

3. SUMMARY OF FORECAST VERIFICATION

3.1 ANNUAL FORECAST VERIFICATION

Verification of warning positions and intensities at initial, 12-, 24-, 48-, and 72-hour forecast periods are made against the final best track. The (scalar) track forecast, along-track and cross-track errors (illustrated in Figure 3-1) were calculated for each verifying JTWC forecast. These data, in addition to a detailed summary for each tropical cyclone, are included as Chapter 4. This section summarizes verification data this year and contrasts it with annual verification statistics from previous years.

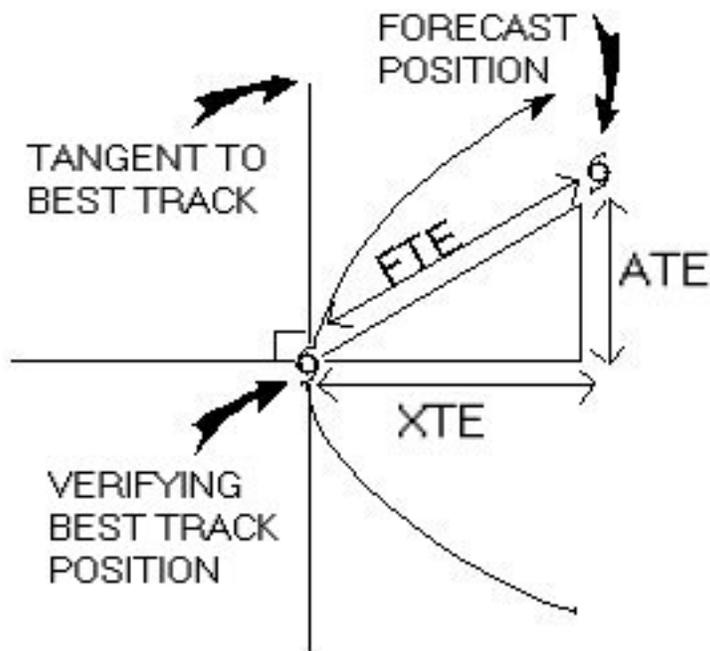


Figure 3-1. Definition of cross-track error (XTE), along-track error (ATE) and forecast track error (FTE). In this example, the forecast position is ahead of and to the right of the verifying best track position. Therefore, the XTE is positive (to the right of the best track) and the ATE is positive (ahead or faster than the best track). Adapted from Tsui and Miller, 1988.

3.1.1 NORTHWEST PACIFIC OCEAN

Table 3-1 includes mean track, along-track and cross-track errors for a 15-year period. Figure 3-2 shows mean track errors and a 5-year running mean of track errors at 24-, 48- and 72-hours since 1974. Table 3-2 lists annual mean track errors from 1959, when JTWC was founded, until the present.

	Initial Position		24-Hour				48-Hour				72-Hour			
	Number	Error	Number	Track	Along	Cross	Number	Track	Along	Cross	Number	Track	Along	Cross
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
1994	1058	24	932	98	85	62	753	176	158	105	608	242	218	144
1995	559	29	539	123	89	67	421	215	159	117	319	325	240	167
1996	922	25	880	105	76	56	711	178	134	89	607	272	203	137
1997	910	20	865	93	76	55	752	164	134	87	642	245	202	120
1998	450	22	375	124	98	58	273	239	178	127	202	370	274	201
1999	583	15	445	106	74	59	307	176	119	102	197	234	155	139
(1985-1999)														
Avg	738	22	645	110	80	62	512	206	151	114	406	309	227	170

YEAR (Notes)	24-HOUR				48-HOUR				72-HOUR			
	TY (1)	TC (3)	CROSS TRACK (2)	ALONG TRACK (2)	TY (1)	TC (3)	CROSS TRACK (2)	ALONG TRACK (2)	TY (1)	TC (3)	CROSS TRACK (2)	ALONG TRACK (2)
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	98	104			181	190			272	279		
1971	99	111	64		203	212	118		308	317	177	

