CHAPTER V - SUMMARY OF FORECAST VERIFICATION

1. ANNUAL FORECAST VERIFICATION

a. Western North Pacific Ocean

The position given for warning times and those at the 24-, 48- and 72-hour forecast times were verified against the final best track positions at the same valid times. The (scalar) forecast, cross track and along track errors (illustrated in Figure 5-1) were then calculated for each tropical cyclone and are presented in Tables 5-1A, 5-1B, 5-1C and 5-1D. Figure 5-2 provides the frequency distributions of forecast errors in 30 nm increments for 24-, 48-, and 72-hour forecasts of all 1986 tropical cyclones in the western North Pacific. A summation of the mean forecast errors, as calculated for all tropical cyclones in each year, is shown in Table 5-2A. Table 5-2B includes cross track and along track errors for 1986. A comparison of the annual mean forecast errors for all tropical cyclones as compared to those tropical cyclones that reached typhoon intensity can be seen in Table 5-3. The mean and median forecast errors for 1986 as compared to the ten previous years are graphed in Figure 5-3.

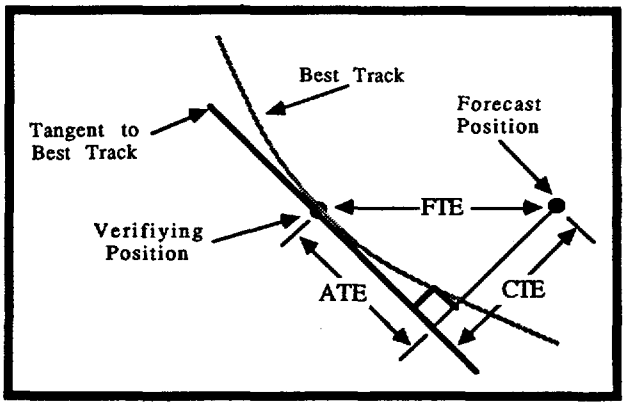
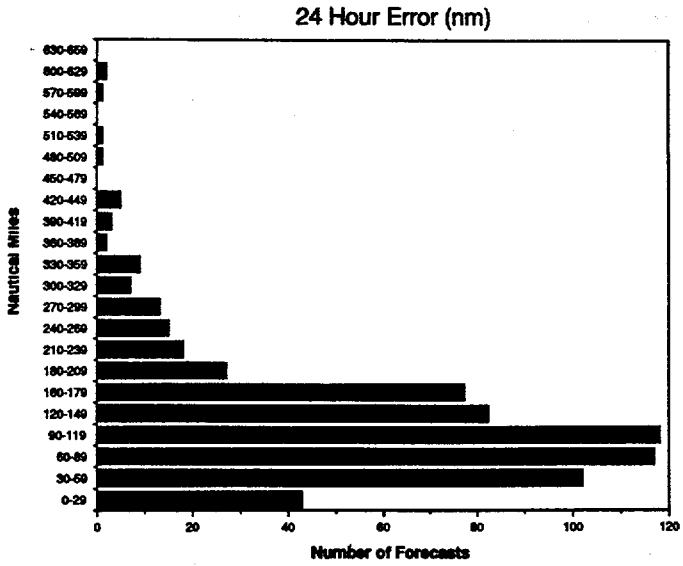


Figure 5-1. Definition of cross track error (CTE), along track error (ATE) and forecast track error (FTE). In this example, the CTE is positive (to the right of the Best Track) and the ATE is negative (behind or slower than the Best Track).

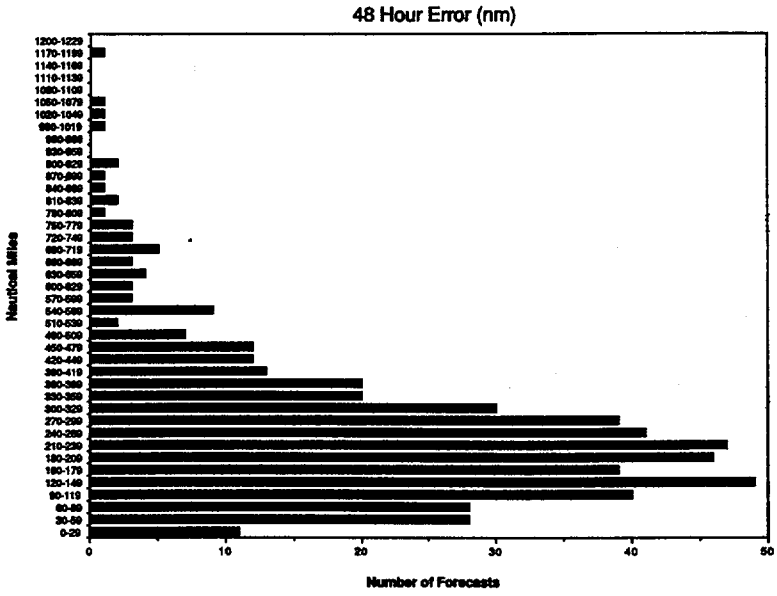
TABLE 5-1A. INITIAL POSITION ERROR SUMMARY FOR THE WESTERN NORTH PACIFIC SIGNIFICANT TROPICAL CYCLONES OF 1986 (ERRORS IN NM)

