5. SUMMARY OF FORECAST VERIFICATION

5.1 ANNUAL FORECAST VERIFICATION

5.1.1 TRACK FORECAST VERIFICATION

5.1.1.1 NORTHWEST PACIFIC OCEAN — Verification of warning positions at initial, 24-, 48- and 72-hour forecast periods was made against the final best track. The (scalar) track forecast, along-track and cross-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 as appropriate. Table 5-2 includes mean along-track and cross-track forecast errors for 1978-1990. The frequency distributions of errors for warning positions and 24-hour, 48-hour, and 72-hour forecasts are in Figures 5-2A through 5-2D, respectively. A comparison of the annual mean track 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 track forecast errors for 1990 as compared to the previous twenty-one years are illustrated graphically in Figure 5-3.

5.1.1.2 NORTH INDIAN OCEAN — The positions given for warning times and those at the 24-, 48-, and 72-hour forecast times were verified for tropical cyclones in the North Indian Ocean by the same methods used for the Northwest Pacific. Table 5-4 summarizes the initial, track forecast, along-track and cross-track errors for the North Indian Ocean. Forecast errors are plotted in Figure 5-4 (72-hour forecast errors were evaluated for the first time in 1979). There were no verifying 72-hour forecasts in 1983 and 1985. Table 5-5 contains a summary of the annual mean forecast errors for each year.

5.1.1.3 SOUTH PACIFIC AND SOUTH INDIAN OCEANS — The positions given for warning times and those at the 24- and 48-hour forecast times were verified for tropical cyclones in the Southern Hemisphere by the same methods used for the western North Pacific. Table 5-6A is the summary of the initial, track forecast, along-track and cross-track errors for the Southern Hemisphere. Table 5-6B shows the number of warnings verified at each forecast period. Forecast errors are plotted in Figure 5-5. Table 5-7 contains a summary of the annual mean forecast errors since 1981, when JTWC first began warning in the Southern Hemisphere.

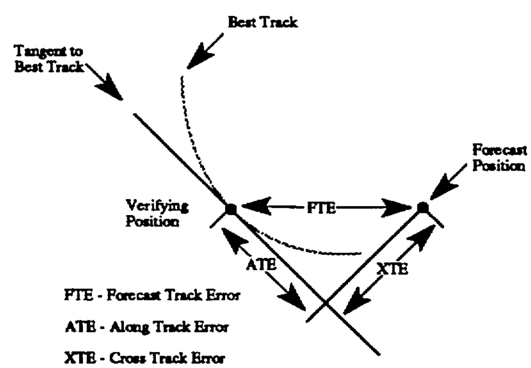

Figure 5-1. Definition of cross-track error (XTE), along-track error (ATE) and forecast track error (FTE). In this example, the XTE is positive (to the right of the best track) and the ATE is negative (behind or slower than the best track).

TABLE 5-1A **INITIAL POSITION ERRORS (NM)**
NORTHWEST PACIFIC OCEAN
1990 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE		ERROR (NM)	NUMBER OF WARNINGS
(01W)	TY Koryn	35	19
(02W)	TS Lewis	16	16
(03W)	TY Marian	12	17
(04W)	TD 04W	79	4
(05W)	TS Nathan	27	14
(06W)	TY Ofelia	23	31
(07W)	TY Percy	17	36
(08W)	TS Robyn	19	18
(09W)	TY Steve	12	31
(10W)	TS Tasha	20	12
(11W)	TY Vernon	17	39
(12W)	TY Winona	27	20
(01C)	TS Aka	45	32
(13W)	TY Yancy	26	31
(14W)	TY Zola	24	23
(15W)	TY Abe	22	36
(16W)	TY Becky	13	25
(17W)	TY Dot	27	25
(18W)	TS Cecil	29	5
(19W)	TY Ed	17	40
(20W)	STY Flo	13	31
(21W)	TY Gene	15	30
(22W)	TY Hattie	21	31
(23W)	TS Ira	33	6
(24W)	TS Jeana	78	6
(25W)	TY Kyle	17	28
(26W)	TS Lola	8	7
(27W)	STY Mike	17	43
(28W)	TS Nell	31	7
(29W)	STY Page	24	45
(30W)	STY Owen	16	48
(31W)	TY Russ	20	38
		Mean: 21	**Total:** 794

TABLE 5-1B

24-HOUR FORECAST ERRORS (NM)
NORTHWEST PACIFIC OCEAN
1990 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE			FORECAST ERROR (NM)	ALONG-TRACK ERROR MEAN*	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN*	CROSS-TRACK ERROR MEDIAN	SAMPLE SIZE
(01W)	TY	Koryn	129	72	-50	95	-48	14
(02W)	TS	Lewis	146	97	57	89	-53	8
(03W)	TY	Marian	117	76	-96	75	-75	13
(04W)	TD	04W	173	139	-83	101	-80	3
(05W)	TS	Nathan	179	110	-84	101	13	10
(06W)	TY	Ofelia	125	73	-44	78	-25	28
(07W)	TY	Percy	113	72	-34	66	7	32
(08W)	TS	Robyn	94	79	-81	43	-35	14
(09W)	TY	Steve	114	68	-42	84	-67	27
(10W)	TS	Tasha	136	102	-95	78	-71	11
(11W)	TY	Vernon	73	41	-12	50	-33	34
(12W)	TY	Winona	133	113	-117	59	26	16
(01C)	TS	Aka	98	75	-64	50	-36	24
(13W)	TY	Yancy	87	57	-7	54	1	26
(14W)	TY	Zola	145	122	-113	56	28	19
(15W)	TY	Abe	102	74	-48	55	-14	32
(16W)	TY	Becky	98	74	-40	49	12	21
(17W)	TY	Dot	80	60	-36	40	-5	18
(18W)	TS	Cecil	40	9	9	39	-39	1
(19W)	TY	Ed	82	55	-28	45	33	36
(20W)	STY	Flo	78	50	-31	49	-15	27
(21W)	TY	Gene	53	32	10	39	-35	25
(22W)	TY	Hattie	79	54	-36	42	-28	26
(23W)	TS	Ira	64	46	2	31	24	3
(24W)	TS	Jeana	151	89	90	100	-100	2
(25W)	TY	Kyle	98	62	-23	60	-10	23
(26W)	TS	Lola	65	62	-71	18	16	3
(27W)	STY	Mike	120	81	-61	74	2	39
(28W)	TS	Nell	104	91	18	35	-11	3
(29W)	STY	Page	134	102	-62	67	-17	41
(30W)	STY	Owen	102	67	-42	65	26	45
(31W)	TY	Russ	102	84	-60	43	-7	34
		Mean:	103	72	-44	60	-12	
							Total:	658

* The mean was computed from absolute values.

NOTE:

1. The mean is the sum of all the values divided by the number of observations.
2. The median is the middle value of the sample.
3. The along-track error component is how far the warning position was displaced ahead or behind the best track position. The sample consists of two parts: The mean (distance) and the median (negative values were behind track or slow, and positive values were ahead of track or fast).
4. The cross-track error component is how far the warning position was displaced to the left or right of the best track position. The sample consists of two parts: The mean (distance) and the median (negative values were left of track and positive values were right of track).

TABLE 5-1C

48-HOUR FORECAST ERRORS (NM)
NORTHWEST PACIFIC OCEAN
1990 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE			FORECAST ERROR (NM)	ALONG-TRACK ERROR MEAN*	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN*	CROSS-TRACK ERROR MEDIAN	SAMPLE SIZE
(01W)	TY	Koryn	261	164	-187	175	-168	10
(02W)	TS	Lewis	245	141	35	176	104	8
(03W)	TY	Marian	315	100	-312	287	-97	9
(04W)	TD	04W	**	**	**	**	**	**
(05W)	TS	Nathan	255	222	-125	100	-118	3
(06W)	TY	Ofelia	255	183	-153	132	-112	24
(07W)	TY	Percy	229	137	-84	144	69	27
(08W)	TS	Robyn	289	268	-278	91	-81	10
(09W)	TY	Steve	291	146	-112	238	-261	23
(10W)	TS	Tasha	239	183	-236	133	-129	7
(11W)	TY	Vernon	152	90	-27	94	-51	30
(12W)	TY	Winona	246	224	-214	88	17	10
(01C)	TS	Aka	189	165	-148	71	32	20
(13W)	TY	Yancy	98	50	-4	73	32	22
(14W)	TY	Zola	282	210	-196	176	141	13
(15W)	TY	Abe	210	128	-53	128	35	28
(16W)	TY	Becky	159	128	-95	75	31	17
(17W)	TY	Dot	178	155	-135	69	-16	14
(18W)	TS	Cecil	**	**	**	**	**	**
(19W)	TY	Ed	178	122	-81	111	99	32
(20W)	STY	Flo	137	98	-37	86	-71	23
(21W)	TY	Gene	107	84	34	47	-25	21
(22W)	TY	Hattie	140	117	-97	66	-58	22
(23W)	TS	Ira	**	**	**	**	**	**
(24W)	TS	Jeana	**	**	**	**	**	**
(25W)	TY	Kyle	166	110	-16	103	-75	19
(26W)	TS	Lola	**	**	**	**	**	**
(27W)	STY	Mike	221	163	-128	110	77	28
(28W)	TS	Nell	**	**	**	**	**	**
(29W)	STY	Page	280	224	-142	126	-37	35
(30W)	STY	Owen	172	126	-76	97	58	40
(31W)	TY	Russ	219	193	-93	72	54	30
		Mean:	203	148	-97	110	8	
							Total:	525

* The mean was computed from absolute values.
** Forecasts were not issued or did not verify.