Table 3-2 MEAN FORECAST TRACK ERRORS (NM) FOR WESTERN NORTH PACIFIC TROPICAL CYCLONES FOR 1959-1999

1972	116	117	72		245	245	146		382	381	210	
1973	102	108	74		193	197	134		245	253	162	
1974	114	120	78		218	226	157		357	348	245	
1975	129	138	84		279	288	181		442	450	290	
1976	117	117	71		232	230	132		336	338	202	
1977	140	148	83		266	283	157		390	407	228	
1978	120	127	71	87	241	271	151	194	459	410	218	296
1979	113	124	76	81	219	226	138	146	319	316	182	214
1980	116	126	76	86	221	243	147	165	362	389	230	266
1981	117	124	77	80	215	221	131	146	342	334	219	206
1982	114	113	70	74	229	238	142	162	337	342	211	223
1983	110	117	73	76	247	260	164	169	384	407	263	259
1984	110	117	64	84	228	232	131	163	361	363	216	238
1985	112	117	68	80	228	231	138	153	355	367	227	230
1986	117	126	70	85	261	261	151	183	403	394	227	276
1987	101	107	64	71	211	204	127	134	318	303	186	198
1988	107	114	58	85	222	216	103	170	327	315	159	244
1989	107	120	69	83	214	231	127	162	325	350	177	265
1990	98	103	60	72	191	203	110	148	299	310	168	225
1991	93	96	53	69	187	185	97	137	298	287	146	229
1992	97	107	59	77	194	205	116	143	295	305	172	210
1993	102	112	63	79	205	212	117	151	320	321	173	226
1994**	96	105	56	76	172	186	105	131	244	258	152	176
1995	105	123	67	89	200	215	117	159	311	325	167	240
1996	85	105	56	76	157	178	89	134	252	272	137	203
1997	86	93	55	76	159	164	87	134	251	245	120	202
1998	127	124	58	98	263	239	127	178	392	370	201	274
1999	88	106	59	74	150	176	102	119	225	234	139	155
Averages	108	108	63	73	215	208	121	140	328	312	181	212

1. Forecasts were verified for typhoons when intensities were at least 35kt at warning times

2. 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 errors after-the fact to extend the data base. See Figure 3-1 for the definitions of cross-track and along-track.

3. Mean forecast errors for all warned systems in Northwest Pacific.

*Forecast positions north of 35 degrees North latitude were not verified.

**1994 statistics were recalculated to resolve earlier Along and Cross-Track discrepancies.

3.1.2 NORTH INDIAN OCEAN

Table 3-3 includes mean track, along-track and cross-track errors for a 15-year period. Figure 3-3 shows mean track errors and a 5-year running mean of track errors at 24-, 48- and 72-hours since 1981.

Table 3-3 JTWC INITIAL POSITION AND FORECAST ERRORS (NM) FOR THE NORTHERN INDIAN OCEAN 1985-1999

	Initial Position		24-Hour				48-Hour				72-Hour				
	Number	Error	Number	Track	Along	Cross	Number	Track	Along	Cross	Number	Track	Along	Cross	
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	97	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	11
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
1994	60	25	44	97	80	44	28	153	124	63	13	213	177	92
1995	54	30	47	138	119	58	32	262	247	77	20	342	304	109
1996	135	33	123	134	94	80	85	238	181	127	58	311	172	237
1997	56	29	42	119	87	49	29	201	168	92	17	228	195	110
1998	80	20	55	106	84	51	34	198	135	106	17	262	188	144
1999	49	8	41	79	59	38	22	184	130	116	10	374	309	177
(1985-1999)														
Avg	68	30	50	120	92	60	31	207	151	112	20	280*	206*	145*
*14 year average (1985 not available)														

3.1.3 SOUTH PACIFIC AND SOUTH INDIAN OCEANS

Table 3-4 includes mean track, along-track and cross-track errors for a 15-year period. Figure 3-4 shows mean track errors and a 5-year running mean of track errors at 24-, 48- and 72-hours since 1981.

	Initial Position		24-Hour				48-Hour				72-Hour			
	Number	Error	Number	Track	Along	Cross	Number	Track	Along	Cross	Number	Track	Along	Cross
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				
1994	386	28	345	115	77	68	282	224	147	134				
1995	245	24	222	108	82	55	175	198	144	108	53	291	169	190
1996	343	24	298	125	90	67	237	240	174	129	46	277	221	133
1997	561	24	499	109	82	72	442	210	163	135	150	288	248	175
1998	329	26	305	111	85	52	245	219	169	108	81	349	261	171
1999	348	17	322	113	80	64	245	226	159	132	59	286	198	164
(1985-1999)														
Avg	302	29	258	123	87	70	205	236	167	132	78*	298*	219*	167*
*5-year average														

