CHAPTER IV - SUMMARY OF FORECAST VERIFICATION

1. ANNUAL FORECAST VERIFICATION

a. Western North Pacific Ocean

The positions given for warning times and those at the 24-, 48-, and 72-hour forecast times were verified against the post-analysis "best-track" positions at the same valid times. The resultant vector and right angle (track) errors (illustrated in Figure 4-1) were then calculated for each tropical cyclone and are presented in Table 4-1. Figure 4-2 provides the frequency distributions of vector errors for 24-, 48- and 72-hour forecasts of all 1983 tropical cyclones in the western North Pacific. A summation of the mean errors, as calculated for all tropical cyclones in each year, is shown in Table 4-2 for comparative purposes. The data used in this table are not to be confused with that presented in earlier years where the sample was restricted to tropical cyclones that reached typhoon intensity and then had the forecast errors calculated only for that portion of the life-cycle when the intensity was greater than 34 knots (last published as Table 5-1, 1977 Annual Typhoon Report). A comparison of the results using the truncated data set and those obtained for all tropical cyclones can be seen directly in Table 4-3. The annual mean vector errors are graphed in Figure 4-3.

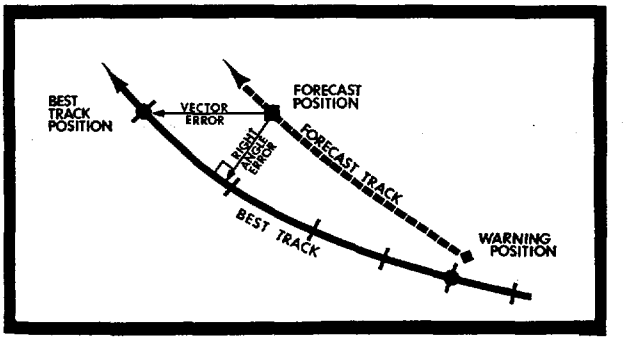

FIGURE 4-1. *Illustration of the method to determine vector error and right angle error.*

TABLE 4-1.

FORECAST ERROR SUMMARY FOR THE WESTERN NORTH PACIFIC SIGNIFICANT TROPICAL CYCLONES OF 1983. (ERRORS IN NM)

	WARNING			24-HOUR			48-HOUR			72-HOUR		
	VECTOR ERROR	RT ANGLE ERROR	NR OF WRNGS	VECTOR ERROR	RT ANGLE ERROR	NR OF WRNGS	VECTOR ERROR	RT ANGLE ERROR	NR OF WRNGS	VECTOR ERROR	RT ANGLE ERROR	NR OF WRNGS
1W. TS SARAH	27	18	6	94	86	3						
2C. TD 02C	36	17	5	168	117	4	276	205	1			
2W. TY TIP	12	8	14	66	53	10	165	160	6	215	204	2
3W. TY VERA	14	9	25	72	39	21	131	66	17	187	70	13
4W. STY WAYNE	12	10	14	96	63	11	226	92	7	454	102	3
5W. STY ABBY	11	8	51	104	84	47	224	199	43	340	307	39
6W. TS CARMEN	20	12	8	199	105	4						
7W. TS BEN	17	12	12	123	41	8	212	46	4			
8W. TS DOM	18	11	23	134	92	19	317	213	13	395	198	7
9W. TD 09W	21	11	4									
10W. TY ELLEN	15	11	47	101	60	43	223	123	39	339	178	35
11W. STY FORREST	11	8	32	97	64	28	224	79	24	366	118	20
12W. TS GEORGIA	10	7	11	53	27	7	52	18	3			
13W. TS HERBERT	18	11	8	33	24	5	43	29	1			
14W. TY IDA	10	6	15	144	58	11	298	95	7	516	25	3
15W. TY JOE	15	10	15	86	61	12	177	151	8	246	200	4
16W. TS KIM	23	11	3	292	55	1						
17W. TY LEX	18	11	18	116	69	14	259	156	10	316	137	5
18W. STY MARGE	19	14	27	191	134	23	484	240	19	755	282	15
19W. TS NORRIS	19	15	7	85	53	3						
20W. TY ORCHID	16	10	38	117	54	33	267	160	30	459	343	26
21W. TY PERCY	21	11	23	173	86	19	409	184	15	660	361	11
22W. TS RUTH	15	8	16	94	56	11	246	162	7	394	353	4
23W. TS SPERRY	33	19	10	149	91	6	343	237	2			
24W. TS THELMA	32	16	10	268	151	6	572	239	2			
ALL FORECASTS:	16	11	445	117	72	349	259	152	258	405	237	187