NOTE:
1. Negative median along-track value denotes behind-track or slow.
2. Negative median cross-track value denotes left of track.

See Table 5-1B for explanations of the terms mean, median, and along-track and cross-track error.

TABLE 5-1D

72-HOUR FORECAST ERRORS (NM)
NORTHWEST PACIFIC OCEAN
1990 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE	FORECAST ERROR (NM)	ALONG-TRACK ERROR MEAN*	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN*	CROSS-TRACK ERROR MEDIAN	SAMPLE SIZE
(01W) TY Koryn	609	493	-459	270	-276	6
(02W) TS Lewis	517	185	-94	446	474	6
(03W) TY Marian	657	650	-653	85	47	5
(04W) TD 04W	**	**	**	**	**	**
(05W) TS Nathan	330	324	324	61	61	1
(06W) TY Ofelia	382	299	-263	165	-128	19
(07W) TY Percy	340	235	-18	213	142	26
(08W) TS Robyn	489	471	-453	93	-65	6
(09W) TY Steve	556	306	-376	437	-388	19
(10W) TS Tasha	278	212	-191	178	-188	3
(11W) TY Vernon	233	149	-15	143	-68	26
(12W) TY Winona	424	410	-438	87	48	6
(01C) TS Aka	314	299	-253	72	54	16
(13W) TY Yancy	108	65	-16	75	41	18
(14W) TY Zola	512	311	-322	358	367	9
(15W) TY Abe	303	167	-85	206	90	24
(16W) TY Becky	216	156	-89	129	110	13
(17W) TY Dot	255	245	-266	57	-66	10
(18W) TS Cecil	**	**	**	**	**	**
(19W) TY Ed	304	208	-99	203	225	28
(20W) STY Flo	220	166	-36	119	-124	19
(21W) TY Gene	195	155	26	97	-106	17
(22W) TY Hattie	226	211	-190	75	-28	18
(23W) TS Ira	**	**	**	**	**	**
(24W) TS Jeana	**	**	**	**	**	**
(25W) TY Kyle	196	97	-42	154	-137	15
(26W) TS Lola	**	**	**	**	**	**
(27W) STY Mike	324	216	-177	192	197	27
(28W) TS Nell	**	**	**	**	**	**
(29W) STY Page	414	382	-191	125	-58	31
(30W) STY Owen	220	148	-78	136	107	38
(31W) TY Russ	287	231	-115	144	88	26
Mean:	310	225	-143	168	24	
					Total:	432

* The mean was computed from absolute values.
** Forecasts were not issued or did not verify.

NOTE:
1. Negative median along-track value denotes behind-track or slow.
2. Negative median cross-track value denotes left of track.

See Table 5-1B for explanations of the terms mean, median, and along-track and cross-track error.

TABLE 5-2. JTWC ANNUAL INITIAL POSITION AND FORECAST POSITION ERRORS (NM) 1978-1990 FOR THE NORTHWEST PACIFIC OCEAN

YEAR	NUMBER OF WARNINGS	INITIAL POSITION	NUMBER OF FORECASTS	24-HOUR TRACK	24-HOUR ALONG	24-HOUR CROSS	NUMBER OF FORECASTS	48-HOUR TRACK	48-HOUR ALONG	48-HOUR CROSS	NUMBER OF FORECASTS	72-HOUR TRACK	72-HOUR ALONG	72-HOUR CROSS
1978	696	21	556	126	87	71	420	274	194	151	295	411	296	218
1979	695	25	589	125	81	76	469	227	146	138	366	316	214	182
1980	590	28	491	127	86	76	369	244	165	147	267	391	266	230
1981	584	25	466	124	80	77	348	221	146	131	246	334	206	219
1972	786	19	666	113	74	70	532	238	162	142	425	342	223	211
1983	445	16	342	117	76	73	253	260	169	164	184	407	259	263
1984	611	22	492	117	84	64	378	232	163	131	286	363	238	216
1985	592	18	477	117	80	68	336	231	153	138	241	367	230	227
1986	743	21	645	126	85	70	535	261	183	151	412	394	276	227
1987	657	18	563	107	71	64	465	204	134	127	389	303	198	186
1988	465	23	373	114	85	58	262	216	170	103	183	315	244	159
1989	710	20	625	120	83	69	481	231	162	127	363	350	265	177
TOTALS:	7574		6285				4848				3657			
AVERAGE 78-89:	631	21	524	120	81	70	404	237	162	138	305	355	242	211
1990	794	21	658	103	72	60	525	203	148	110	432	310	225	168
TOTALS:	8368		6943				5373				4089			
AVERAGE 78-90:	644	21	534	118	80	69	413	234	161	135	314	354	242	206

SOURCES: 1978-85 24-, 48-, 72-hour errors are from Tsui and Miller (1986)
Initial position and 1986-1990 errors are from the ATCR

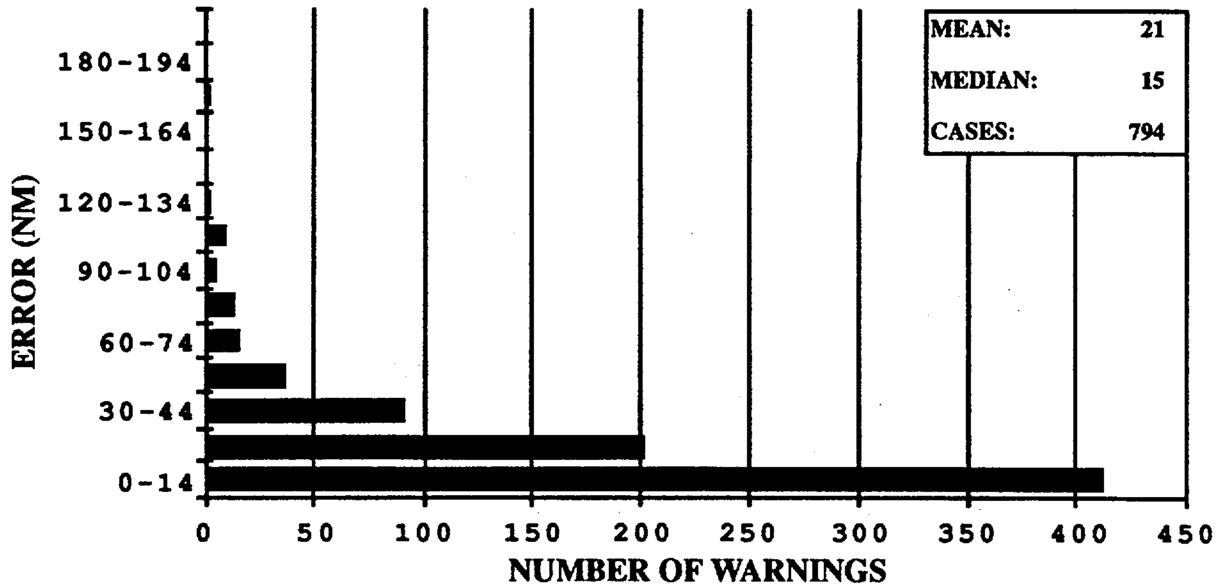

Figure 5-2A. Frequency distribution of initial position errors (15 nm increments) for the Northwest Pacific in 1990.

