5. SUMMARY OF FORECAST VERIFICATION

5.1 ANNUAL FORECAST VERIFICATION

Verification of warning positions and intensities 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 calculated for each verifying JTWC forecast. These data, in addition to a detailed summary for each tropical cyclone, are included as Chapter 6. This section summarizes verification data for 1993 and contrasts it with annual verification statistics from previous years.

5.1.1 NORTHWEST PACIFIC OCEAN — The frequency distributions of errors for initial warning positions and 12-, 24-, 36-, 48- and 72-hour forecasts are presented in Figures 5-2a through 5-2f, respectively. Table 5-1 includes mean track, along-track and cross-track errors for 1978-1993. Figure 5-3 shows mean track errors and a 5-year running mean of track errors at 24-, 48- and 72-hours for the past 20 years. Table 5-2 lists annual mean track errors from 1959, when the JTWC was founded, until the present. Figure 5-4 illustrates JTWC intensity forecast errors at 24-, 48- and 72-hours for the past 20 years.

5.1.2 NORTH INDIAN OCEAN — The frequency distributions of errors for warning positions and 12-, 24-, 36-, 48- and 72-hour forecasts are presented in Figures 5-5a through 5-5f, respectively. Table 5-3 includes mean track, along-track and cross-track errors for 1978-1993. Figure 5-6 shows mean track errors and a 5-year running mean of track errors at 24-, 48- and 72-hours for the 20 years that the JTWC has issued warnings in the region.

5.1.3 SOUTH PACIFIC AND SOUTH INDIAN OCEANS — The frequency distributions of errors for warning positions and 12-, 24-, 36-, and 48-hour forecasts are presented in Figures 5-7a through 5-7e, respectively. Table 5-4 includes mean track, along-track and cross-track errors for 1981-1993. Figure 5-8 shows mean track errors and a 5-year running mean of track errors at 24- and 48-hours for the 13 years that the JTWC has issued warnings in the region.

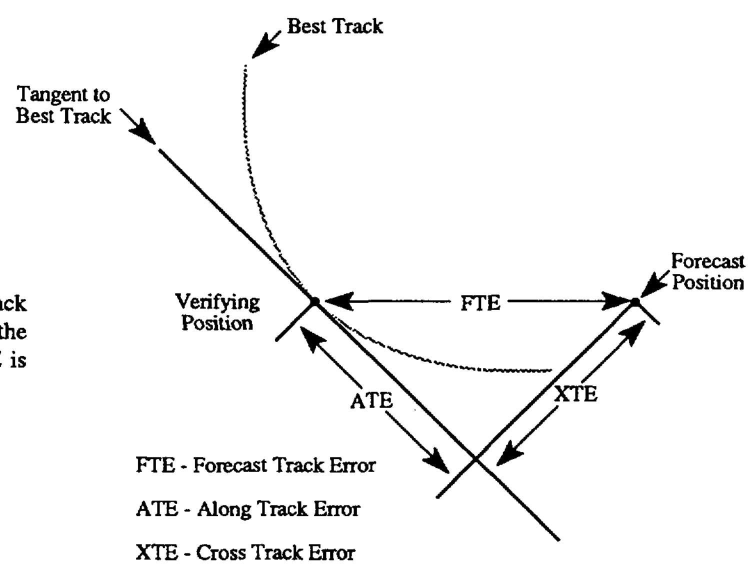

Figure 5-1 Definition of cross-track error (XTE), along-track error (ATE) and forecast track error (FTE). In this example, the XTE is positive (to the right of the best track) and the ATE is negative (behind or slower than the best track).

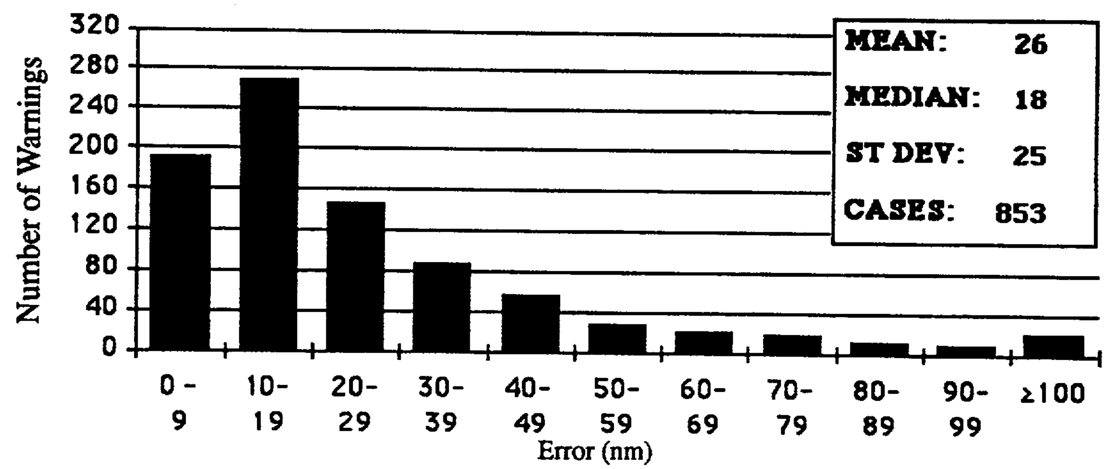

Figure 5-2a Frequency distribution of initial warning position errors (10-nm increments) for the western North Pacific Ocean in 1993. The largest error, 160 nm, occurred on Tropical Storm Marian (09W).

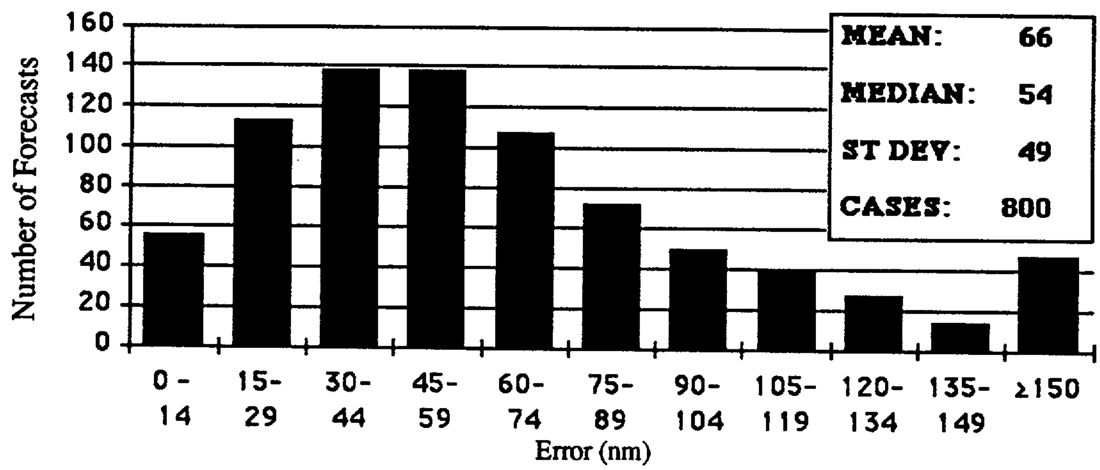

Figure 5-2b Frequency distribution of 12-hour forecast errors (15-nm increments) for the western North Pacific Ocean in 1993. The largest error, 427 nm, occurred on Super Typhoon Yancy (19W).

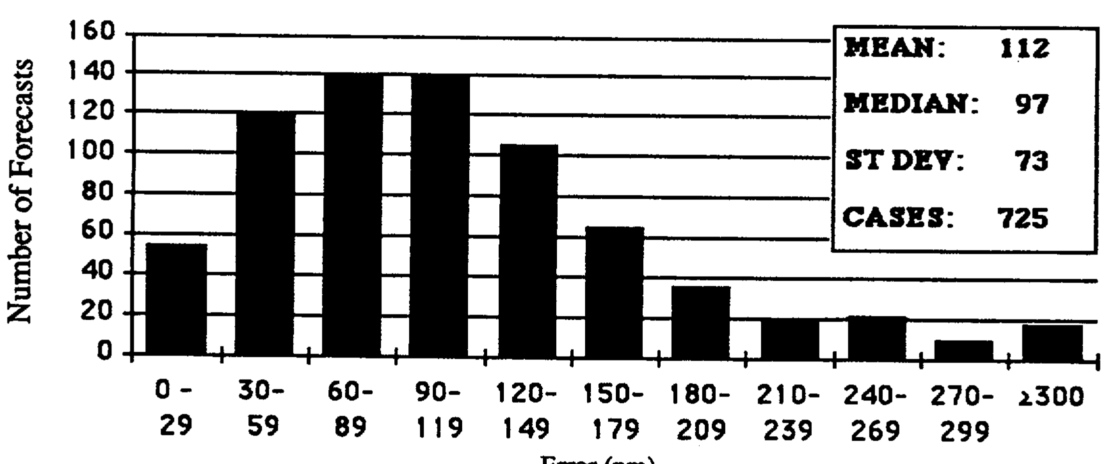

Figure 5-2c Frequency distribution of 24-hour forecast errors (30-nm increments) for the western North Pacific Ocean in 1993. The largest error, 484 nm, occurred on Tropical Storm Irma (02W).