TABLE 4-2. ANNUAL MEAN FORECAST ERRORS (NM) FOR THE WESTERN PACIFIC

	24-HOUR		48-HOUR		72-HOUR	
YEAR	VECTOR	RIGHT ANGLE	VECTOR	RIGHT ANGLE	VECTOR	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

* 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.

TABLE 4-3. ANNUAL MEAN FORECAST ERRORS (NM) FOR WESTERN NORTH PACIFIC

	24-HOUR		48-HOUR		72-HOUR	
YEAR	ALL	TYPHOON*	ALL	TYPHOON*	ALL	TYPHOON*
1950-58		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	351
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

* For Typhoons only while winds were over 35 kt (18 m/sec).

** Forecast positions north of 35°N were not verified.

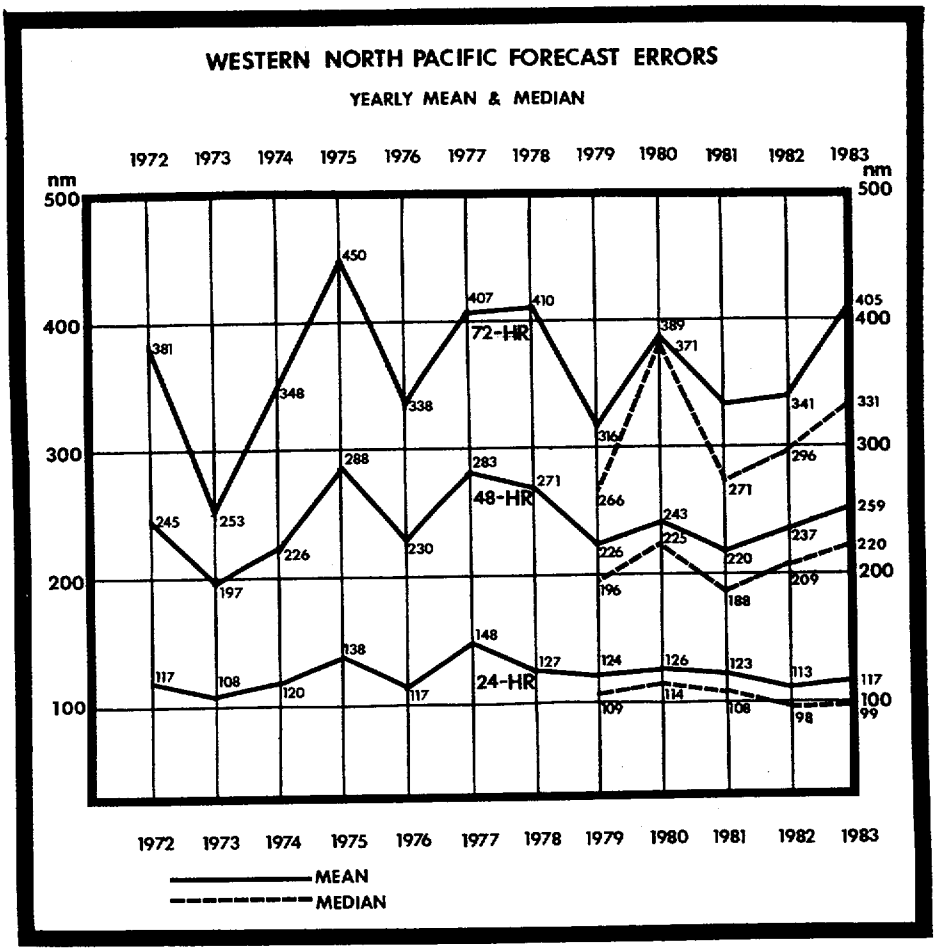

FIGURE 4-3. *Annual mean and median vector errors [nm] for all tropical cyclones in the western North Pacific.*