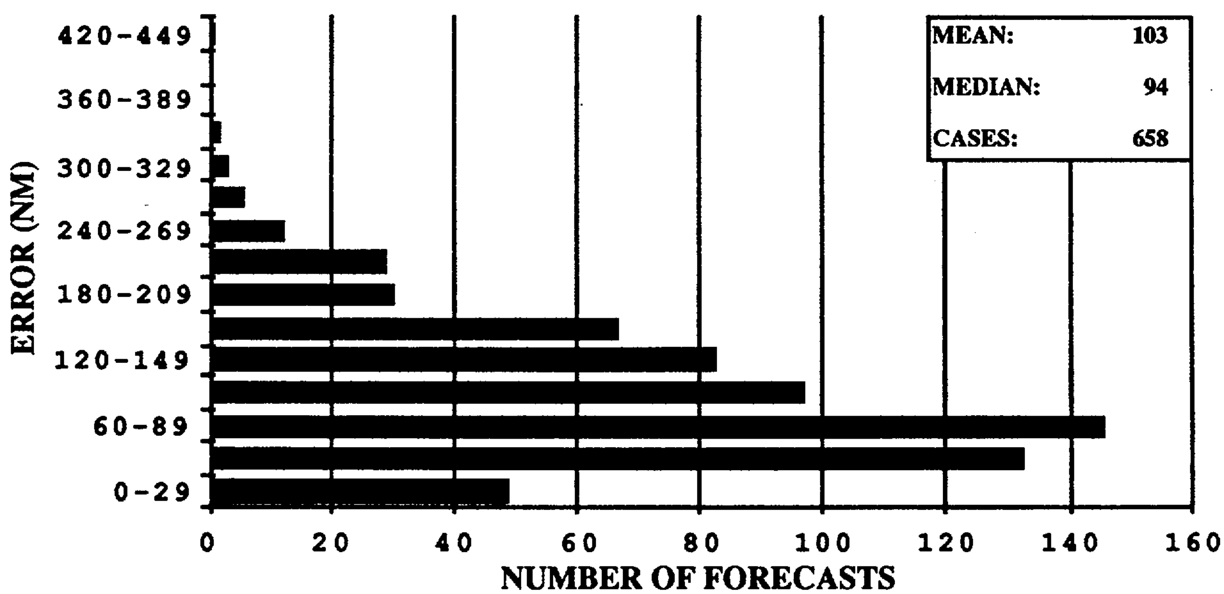

Figure 5-2B. Frequency distribution of 24-hour forecast errors (30 nm increments) for the Northwest Pacific in 1990.

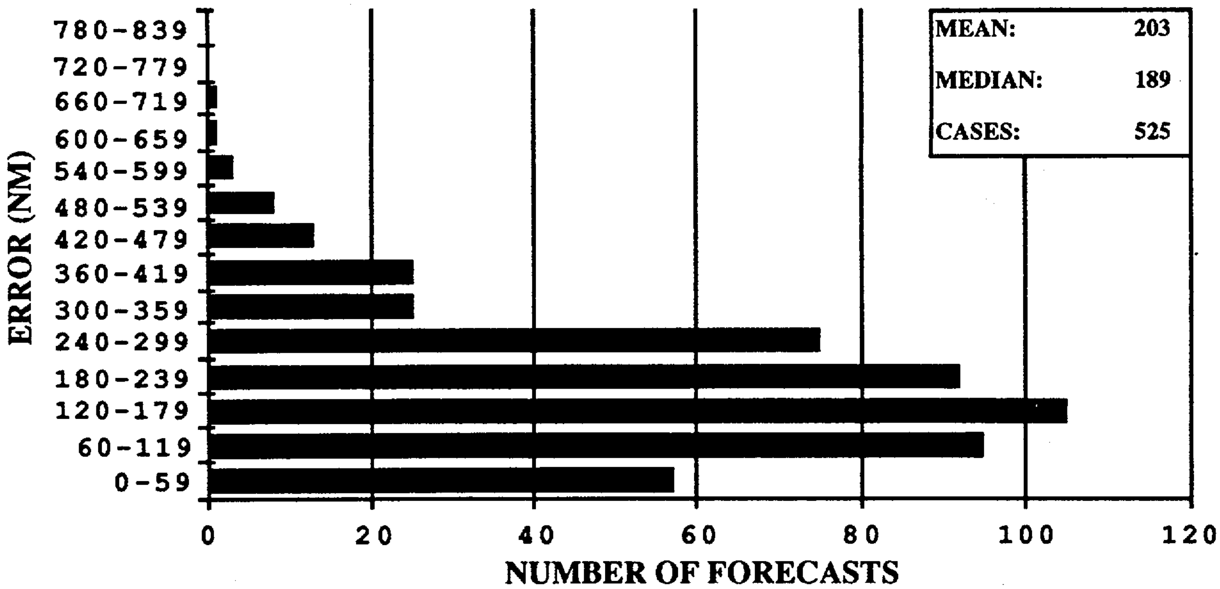

Figure 5-2C. Frequency distribution of 48-hour forecast errors (60 nm increments) for the Northwest Pacific in 1989.

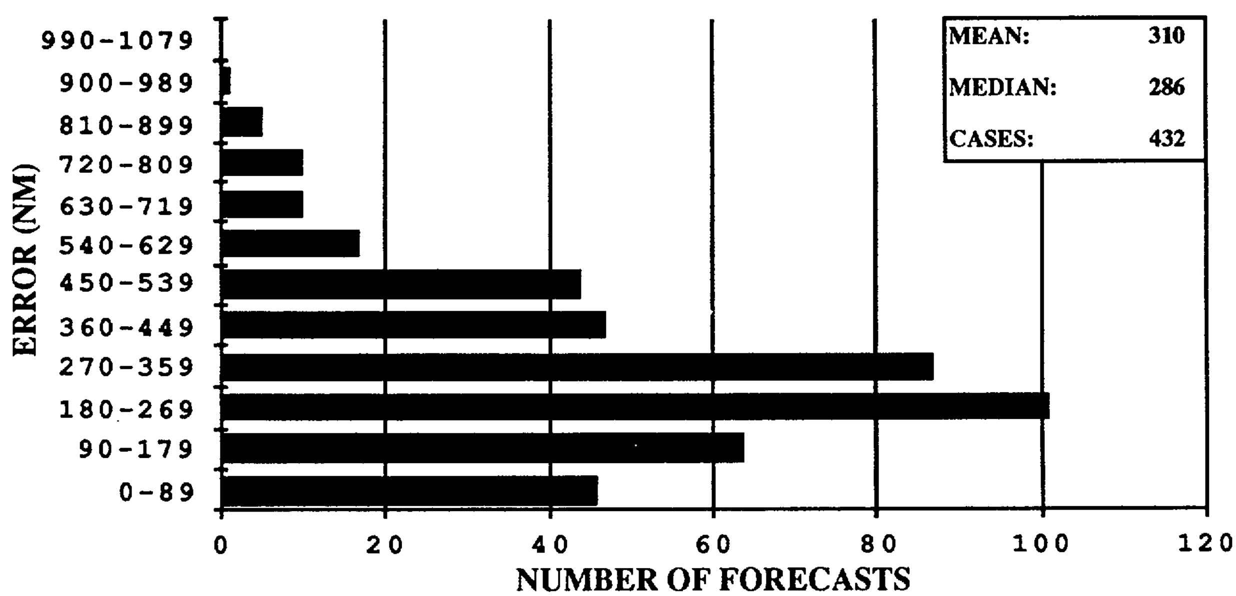

Figure 5-2D. Frequency distribution of 72-hour forecast errors (90 nm increments) for the Northwest Pacific in 1989.

TABLE 5-3

ANNUAL MEAN FORECAST ERRORS (NM)
NORTHWEST PACIFIC OCEAN

YEAR	24-HOUR ALL	24-HOUR TYPHOONS*	48-HOUR ALL	48-HOUR TYPHOONS*	72-HOUR ALL	72-HOUR TYPHOONS*
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
1987	107	101	204	211	303	318
1988	114	107	216	222	315	327
1989	120	107	231	214	350	325
1990	103	98	203	191	310	299

* Forecasts were verified when the tropical cyclone intensities were at least 35 kt (18 m/sec).
** Forecast positions north of 35 degrees north latitude were not verified.

