FRANCISCO 96630

DIRECTOR OF METEOROLOGY & OCEANOGRAPHY
NATIONAL DEFENSE HDQ
OTTAWA, ONTARIO
K1A OK2
CANADA

METOC CENTRE
MARITIME FORCES PACIFIC HDQ
FORCES MAIL OFFICE
VICTORIA, BRITISH COLUMBIA VOS-1BO
CANADA

DEPARTMENT OF METEOROLOGY
UNIVERSITY OF READING
2 EARLYGATE, WHITEKNIGHTS
READING RG6 2AU
ENGLAND

EUROPEAN CENTRE FOR MEDIUM RANGE
WEATHER FORECASTS
SHINFIELD PARK, READING
BERKSHIRE RG29AX, ENGLAND

DIRECTION DE LA METEOROLOGIE MN/RE
ATTN: J. DETTWILLER
77 RUE DE SEVRES
92106 BOULOGNE-BILLANCOURT CEDEX
FRANCE

DEUTSCHER HYDROGRAPHISCHES INSTITUT
ATTN: DIRECTOR
TAUSCHSTELLE
POSTFACH 220
D2000 HAMBURG 4
FEDERAL REPUBLIC OF GERMANY

DIRECTOR (2)
ROYAL OBSERVATORY
NATHAN ROAD. KOWLOON
HONG KONG, B.C.C.

NATIONAL INSTITUTE OF OCEANOGRAPHY
REGIONAL CENTRE
P.B. 1913
COCHIN-682018
INDIA

DEPARTMENT OF METEOROLOGY
ANDHRA UNIVERSITY
WALTAIR, INDIA 530-003

LIBRARY
IRISH METEOROLOGICAL SERVICE
GLASNEVIN HILL
DUBLIN 9, IRELAND

OCEAN RESEARCH INSTITUTE LIBRARY
UNIVERSITY OF TOKYO
15-1, 1-CHOME
MINAMIDAI, NAKANO-KU
TOKYO, JAPAN

MARITIME METEOROLOGY DIVISION
JAPAN METEOROLOGICAL AGENCY
OTE-MACHI 1-3-4 CHIYODA-KU
TOKYO, JAPAN

METEOROLOGICAL INSTITUTE
FACULTY OF SCIENCE
KYOTO UNIVERSITY
ATTN: DR. R. YAMAMOTO
SAKYO, KYOTO 606
JAPAN

DIRECTOR GENERAL
MALAYSIAN METEOROLOGICAL SERVICE
JALAN SULTAN
PETALING JAYA
SELANGOR, WEST MALAYSIA

DIRECTOR
UNIVERSIDAD AUTONOMA DE BAJA CALIFORNIA
INSTITUTO DE INVESTIGACIONES OCEANOGICAS
APDO POSTAL 453
ENSENADA, B.C., MEXICO

DIRECCION GENERAL DE OCEANOGRAFIA
SENALAMIENTO MARITIMO
MEDELLIN NO. 10
MEXICO, 7, D.F.

INSTITUTO DE GEOFISICA
U.N.A.M. BIBLIOTECA
TORRE DE CIENCIAS, 3ER PISO
CIUDAD UNIVERSITARIA
MEXICO 20, D.F.

BUREAU HYDROGRAFIE DER KONINKLIJKE MARINE
AFD MILOC/METEO
BADHUISWEG 171
DEN HAAG, NETHERLANDS

DEPARTMENT OF METEOROLOGY
COLLEGE OF ARTS & SCIENCES
UNIVERSITY OF THE PHILIPPINES
DILMAN, QUEZON CITY 3004
PHILIPPINES

THE LIBRARIAN
PHILIPPINE ATMOSPHERIC GEOPHYSICAL &
ASTRONOMICAL SERVICES ADMIN (PAGASA)
1424 QUEZON AVE.
QUEZON CITY, PHILIPPINES

DIRECTOR
TYPHOON MODERATION RSCH & DEVELOPMENT
OFFICE PAGASA
MINISTRY OF NATIONAL DEFENSE
1424 QUEZON AVE.
QUEZON CITY, PHILIPPINES

COORDINATOR, NATIONAL ATMOSPHERIC
RESEARCH PROGRAM
INSTITUTE OF PHYSICS
ACADEMIA SINICA
TAIPEI, TAIWAN

CENTRAL WX BUREAU
64, KUNG YUAN RD
TAIPEI, TAIWAN 100

METEOROLOGICAL DEPARTMENT
BOX 200 LUSAKA
ZAMBIA