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 the low number of North Indian Ocean tropical cyclones, these error statistics should not be taken as representative of any trend. Table 4-4 is the forecast error summary for the North Indian Ocean and Table 4-5 contains the annual average of forecast errors back through 1971. Vector errors are plotted in Figure 4-4. (Seventy-two hour forecast errors were evaluated for the first time in 1979).

TABLE 4-4.

FORECAST ERROR SUMMARY FOR THE NORTH INDIAN OCEAN
SIGNIFICANT TROPICAL CYCLONES OF 1983. (ERRORS IN NM)

	WARNING			24-HOUR			48-HOUR			72-HOUR		
	POSIT ERROR	RT ANGLE ERROR	NR OF WRNGS	POSIT ERROR	RT ANGLE ERROR	NR OF WRNGS	POSIT ERROR	RT ANGLE ERROR	NR OF WRNGS	POSIT ERROR	RT ANGLE ERROR	NR OF WRNGS
1. TC 01A	48	35	3	-	-	-	-	-	-	-	-	-
2. TC 02B	23	25	5	162	114	1	-	-	-	-	-	-
3. TC 03B	42	21	10	109	35	6	153	67	2	-	-	-
ALL FORECASTS:	38	24	18	117	46	7	153	67	2			

TABLE 4-5.

ANNUAL MEAN FORECAST ERRORS FOR THE NORTH INDIAN OCEAN

	24-HOUR		48-HOUR		72-HOUR	
YEAR	VECTOR	RIGHT ANGLE	VECTOR	RIGHT ANGLE	VECTOR	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	-	-

* The western Bay of Bengal and the 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.