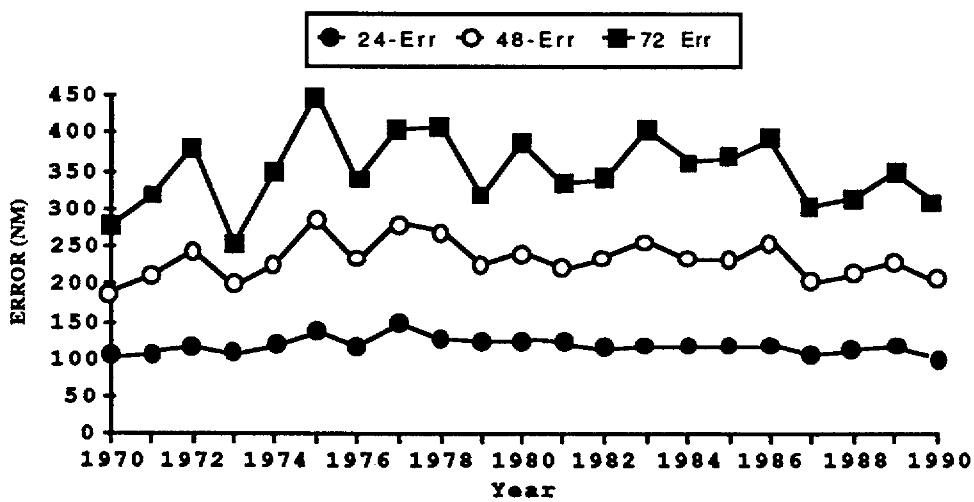

Figure 5-3. Annual mean forecast errors (nm) for all significant tropical cyclones in the Northwest Pacific Ocean.

TABLE 5-4

**INITIAL POSITION AND FORECAST ERRORS (NM)
FOR THE NORTH INDIAN OCEAN
1990 SIGNIFICANT TROPICAL CYCLONES**

TROPICAL CYCLONE	INITIAL POSITION ERROR (NM)	NUMBER OF WARNINGS
TC 01B	66	2
TC 02B	21	24
TC 03B	36	6
TC 04B	42	14
	Mean: 31	**Total:** 46

24-HOUR FORECASTS

TROPICAL CYCLONE	FCST ERROR	ALONG-TRACK ERROR MEAN*	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN	CROSS-TRACK ERROR MEDIAN	SAMPLE SIZE
TC 01B	**	**	**	**	**	**
TC 02B	81	62	-21	41	-7	22
TC 03B	156	142	144	61	-2	4
TC 04B	123	111	-18	41	-33	10
Mean:	101	85	-16	43	-17	**Total:** 36

48-HOUR FORECASTS

TROPICAL CYCLONE	FCST ERROR	ALONG-TRACK ERROR MEAN*	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN	CROSS-TRACK ERROR MEDIAN	SAMPLE SIZE
TC 01B	**	**	**	**	**	**
TC 02B	116	86	-43	70	-38	17
TC 03B	**	**	**	**	**	**
TC 04B	221	192	-128	57	-30	7
Mean:	146	117	-68	67	-44	**Total:** 24

72-HOUR FORECASTS

TROPICAL CYCLONE	FCST ERROR	ALONG-TRACK ERROR MEAN*	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN	CROSS-TRACK ERROR MEDIAN	SAMPLE SIZE
TC 01B	**	**	**	**	**	**
TC 02B	162	97	-97	117	-89	14
TC 03B	**	**	**	**	**	**
TC 04B	292	286	-218	44	-45	3
Mean:	185	130	-120	104	-82	**Total:** 17

* The mean was computed from absolute values.
** Forecasts were not issued or did not verify.

NOTE:
1. Negative median along-track value denotes behind-track or slow.
2. Negative median cross-track value denotes left of track.

See Table 5-1B for explanations of the terms mean, median, and along-track and cross-track error.

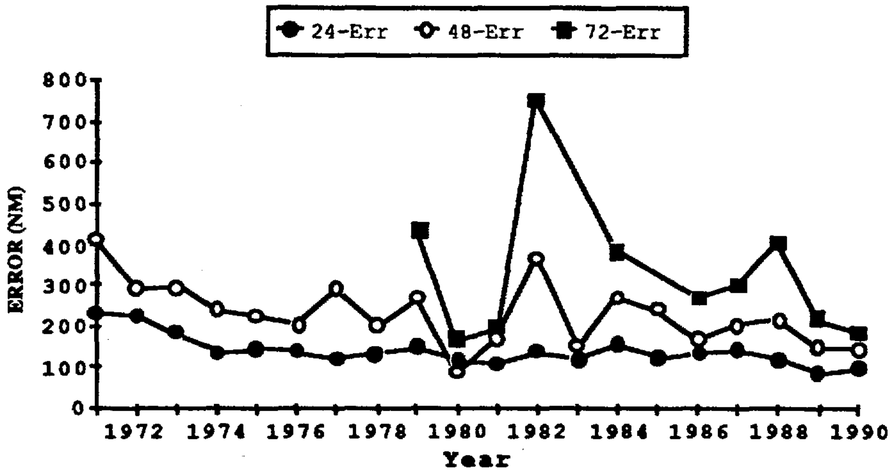

Figure 5-4. Annual mean forecast errors (nm) for all significant tropical cyclones in the North Indian Ocean.

TABLE 5-5

ANNUAL MEAN FORECAST ERRORS (NM)
FOR THE NORTH INDIAN OCEAN

	24-HOUR		48-HOUR		72-HOUR	
YEAR	FORECAST	RIGHT-ANGLE	FORECAST	RIGHT-ANGLE	FORECAST	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	53	168	80	269	180
1987***	144	100	205	140	305	188
1988***	120	63	219	176	409	303
1989***	84	50	146	86	216	111
1990***	101	43	146	67	185	104

* The Western Bay of Bengal and Arabian Sea were not included in the JTWC area of responsibility until 1975.

** The technique for calculating right-angle error was revised in 1981. therefore, a direct comparison in right-angle error statistics cannot be made between errors computed before 1981 and those computed since 1981.

*** In 1986, right-angle error was replaced by cross-track error.

See Table 5-1B for the definition of cross-track error.

TABLE 5-6A

INITIAL POSITION AND FORECAST ERRORS (NM) FOR THE SOUTH PACIFIC AND SOUTH INDIAN OCEANS 1990 SIGNIFICANT TROPICAL CYCLONES (1 JULY 1989 - 30 JUNE 1990)

TROPICAL CYCLONE	INITIAL POSIT ERROR	24-HR FCST ERROR	24-HR ALONG-TRACK MEAN*	24-HR ALONG-TRACK MEDIAN	24-HR CROSS-TRACK MEAN*	24-HR CROSS-TRACK MEDIAN	48-HR FCST ERROR	48-HR ALONG-TRACK MEAN*	48-HR ALONG-TRACK MEDIAN	48-HR CROSS-TRACK MEAN*	48-HR CROSS-TRACK MEDIAN
TC 01S	31	56	48	30	30	30	**	**	**	**	**
TC 02S	50	182	149	-34	74	22	453	345	-345	294	294
TC 03S	25	110	94	-92	50	37	323	306	-306	105	-105
TC 04S	26	95	16	-2	94	-73	215	77	52	200	-173
TC 05S	16	177	125	-90	120	-90	303	176	-176	247	-247
TC 06S	25	118	60	16	96	-46	295	60	-20	282	-179
TC 07P	13	106	69	-47	59	35	183	168	-168	72	-72
TC 08S	19	96	61	-28	63	-26	199	123	-56	140	-48
TC 09S	29	143	97	-68	87	36	329	281	-291	152	126
TC 10S	27	93	59	-33	66	-29	168	105	-28	100	-37
TC 11S	21	152	84	18	110	57	423	362	-443	184	212
TC 12P	48	228	189	-167	109	-10	436	202	-184	342	62
TC 13P	25	110	90	-3	51	6	203	92	-34	164	12
TC 14S	21	139	104	-96	73	46	294	233	-212	130	-62
TC 15S	69	171	127	-103	99	38	360	208	-214	240	72
TC 16P	33	169	121	-9	92	-108	297	252	-184	122	-111
TC 17S	15	154	117	-84	65	-4	213	132	-90	144	-107
TC 18S	29	153	106	-52	79	27	285	202	-51	144	134
TC 19P	39	91	84	-52	25	-5	242	230	-230	76	76
TC 20S	22	83	75	-39	30	15	59	7	8	58	59
TC 21P	28	238	193	-182	90	15	511	280	-239	389	393
TC 22S	27	100	74	-12	50	4	155	123	-137	84	71
TC 23S	28	105	72	-24	66	10	150	118	-6	73	51
TC 24S	17	101	84	-63	45	4	197	181	-150	63	42
TC 25P	17	120	84	-62	67	12	233	155	-106	137	-67
TC 26P	23	218	186	-152	92	110	453	367	-367	266	266
TC 27S	26	83	54	-54	62	40	**	**	**	**	**
TC 28S	55	402	235	235	326	-326	**	**	**	**	**
TC 29S	29	126	60	-25	102	-58	234	117	-40	170	-134
MEAN	**27**	**143**	**105**	**-44**	**74**	**-8**	**263**	**178**	**-138**	**152**	**18**

* The mean was computed from absolute values.
** Not enough warnings were issued to verify the forecast.