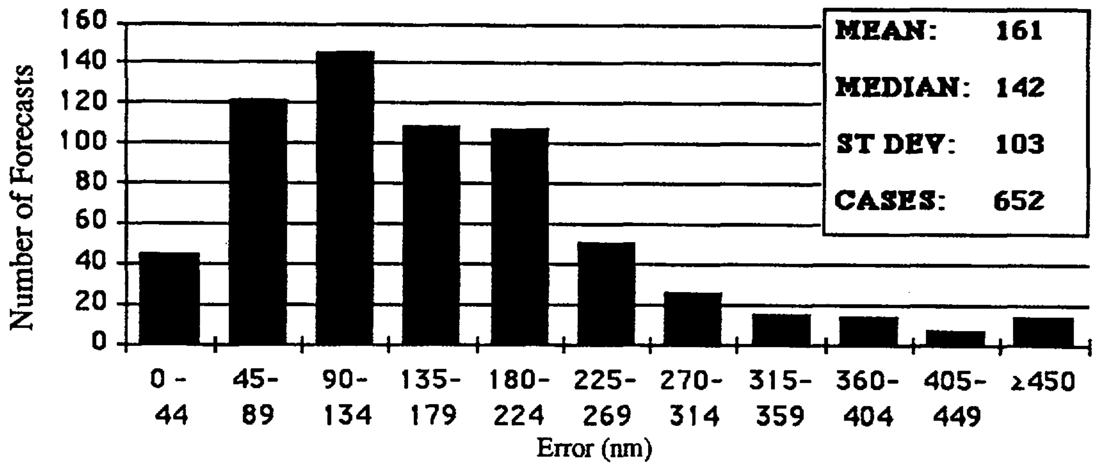

Figure 5-2d Frequency distribution of 36-hour forecast errors (45-nm increments) for the western North Pacific Ocean in 1993. The largest error, 674 nm, occurred on Typhoon Flo (26W).

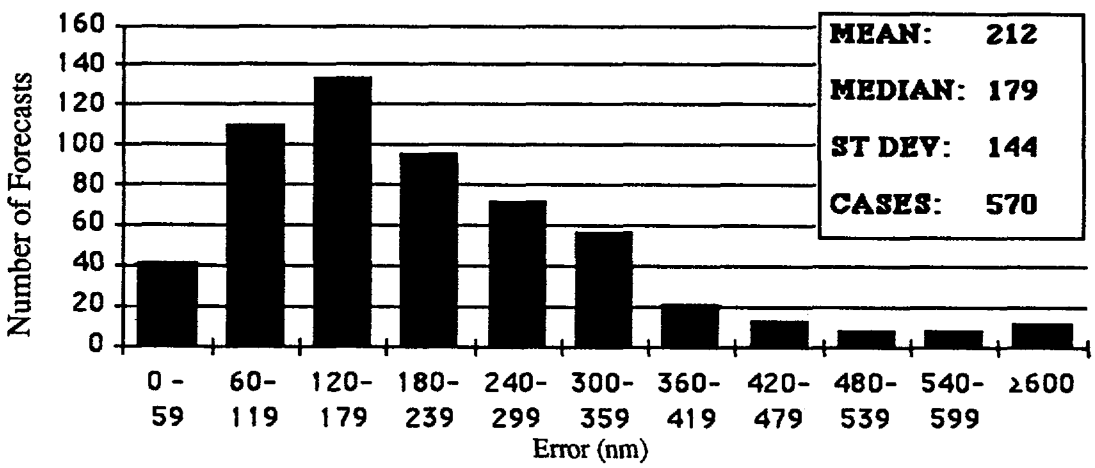

Figure 5-2e Frequency distribution of 48- hour forecast errors (60-nm increments) for the western North Pacific Ocean in 1993. The largest error, 1075 nm, occurred on Typhoon Flo (26W).

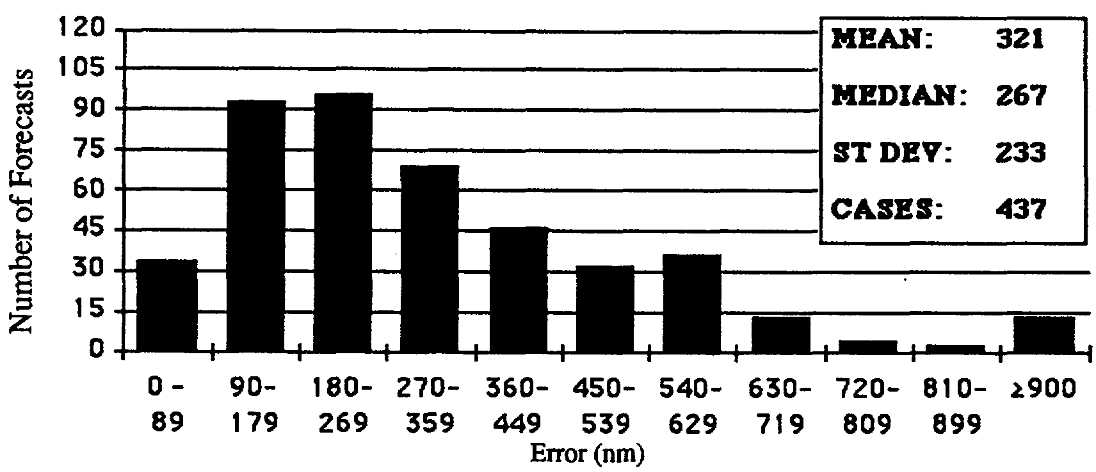

Figure 5-2f Frequency distribution of 72-hour forecast errors (90-nm increments) for the western North Pacific Ocean in 1993. The largest error, 1732 nm, occurred on Typhoon Flo (26W).

Table 5-1 INITIAL WARNING POSITION AND FORECAST ERRORS (NM) FOR THE WESTERN NORTH PACIFIC 1978-1993.

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
1982	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
1990	794	21	658	103	72	60	525	203	148	110	432	310	225	168
1991	835	22	733	96	69	53	599	185	137	97	484	287	229	146
1992	941	25	841	107	77	59	687	205	143	116	568	305	210	172
1993	853	26	725	112	79	63	570	212	151	117	437	321	226	173
AVERAGE 1978-1993	687	22	578	116	79	67	452	227	157	131	348	345	238	198

Note: Cross-track and along-track errors were adopted by the JTWC in 1986. Right-angle errors (used prior to 1986) were recomputed as cross-track and along-track errors after-the-fact to extend the data base. See Figure 5-1 for the definitions of cross-track and along-track errors.

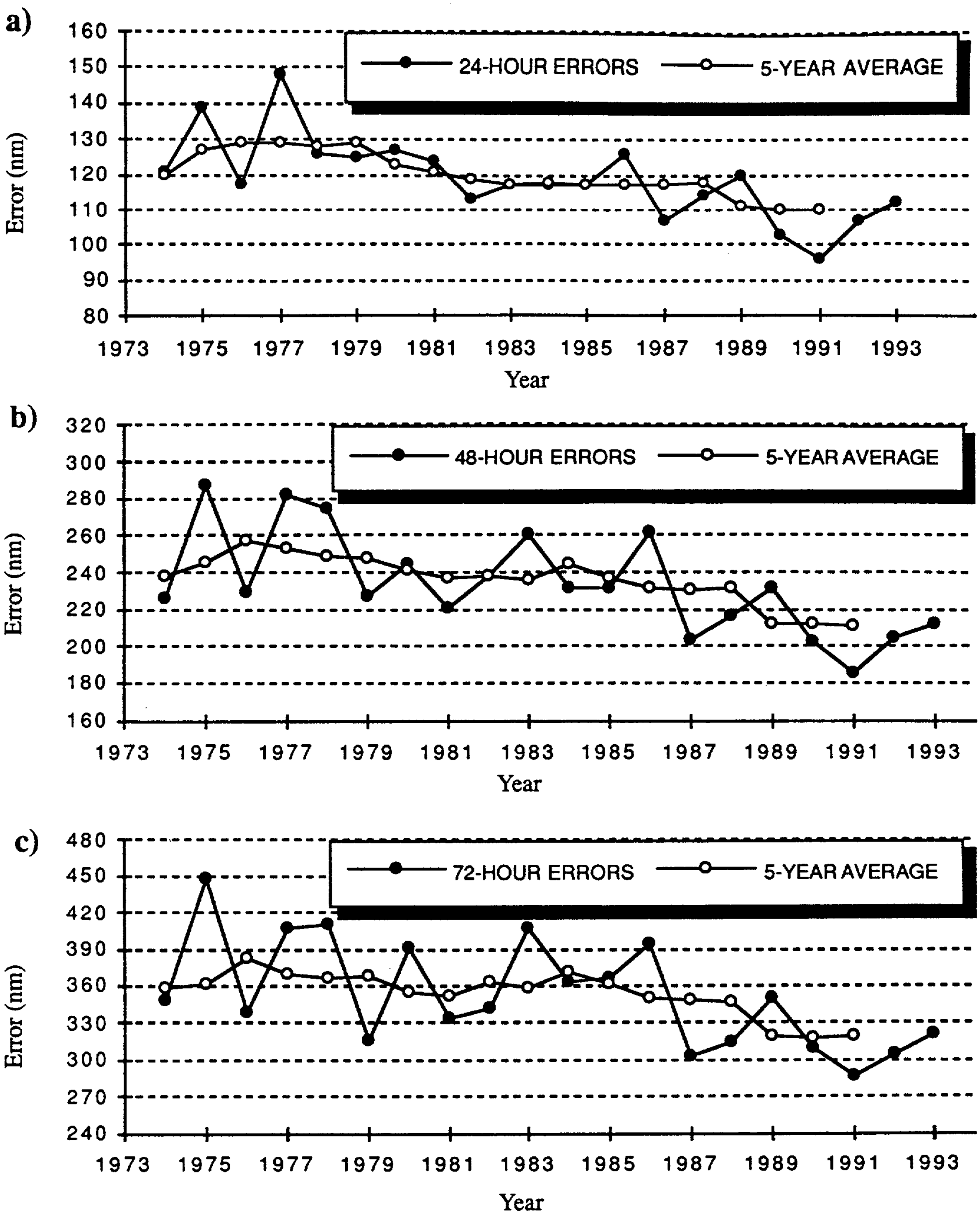

Figure 5-3 Mean track forecast error (nm) and 5-year running mean for a) 24 hours, b) 48 hours and c) 72 hours for the western North Pacific Ocean for the period 1974 to 1993.