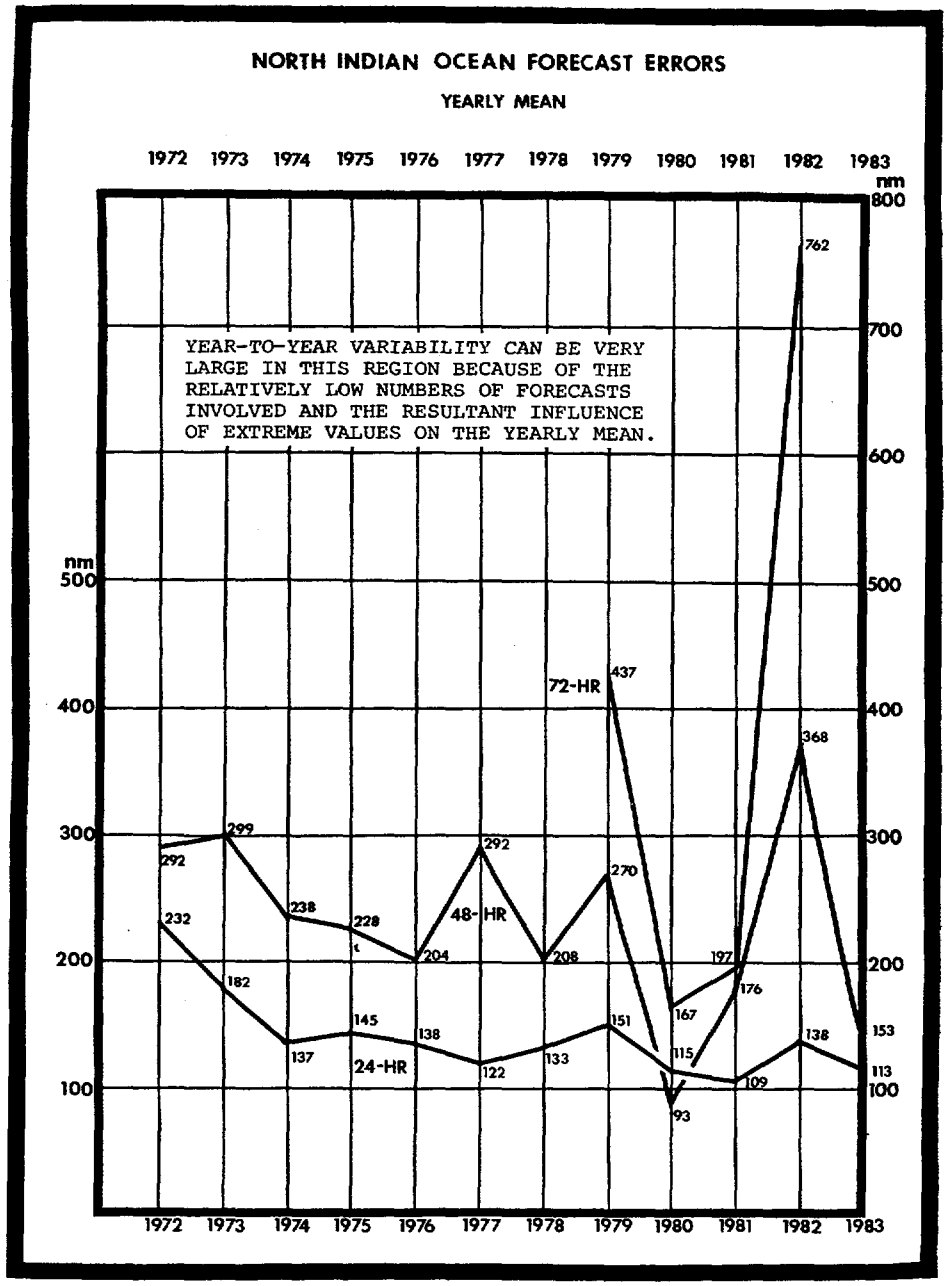

FIGURE 4-4. *Annual mean vector errors (nm) for all tropical cyclones in the North Indian Ocean.*

2. COMPARISION OF OBJECTIVE TECHNIQUES

a. General

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

(1) climatological and analog techniques;

(2) extrapolation;

(3) steering techniques;

(4) dynamic models;

(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 on, or after the valid time of the previous warning;

*receipt of these techniques is virtually assured prior to development of the next warning

*improved (mean) forecast accuracy.

This latter aspect arises because JTWC now has a more reliable approximation of the short-term tropical cyclone movement. Further, since most of the objective techniques are biased for 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) 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.

(2) TYAN78 -- An updated analog program which combines the earlier versions TYFN 75 and INJAH 74. The program scans history tapes for tropical cyclones similar (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 accepted 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; and TOTL - a weighted mean of all accepted tropical cyclones, including those used in the RECR and STRA forecasts. For the North Indian Ocean, a single (total) forecast track is provided for 12-hour intervals to 72 hours.

(3) BPAC -- A program which generates 12- to 72-hour forecast positions based on blending the past motion of the tropical cyclone with the CLIM forecast positions. The blending routine gives less weight to persistence at each succeeding forecast interval.

(4) 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.

(5) HPAC -- 24- and 48-hour forecast positions are derived by merely connecting the mid-points of straight lines which connect these positions on the XTRP and CLIM tracks, respectively.

(6) CYCLOPS -- An updated version of the HATTRACK/MOHATT steering program which can provide geostrophic steering forecasts at the 1000-, 850-, 700-, 500-, 400-, and 200-mb levels. The program can be run in a modified (includes a 12-hour persistence bias) or unmodified mode applied to either analysis or prognostic fields. The program advects a point vortex on a preselected analysis and/or smoothed prognostic field at designated levels in six-hour time steps through 72 hours. In 1983, only the modified version, in the prognostic mode for the 500-mb level was verified; however, JTWC routinely uses many of the other levels and modes as operational forecast aids.