TROPICAL CYCLONE		ERROR	NUMBER OF WARNINGS
(01W)	TY JUDY	16	21
(02W)	TY KEN	17	18
(03W)	STY LOLA	11	26
(04W)	TS MAC	13	15
(05W)	TY NANCY	23	15
(06W)	TS OWEN	16	17
(07W)	STY PEGGY	11	35
(08W)	TY ROGER	12	19
(09W)	TS SARAH	55	22
(11E)	TY GEORGETTE	16	26
(10W)	TY TIP	24	25
(11W)	TS VERA #1	54	7
(11W)	TY VERA #2	17	48
(12W)	TY WAYNE	14	67
(13W)	TY ABBY	19	30
(14W)	TY BEN	22	46
(15W)	TY CARMEN	15	27
(16W)	TS DOM	25	11
(17W)	TY ELLEN	14	33
(18W)	TY FORREST	18	19
(19W)	TS GEORGIA	10	15
(20W)	TS HERBERT	26	16
(21W)	TS IDA	32	22
(22W)	TY JOE	12	24
(23W)	STY KIM	15	52
(24W)	TS LEX	34	8
(25W)	TY MARGE	29	38
(26W)	TY NORRIS	17	41
	MEAN	21	TOTAL 743



FORECAST ERRORS (NM)

	24-HR	48-HR	72-HR
MEAN:	121	261	394
MEDIAN:	121	255	383
STANDARD DEVIATION:	89	183	254
CASES:	646	531	409



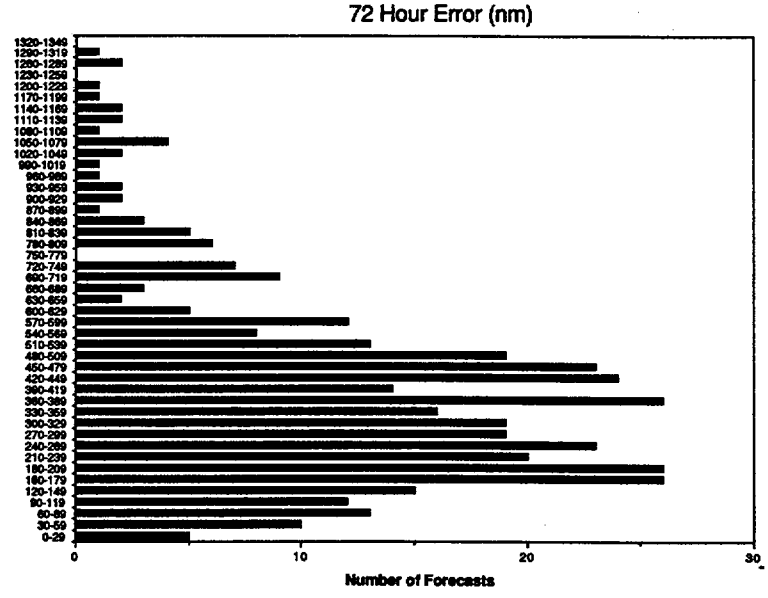


Figure 5-2. Frequency distribution of the 24-, 48-, and 72-hour forecast errors in 30 nm (56 km) increments for all significant tropical cyclones in the western North Pacific during 1986.

TABLE 5-1B. 24-HOUR FORECAST ERROR SUMMARY FOR THE WESTERN NORTH PACIFIC SIGNIFICANT TROPICAL CYCLONES OF 1986 (ERRORS IN NM)

TROPICAL CYCLONE		FORECAST ERROR	NUMBER OF WARNINGS	ALONG TRACK ERROR		CROSS TRACK ERROR	
				ABS MAG *	BIAS **	ABS MAG *	BIAS **
(01W)	TY JUDY	138	17	84	-56	93	-78
(02W)	TY KEN	78	15	62	11	31	-16
(03W)	STY LOLA	130	22	104	-86	63	-43
(04W)	TS MAC	123	11	96	-56	55	11
(05W)	TY NANCY	104	11	95	-92	32	20
(06W)	TS OWEN	70	14	63	-15	22	-9
(07W)	STY PEGGY	68	31	36	-1	47	29
(08W)	TY ROGER	75	15	59	-19	33	-18
(09W)	TS SARAH	273	18	208	-177	153	-104
(11E)	TY GEORGETTE	154	19	94	-78	87	-72
(10W)	TY TIP	180	23	114	-96	107	-107
(11W)	TS VERA #1	150	5	76	27	123	122
(11W)	TY VERA #2	131	44	96	-67	76	29
(12W)	TY WAYNE	124	59	101	-89	54	0
(13W)	TY ABBY	104	26	79	-37	51	38
(14W)	TY BEN	112	42	61	-2	81	-42
(15W)	TY CARMEN	84	23	57	-17	54	18
(16W)	TS DOM	66	9	56	-12	74	-66
(17W)	TY ELLEN	78	29	42	-4	54	-2
(18W)	TY FORREST	196	16	171	-158	58	-17
(19W)	TS GEORGIA	92	14	67	-61	46	46
(20W)	TS HERBERT	89	11	31	11	77	32
(21W)	TS IDA	139	19	87	-66	84	-24
(22W)	TY JOE	169	22	85	24	142	62
(23W)	STY KIM	116	51	82	-36	76	13
(24W)	TS LEX	78	7	41	7	62	-48
(25W)	TY MARGE	130	33	92	-59	68	33
(26W)	TY MORRIS	118	39	84	-75	73	13
	TOTALS	121	645	85	-50	70	-4

* ABS MAG = Absolute Magnitude (distance)
** BIAS is the median (middle value) of the sample.

Note: To measure forecast content with relation to a tropical cyclone track reference frame cross track and along track errors components have been generated in addition to the usual forecast errors. Specifics follow:

1. Cross track error component is a measure of how far a warning position is displaced left or right of the best track position. The samples consist of two parts: the absolute magnitude (distance) and the bias (negative values (minus sign) were left of track and positive values (plus sign) were right of track).