Table 5-2 MEAN FORECAST ERRORS (NM) WESTERN NORTH PACIFIC FOR 1959-1993

	24-HOUR		48-HOUR		72-HOUR	
YEAR	ALL /	TYPHOONS*	ALL /	TYPHOONS*	ALL /	TYPHOONS*
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
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
1991	96	93	185	187	286	298
1992	107	97	205	194	305	295
1993	112	102	212	205	321	320

* Forecasts were verified when the tropical cyclone intensities were at least 35 kt (18 m/sec).

** Forecast positions north of 35° north latitude were not verified

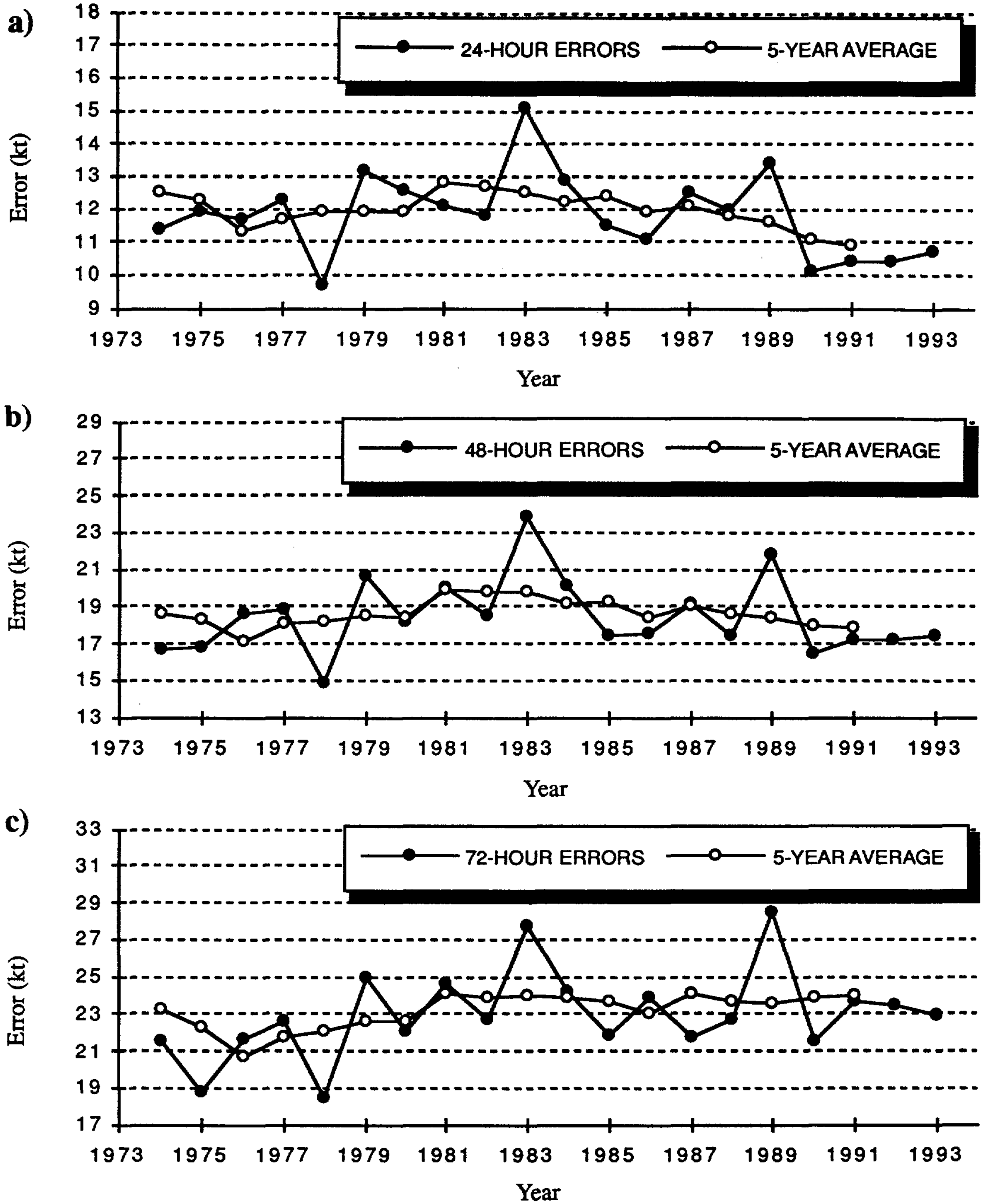

Figure 5-4 Mean intensity forecast errors (kt) and 5-year running mean for a) 24 hours, b) 48 hours and c) 72 hours for the western North Pacific Ocean for the period 1974 to 1993.

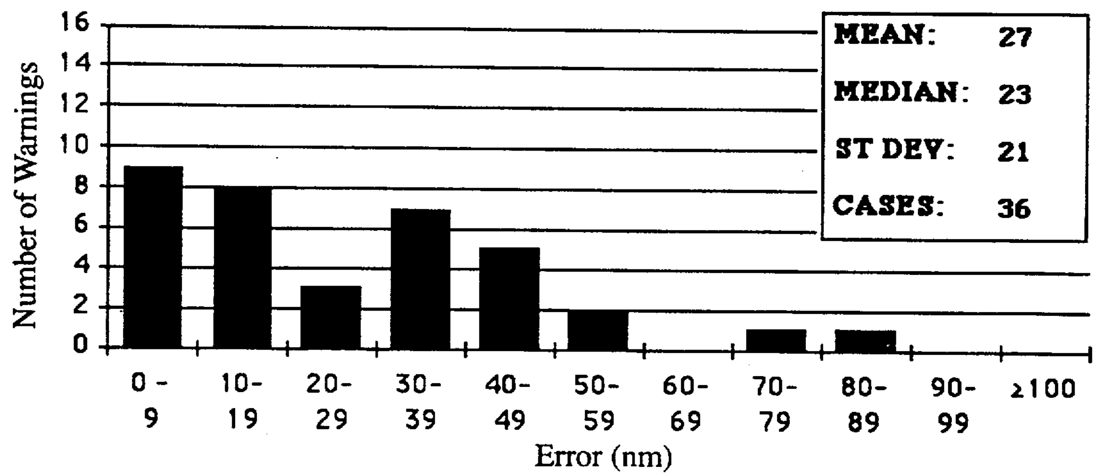

Figure 5-5a Frequency distribution of initial warning position errors (10-nm increments) for the North Indian Ocean in 1993. The largest error, 85 nm, was on TC02B.

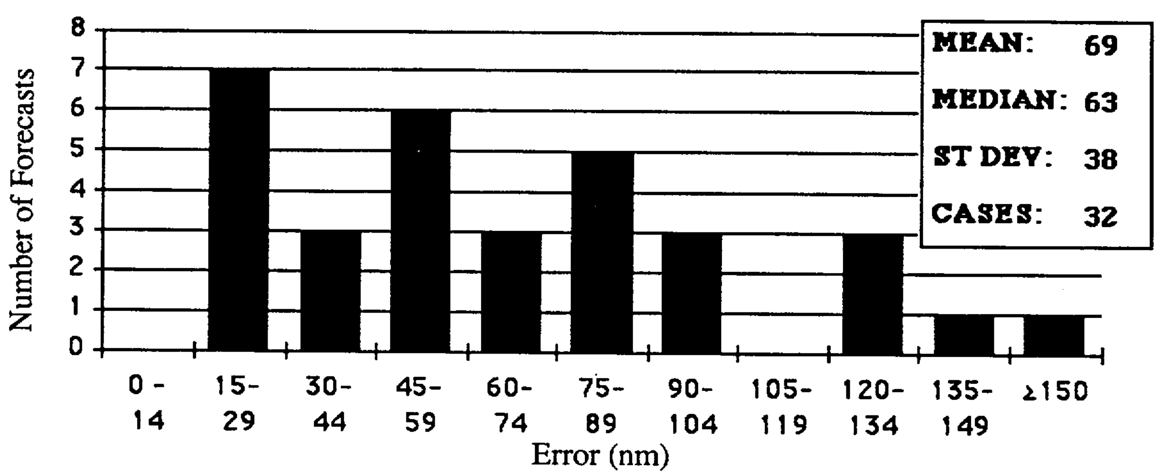

Figure 5-5b Frequency distribution of 12-hour forecast errors (15-nm increments) for the North Indian Ocean in 1993. The largest error, 163 nm, was on TC01A.