(7) OTCM -- (One-way Tropical Cyclone Model) A coarse-mesh, three-layer in the vertical, primitive equation model with a 205 km grid spacing over a 6400 x 4700 km domain. The model's fields are computed around a bogused, digitized cyclone vortex using FLENUMOCEANCEN Global Bands 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 hemispheric 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. In 1983, the OTCM was requested for each warning; and when computer resources were available, the OTCM forecast was normally available to the TDO within one hour of the request.

(8) NTCM -- (Nested Tropical Cyclone Model) A primitive equation model with similar properties as the OTCM. The NTCM differs by containing a finer scale "nested" grid, initializing on Global Bands analysis fields, not containing a (persistence) bias correction, and being a channel model which runs independent of FLENUMOCEANCEN prognostic fields (not requiring 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.

(9) TAPT -- A technique which utilizes upper-tropospheric wind fields to estimate the latitude of initial acceleration associated with the tropical cyclone's interaction with the mid-latitude westerly steering currents. Further, the technique provides speed of movement guidelines for duration and upper-limits, and insight on the probable path of the tropical cyclone, given a prevailing upper-wind pattern during the acceleration process.

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

(11) WIND RADIUS -- Following an analytic 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 intensity and radius of maximum winds have been produced to aid the forecaster in determining forecast wind radii.

(12) DVORAK -- An estimation of a tropical cyclone's current and 24-hour forecast intensity is made from interpretation of visual satellite imagery (Dvorak, 1973) and provided to the forecaster. These intensity estimates are used in conjunction with other intensity-related data and trends to forecast tropical cyclone intensity.

c. Testing and Results

A comparison of selected techniques is included in Table 4-6 for all western North Pacific tropical cyclones and in Table 4-7 for all North Indian Ocean tropical cyclones. In these tables, "X-AXIS" refers to techniques listed vertically. The example in Table 4-6 compares CY50 to OTCM, i.e. in the 273 cases available for a (homogeneous) comparison, the average vector error at 24 hours was 114 nm for CY50 and 105 for OTCM. The difference of 8 nm 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 4-6. 1983 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE WESTERN NORTH PACIFIC OCEAN

24-HOUR FORECAST ERRORS (NM)

24-	JTWC		RECR		STRA		TOTL		CY50		NTCM		OTCM		BPAC		CLIM		XTRP		HPAC	
JTWC	349	117																				
	117	0																				
RECR	310	113	310	126																		
	126	13	126	0																		
STRA	317	114	299	121	317	133																
	133	18	127	6	133	0																
TOTL	328	117	309	126	316	133	328	120														
	120	4	113	-11	117	-15	120	0														
CY50	321	117	293	126	296	132	307	119	321	114												
	114	-1	111	-14	111	-20	113	-5	114	0												
NTCM	274	119	239	122	248	137	257	122	251	109	274	161										
	161	42	157	35	154	17	161	39	164	54	161	0										
OTCM	288	118	258	124	260	131	271	119	273	114	232	162	289	107								
	104	-13	101	-23	100	-30	104	-13	105	-8	101	-59	107	0								
BPAC	323	117	292	126	298	133	309	121	301	114	255	161	273	103	323	128						
	128	11	124	-1	122	-10	126	6	128	14	127	-33	127	24	128	0						
CLIM	341	116	307	126	314	133	325	121	315	114	268	160	282	103	323	128	341	148				
	148	32	141	15	144	11	150	29	150	36	152	-7	147	44	148	20	148	0				
XTRP	341	117	305	126	311	134	322	121	316	115	268	161	282	104	321	128	337	149	341	112		
	112	-4	111	-14	108	-24	111	-9	112	-1	109	-50	113	9	113	-14	112	-36	112	0		
HPAC	337	117	305	126	311	134	322	121	313	114	264	160	280	103	321	128	337	149	337	112	337	111
	111	-4	106	-18	107	-25	111	-8	112	-1	113	-46	111	8	111	-16	111	-36	111	0	111	0