NOTE:

1. Negative median along-track value denotes behind-track or slow.
2. Negative median cross-track value denotes left-of-track.

See Table 5-1B for explanations of the mean, median, and along-track and cross-track error.

TABLE 5-6B

NUMBER OF WARNINGS
SOUTH PACIFIC AND SOUTH INDIAN OCEAN
(1 JUL 1989 - 30 JUN 1990)

TROPICAL CYCLONE	INITIAL POSITION	24-HOUR FORECAST	48-HOUR FORECAST
TC 01S ----	4	2	0
TC 02S ----	6	4	1
TC 03S ----	5	3	1
TC 04S ----	4	3	3
TC 05S ----	8	4	1
TC 06S Pedro	9	8	6
TC 07P Felicity	6	4	1
TC 08S Alibera	31	30	28
TC 09S Baomavo	13	12	10
TC 10S Sam	11	10	9
TC 11S Tina	6	5	3
TC 12P Nancy	8	6	6
TC 13P Ofa*	17	16	16
TC 14S Cezera	16	15	13
TC 15S Dety	12	10	8
TC 16P Peni*	9	7	5
TC 17S Vincent	11	9	7
TC 18S Edisaona	14	13	11
TC 19P Greg	5	3	1
TC 20S Walter	6	4	2
TC 21P Hilda	7	6	4
TC 22S Felana	13	9	6
TC 23S Gregoara	18	17	15
TC 24S Alex	17	15	13
TC 25P Ivor	14	13	11
TC 26P Rae	4	3	1
TC 27P ----	3	2	0
TC 28S Bessi	3	1	0
TC 29S Ikonjo	18	17	16
Total:	**298**	**251**	**198**

* Naval Western Oceanography Center Pearl Harbor, Hawaii, forecast systems.

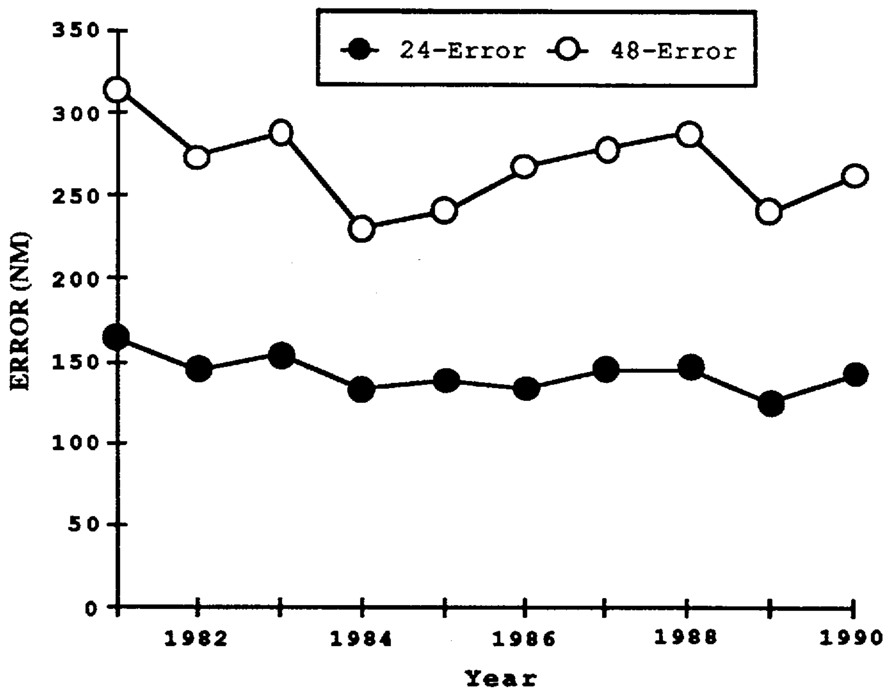

Figure 5-5. Annual mean forecast errors (nm) for all significant tropical cyclones in the South Pacific and South Indian Oceans.

Table 5-7 **ANNUAL MEAN FORECAST ERRORS (NM)**
SOUTH PACIFIC AND SOUTH INDIAN OCEANS

Year	24-Hour Forecast	24-Hour Right-Angle	48-Hour Forecast	48-Hour Right-Angle
1981	165	119	315	216
1982	144	91	274	174
1983	154	84	288	150
1984	133	73	231	124
1985	138	78	242	133
1986*	133	**	268	**
1987*	145	90	280	161
1988*	146	83	290	144
1989*	125	73	242	137
1990*	142	74	263	152

* In 1986, Right-angle error was replaced by cross-track error.
** Data not available
See Table 5-1B for an explanation of cross-track error.

5.1.2 INTENSITY — The mean intensity forecast errors for each Northwest Pacific tropical cyclone are presented in Table 5-8. A comparison of the annual mean intensity forecast errors in the Northwest Pacific for the past twenty years is shown in Figure 5-6. Table 5-9 summarizes intensity forecast errors for the North Indian Ocean. Table 5-10 contains a summary of intensity forecast errors for each tropical cyclone in the Southern Hemisphere.

5.2 COMPARISON OF OBJECTIVE TECHNIQUES

5.2.1 GENERAL — JTWC uses a variety of objective techniques as guidance in the warning development process. Multiple techniques are required, because each technique has particular strengths and weaknesses which vary by basin, time of year, synoptic situation and forecast period.

The accuracy of objective aid forecasts depends on both the specified position and the past motion of the tropical cyclone as determined by the working best track. For nearly a decade, standard procedure was to request objective technique forecasts based on the 6-hour old working best track position. For example, the 0600Z JTWC forecast was based on objective technique forecasts initialized with the 0000Z position. This approach avoided the use of the generally less accurate extrapolated position that would coincide with the upcoming warning. Thus, objective techniques that incorporate past storm motion (persistence) were better initialized, and lower 24-hour forecasts errors generally resulted. However, recent analysis based on the work of DeMaria (1985) indicated that an objective technique forecast based on a 6-hour old best track position can differ significantly at 72-hours (up to 500 nm (925 km)) from a forecast by the same technique initialized at the correct warning position. This is due to the tendency for tracks to diverge in a spatially and temporally variable environment, especially when significant turning (e.g., recurvature) is anticipated.

In July 1990, JTWC began initializing objective techniques using the extrapolated warning position. Although a small increase in 24-hour forecast error was noted, a significant improvement in official forecast errors at 48- and 72-hours resulted. Not only did JTWC's absolute forecast error decrease, but also JTWC's forecast standing relative to the objective techniques improved significantly for the second half of 1990 in the Northwest Pacific compared to the first half. The improvement in forecast accuracy, particularly at the 72-hour point, outweighed the degradation at 24-hours. Thus, JTWC procedures have been modified to use the extrapolated warning position when computing objective technique forecasts. Current best track procedures emphasize the importance of conservatively integrating new fixes with 12-hr persistence to minimize degradation of 24-hour forecast accuracy due to "chasing" the fixes.

Two existing objective techniques have been retired from service. The CYCLone OPerational Steering (CYCLOPS) model, which is based on an antiquated geostrophic steering concept, was documented by Tsui and Miller (1986) as JTWC's least accurate aid. CYCLOPS performance has also shown further deterioration with the introduction of the NOGAPS 3.2 in August 1989. Since more accurate windfield-based steering models are presently available, an attempt to update and fix CYCLOPS was not considered worthwhile. The CYCLOPS Objective Steering Model Output Statistics (COSMOS) model, which was intended to use CYCLOPS forecasts generated from the Primitive Equation Global Model, has also been retired. This decision was motivated by serious degradations in the performance of COSMOS after the switch to NOGAPS 3.2, and by the ineffectiveness that would result from updating CYCLOPS and recomputing COSMOS regression coefficients.