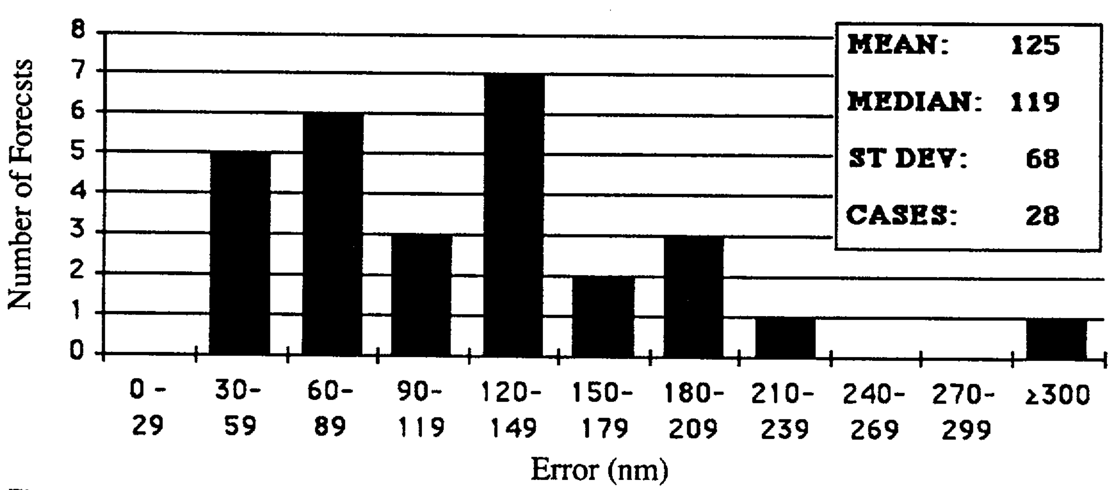

Figure 5-5c Frequency distribution of 24-hour forecast errors (30-nm increments) for the North Indian Ocean in 1993. The largest error, 356 nm, was on TC01A.

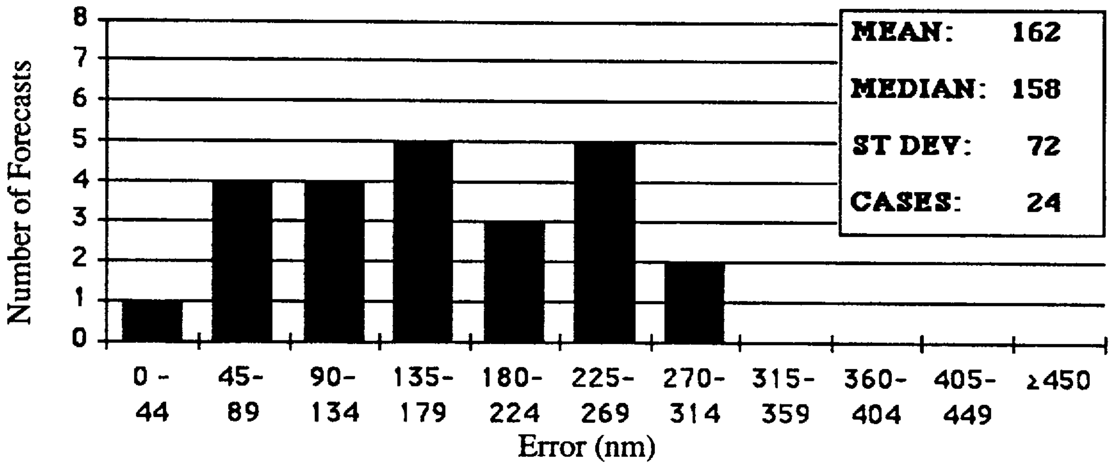

Figure 5-5d Frequency distribution of 36-hour forecast errors (45-nm increments) for the North Indian Ocean in 1993. The largest error, 286 nm, was on TC01A.

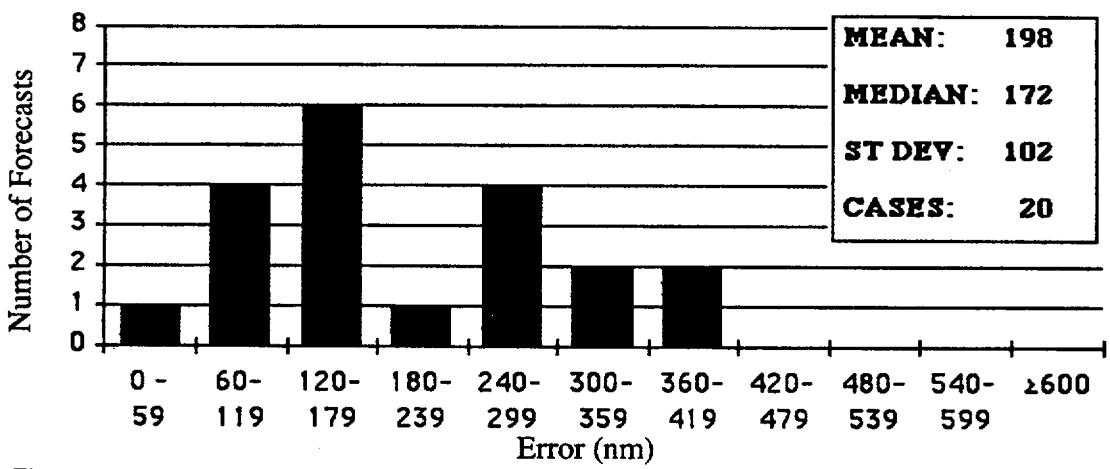

Figure 5-5e Frequency distribution of 48-hour forecast errors (60-nm increments) for the North Indian Ocean in 1993. The largest error, 395 nm, was on TC01A.

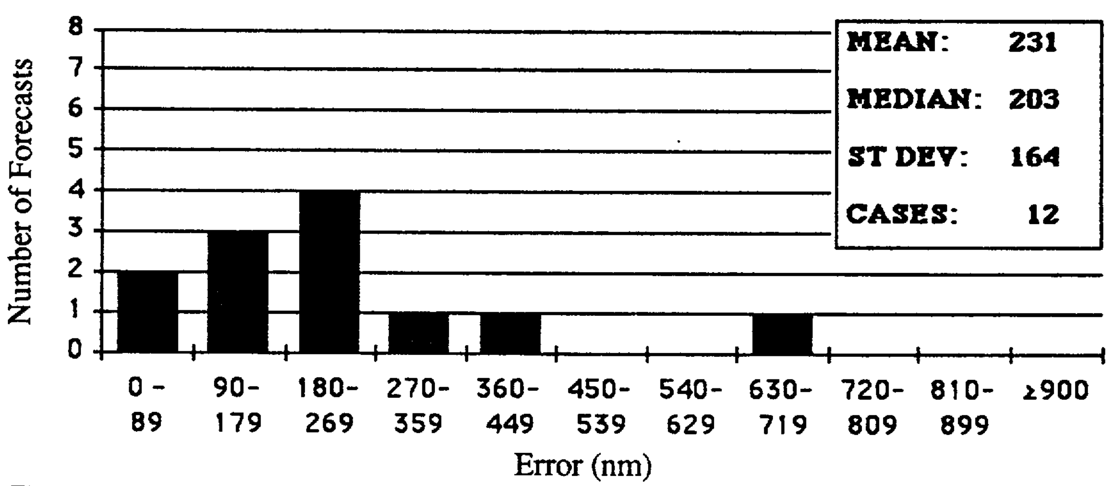

Figure 5-5f Frequency distribution of 72-hour forecast errors (90-nm increments) for the North Indian Ocean in 1993. The largest error, 651 nm, was on TC01A.

Table 5-3 INITIAL POSITION AND FORECAST POSITION ERRORS (NM) FOR THE NORTH INDIAN OCEAN 1978-1993

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	32	43	28	133	90	82	19	202	147	109	N/A			
1979	93	46	63	151	96	95	17	278	193	161	17	437	251	320
1980	14	41	7	115	81	71	38	93	25	88	1	167	97	137
1981	41	28	29	109	76	63	2	176	120	109	5	197	150	111
1982	55	35	37	138	110	68	17	368	292	209	7	762	653	332
1983	18	38	7	117	90	50	18	153	137	53	0			
1984	67	33	42	154	124	67	20	274	217	139	16	388	339	121
1985	53	31	30	122	102	53	8	242	119	194	0			
1986	28	52	16	134	118	53	7	168	131	80	5	269	189	180
1987	83	42	54	144	91	100	25	205	125	140	21	305	219	188
1988	44	34	30	120	89	63	18	219	112	176	12	409	227	303
1989	44	19	33	88	62	50	17	146	94	86	12	216	164	111
1990	46	31	36	101	85	43	24	146	117	67	17	185	130	104
1991	56	38	43	129	107	54	27	235	200	89	14	450	356	178
1992	191	35	149	128	73	86	100	244	141	166	62	398	276	218
1993	36	27	28	125	87	79	20	198	171	74	12	231	176	116
AVERAGE 1978-1993	56	36	40	129	90	74	24	212	142	127	13	360	258	196

Note: Cross-track and along-track errors were adopted by the JTWC in 1986. Right-angle errors (used prior to 1986) were recomputed as cross-track and along-track errors after-the-fact to extend the data base. See Figure 5-1 for the definitions of cross-track and along-track errors.