2. Along track error component is a measure of how far the warning position was displaced ahead or behind the best track position. It also consists of two parts: the absolute magnitude (distance) and the bias (negative values (minus sign) were behind/slow and positive values (plus sign) were ahead/fast).

TABLE 5-1C. 48-HOUR FORECAST ERROR SUMMARY FOR THE WESTERN NORTH PACIFIC SIGNIFICANT TROPICAL CYCLONES OF 1986 (ERRORS IN NM)

TROPICAL CYCLONE		FORECAST ERROR	NUMBER OF WARNINGS	ALONG TRACK ERROR		CROSS TRACK ERROR	
				ABS MAG	BIAS	ABS MAG	BIAS
(01W)	TY JUDY	331	11	310	-316	85	-75
(02W)	TY KEN	178	14	125	-29	86	-88
(03W)	STY LOLA	326	18	292	-300	105	-70
(04W)	TS MAC	188	7	147	-22	103	-79
(05W)	TY NANCY	198	7	180	-173	60	44
(06W)	TS OWEN	140	10	114	-64	72	-33
(07W)	STY PEGGY	172	27	100	8	117	110
(08W)	TY ROGER	105	9	83	-14	58	-38
(09W)	TS SARAH	671	14	507	-497	405	-394
(11E)	TY GEORGETTE	363	17	187	-63	267	-269
(10W)	TY TIP	447	18	362	-370	194	-191
(11W)	TS VERA #1	226	1	207	---	91	---
(11W)	TY VERA #2	289	40	207	-137	169	74
(12W)	TY WAYNE	274	46	237	-215	109	49
(13W)	TY ABBY	160	22	94	9	107	81
(14W)	TY BEN	204	38	124	26	131	-33
(15W)	TY CARMEN	140	19	104	-70	68	14
(16W)	TS DOM	60	4	18	-4	50	-36
(17W)	TY ELLEN	159	25	65	17	135	41
(18W)	TY FORREST	345	12	308	-257	124	-57
(19W)	TS GEORGIA	226	12	192	-194	101	99
(20W)	TS HERBERT	130	8	106	103	55	26
(21W)	TS IDA	236	15	147	-123	147	-55
(22W)	TY JOE	508	18	227	-22	424	-33
(23W)	STY KIM	280	51	167	-62	210	-54
(24W)	TS LEX	189	7	131	-117	112	-24
(25W)	TY MARGE	233	30	168	-97	139	89
(26W)	TY MORRIS	254	35	171	-151	168	108
	TOTALS	261	535	183	-115	151	-12

TABLE 5-1D. 72-HOUR FORECAST ERROR SUMMARY FOR THE WESTERN NORTH PACIFIC SIGNIFICANT TROPICAL CYCLONES OF 1986 (ERRORS IN NM)

TROPICAL CYCLONE		FORECAST ERROR	NUMBER OF WARNINGS	ALONG TRACK ERROR		CROSS TRACK ERROR	
				ABS MAG	BIAS	ABS MAG	BIAS
(01W)	TY JUDY	599	9	586	-594	92	-23
(02W)	TY KEN	288	14	184	80	179	25
(03W)	STY LOLA	581	14	560	-576	127	-27
(04W)	TS MAC	89	3	82	43	31	-10
(05W)	TY NANCY	521	3	498	-505	101	100
(06W)	TS OWEN	128	6	67	-47	82	-17
(07W)	STY PEGGY	332	23	163	7	257	252
(08W)	TY ROGER	198	5	154	-155	101	-103
(09W)	TS SARAH	800	8	530	-540	585	-594
(11E)	TY GEORGETTE	374	16	219	101	276	-263
(10W)	TY TIP	774	16	544	-518	420	-369
(11W)	TS VERA #1	---	0	---	---	---	---
(11W)	TY VERA #2	543	36	363	-253	340	-10
(12W)	TY WAYNE	468	38	390	-377	196	119
(13W)	TY ABBY	225	18	158	83	147	114
(14W)	TY BEN	261	32	139	38	190	-133
(15W)	TY CARMEN	173	15	141	-138	73	-21
(16W)	TS DOM	29	1	24	---	17	---
(17W)	TY ELLEN	291	21	139	17	227	36
(18W)	TY FORREST	427	8	353	-388	172	-176
(19W)	TS GEORGIA	402	8	354	-356	205	202
(20W)	TS HERBERT	217	4	134	133	162	-28
(21W)	TS IDA	325	11	211	-207	205	-35
(22W)	TY JOE	431	8	113	-104	334	-246
(23W)	STY KIM	488	31	355	14	317	-153
(24W)	TS LEX	416	7	366	-369	183	143
(25W)	TY MARGE	288	26	180	-105	189	150
(26W)	TY NORRIS	334	31	214	-151	224	214
	TOTALS	394	412	276	-170	227	-12

TABLE 5-2A. ANNUAL MEAN FORECAST ERRORS FOR THE WESTERN NORTH PACIFIC

YEAR	24-HOUR		48-HOUR		72-HOUR	
	FORECAST	RIGHT-ANGLE	FORECAST	RIGHT-ANGLE	FORECAST	RIGHT-ANGLE
1971	111	64	212	118	317	117
1972	117	72	245	146	381	210
1973	108	74	197	134	253	162
1974	120	78	226	157	348	245
1975	138	84	288	181	450	290
1976	117	71	230	132	338	202
1977	148	83	283	157	407	228
1978	127	75	271	179	410	297
1979	124	77	226	151	316	223
1980	126	79	243	164	389	287
1981 *	123	75	220	119	334	168
1982 *	113	67	237	139	341	206
1983 *	117	72	259	152	405	237
1984 *	117	66	233	137	363	231
1985 *	117	66	231	134	367	214
1986	121	**	261	**	394	**

* THE TECHNIQUE FOR CALCULATING RIGHT-ANGLE ERROR WAS REVISED IN 1981; THEREFORE, A DIRECT CORRELATION IN RIGHT-ANGLE STATISTICS CANNOT BE MADE FOR THE ERRORS COMPUTED BEFORE 1981 AND THE ERRORS COMPUTED SINCE 1981.