5.2.2 DESCRIPTION OF OBJECTIVE TECHNIQUES — Unless stated otherwise, all the objective techniques discussed below run in all basins covered by JTWC's AOR and provide forecast positions at 24-, 48-, and 72-hours unless the technique aborts prematurely during

TABLE 5-8 **ANNUAL MEAN INTENSITY FORECAST ERRORS (KT) NORTHWEST PACIFIC OCEAN**

TROPICAL CYCLONE	MAXIMUM INTENSITY	24-HOUR FORECAST ERROR KT (M/SEC)	48-HOUR FORECAST ERROR KT (M/SEC)	72-HOUR FORECAST ERROR KT (M/SEC)
(01W) TY Koryn	75 (39)	8 (4)	14 (7)	38 (20)
(02W) TS Lewis	35 (18)	10 (5)	17 (9)	14 (7)
(03W) TY Marian	90 (46)	14 (7)	15 (8)	25 (13)
(04W) TD 04W	30 (15)	10 (5)	*	*
(05W) TS Nathan	55 (28)	8 (4)	7 (4)	15 (8)
(06W) TY Ofelia	90 (46)	10 (5)	15 (8)	16 (8)
(07W) TY Percy	115 (59)	14 (7)	17 (9)	19 (10)
(08W) TS Robyn	45 (23)	3 (2)	8 (4)	22 (11)
(09W) TY Steve	115 (59)	9 (5)	18 (9)	21 (11)
(10W) TS Tasha	55 (28)	6 (3)	14 (7)	17 (9)
(11W) TY Vernon	95 (49)	8 (4)	10 (5)	8 (4)
(12W) TY Winona	65 (33)	4 (2)	4 (2)	16 (8)
(01C) TS Aka	45 (23)	9 (5)	15 (8)	20 (10)
(13W) TY Yancy	90 (46)	9 (5)	10 (5)	9 (5)
(14W) TY Zola	100 (51)	8 (4)	13 (7)	14 (7)
(15W) TY Abe	90 (46)	8 (4)	20 (10)	27 (14)
(16W) TY Becky	70 (36)	8 (4)	11 (6)	15 (8)
(17W) TY Dot	80 (41)	10 (5)	14 (7)	8 (4)
(18W) TS Cecil	45 (23)	20 (10)	*	*
(19W) TY Ed	90 (46)	6 (3)	11 (6)	16 (8)
(20W) STY Flo	145 (75)	13 (7)	23 (12)	28 (14)
(21W) TY Gene	80 (41)	8 (4)	11 (6)	5 (3)
(22W) TY Hattie	90 (46)	9 (5)	21 (11)	28 (14)
(23W) TS Ira	35 (18)	10 (5)	*	*
(24W) TS Jeana	35 (18)	12 (6)	*	*
(25W) TY Kyle	90 (46)	4 (2)	9 (5)	8 (4)
(26W) TS Lola	40 (21)	12 (6)	*	*
(27W) STY Mike	150 (77)	17 (9)	23 (12)	27 (14)
(28W) TS Nell	50 (26)	12 (6)	*	*
(29W) STY Page	140 (72)	10 (5)	18 (9)	24 (12)
(30W) STY Owen	140 (72)	18 (9)	32 (16)	44 (23)
(31W) TY Russ	125 (64)	9 (5)	11 (6)	10 (5)
	Average:	**10 (5)**	**16 (8)**	**20 (10)**

* Forecast was not issued or did not verify.

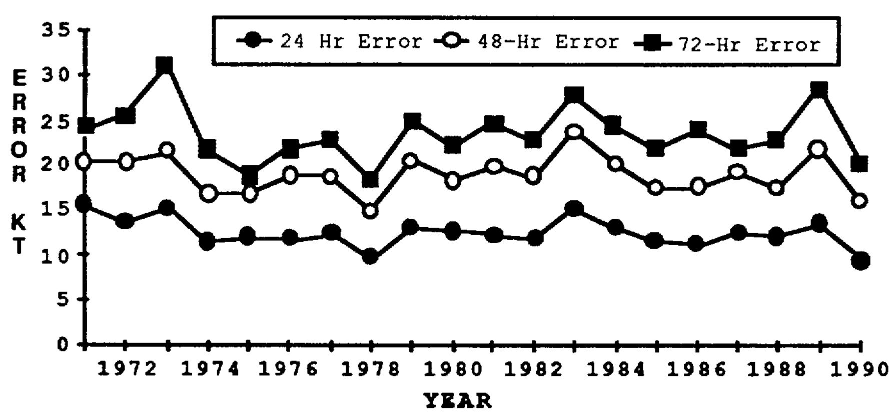

Figure 5-6. Annual mean intensity forecast errors (kt) for all significant tropical cyclones in the Northwest Pacific Ocean. 1971-1989 errors from Mundell (1990).

TABLE 5-9

ANNUAL MEAN INTENSITY FORECAST ERRORS (KT) NORTHERN INDIAN OCEAN

TROPICAL CYCLONE	MAXIMUM INTENSITY	24-HOUR FORECAST ERROR KT (M/SEC)	48-HOUR FORECAST ERROR KT (M/SEC)	72-HOUR FORECAST ERROR KT (M/SEC)
01B ----	25(13)	*	*	*
02B ----	125(64)	12	28	50
03B ----	30(15)	0	*	*
04B ----	45(23)	8	16	42
	Average:	**9(5)**	**24(13)**	**48(25)**

*Forecast was not issued or did not verify.

TABLE 5-10

ANNUAL MEAN INTENSITY FORECAST ERRORS (KT) SOUTHERN HEMISPHERE

TROPICAL CYCLONE	MAXIMUM INTENSITY	24-HOUR FORECAST ERROR KT (M/SEC)	48-HOUR FORECAST ERROR KT (M/SEC)
01S ----	25(13)	5	*
02S ----	35(18)	1	5
03S ----	30(15)	5	15
04S ----	30(15)	7	12
05S ----	35(18)	8	15
06S Pedro	65(33)	8	12
07P Felicity	60(31)	6	0
08S Alibera	135(69)	12	16
09S Bavomavo	85(44)	8	16
10S Sam	50(26)	10	19
11S Tina	45(23)	5	8
12P Nancy	65(33)	9	6
13P Ofa	115(59)	16	20
14S Cezera	80(41)	10	16
15S Dety	95(49)	16	21
16P Peni	60(31)	9	20
17S Vincent	70(36)	4	9
18S Edisaona	100(51)	15	24
19P Greg	30(15)	8	35
20S Walter	30(15)	4	8
21P Hilda	60(31)	11	8
22S Felana	45(23)	6	18
23S Gregoara	110(57)	15	18
24S Alex	130(67)	11	21
25P Ivor	75(39)	7	14
26P Rae	40(21)	3	10
27S ----	45(23)	5	*
28S Bessi	40(21)	0	*
29S Ikonjo	55(28)	10	16
	Average:	**10(5)**	**16(8)**

*Forecast was not issued or did not verify.

computations. An initiative is presently underway to convert most of the objective techniques that currently run on mainframe computers at FNOC to desktop computer versions that run on ATCF workstations. These will eventually replace the FNOC-generated techniques. As of this writing, three of these new aids have been received and are under evaluation.

5.2.2.1 EXTRAPOLATION (XTRP) — Past speed and direction are computed using the rhumb line distance between the current and 12-hour old positions of the tropical cyclone. Extrapolation from the current warning position is used to compute forecast positions.

5.2.2.2 CLIMATOLOGY (CLIM, PCLM) — JTWC has access to three climatology objective techniques at present. Two run on the ATCF. They are: 1) CLIM which continues to run operationally at FNOC, and 2) PCLM which is the PC-based version. The historical data base for both has been recently updated to 1945-1981 for the Northwest Pacific, and 1900 to 1989 for the rest of JTWC's AOR. Both techniques employ time and location windows relative to the current position of the storm to determine which historical storms will be used to compute the forecast. PCLM differs from CLIM in that it looks symmetrically in time about the current best track position and corrects CLIM's tendency to place more weight on slow-moving historical storms. The third climatology-based technique exists on JTWC's Macintosh®™ II computers. It employs data bases from 1945 to 1989 and from 1970 to 1989. The latter is referred to as the satellite-era data base. Objective intensity forecasts are available from these data bases. Scatter diagrams of expected tropical cyclone motion at bifurcation points are also available from these data bases.

5.2.2.3 HALF PERSISTENCE AND CLIMATOLOGY (HPAC, PCHP) — Forecast positions are generated by equally weighting the forecasts given by XTRP and CLIM in the case of HPAC, and by XTRP and PCLM in the case of PCHP.