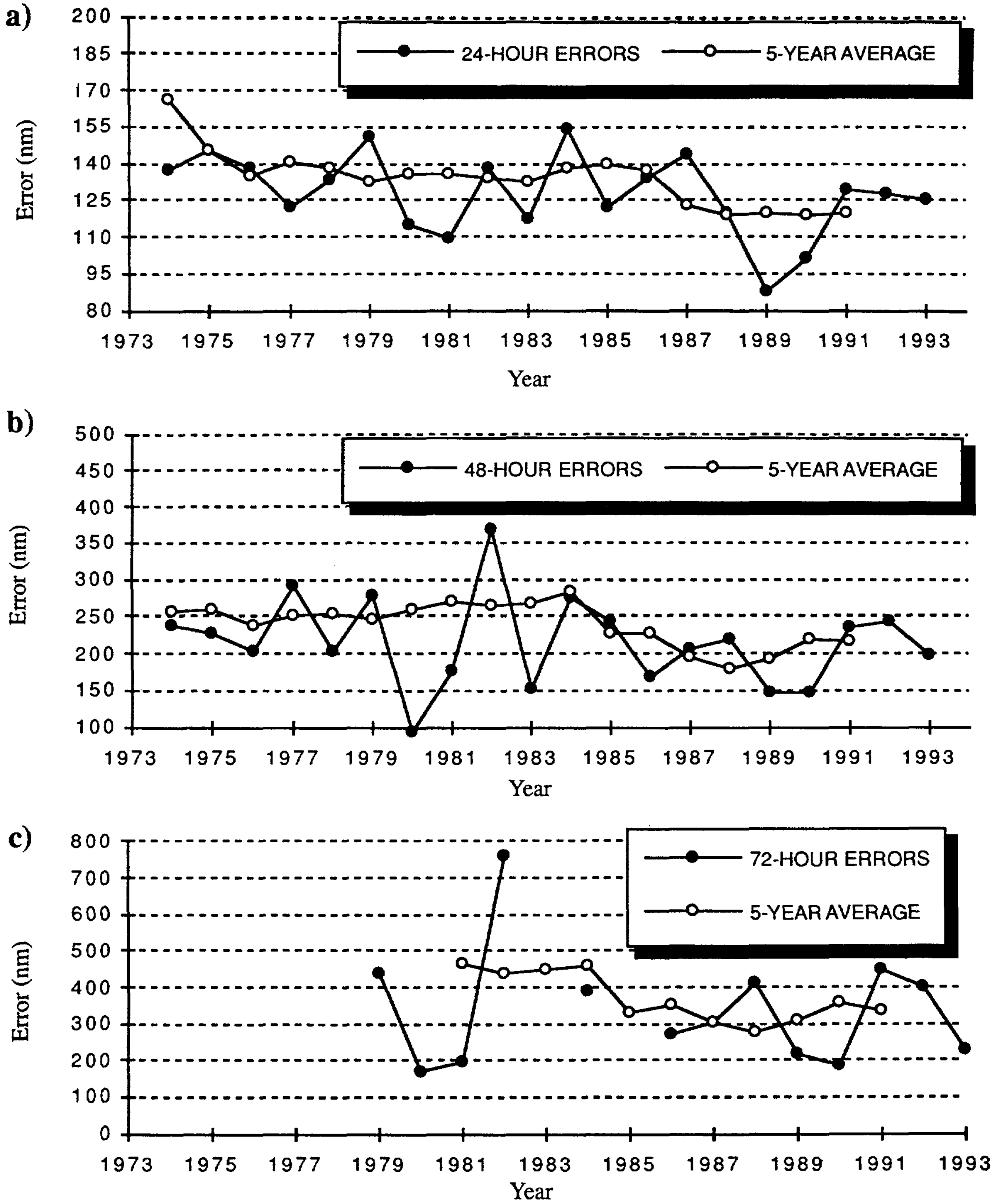

Figure 5-6 Mean track errors (nm) and 5-year running mean for a) 24 hours, b) 48 hours and c) 72 hours in the North Indian Ocean for the period 1974 to 1993. Note: no 72-hour forecasts verified prior to 1979, and in 1983 and 1985.

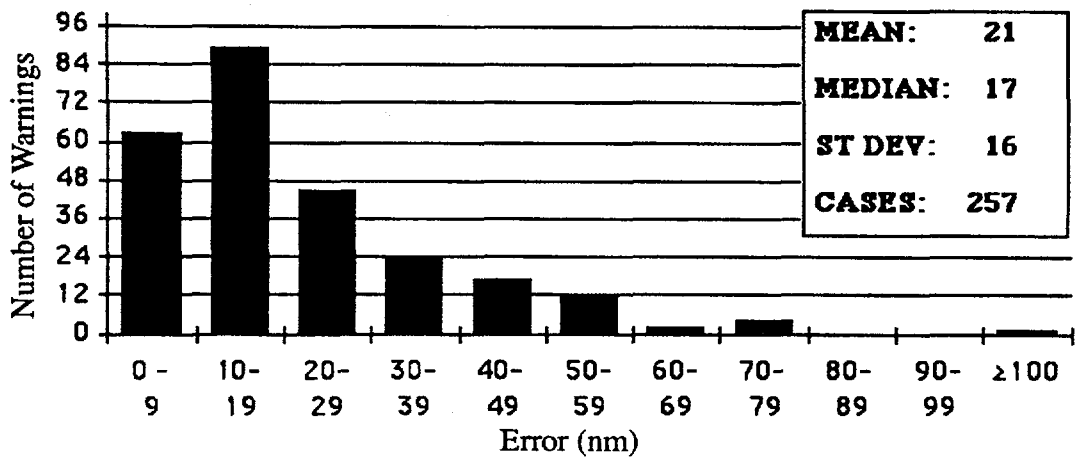

Figure 5-7a Frequency distribution of initial warning position errors (10-nm increments) for the South Pacific and South Indian Oceans in 1993. The largest error, 101 nm, occurred on Tropical Cyclone 02S (Babie).

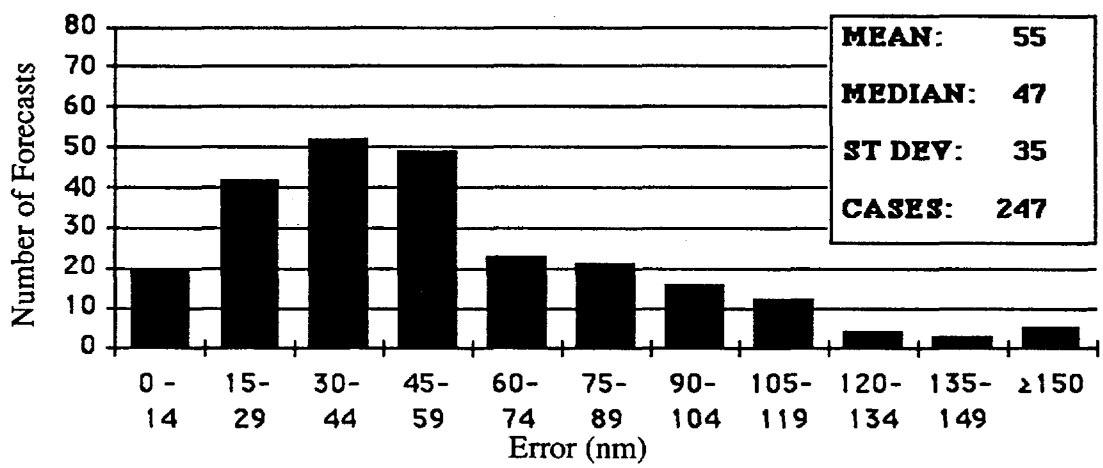

Figure 5-7b Frequency distribution of 12-hour forecast errors (15-nm increments) for the South Pacific and South Indian Oceans in 1993. The largest error, 217 nm, occurred on Tropical Cyclone 27P (Adel).

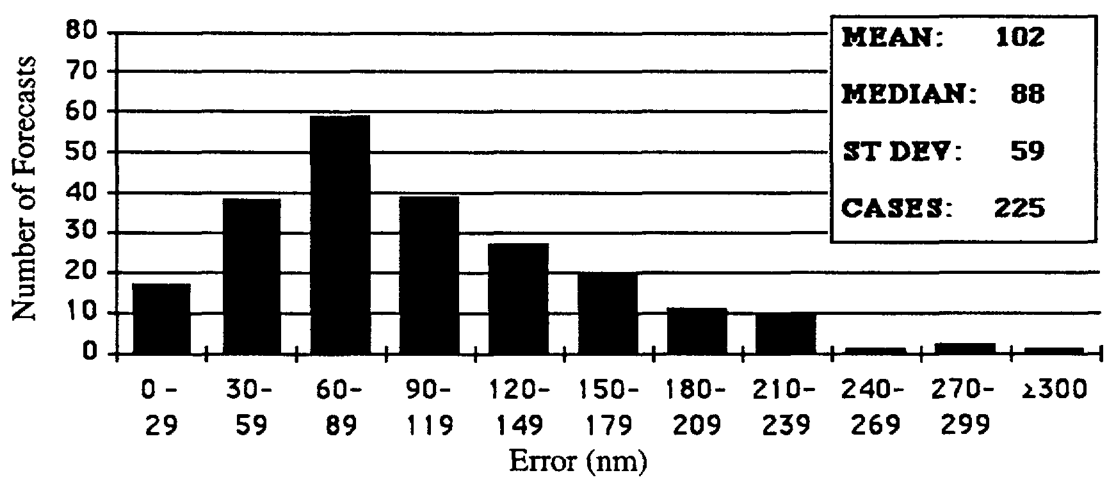

Figure 5-7c Frequency distribution of 24-hour forecast errors (30-nm increments) for the South Pacific and South Indian Oceans in 1993. The largest error, 310 nm, occurred on Tropical Cyclone 21P (Polly).