** IN 1986 RIGHT-ANGLE ERROR WAS REPLACED BY CROSS TRACK ERROR (SEE FIGURE 5-1 FOR THE DEFINITION OF CROSS TRACK ERROR).

TABLE 5-2B. 1986 MEAN FORECAST, CROSS TRACK AND ALONG TRACK ERRORS FOR THE WESTERN NORTH PACIFIC. (ERRORS IN NM)

FORECAST ERROR:		CROSS TRACK		ALONG TRACK	
	FORECAST	ABS MAG	BIAS	ABS MAG	BIAS
24-HOUR	121	70	(-4)	85	(-50)
48-HOUR	261	151	(-12)	183	(-115)
72-HOUR	394	227	(-12)	276	(-170)

TABLE 5-3. ANNUAL MEAN FORECAST ERRORS FOR THE WESTERN NORTH PACIFIC (ERRORS ARE IN NAUTICAL MILES)

YEAR	24-HOUR ALL	24-HOUR TYPHOON*	48-HOUR ALL	48-HOUR TYPHOON*	72-HOUR ALL	72-HOUR TYPHOON*
1950-1958		170				
1959		117 **		267 **		
1960		177 **		354 **		
1961		136		274		
1962		144		287		476
1963		127		246		374
1964		133		284		429
1965		151		303		418
1966		136		280		432
1967		125		276		414
1968		105		229		337
1969		111		237		349
1970	104	98	190	181	279	272
1971	111	99	212	203	317	308
1972	117	116	245	245	381	382
1973	108	102	197	193	253	245
1974	120	114	226	218	348	357
1975	138	129	288	279	450	442
1976	117	117	230	232	338	336
1977	148	140	283	266	407	390
1978	127	120	271	241	410	459
1979	124	113	226	219	316	319
1980	126	116	243	221	389	362
1981	123	117	220	215	334	342
1982	113	114	237	229	341	337
1983	117	110	259	247	405	384
1984	117	110	233	228	363	361
1985	117	112	231	228	367	355
1986	121	117	261	261	394	403

* Forecasts were verified when the Tropical Cyclone intensities were over 35 (18 m/sec).
** Forecast positions north of 35 degrees North Latitude were not verified.

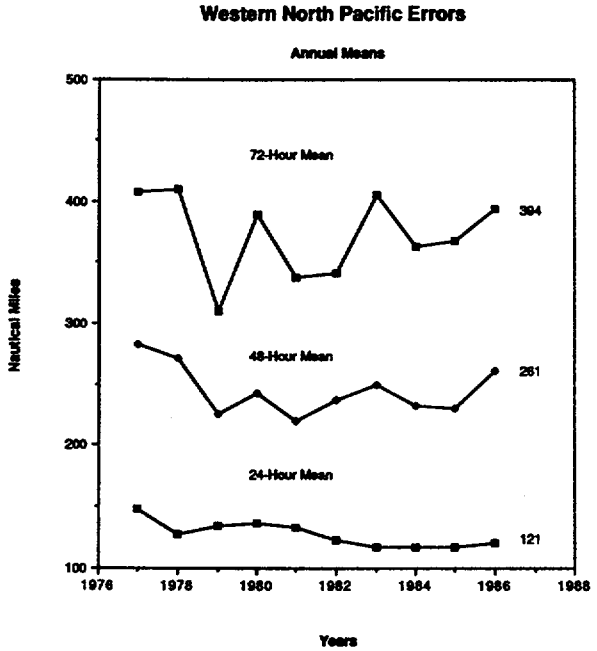


Figure 5-3. Annual mean forecast errors (in nm) for all tropical cyclones in the western North Pacific.

b. North Indian Ocean

The positions given for warning times and those at the 24-, 48-, and 72-hour valid times were verified for tropical cyclones in the North Indian Ocean by the same methods used for the western North Pacific. It should be noted that due to low number of North Indian Ocean tropical cyclones, these error statistics should not be taken as representative of any trend. Table 5-4 is the forecast along track and cross track error summary for the North Indian Ocean. Table 5-5A contains a summary of the annual mean forecast errors for each year. Table 5-5B includes cross and along track error for 1986. Forecast errors are plotted in Figure 5-4 (Seventy-two hour forecast errors were evaluated for the first time in 1979). There were no verifying 72-hour forecast in 1983 and 1985.