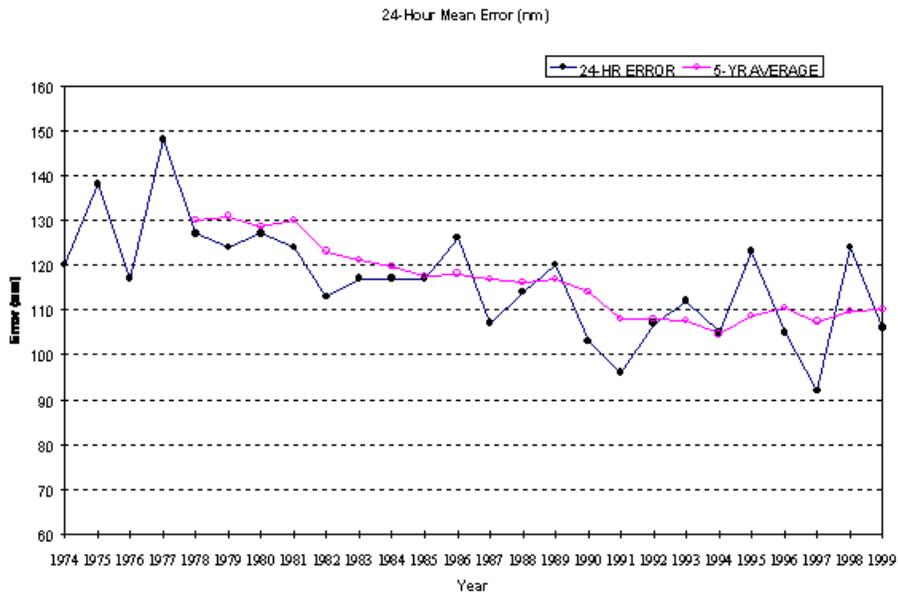


Figure 3-2a. Mean track forecast error (nm) and 5-year running mean for 24 hours for North West Pacific Ocean tropical cyclones from 1974-1999.

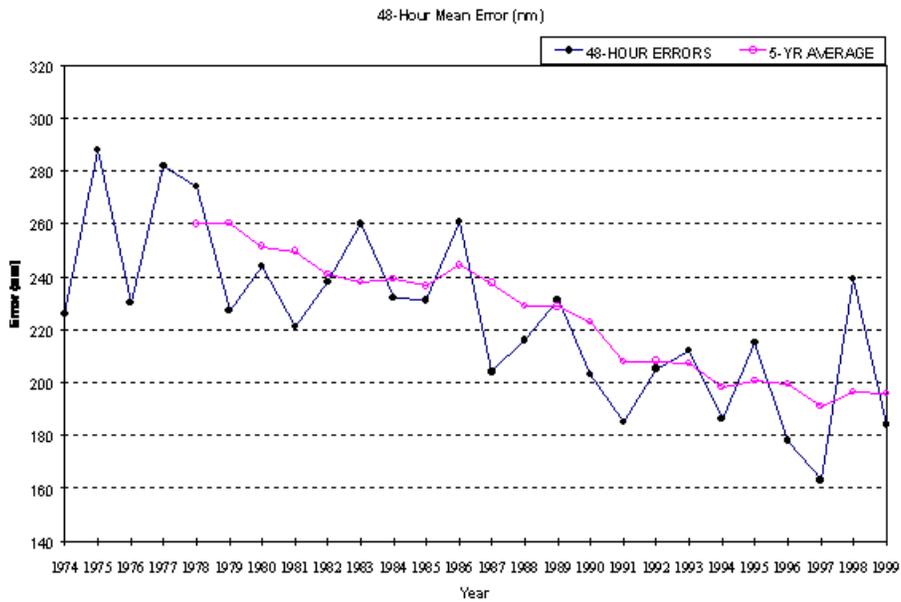


Figure 3-2b. Mean track forecast error (nm) and 5-year running mean for 48 hours for North West Pacific Ocean tropical cyclones from 1974-1999.