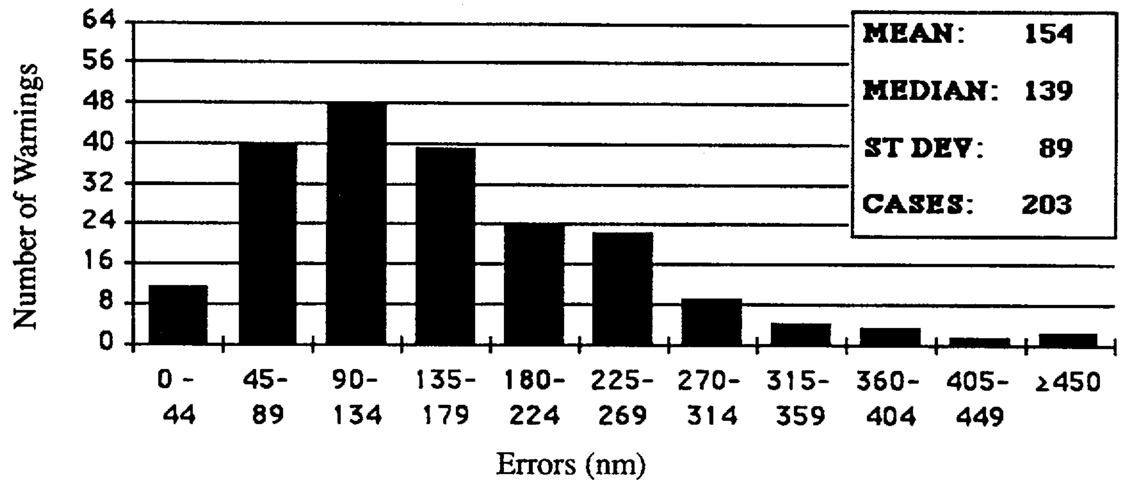

Figure 5-7d Frequency distribution of 36-hr forecast errors (45-nm increments) for the South Pacific and South Indian Oceans in 1993. The largest error, 485 nm, occurred on Tropical Cyclone 21P (Polly).

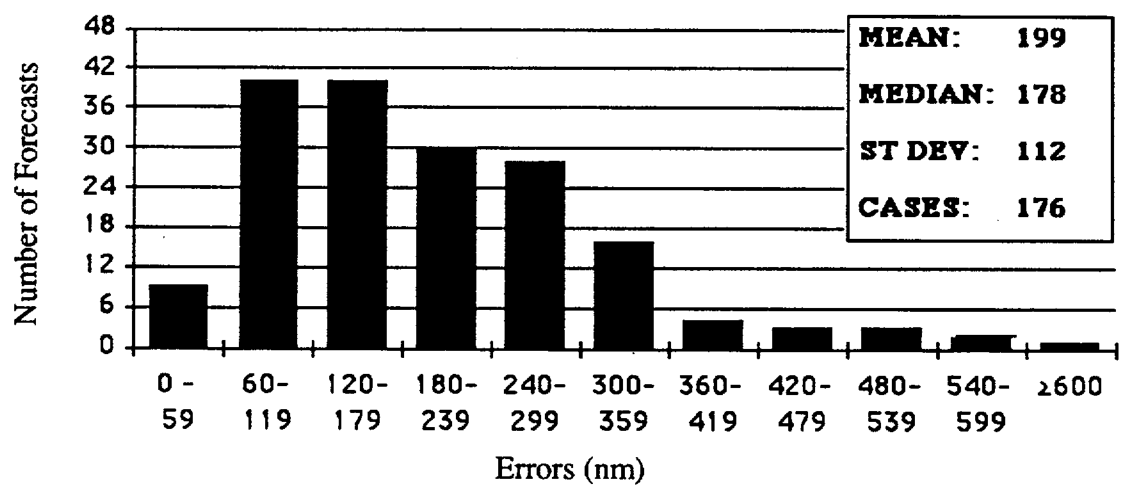

Figure 5-7e Frequency distribution of 48-hour forecast errors (60-nm increments) for the South Pacific and South Indian Oceans in 1993. The largest error, 618 nm, occurred on Tropical Cyclone 23P (Prema).

Table 5-4 INITIAL POSITION AND FORECAST POSITION ERRORS (NM) FOR THE SOUTHERN HEMISPHERE 1981-1993

YEAR	NUMBER OF WARNINGS	INITIAL POSITION	24-HOUR NUMBER OF FORECASTS	24-HOUR TRACK	24-HOUR ALONG	24-HOUR CROSS	48-HOUR NUMBER OF FORECASTS	48-HOUR TRACK	48-HOUR ALONG	48-HOUR CROSS
1981	226	48	190	165	103	106	140	315	204	201
1982	275	38	238	144	98	86	176	274	188	164
1983*	191	35	163	130	88	77	126	241	158	145
1984	301	36	252	133	90	79	191	231	159	134
1985*	306	36	257	134	92	79	193	236	169	132
1986*	279	40	227	129	86	77	171	262	169	164
1987*	189	46	138	145	94	90	101	280	153	138
1988*	204	34	99	146	98	83	48	290	246	144
1989*	287	31	242	124	84	73	186	240	166	136
1990*	272	27	228	143	105	74	177	263	178	152
1991*	264	24	231	115	75	69	185	220	152	129
1992*	267	28	230	124	91	64	208	240	177	129
1993*	257	21	225	102	74	57	176	199	142	114
AVERAGE 1981-1993	255	34	209	132	90	77	160	248	170	144

* These statistics are for JTWC forecasts only. NPMOC statistics are not included.

Note: Cross-track and along-track errors were adopted by the JTWC in 1986. Right-angle errors (used prior to 1986) were recomputed as cross-track and along-track errors after-the-fact to extend the data base. See Figure 5-1 for the definitions of cross-track and along-track errors.

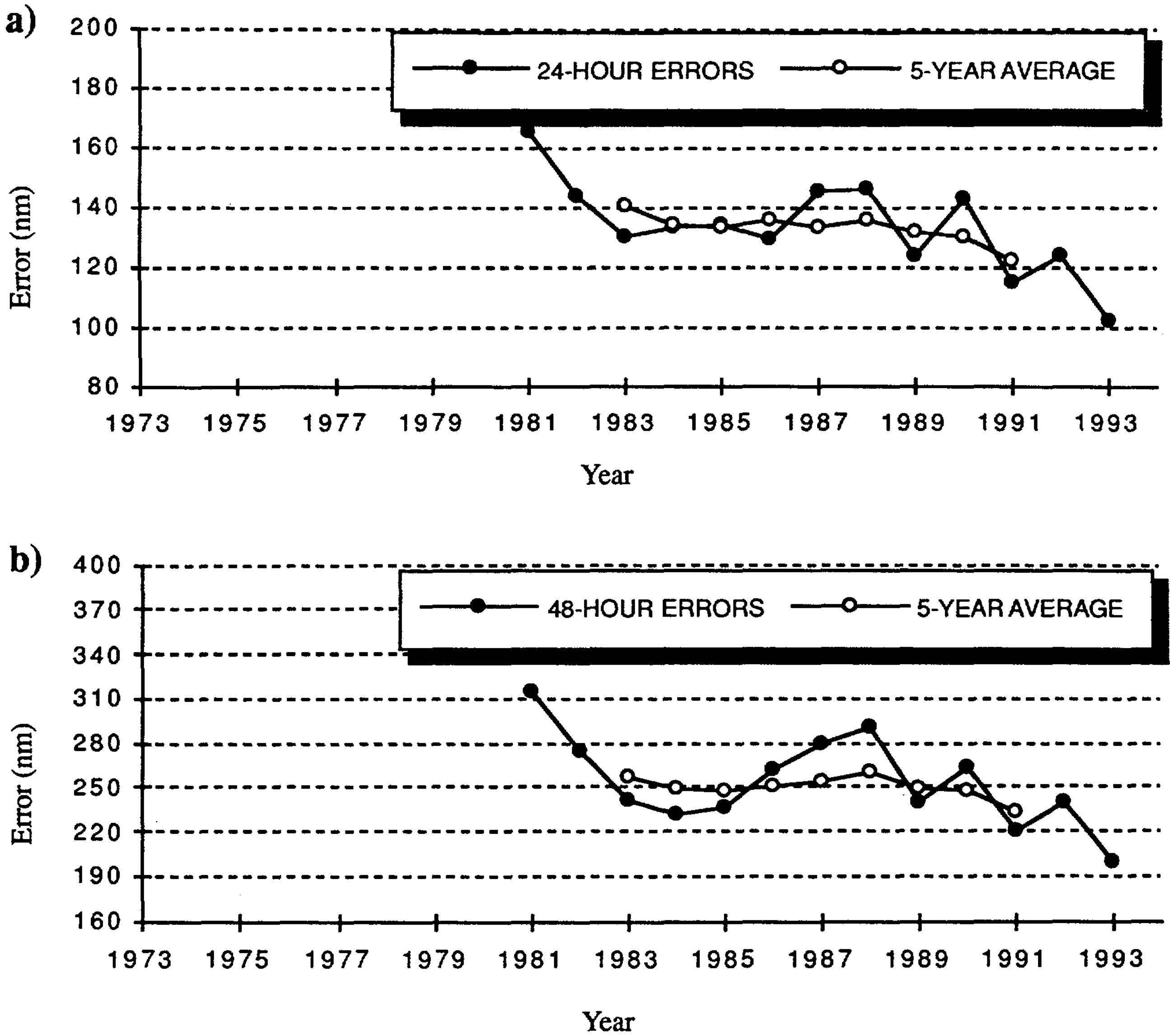

Figure 5-8 Mean track forecast errors (nm) and 5-year running mean for a) 24 hours and b) 48 hours for the South Pacific and South Indian Oceans for the period 1981 to 1993.