TABLE 5-4. FORECAST ERROR SUMMARY FOR THE NORTH INDIAN OCEAN SIGNIFICANT TROPICAL CYCLONES OF 1986 (ERRORS IN NM)

INITIAL POSITION

TROPICAL CYCLONE	ERROR	NUMBER OF WARNINGS
TC 01B	36	17
TC 02B	70	2
TC 03A	78	9
MEAN	52	TOTAL 28

24-HOUR FORECASTS

TROPICAL CYCLONE	FORECAST ERROR	ALONG TRACK ERROR		CROSS TRACK ERROR	
		ABS MAG	BIAS	ABS MAG	BIAS
TC 01B	78	59	-56	46	-41
TC 02B	---	---	---	---	---
TC 03A	259	247	-250	69	68
MEAN	134	118	-117	53	-7

48-HOUR FORECASTS

TROPICAL CYCLONE	FORECAST ERROR	ALONG TRACK ERROR		CROSS TRACK ERROR	
		ABS MAG	BIAS	ABS MAG	BIAS
TC 01B	129	89	-89	74	-75
TC 02B	---	---	---	---	---
TC 03A	401	384	N/A *	113	N/A *
MEAN	168	131	-89	80	-75

72-HOUR FORECASTS

TROPICAL CYCLONE	FORECAST ERROR	ALONG TRACK ERROR		CROSS TRACK ERROR	
		ABS MAG	BIAS	ABS MAG	BIAS
TC 01B	269	189	-190	180	-182
TC 02B	---	---	---	---	---
TC 03A	---	---	---	---	---
MEAN	269	189	-190	180	-182

* SAMPLE TOO SMALL TO COMPUTE MEDIAN FOR BIAS.

TABLE 5-5A. ANNUAL MEAN FORECAST ERRORS FOR THE NORTH INDIAN OCEAN

YEAR	24-HOUR FORECAST	24-HOUR RIGHT-ANGLE	48-HOUR FORECAST	48-HOUR RIGHT-ANGLE	72-HOUR FORECAST	72-HOUR RIGHT-ANGLE
1971 *	232	---	410	---	---	---
1972 *	224	101	292	112	---	---
1973 *	182	99	299	160	---	---
1974 *	137	81	238	146	---	---
1975	145	99	228	144	---	---
1976	138	108	204	159	---	---
1977	122	94	292	214	---	---
1978	133	86	202	128	---	---
1979	151	99	270	202	437	371
1980	115	73	93	87	167	126
1981 **	109	65	176	103	197	73
1982 **	138	66	368	175	762	404
1983 **	117	46	153	67	---	---
1984 **	154	71	274	127	388	159
1985 **	123	51	242	109	---	---
1986	134	***	168	***	269	***

* THE WESTERN BAY OF BENGAL AND ARABIAN SEA WERE NOT INCLUDED IN THE JTWC AREA OF RESPONSIBILITY UNTIL THE 1975 TROPICAL CYCLONE SEASON.

** THE TECHNIQUE FOR CALCULATING RIGHT-ANGLE ERROR WAS REVISED IN 1981; THEREFORE, A DIRECT CORRELATION IN RIGHT-ANGLE STATISTICS CANNOT BE MADE FOR THE ERRORS COMPUTED BEFORE 1981 AND THE ERRORS COMPUTED SINCE 1981.

*** IN 1986 RIGHT-ANGLE ERROR WAS REPLACED BY CROSS TRACK ERROR (SEE FIGURE 5-1 FOR THE DEFINITION OF CROSS TRACK ERROR).

TABLE 5-5B. ANNUAL MEAN FORECAST ERRORS FOR THE NORTH INDIAN OCEAN (ERRORS IN NAUTICAL MILES)

FORECAST ERROR:

YEAR	24-HOUR	48-HOUR	72-HOUR
1986	134	168	269

CROSS TRACK ERROR:

	24-HOUR		48-HOUR		72-HOUR	
YEAR	ABS MAG	BIAS	ABS MAG	BIAS	ABS MAG	BIAS
1986	53	-7	80	-49	180	-182

ALONG TRACK ERROR:

	24-HOUR		48-HOUR		72-HOUR	
YEAR	ABS MAG	BIAS	ABS MAG	BIAS	ABS MAG	BIAS
1986	118	-118	131	-134	189	-190

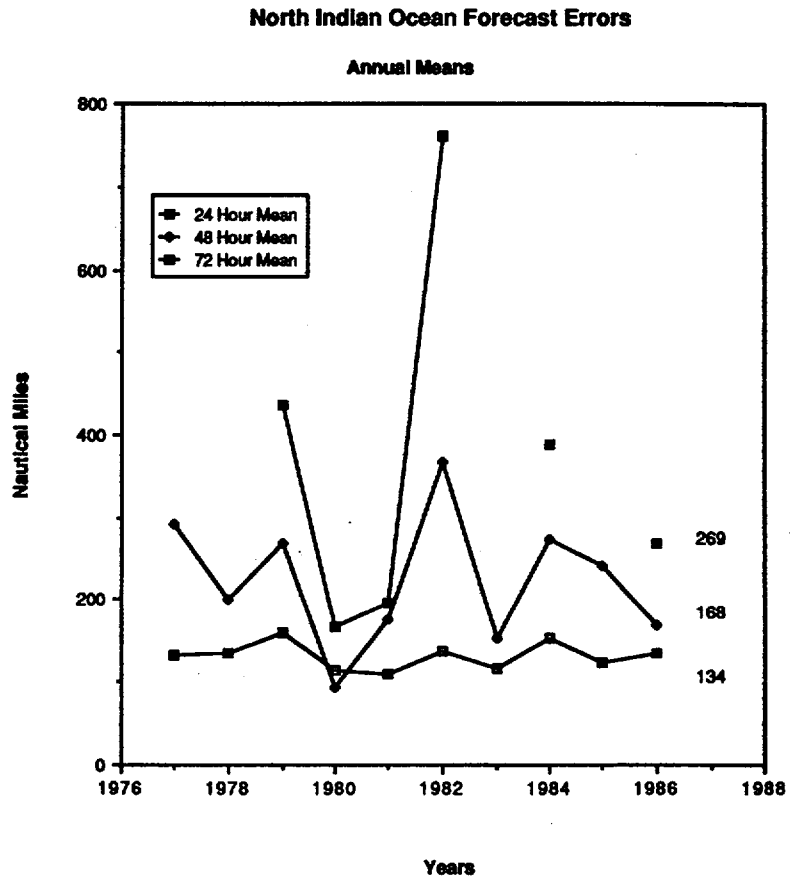


Figure 5-4. Annual mean forecast errors (in nm) for all tropical cyclones in the North Indian Ocean.

c. South Pacific and South Indian Oceans

Verification statistics for forecasts in the southern hemisphere can be obtained from the raw data sets addressed in Annex A.