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

48-HOUR FORECAST ERRORS (NM)

48-	JTWC		RECR		STRA		TOTL		CY50		NTCM		OTCM		BPAC		CLIM		XTRP		HPAC	
JTWC	258	259																				
	259	0																				
RECR	233	252	235	236																		
	235	-17	236	0																		
STRA	238	259	228	230	240	284																
	282	23	274	44	284	0																
TOTL	246	261	235	236	240	284	248	253														
	252	-9	236	0	250	-34	253	0														
CY50	237	260	223	239	224	283	232	248	239	319												
	318	59	321	83	321	38	322	74	319	0												
NTCM	200	270	179	232	185	292	192	258	185	326	202	250										
	251	-19	240	7	240	-50	250	-7	252	-73	250	0										
OTCM	209	262	192	234	193	276	200	245	199	318	166	246	211	202								
	200	-60	193	-40	192	-83	201	-44	204	-113	201	-44	202	0								
BPAC	241	261	221	236	225	286	233	251	225	326	191	248	200	200	243	241						
	241	-19	230	-5	233	-52	237	-13	241	-83	240	-7	237	37	241	0						
CLIM	254	261	232	235	237	286	245	254	236	320	200	249	207	201	243	241	256	262				
	261	0	249	13	255	-30	262	9	263	-57	274	25	254	53	258	17	262	0				
XTRP	252	260	230	235	234	286	242	253	234	316	198	249	205	201	241	242	253	261	254	239		
	239	-21	234	0	237	-47	238	-14	242	-73	232	-17	240	39	242	0	240	-20	239	0		
HPAC	251	261	230	235	234	286	242	253	234	316	197	250	205	201	241	242	253	261	253	240	253	211
	210	-50	200	-34	205	-79	210	-42	212	-102	215	-33	208	7	210	-31	211	-49	211	-28	211	0

JTWC - OFFICIAL JTWC FORECAST
RECR - RECURVER (TYAN 78)
STRA - STRAIGHT (TYAN 78)
TOTL - TOTAL (TYAN 78)
CY50 - CYCLOPS MODIFIED 500 MB PROG
NTCM - NESTED TROPICAL CYCLONE MODEL
OTCM - ONE-WAY TROPICAL CYCLONE MODEL
BPAC - BLENDED PERSISTENCE AND CLIM
CLIM - CLIMATOLOGY
XTRP - 12-HOUR EXTRAPOLATION
HPAC - MEAN OF XTRP AND CLIM

72-HOUR FORECAST ERRORS (NM)

72-	JTWC		RECR		STRA		TOTL		CY50		NTCM		OTCM		BPAC		CLIM	
JTWC	187	405																
	405	0																
RECR	171	388	176	359														
	359	-28	359	0														
STRA	173	393	169	350	177	418												
	410	17	404	54	418	0												
TOTL	180	402	176	359	177	418	185	389										
	389	-13	366	7	385	-31	389	0										
CY50	171	393	167	364	164	402	172	368	176	522								
	526	132	533	169	520	117	530	161	522	0								
NTCM	149	412	137	348	139	438	146	404	139	540	152	336						
	335	-77	325	-22	316	-121	338	-66	336	-203	336	0						
OTCM	145	407	139	355	136	412	144	381	142	509	123	337	150	347				
	344	-62	336	-18	321	-90	343	-37	349	-160	346	9	347	0				
BPAC	171	405	163	361	163	417	171	382	163	532	142	332	140	346	176	359		
	354	-50	334	-26	337	-79	349	-32	350	-181	359	28	349	3	359	0		
CLIM	183	405	173	357	175	418	182	388	173	524	150	333	146	346	175	357	188	341
	340	-64	319	-37	332	-85	337	-50	333	-190	356	23	319	-25	334	-22	341	0