5.2 COMPARISON OF OBJECTIVE TECHNIQUES

JTWC uses a variety of objective techniques for guidance in the warning preparation process. Multiple techniques are required, because each technique has particular strengths and weaknesses which vary by basin, numerical model initialization, 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. JTWC initializes its objective techniques using an extrapolated working best track position so that the output of the techniques will start at the valid time of the next warning initial position.

Unless stated otherwise, all the objective techniques discussed below run in all basins covered by JTWC's AOR and provide forecast positions at 12-, 24-, 36-, 48-, and 72-hours unless the technique aborts prematurely during computations. The techniques can be divided into six general categories: extrapolation, climatology and analogs, statistical, dynamic, hybrids, and empirical or analytical.

5.2.1 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 CLIMATOLOGY and ANALOGS

5.2.2.1 CLIMATOLOGY (CLIM) — Employs time and location windows relative to the current position of the storm to determine which historical storms will be used to compute the forecast. The historical data base is 1945-1981 for the Northwest Pacific, and 1900 to 1990 for the rest of JTWC's AOR. A second climatology-based technique exists on JTWC's Macintosh®™ computers. It employs data bases from 1945 to 1992 and from 1970 to 1993. 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.

5.2.2.2 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. In the western North Pacific basin, 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 AOR, a forecast based on all acceptable straight-running analogs called STRT, as well as a forecast based only on historical recurvers called RECR are available.

5.2.3 STATISTICAL

5.2.3.1 CLIMATOLOGY AND PERSISTENCE (CLIPER or CLIP) — 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 Neumann (1985). CLIPER has been available outside this basin since mid-1990, with regression coefficients recently recomputed by FNOC based on the updated 1900-1989 data base.

5.2.3.2 COLORADO STATE UNIVERSITY MODEL (CSUM) — A statistical-dynamical 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 kt 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.

5.2.3.3 JTWC92 or JT92 - JTWC92 is a statistical-dynamical model for the western North Pacific Ocean basin which forecasts tropical cyclone positions at 12-hour intervals to 72 hours. The model uses the deep-layer mean height field derived from the NOGAPS forecast fields. These deep-layer mean height fields are spectrally truncated to wave numbers 0 through 18 prior to use in JTWC92. Separate forecasts are made for each position. That is, the forecast 24 hour position is not a 12-hour forecast from the forecasted 12-hour position.

JTWC92 uses five internal sub-models which are blended and iterated to produce the final forecasts. The first sub-model is a statistical blend of climatology and persistence, known as CLIPER. The second sub-model is an analysis mode predictor, which only uses the "analysis" field. The third sub-model is the forecast mode predictor, which uses only the forecast fields. The fourth sub-model is a combination of 1 and 2 to produce a "first guess" of the 12-hourly forecast positions. The fifth sub-model uses the output of the "first guess" combined with 1,2, and 3 to produce the forecasts. The iteration is accomplished by using the output of sub-model 5 as though it were the output from sub-model 4. The optimum number of iterations has been determined to be three.

When JTWC92 is used in the operational mode, all the NOGAPS fields are forecast fields. The 00Z and 12Z tropical forecasts are based upon the previous 12-hour old synoptic time NOGAPS forecasts. The 06Z and 18Z tropical forecasts are based on the previous 00Z and 12Z NOGAPS forecasts, respectively. Therefore, operationally, the second sub-model uses forecast fields and not analysis fields.

5.2.4 DYNAMIC

5.2.4.1 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 has improved the ability of the NOGAPS technique to track the vortex.

5.2.4.2 ONE-WAY (INTERACTIVE) 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).

5.2.4.3 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.

5.2.5 HYBRIDS

Note: For information on hybrid aids under development, refer to Chapter 7, section 7.7 Hybrid Forecast Aids.

5.2.5.1 HALF PERSISTENCE AND CLIMATOLOGY (HPAC) — Forecast positions are generated by equally weighting the forecasts given by XTRP and CLIM.

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

5.2.6 EMPIRICAL OR ANALYTICAL

5.2.6.1 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.

5.2.6.2 MARTIN/HOLLAND — The technique adapts an earlier work (Holland, 1980) and specifically addresses the need for realistic 35-, 50- and 100-kt (18-,26- and 51-m/sec) 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".

5.2.6.3 TYPHOON ACCELERATION PREDICTION TECHNIQUE (TAPT) — This technique (Weir, 1982) utilizes upper-tropospheric and surface 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.

5.3 TESTING AND RESULTS

A comparison of selected techniques is included in Table 5-5 for all Northwest Pacific tropical cyclones, Table 5-6 for all North Indian Ocean tropical cyclones and Table 5-7 for the Southern Hemisphere. For example in Table 5-5 for the 12-hour mean forecast error, 762 cases available for a (homogeneous) comparison, the average forecast error at 12 hours was 74 nm (137 km) for JT92 and 78 nm (145 km) for CLIP. The difference of 4 nm (7 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 5-5 1993 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTHWEST PACIFIC (1 JAN 1993 - 31 DEC 1993)

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

12-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		OTCM		CSUM		FBAM		JT92		CLIP		HPAC	
JTWC	800	66														
	66	0														
NGPS	394	56	397	106												
	106	50	106	0												
OTCM	739	65	378	106	755	82										
	82	17	75	-31	82	0										
CSUM	751	65	383	106	753	82	767	78								
	77	12	70	-36	77	-5	78	0								
FBAM	743	65	380	106	744	81	756	77	758	76						
	76	11	70	-36	76	-5	76	-1	76	0						
JT92	749	65	382	106	751	82	763	78	756	76	765	74				
	74	9	67	-39	74	-8	74	-4	74	-2	74	0				
CLIP	751	65	382	106	752	82	764	78	755	76	762	74	767	78		
	78	13	69	-37	78	-4	78	0	78	2	78	4	78	0		
HPAC	749	65	382	106	751	82	764	78	754	76	761	74	765	78	765	80
	80	15	71	-35	79	-3	80	2	80	4	80	6	80	2	80	0

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		OTCM		CSUM		FBAM		JT92		CLIP		HPAC	
JTWC	725	112														
	112	0														
NGPS	329	98	332	159												
	158	60	159	0												
OTCM	667	110	316	156	684	132										
	132	22	126	-30	132	0										
CSUM	689	111	322	158	682	132	707	129								
	129	18	125	-33	128	-4	129	0								
FBAM	684	111	318	158	676	132	699	129	701	121						
	121	10	118	-40	121	-11	121	-8	121	0						
JT92	689	111	321	157	682	132	705	129	700	121	707	119				
	119	8	115	-42	119	-13	119	-10	119	-2	119	0				
CLIP	687	111	320	158	680	132	703	129	698	122	703	119	705	129		
	129	18	120	-38	127	-5	129	0	129	7	129	10	129	0		
HPAC	686	111	320	158	679	132	703	129	697	121	702	119	704	129	704	135
	135	24	129	-29	133	1	135	6	135	14	135	16	135	6	135	0

Table 5-5 (CONTINUED) 1993 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTHWESTERN PACIFIC (1 JAN 1993 - 31 DEC 1993)

36-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	OTCM	CSUM	FBAM	JT92	CLIP	HPAC
JTWC	652 161							
	161 0							
NGPS	262 141	265 206						
	206 65	206 0						
OTCM	582 156	249 203	599 186					
	186 30	173 -30	186 0					
CSUM	619 160	257 205	597 186	638 183				
	183 23	180 -25	177 -9	183 0				
FBAM	616 160	254 205	593 185	632 183	634 173			
	173 13	174 -31	169 -16	173 -10	173 0			
JT92	619 160	256 205	597 186	636 183	633 173	638 167		
	167 7	165 -40	164 -22	167 -16	168 -5	167 0		
CLIP	618 160	256 205	597 186	635 183	631 173	635 168	637 187	
	187 27	176 -29	182 -4	187 4	188 15	187 19	187 0	
HPAC	617 160	256 205	596 186	635 183	630 173	634 167	636 187	636 195
	195 35	190 -15	188 2	195 12	195 22	195 28	195 8	195 0

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	OTCM	CSUM	FBAM	JT92	CLIP	HPAC
JTWC	570 212							
	212 0							
NGPS	200 185	206 250						
	250 65	250 0						
OTCM	499 204	194 246	531 237					
	235 31	218 -28	237 0					
CSUM	544 210	202 249	529 237	580 236				
	233 23	227 -22	227 -10	236 0				
FBAM	540 210	199 250	524 237	573 236	575 230			
	228 18	237 -13	224 -13	229 -7	230 0			
JT92	544 210	202 249	529 238	578 236	574 230	580 224		
	223 13	218 -31	219 -19	224 -12	224 -6	224 0		
CLIP	543 211	200 249	528 238	577 236	573 230	577 224	579 246	
	245 34	227 -22	239 1	247 11	246 16	247 23	246 0	
HPAC	542 210	200 249	527 238	577 236	572 230	576 224	578 246	578 255
	254 44	246 -3	245 7	255 19	254 24	255 31	255 9	255 0