5.2.2.4 ANALOGS — JTWC's analog and climatology techniques use the same historical data base, except that the analog approach imposes more restrictions on which storms will be used to compute the forecast positions. Analogs in all basins must satisfy time, location, speed, and direction windows, although the window definitions are distinctly different in the Northwest Pacific. In this basin, acceptable analogs are also ranked in terms of a similarity index that includes the above parameters and: storm size and size change, intensity and intensity change, and heights and locations of the 700-mb subtropical ridge and upstream midlatitude trough. In other basins, all acceptable analogs receive equal weighting and a persistence bias is explicitly added to the forecast. Inside the Northwest Pacific, analog weighting is varied using the similarity index, and a persistence bias is implicitly incorporated by rotating the analog tracks so that they initially match the 12-hr old motion of the current storm. In the Northwest Pacific, a forecast based on all acceptable analogs called TOTL, as well as a forecast based only on historical recurvers called RECR are available. Outside this basin, only the TOTL technique is available.

5.2.2.5 CLIMATOLOGY AND PERSISTENCE (CLIP) — This is a statistical regression technique that is based on climatology, current position and 12-hour and 24-hour past movement. This technique is used as a crude baseline against which to measure the forecast skill of other more sophisticated techniques. CLIP in the Northwest Pacific uses third-order regression equations and is based on the work of Xu and Neuman (1985). CLIP has been available outside this basin only since mid-1990, and it uses second-order equations developed by Neuman and Randrianarison (1976) with regression coefficients recently recomputed by FNOC based on the updated 1900-1989 data base.

5.2.2.6 COLORADO STATE UNIVERSITY MODEL (CSUM) — CSUM is a statisticaldynamical technique based on the work of Matsumoto (1984). Predictor parameters include the current and 24-hr old position of the storm, heights from the current and 24-hr old NOGAPS 500-mb analyses, and heights from the 24-hr and 48-hr NOGAPS 500 mb prognoses. Height values from 200-mb fields are substituted for storms that have an intensity exceeding 90 knots and are located north of the subtropical ridge. Three distinct sets of regression equations are used depending on whether the storm's direction of motion falls into "below," "on," or "above" the subtropical ridge categories. During the development of the regression equation coefficients for CSUM, the so-called "perfect prog" approach was used, in which verifying analyses were substituted for the numerical prognoses that are used when CSUM is run operationally. Thus, CSUM was not "tuned" to any particular version of NOGAPS, and in fact, the performance of CSUM should presumably improve as new versions of NOGAPS improve. CSUM runs only in the Northwest Pacific, South China Sea, and North Indian Ocean basins.

5.2.2.7 NOGAPS VORTEX TRACKING ROUTINE (NGPS) — This objective technique follows the movement of the point of minimum height on the 1000 mb pressure surface analyzed and predicted by NOGAPS. A search in the expected vicinity of the storm is conducted every six hours through 72 hours, even if the tracking routine temporarily fails to discern a minimum height point. Explicit insertion of a tropical cyclone bogus via data provided over TYMNET by JTWC began in mid-1990, and should improve the ability of the NOGAPS technique to track the vortex.

5.2.2.8 ONE-WAY INFLUENCE TROPICAL CYCLONE MODEL (OTCM) — This technique is a coarse resolution (205 km grid), three layer, primitive equation model with a horizontal domain of 6400 x 4700 km. OTCM is initialized using 6-hour or 12-hour prognostic fields from the latest NOGAPS run, and the initial fields are smoothed and adjusted in the vicinity of the storm to induce a persistence bias into OTCM's forecast. A symmetric bogus vortex is then inserted, and the boundaries updated every 12 hours by NOGAPS fields as the integration proceeds. The bogus vortex is maintained against frictional dissipation by an analytical heating function. The forecast positions are based on the movement of the vortex in the lowest layer of the model (effectively 850-mb).

5.2.2.9 FNOC BETA AND ADVECTION MODEL (FBAM) — This model is an adaptation of the Beta and Advection model used by NMC. The forecast motion results from a calculation of environmental steering and an empirical correction for the observed vector difference between that steering and the 12-hour old storm motion. The steering is computed from the NOGAPS Deep Layer Mean (DLM) wind fields which are a weighted average of the wind fields computed for the 1000-mb to 100-mb levels. The difference between past storm motion and the DLM steering is treated as if the storm were a Rossby wave with an "effective radius" propagating in response to the horizontal gradient of the coriolis parameter, Beta. The forecast proceeds in one-hour steps, recomputing the effective radius as Beta changes with storm latitude, and blending in a persistence bias for the first 12 hours.

5.2.2.10 COMBINED CONFIDENCE WEIGHTED FORECASTS (CCWF) — An optimal blend of objective techniques produced by the ATCF. The ATCF blends the selected techniques by using the inverse of the covariance matrices computed from historical and real-time cross-track and along-track errors as the weighting function.

5.2.2.11 DVORAK — An estimation of a tropical cyclone's current and 24-hour forecast intensity is made from the interpretation of satellite imagery (Dvorak, 1984) . These intensity estimates are used with other intensity related data and trends to forecast short-term tropical cyclone intensity.

5.2.2.12 MARTIN/HOLLAND — The technique adapts an earlier work (Holland, 1980) and specifically addresses the need for realistic 30-kt, 50-kt and 100-kt wind radii around tropical cyclones. It solves equations for basic gradient wind relations within the tropical cyclone area, using input parameters obtained from enhanced infrared satellite imagery. The diagnosis also includes an asymmetric area of winds caused by tropical cyclone movement. Satellite-derived size and intensity parameters are also used to diagnose internal steering components of tropical cyclone motion known collectively as "beta-drift".

5.2.2.13 Navy Operational Regional Prediction System (NRPS) — The Advanced Tropical Cyclone Model (ATCM) produced from NORAPS fields.

5.3 TESTING AND RESULTS

A comparison of selected techniques is included in Tables 5-11A and 5-11B for all Northwest Pacific tropical cyclones; Table 5-12 for all North Indian Ocean tropical cyclones and Table 5-13 for the Southern Hemisphere. In these tables, " x-axis " refers to techniques listed vertically. For example (Table 5-11A) in the 748 cases available for a (homogeneous) comparison, the average forecast error at 24 hours was 161 nm (298 km) for CLIM and 129 nm (239 km) for HPAC. The difference of 32 nm (59 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 5-11A **1990 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTHWEST PACIFIC (1 JAN 1990 - 31 DEC 1990)**

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	FBAM	CLIP	HPAC	CLIM	XTRP	CSUM	TOTL	RECR
JTWC	658 103 104 0									
OTCM	616 102 109 7	744 117 117 0								
FBAM	583 100 121 21	687 118 125 7	712 129 129 0							
CLIP	622 102 115 13	734 117 123 6	710 129 124 -5	759 125 125 0						
HPAC	619 102 123 21	729 117 128 11	706 129 130 1	754 125 131 6	755 131 131 0					
CLIM	616 102 158 56	728 114 159 45	700 126 158 32	747 122 161 39	748 129 161 32	756 162 162 0				
XTRP	611 102 131 29	720 114 134 20	697 126 138 12	744 122 138 16	741 129 138 9	741 161 138 -23	745 138 138 0			
CSUM	599 102 115 13	703 117 123 6	678 130 125 -5	724 123 125 2	724 132 125 -7	718 162 122 -40	711 138 122 -16	728 125 125 0		
TOTL	594 102 125 21	687 114 130 16	656 126 127 1	697 120 131 11	694 127 131 4	694 156 129 -27	686 134 128 -6	675 120 131 11	707 132 132 0	
RECR	561 103 124 21	648 116 134 18	625 127 133 6	658 120 135 15	658 128 135 7	661 156 133 -23	652 134 132 -2	659 120 134 14	668 131 135 4	668 135 135 0

Number of Cases	X-Axis Technique Error
Y-Axis Technique Error	Error Difference (Y-X)

CLIM - Climatology
CLIP - Climatology/Persistence
CSUM - Colorado State University Model
FBAM - FNOC Beta and Advection Model
HPAC - Half Persistence and Climatology
JTWC - Offical JTWC Forecast
OTCM - One-Way Tropical Cyclone Model
RECR - Recurve Analog
TOTL - Total Analog
XTRP - Extrapolation

TABLE 5-11B

1990 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTHWEST PACIFIC (1 JAN 1990 - 31 DEC 1990)