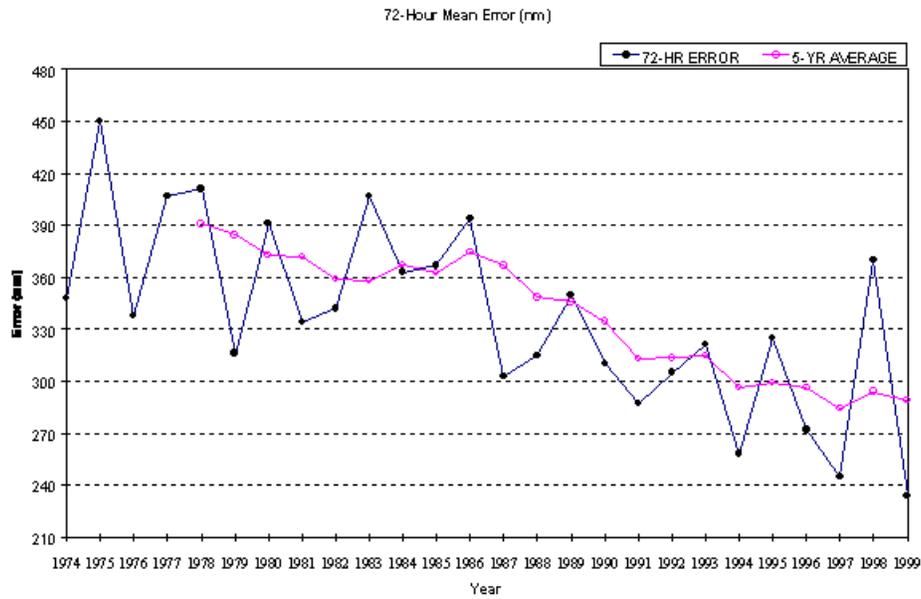


Figure 3-2c. Mean track forecast error (nm) and 5-year running mean for 72 hours for North West Pacific Ocean tropical cyclones from 1974-1999.

3.2 TESTING AND RESULTS

A comparison of selected techniques is included in Table 3-5 for all North West Pacific tropical cyclones, Table 3-6 for North Indian Ocean tropical cyclones and Table 3-7 for Southern Hemisphere tropical cyclones. For example, in Table 3-5 for the 12-hour mean forecast error, 212 cases were available for a homogeneous comparison. The average forecast error at 12 hours was 73 nm for NGPS and 61 nm for JTWC. The difference of 13 nm is shown in the lower right. Due to computational round-off, differences are not always exact.

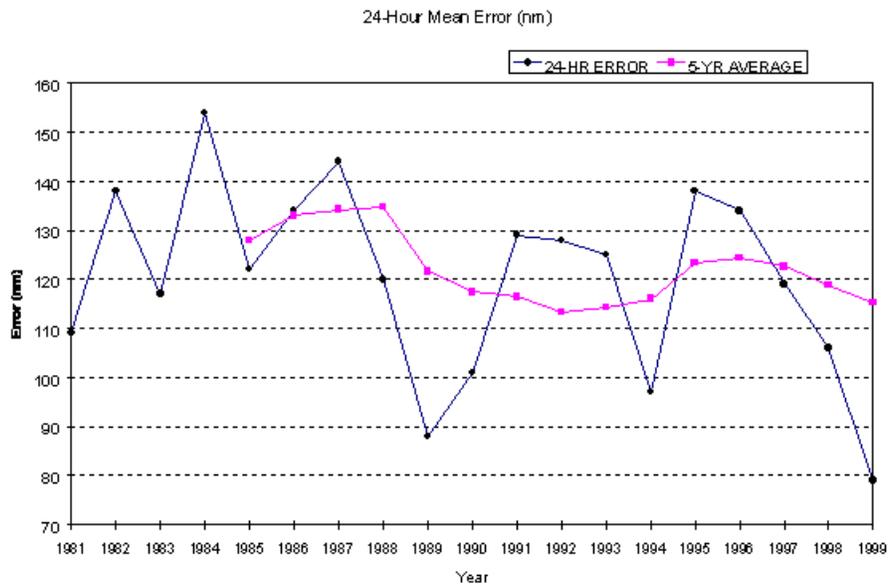


Figure 3-3a. Mean track forecast error (nm) and 5-year running mean for 24 hours for Northern Indian Ocean tropical cyclones from 1981-1999.