2. COMPARISON OF OBJECTIVE TECHNIQUES

a. General

Objective techniques used by JTWC are divided into five main categories:

(1) extrapolation;

(2) climatological and analog techniques;

(3) model output statistics;

(4) dynamic models; and

(5) empirical and analytical techniques;

In September 1981, JTWC began to initialize its array of objective forecast techniques (described below) on the six-hour old preliminary best track position (an interpolative process) rather than the forecast (partially extrapolated) warning position, e.g. the 0600Z warning is now supported by objective techniques developed from the 0000Z preliminary best track position. This operational change has yielded several advantages:

*Techniques can now be requested much earlier in the warning development time line, i.e. as soon as the track can be approximated by one or more fix positions after the valid time of the previous warning;

*Receipt of these techniques is virtually assured prior to the development of the next warning; and

*Improved (mean) forecast accuracy. This latter aspect arises because JTWC now has more reliable approximation of the short-term tropical cyclone movement. Further, since most of the objective techniques are biased towards persistence, this new procedure optimizes their performance and provides more consistent guidance on short-term movement, indirectly yielding a more accurate initial position estimate as well as lowering 24-hour forecast errors.

b. Description of Objective Techniques

(1). XTRP — Forecast positions for 24- and 48-hours are derived from the extension of a straight line which connects the most recent and 12-hour old preliminary best track positions.

(2). CLIM — A climatological aid providing 24-, 48-, and 72-hour tropical cyclone forecast positions (and intensity changes in the western North Pacific) based upon the position of the tropical cyclone. The output is based upon data records from 1945 to 1981 for the western North Pacific Ocean and 1900 to 1981 for the North Indian Ocean.

(3). TPAC — Forecast positions are generated from a blend of climatology and persistence. The 24- and 48-hour positions are equally weighted between climatology and persistence and three quarters climatology and persistence, respectively; the 72-hour position is one quarter persistence and three quarters climatology. Persistence is a straight line extension of a line connecting the current and 12-hour old positions. Climatology is based on data from 1945 to 1981 for the western North Pacific Ocean and 1900 to 1981 for the North Indian Ocean.

(4). TYAN — An updated analog program which combines the earlier versions TYFN 75 and INJAN 74. The program scans a 30-year climatology with a similar history (within a specified acceptance envelope) to the current tropical cyclone. For the western North Pacific Ocean, three forecasts of position and intensity are provided for 24-, 48-, and 72-hours: RECR - a weighted mean of all tropical cyclones which were categorized as "recurving" during their best track period; STRA - a weighted mean of all accepted tropical cyclones which were categorized as moving "straight" (westward) during their best track period: TOTL - a weighted mean of all accepted tropical cyclones, including those used in the RECR and STRA forecast. For the North Indian Ocean, a single (total) forecast track is provided for the 12-hour intervals to 72-hours.

(5). COSMOS — A model output statistics (MOS) routine based on the geostrophic steering at the 850-, 700-, and 500-mb levels. The steering is derived from the HATTRACK point advection model run on Global prognostic fields from the FLENUMOCEANCEN's NOGAPS prediction system. The MOS forecast is then blended with the 6-hour past movement to generate the forecast track.

(6). One-way Interactive Tropical Cyclone Model (OTCM) — A coarse-mesh, three-layer in the vertical, primitive equation model with a 205km grid spacing over a 6400 x 4700 km domain. The model's fields are computed around a bogused, digitized cyclone vortex using FLENUMOCEANCEN's Numerical Variational Analysis (NVA) or NOGAPS prognostic fields for the specified valid time. The past motion of the tropical cyclone is compared to initial steering fields and a bias correction is computed and applied to the model. FLENUMOCEANCEN's NOGAPS global prognostic fields are used at 12-hour intervals to update the model's boundaries. The resultant forecast positions are derived by locating the 850 mb vortex at six-hour intervals to 72-hours.

(7). Nested Tropical Cyclone Model (NTCM) — A primitive equation model with properties similar to the OTCM. The NTCM differs by containing a finer scale "nested "grid, initializing on NVA analysis fields only, not containing a (persistence) bias correction, and being a channel model which runs independent of FLENUMOCEANCEN's prognostic fields (i.e., it does not require updating of its boundaries). The "nested grid" covers a 1200 x 1200 km area with a 41 km grid spacing which moves within the coarse-mesh domain to keep an 850 mb vortex at its center.

(8). TAPT — An empirical technique which utilizes upper-tropospheric wind fields to estimate acceleration associated with the tropical cyclone's interaction with the mid-latitude westerlies. It includes guidelines for the duration of acceleration, upper-limits, and probable path of the cyclone.

(9). CLIPER — A statistical regression technique based on climatology, current intensity, position and past movement. This technique is used as a crude measure of real forecast skill when verifying forecast accuracy.

(10). THETA-E — An empirically derived relationship between a tropical cyclone's minimum sea-level pressure (MSLP) and 700 mb equivalent potential temperature (Theta-E) was developed by Sikora (1976) and Dunnavan (1981). By monitoring MSLP and trends, the forecaster can evaluate the potential for sudden, rapid deepening of a tropical cyclone.