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	OTCM	CSUM	FBAM	JT92	CLIP	HPAC
JTWC	437 321							
	321 0							
NGPS	129 271	136 306						
	305 34	306 0						
OTCM	365 297	120 302	399 341					
	341 44	317 15	341 0					
CSUM	414 319	134 305	398 341	456 342				
	342 23	341 36	322 -19	342 0				
FBAM	412 320	131 308	395 342	452 343	453 348			
	343 23	339 31	332 -10	348 5	348 0			
JT92	325 328	108 311	309 340	356 346	355 346	357 336		
	336 8	341 30	317 -23	336 -10	337 -9	336 0		
CLIP	413 320	133 305	397 342	454 343	452 349	355 337	455 364	
	368 48	357 52	343 1	364 21	364 15	365 28	364 0	
HPAC	412 320	133 305	396 341	454 343	451 349	354 337	454 364	454 365
	363 43	360 55	339 -2	365 22	365 16	366 29	365 1	365 0

TABLE 5-6 1993 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTH INDIAN OCEAN (1 JAN 1993 - 31 DEC 1993)

12-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	FBAM	CLIP	HPAC	STRT	CLIM
JTWC	32 69						
	69 0						
OTCM	29 67	29 84					
	84 17	84 0					
FBAM	29 65	28 84	29 83				
	83 18	83 -1	83 0				
CLIP	31 69	29 84	29 83	31 79			
	79 10	80 -4	78 -5	79 0			
HPAC	30 66	29 84	29 83	30 78	30 73		
	73 7	75 -9	73 -10	73 -5	73 0		
STRT	26 62	25 76	26 72	26 72	26 67	26 77	
	77 15	79 3	77 5	77 5	77 10	77 0	
CLIM	30 66	29 84	29 83	30 78	30 73	26 77	30 77
	77 11	79 -5	77 -6	77 -1	77 4	74 -3	77 0

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	FBAM	CLIP	HPAC	STRT	CLIM
JTWC	28 125						
	125 0						
OTCM	25 118	25 149					
	149 31	149 0					
FBAM	25 117	24 148	25 143				
	143 26	143 -5	143 0				
CLIP	27 127	25 149	25 143	27 126			
	126 -1	122 -27	121 -22	126 0			
HPAC	26 118	25 149	25 143	26 120	26 115		
	115 -3	117 -32	114 -29	115 -5	115 0		
STRT	24 115	23 144	24 135	24 119	24 112	24 128	
	128 13	131 -13	128 -7	128 9	128 16	128 0	
CLIM	26 118	25 149	25 143	26 120	26 115	24 128	26 128
	128 10	130 -19	130 -13	128 8	128 13	129 1	128 0

36-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	FBAM	CLIP	HPAC	STRT	CLIM
JTWC	24 162						
	162 0						
OTCM	17 149	17 201					
	201 52	201 0					
FBAM	22 166	17 201	22 205				
	205 39	213 12	205 0				
CLIP	23 166	17 201	22 205	23 165			
	165 -1	156 -45	166 -39	165 0			
HPAC	23 166	17 201	22 205	23 165	23 167		
	167 1	147 -54	166 -39	167 2	167 0		
STRT	21 162	16 200	21 196	21 168	21 167	21 175	
	175 13	141 -59	175 -21	175 7	175 8	175 0	
CLIM	23 166	17 201	22 205	23 165	23 167	21 175	23 178
	178 12	168 -33	182 -23	178 13	178 11	189 14	178 0

TABLE 5-6 (CONTINUED 1993 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTH INDIAN OCEAN (1 JAN 1993 - 31 DEC 1993)

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	FBAM	CLIP	HPAC	STRT	CLIM
JTWC	20 198						
	198 0						
OTCM	14 177	14 264					
	264 87	264 0					
FBAM	19 206	14 264	19 276				
	276 70	282 18	276 0				
CLIP	19 206	14 264	19 276	19 205			
	205 -1	187 -77	205 -71	205 0			
HPAC	19 206	14 264	19 276	19 205	19 217		
	217 11	184 -80	217 -59	217 12	217 0		
STRT	19 206	14 264	19 276	19 205	19 217	19 232	
	232 26	171 -93	232 -44	232 27	232 15	232 0	
CLIM	19 206	14 264	19 276	19 205	19 217	19 232	19 242
	242 36	228 -36	242 -34	242 37	242 25	242 10	242 0

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	FBAM	CLIP	HPAC	STRT	CLIM
JTWC	12 231						
	231 0						
OTCM	10 224	10 367					
	367 143	367 0					
FBAM	11 240	10 367	11 406				
	406 166	368 1	406 0				
CLIP	11 240	10 367	11 406	11 235			
	235 -5	236 -131	235 -171	235 0			
HPAC	11 240	10 367	11 406	11 235	11 242		
	242 2	229 -138	242 -164	242 7	242 0		
STRT	11 240	10 367	11 406	11 235	11 242	11 213	
	213 -27	185 -182	213 -193	213 -22	213 -29	213 0	
CLIM	11 240	10 367	11 406	11 235	11 242	11 213	11 376
	376 136	382 15	376 -30	376 141	376 134	376 163	376 0

TABLE 5-7 1993 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE SOUTHERN HEMISPHERE (1 JUL 1992 - 30 JUN 1993)

12-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	OTCM	FBAM	CLIP	HPAC	STRT	CLIM
JTWC	246 55							
	55 0							
NGPS	123 52	213 99						
	103 51	99 0						
OTCM	224 54	167 100	328 69					
	71 17	62 -38	69 0					
FBAM	227 54	166 101	325 69	332 80				
	83 29	78 -23	79 10	80 0				
CLIP	229 54	167 100	328 69	332 80	335 86			
	88 34	77 -23	84 15	86 6	86 0			
HPAC	213 55	157 102	311 69	310 78	313 83	313 69		
	71 16	64 -38	68 -1	69 -9	69 -14	69 0		
STRT	179 52	142 95	260 66	264 79	266 83	244 67	266 67	
	69 17	64 -31	66 0	67 -12	67 -16	67 0	67 0	
CLIM	213 55	157 102	311 69	310 78	313 83	313 69	244 67	313 79
	80 25	73 -29	78 9	79 1	79 -4	79 10	76 9	79 0

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	OTCM	FBAM	CLIP	HPAC	STRT	CLIM
JTWC	225 102							
	102 0							
NGPS	119 101	208 149						
	151 50	149 0						
OTCM	203 100	161 149	303 116					
	120 20	106 -43	116 0					
FBAM	212 102	164 151	300 116	315 139				
	140 38	135 -16	137 21	139 0				
CLIP	214 102	165 150	303 116	315 139	318 161			
	164 62	143 -7	155 39	161 22	161 0			
HPAC	198 100	155 151	286 116	293 132	296 151	296 120		
	122 22	113 -38	118 2	119 -13	120 -31	120 0		
STRT	168 98	140 139	245 111	255 135	257 157	235 115	257 120	
	121 23	115 -24	118 7	119 -16	120 -37	117 2	120 0	
CLIM	198 100	155 151	286 116	293 132	296 151	296 120	235 117	296 145
	142 42	135 -16	143 27	145 13	145 -6	145 25	140 23	145 0

36-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	OTCM	FBAM	CLIP	HPAC	STRT	CLIM
JTWC	203 154							
	154 0							
NGPS	105 157	186 182						
	188 31	182 0						
OTCM	180 149	138 174	273 171					
	178 29	156 -18	171 0					
FBAM	190 153	140 178	270 171	288 201				
	203 50	191 13	201 30	201 0				
CLIP	192 153	141 177	273 171	288 201	291 217			
	219 66	198 21	207 36	217 16	217 0			
HPAC	179 148	133 176	259 172	269 191	272 201	272 170		
	170 22	158 -18	166 -6	169 -22	170 -31	170 0		
STRT	152 148	122 163	221 163	236 196	238 210	219 163	238 188	
	175 27	168 5	182 19	187 -9	188 -22	181 18	188 0	
CLIM	179 148	133 176	259 172	269 191	272 201	272 170	219 181	272 207
	200 52	187 11	207 35	207 16	207 6	207 37	202 21	207 0

TABLE 5-7 (CONTINUED)

1993 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES
IN THE SOUTHERN HEMISPHERE (1 JUL 1992 - 30 JUN 1993)

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	OTCM	FBAM	CLIP	HPAC	STRT	CLIM
JTWC	176 199							
	199 0							
NGPS	92 208	172 230						
	242 34	230 0						
OTCM	160 197	128 225	248 221					
	229 32	210 -15	221 0					
FBAM	168 199	131 229	245 219	262 265				
	271 72	248 19	263 44	265 0				
CLIP	170 199	132 229	248 221	262 265	265 273			
	269 70	257 28	264 43	273 8	273 0			
HPAC	160 195	124 223	235 222	246 250	249 253	249 218		
	216 21	211 -12	215 -7	217 -33	218 -35	218 0		
STRT	135 192	114 210	202 211	215 262	217 263	201 208	217 237	
	228 36	227 17	231 20	236 -26	237 -26	223 15	237 0	
CLIM	160 195	124 223	235 222	246 250	249 253	249 218	201 223	249 262
	252 57	245 22	265 43	262 12	262 9	262 44	257 34	262 0