TABLE 4-7. 1983 ERROR STATISTICS FOR SELECTED OBJTECTIVE TECHNIQUES IN THE NORTH INDIAN OCEAN

24-HOUR FORECAST ERRORS (NM)

24-	JTWC		TOTL		NTCM		CY50		CY85		OTCM		BPAC		CLIM		XTRP		HPAC	
JTWC	10	113																		
	113	0																		
TOTL	9	114	9	109																
	109	-4	109	0																
NTCM	0	0	0	0	0	0														
	0	0	0	0	0	0														
CY50	8	102	8	101	0	0	8	273												
	273	171	273	172	0	0	273	0												
CY85	8	102	8	101	0	0	8	273	8	157										
	157	55	157	56			157	-115	157	0										
OTCM	6	130	6	118	0	0	5	266	5	174	6	165								
	165	35	165	47	0	0	147	-119	147	-26	165	0								
BPAC	9	114	9	109	0	0	8	273	8	157	6	165	9	97						
	97	-16	97	-11	0	0	95	-177	95	-61	112	-52	97	0						
CLIM	10	113	9	109	0	0	8	273	8	157	6	165	9	97	10	95				
	95	-18	97	-11	0	0	90	-182	90	-66	92	-72	97	0	95	0				
XTRP	10	113	9	109	0	0	8	273	8	157	6	165	9	97	10	95	10	135		
	135	21	130	20	0	0	120	-152	120	-37	142	-23	130	33	135	40	135	0		
HPAC	10	113	9	109	0	0	8	273	8	157	6	165	9	97	10	95	10	135	10	103
	103	-9	105	-3	0	0	96	-176	96	-60	112	-52	105	9	103	9	103	-31	103	0

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

48-HOUR FORECAST ERRORS (NM)

48-	JTWC		TOTL		NTCM		CY50		CY85		OTCM		BPAC		CLIM		XTRP		HPAC	
JTWC	2	153																		
	153	0																		
TOTL	2	153	2	84																
	84	-68	84	0																
NTCM	0	0	0	0	0	0														
	0	0	0	0	0	0														
CY50	2	153	2	84	0	0	2	505												
	505	353	505	421	0	0	505	0												
CY85	2	153	2	84	0	0	2	505	2	435										
	435	282	435	351	0	0	435	-70	435	0										
OTCM	2	153	2	84	0	0	2	505	2	435	2	304								
	304	152	304	220	0	0	304	-200	304	-129	304	0								
BPAC	2	153	2	84	0	0	2	505	2	435	2	304	2	113						
	113	-39	113	29	0	0	113	-391	113	-321	113	-191	113	0						
CLIM	2	153	2	84	0	0	2	505	2	435	2	304	2	113	2	273				
	273	120	273	189	0	0	273	-231	273	-161	273	-30	273	160	273	0				
XTRP	2	153	2	84	0	0	2	505	2	435	2	304	2	113	2	273	2	145		
	145	-7	145	61	0	0	145	-360	145	-289	145	-159	145	32	145	-127	145	0		
HPAC	2	153	2	84	0	0	2	505	2	435	2	304	2	113	2	273	2	145	2	205
	205	52	205	120	0	0	205	-300	205	-229	205	-99	205	92	205	-67	205	60	205	0

JTWC - OFFICIAL JTWC FORECAST
TOTL - ANALOG (TYAN 78)
NTCM - NESTED TROPICAL CYCLONE MODEL
CY85 - CYCLOPS MODIFIED 850 MB PROG
CY50 - CYCLOPS MODIFIED 500 MB PROG
OTCM - ONE-WAY TROPICAL CYCLONE MODEL
BPAC - BLENDED PERSISTENCE AND CLIM
CLIM - CLIMATOLOGY
XTRP - 12-HOUR EXTRAPOLATION
HPAC - MEAN OF XTRP AND CLIM