(11). WIND RADIUS — Following an analytical model of the radial profiles of sea-level pressures and winds in mature tropical cyclones (Holland, 1980),

a set of radii for 30-, 50-, and 100-knot winds based on the tropical cyclone's maximum winds have been produced to aid the forecaster in determining forecast wind radii.

(12). DVORAK — An estimation of tropical cyclone's current and 24-hour forecast intensity is made from interpolation of satellite imagery (DVORAK, 1984) and provided to the forecaster. These intensity estimates are used in conjunction with other intensity-related data and trends to forecast tropical cyclone intensity.

JTWC uses TPAC, TAPT, TYAN78, COSMOS, OTCM and NTCM operationally to develop track forecasts.

c. Testing and Results

A comparison of selected techniques is included in Table 5-6 for all western North Pacific tropical cyclones, Table 5-7 for all North Indian Ocean tropical cyclones. In these tables, " x-axis " refers to techniques listed vertically. For example (Table 5-6) in the 470 cases available for a (homogeneous) comparison, the average forecast error at 24-hours was 124 nm (230 km) for RECR and 110 nm (204 km) for COSM. The difference of 14 nm (26 km) is shown in the lower right. (Differences are not always exact, due to computational round-off which occurs for each of the cases available for comparison).

TABLE 5-6. 1986 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE WESTERN NORTH PACIFIC OCEAN

24-HOUR FTE MEAN ERRORS (N. MI)

	JTWC		NTCM		CLIP		OTCM		CSUM		RECR		TOTL		COSM		TPAC		CLIM		XTRP	
JTWC	643	122																				
	122	0																				
NTCM	529	121	544	129																		
	127	6	129	0																		
CLIP	490	121	502	127	502	126																
	126	5	126	-1	126	0																
OTCM	589	120	514	126	475	123	603	126														
	125	5	126	0	125	2	126	0														
CSUM	498	122	431	125	407	127	501	125	505	111												
	111	-11	112	-13	113	-14	110	-15	111	0												
RECR	576	121	499	127	463	125	561	123	470	110	589	128										
	126	5	130	3	127	2	124	1	124	14	128	0										
TOTL	589	121	510	127	472	124	575	125	483	110	588	128	603	129								
	128	7	131	4	128	4	125	0	125	15	130	2	129	0								
COSM	583	119	505	123	480	124	567	124	492	110	555	120	566	121	593	121						
	121	2	123	0	123	-1	120	-4	122	12	122	2	122	1	121	0						
TPAC	593	121	512	125	475	123	578	126	489	111	571	126	585	128	572	121	607	129				
	128	7	130	5	128	5	125	-1	126	15	129	3	128	0	121	0	129	0				
CLIM	593	121	512	125	475	123	578	126	489	111	571	126	585	128	572	121	607	129	607	171		
	171	50	171	46	171	48	168	42	173	62	168	42	168	40	163	42	171	42	171	0		
XTRP	597	120	516	126	477	123	582	126	492	111	571	126	585	128	575	121	607	129	607	171	611	133
	129	9	134	8	131	8	128	2	129	18	134	8	132	4	125	4	133	4	133	-38	133	0

NUMBER OF CASES	X-AXIS TECHNIQUE ERROR
Y-AXIS TECHNIQUE ERROR	ERROR DIFFERENCE (Y - X)

48-HOUR FTE MEAN ERRORS (N. MI)

	JTWC		NTCM		CLIP		OTCM		CSUM		RECR		TOTL		COSM		TPAC		CLIM		XTRP	
JTWC	528	260																				
	260	0																				
NTCM	430	258	466	276																		
	269	11	276	0																		
CLIP	402	254	432	271	432	269																
	261	7	269	-2	269	0																
OTCM	469	256	432	270	402	261	505	231														
	224	-32	228	-42	225	-36	231	0														
CSUM	398	261	362	270	345	269	414	224	424	227												
	225	-36	223	-47	220	-49	224	0	227	0												
RECR	476	259	432	271	402	264	475	226	399	221	510	265										
	262	3	263	-8	257	-7	260	34	268	47	265	0										
TOTL	485	259	439	271	407	264	484	229	407	223	508	266	519	265								
	262	3	259	-12	251	-13	260	31	268	45	267	1	265	0								
COSM	475	256	433	263	415	266	472	226	412	227	480	259	486	257	507	249						
	248	-8	247	-16	244	-22	243	17	244	17	250	-9	251	-6	249	0						
TPAC	485	258	439	268	409	263	483	230	411	227	492	263	501	262	489	250	520	255				
	247	-11	248	-20	240	-23	247	17	255	28	251	-12	250	-12	245	-5	255	0				
CLIM	485	258	439	268	409	263	483	230	411	227	492	263	501	262	489	250	520	255	520	316		
	306	48	311	43	308	45	314	84	328	101	308	45	308	46	307	57	316	61	316	0		
XTRP	486	258	440	268	409	263	484	230	411	227	492	263	501	262	489	250	520	255	520	316	521	299
	292	34	289	21	278	15	290	60	299	72	298	35	297	35	288	38	299	44	299	-17	299	0

JTWC - OFFICIAL JTWC FORECAST
NTCM - NESTED TROPICAL CYCLONE MODEL
CLIP - CLIPER (CLImatolgy and PERsistence)
OTCM - ONE-WAY TROPICAL CYCLONE MODEL
CSUM - C.S.U. MODEL (Synoptic-Statistical)
RECR - RECURVER ANALOG (TYAN 78)
TOTL - TOTAL ANALOG (TYAN 78)
COSM - COSMOS (Model Output Statistics)
TPAC - CLIMATOLOGY AND PERSISTENCE BLEND
CLIM - CLIMATOLOGY
XTRP - 12-HOUR EXTRAPOLATION