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	FBAM	CLIP	HPAC	CLIM	XTRP	CSUM	TOTL	RECR
JTWC	525 203 203 0									
OTCM	483 199 203 4	642 219 219 0								
FBAM	468 197 247 50	591 221 248 27	628 257 257 0							
CLIP	503 199 229 30	632 219 240 21	626 256 242 -14	670 243 243 0						
HPAC	500 199 233 34	626 219 245 26	622 257 247 -10	663 242 250 8	664 250 250 0					
CLIM	496 200 286 86	626 216 293 77	617 253 294 41	657 239 297 58	658 247 297 50	666 299 299 0				
XTRP	493 200 276 76	620 216 289 73	615 252 293 41	657 240 295 55	652 246 295 49	652 297 295 -2	658 295 295 0			
CSUM	484 199 229 30	603 220 239 19	595 259 243 -16	636 235 243 8	634 250 243 -7	629 297 240 -57	625 295 240 -55	640 243 243 0		
TOTL	490 200 253 53	601 214 264 50	589 250 261 11	625 241 266 25	622 246 266 20	622 292 265 -27	614 289 263 -26	604 238 268 30	635 267 267 0	
RECR	464 201 246 45	566 218 259 41	557 253 259 6	589 234 260 26	589 247 260 13	592 292 259 -33	583 292 258 -34	591 239 259 20	599 269 262 -7	599 262 262 0

Number of Cases	**X-Axis Technique Error**
Y-Axis Technique Error	**Error Difference (Y-X)**

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	FBAM	CLIP	HPAC	CLIM	XTRP	CSUM	TOTL	RECR
JTWC	432 310 310 0									
OTCM	388 303 317 14	524 340 340 0								
FBAM	384 300 364 64	481 344 383 39	528 386 386 0							
CLIP	414 301 341 40	515 341 367 26	526 385 370 -15	565 370 370 0						
HPAC	410 300 327 27	510 342 360 18	521 385 362 -23	559 365 364 -1	560 364 364 0					
CLIM	407 302 385 83	511 337 402 65	517 382 406 24	554 362 408 46	555 362 408 46	562 409 409 0				
XTRP	406 302 435 133	507 338 471 133	519 382 477 95	556 367 479 112	552 361 479 118	552 408 479 71	557 479 479 0			
CSUM	399 302 339 37	492 345 356 11	495 391 360 -31	531 348 358 10	531 365 358 -7	527 405 355 -50	524 482 356 -126	535 359 359 0		
TOTL	412 302 386 84	503 336 419 83	503 386 412 26	537 369 416 47	533 362 418 56	534 405 415 10	530 473 414 -59	516 356 424 68	547 416 416 0	
RECR	391 302 376 74	474 345 404 59	473 393 408 15	505 351 405 54	505 365 405 40	509 403 402 -1	502 481 401 -80	507 359 403 44	515 421 406 -15	515 406 406 0

CLIM - Climatology
CLIP - Climatology/Persistence
CSUM - Colorado State University Model
FBAM - FNOC Beta and Advection Model
HPAC - Half Persistence and Climatology
JTWC - Offical JTWC Forecast
OTCM - One-Way Tropical Cyclone Model
RECR - Recurve Analog
TOTL - Total Analog
XTRP - Extrapolation

TABLE 5-12 **1990 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTH INDIAN OCEAN**

Number of Cases	X-Axis Technique Error
Y-Axis Technique Error	Error Difference (Y-X)

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	FBAM	HPAC	CLIM	XTRP	CSUM	TOTL
JTWC	36 101							
	101 0							
OTCM	28 100	30 99						
	99 -1	99 0						
FBAM	25 98	27 101	27 151					
	150 52	151 50	151 0					
HPAC	28 100	30 99	27 151	30 91				
	88 -12	91 -8	93 -58	91 0				
CLIM	28 100	30 99	27 151	30 91	30 88			
	86 -14	88 -11	91 -60	88 -3	88 0			
XTRP	27 101	29 100	26 153	29 93	29 91	29 115		
	112 11	115 15	118 -35	115 22	115 24	115 0		
CSUM	25 92	27 101	25 152	27 87	27 85	26 108	27 229	
	222 130	229 128	226 74	229 142	229 144	229 121	229 0	
TOTL	28 100	29 99	26 151	29 88	29 84	28 114	26 224	29 91
	91 -9	91 -8	92 -59	91 3	91 7	93 -21	86 -138	91 0

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	FBAM	HPAC	CLIM	XTRP	CSUM	TOTL
JTWC	24 146							
	146 0							
OTCM	18 135	22 157						
	166 31	157 0						
FBAM	19 152	19 153	23 251					
	261 109	243 90	251 0					
HPAC	21 146	22 157	23 251	26 162				
	150 4	149 -8	171 -80	162 0				
CLIM	21 146	22 157	23 251	26 162	26 171			
	174 28	159 2	185 -66	171 9	171 0			
XTRP	20 144	21 158	22 251	25 163	25 175	25 210		
	183 39	198 40	216 -35	210 47	210 35	210 0		
CSUM	21 146	19 163	21 261	23 156	23 183	22 187	23 594	
	582 436	602 439	588 327	594 438	594 411	589 402	594 0	
TOTL	21 146	21 158	22 250	25 155	25 161	24 208	22 583	25 149
	146 0	146 -12	147 -103	149 -6	149 -12	150 -58	142 -441	149 0

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	FBAM	HPAC	CLIM	XTRP	CSUM	TOTL
JTWC	17 185							
	185 0							
OTCM	12 174	16 183						
	192 18	183 0						
FBAM	13 208	13 163	17 389					
	410 202	323 160	389 0					
HPAC	15 198	16 183	17 389	20 248				
	209 11	204 21	262 -127	248 0				
CLIM	15 198	16 183	17 389	20 248	20 262			
	257 59	217 34	277 -112	262 14	262 0			
XTRP	14 195	15 187	16 383	19 251	19 270	19 343		
	286 91	308 121	361 -22	343 92	343 73	343 0		
CSUM	15 198	13 185	15 407	17 226	17 281	16 293	17 1037	
	1033 835	1126 941	1043 636	1037 811	1037 756	1030 737	1037 0	
TOTL	15 198	15 188	16 390	19 241	19 248	18 347	16 1023	19 220
	215 17	191 3	222 -168	220 -21	220 -28	221 -126	220 -803	220 0

CLIM - Climatology
FBAM - FNOC Beta and Advection Model
HPAC - Half Persistence and Climatology Blend
JTWC - Official JTWC Forecast
OTCM - One-Way Tropical Cyclone Model
TOTL - Total Analog

TABLE 5-13 **1990 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE SOUTHERN HEMISPHERE (1 JULY 1989 - 30 JUNE 1990)**

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	FBAM	HPAC	CLIM	TOTL
JTWC	251 143					
	143 0					
OTCM	105 148	348 144				
	159 11	144 0				
FBAM	84 157	270 142	279 131			
	147 -10	129 -13	131 0			
HPAC	94 151	308 146	278 131	318 141		
	152 1	141 -5	142 11	141 0		
CLIM	93 152	325 145	278 131	317 141	335 186	
	200 48	187 42	188 57	187 46	186 0	
TOTL	56 182	184 139	178 128	188 154	188 200	188 166
	204 22	161 22	168 40	166 12	166 -34	166 0

Number of Cases	X-Axis Technique Error
Y-Axis Technique Error	**Error Difference (Y-X)**

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	FBAM	HPAC	CLIM	TOTL
JTWC	198 263					
	263 0					
OTCM	81 277	281 256				
	271 -6	256 0				
FBAM	69 294	219 251	238 233			
	239 -55	230 -21	233 0			
HPAC	73 285	243 261	233 228	264 243		
	257 -28	245 -16	243 15	243 0		
CLIM	73 285	260 261	233 228	264 243	282 299	
	309 24	301 40	294 66	297 54	299 0	
TOTL	44 329	146 246	146 229	155 267	155 312	155 304
	366 37	309 63	308 79	304 37	304 -8	304 0

72-HOUR MEAN FORECAST ERROR (NM)

	OTCM	FBAM	HPAC	CLIMO	TOTL
OTCM	223 348				
	348 0				
FBAM	174 327	197 332			
	319 -8	332 0			
HPAC	192 347	193 324	218 319		
	314 -33	314 -10	319 0		
CLIM	208 350	193 324	218 319	236 387	
	378 28	370 46	382 63	387 0	
TOTL	118 306	118 320	124 321	124 361	124 385
	388 82	388 68	385 64	385 24	385 0

CLIM - Climatology
FBAM - FNOC Beta and Advection Model
HPAC - Half Persistence and Climatology Blend
JTWC - Official JTWC Forecast
OTCM - One-Way Tropical Cyclone Model
TOTL - Total Analog

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