72-HOUR FTE MEAN ERRORS (N. MI)

	JTWC		NTCM		CLIP		OTCM		CSUM		RECR		TOTL		COSM		TPAC		CLIM		XTRP	
JTWC	406	392																				
	392	0																				
NTCM	332	396	386	457																		
	438	42	457	0																		
CLIP	312	397	363	460	363	430																
	414	17	430	-30	430	0																
OTCM	315	404	318	449	300	414	369	355														
	348	-56	356	-93	354	-60	355	0														
CSUM	283	401	288	458	279	429	301	347	335	349												
	346	-55	348	-110	346	-83	346	-1	349	0												
RECR	360	397	355	455	336	426	341	349	314	342	416	423										
	414	17	426	-29	425	-1	423	74	439	97	423	0										
TOTL	367	398	363	455	341	427	349	351	320	345	414	422	424	406								
	387	-11	399	-56	393	-34	409	58	418	73	408	-14	406	0								
COSM	359	398	358	450	348	428	343	352	324	351	389	423	398	402	414	431						
	429	31	428	-22	430	2	399	47	406	55	435	12	435	33	431	0						
TPAC	368	397	361	448	341	425	349	355	322	350	398	421	407	404	396	437	423	376				
	341	-56	376	-72	375	-50	380	25	388	38	369	-52	371	-33	377	-60	376	0				
CLIM	368	397	361	448	341	425	349	355	322	350	398	421	407	404	396	437	423	376	423	417		
	371	-26	421	-27	421	-4	428	73	437	87	407	-14	410	6	419	-18	417	41	417	0		
XTRP	364	395	355	447	335	422	344	357	318	350	394	419	401	402	392	440	417	374	417	414	418	478
	468	73	463	16	461	39	470	113	498	148	476	57	477	75	472	32	477	103	477	63	478	0

TABLE 5-7. 1986 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTHERN INDIAN OCEAN

24-HOUR FTE MEAN ERRORS (N. MI)

	JTWC		NTCM		OTCM		RECR		TOTL		TPAC		CLIM		XTRP	
JTWC	16	134														
	134	0														
NTCM	13	138	15	137												
	137	-1	137	0												
OTCM	11	160	9	178	11	277										
	277	117	271	93	277	0										
RECR	12	141	12	150	9	270	14	143								
	140	-1	145	-5	150	-120	143	0								
TOTL	8	189	8	191	6	303	10	177	10	177						
	182	-7	190	-1	199	-104	177	0	177	0						
TPAC	15	140	14	146	11	277	14	143	10	177	17	161				
	164	24	163	17	188	-89	156	13	201	24	161	0				
CLIM	15	140	14	146	11	277	14	143	10	177	17	161	17	176		
	183	43	179	33	211	-66	177	34	233	56	176	15	176	0		
XTRP	15	140	14	146	11	277	14	143	10	177	17	161	17	176	17	153
	153	13	155	9	173	-104	140	-3	174	-3	153	-8	153	-23	153	0

NUMBER OF CASES	X-AXIS TECHNIQUE ERROR
Y-AXIS TECHNIQUE ERROR	ERROR DIFFERENCE (Y - X)

48-HOUR FTE MEAN ERRORS (N. MI)

	JTWC		NTCM		OTCM		RECR		TOTL		TPAC		CLIM		XTRP	
JTWC	7	168														
	168	0														
NTCM	6	129	8	199												
	208	79	199	0												
OTCM	2	134	2	254	2	528										
	528	394	528	274	528	0										
RECR	4	200	3	247	1	602	5	249								
	232	32	157	-90	166	-436	249	0								
TOTL	1	401	0	0	0	0	2	387	2	387						
	459	58	0	0	0	0	387	0	387	0						
TPAC	6	179	7	209	2	528	5	249	2	387	9	174				
	162	-17	118	-91	98	-430	211	-38	370	-17	174	0				
CLIM	6	179	7	209	2	528	5	249	2	387	9	174	9	170		
	178	-1	102	-107	68	-460	207	-42	408	21	170	-4	170	0		
XTRP	6	179	7	209	2	528	5	249	2	387	9	174	9	170	9	196
	172	-7	153	-56	135	-393	220	-29	345	-42	196	22	196	26	196	0

JTWC - OFFICIAL JTWC FORECAST
NTCM - NESTED TROPICAL CYCLONE MODEL
OTCM - ONE-WAY TROPICAL CYCLONE MODEL
RECR - RECURVER ANALOG (TYAN 78)
TOTL - TOTAL ANALOG (TYAN 78)
TPAC - CLIMATOLOGY AND PERSISTENCE BLEND
CLIM - CLIMATOLOGY
XTRP - 12-HOUR EXTRAPOLATION

72-HOUR FTE MEAN ERRORS (N. MI)

	JTWC		NTCM		OTCM		TPAC		CLIM		XTRP	
JTWC	5	269										
	269	0										
NTCM	5	269	5	438								
	438	169	438	0								
OTCM	1	254	1	400	1	1015						
	1015	761	1015	615	1015	0						
TPAC	4	286	4	451	1	1015	4	142				
	142	-144	142	-309	182	-833	142	0				
CLIM	4	286	4	451	1	1015	4	142	4	152		
	152	-134	152	-299	166	-849	152	10	152	0		
XTRP	4	286	4	451	1	1015	4	142	4	152	4	196
	196	-90	196	-255	229	-786	196	54	196	44	196	0