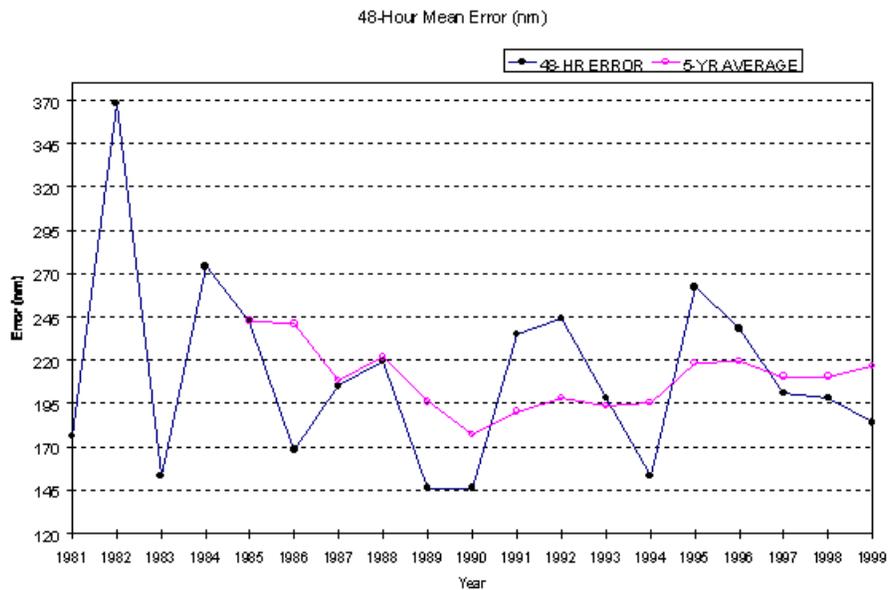


Figure 3-3b. Mean track forecast error (nm) and 5-year running mean for 48 hours, for Northern Indian Ocean tropical cyclones from 1981-1999.

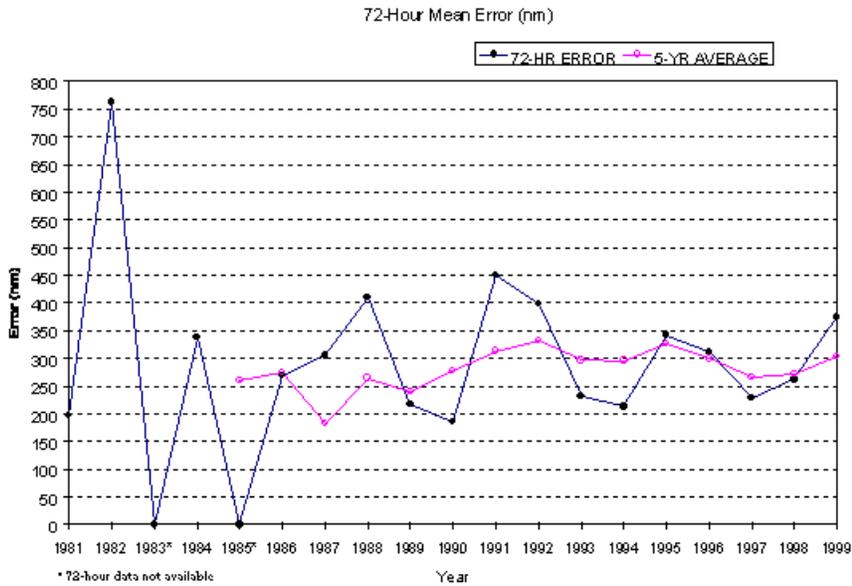


Figure 3-3c. Mean track forecast error (nm) and 5-year running mean for 72 hours for Northern Indian Ocean tropical cyclones from 1981-1999. The 1983 and 1985 zero values in the chart are due to no 72 hour forecasts during those years.

Table 3-5 1999 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES																
12-HOUR MEAN FORECAST ERROR (NM)																
	JTWC	NGPS	CSUM	EGRR	GFDN	JGSM	JTYM	CLIP								
JTWC	498	61														
	61	0														
NGPS	212	61	238	70												
	73	12	70	0												
CSUM	460	61	202	72	520	67										
	65	4	64	-8	67	0										
EGRR	0	0	5	34	1	102	6	83								
	0	0	42	8	290	188	83	0								
GFDN	159	54	0	0	151	56	0	0	161	130						
	131	77	0	0	97	41	0	0	130	0						
JGSM	139	58	119	66	141	64	1	290	10	67	145	65				
	64	6	63	-3	65	1	70	-220	58	-9	65	0				
JTYM	146	55	9	62	142	60	0	0	100	54	14	70	147	59		
	59	4	81	19	59	-1	0	0	57	3	72	2	59	0		
CLIP	497	61	237	70	520	67	6	83	161	130	144	65	147	59	633	67
	66	5	64	-6	69	2	39	-44	58	-72	67	2	63	4	67	0

Table 3-5 1999 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	CSUM	EGRR	GFDN	JGSM	JTYM	CLIP
JTWC	445 106							
	106 0							
NGPS	191 104	218 115						
	120 16	115 0						
CSUM	414 106	185 118	473 126					
	124 18	119 1	126 0					
EGRR	172 104	156 114	181 122	214 105				
	96 -8	91 -23	104 -18	105 0				
GFDN	143 101	0 0	139 114	5 140	145 177			
	178 77	0 0	139 25	92 -48	177 0			
JGSM	128 97	111 109	131 116	103 92	9 116	136 92		
	88 -9	89 -20	91 -25	91 -1	75 -41	92 0		
JTYM	134 98	8 97	130 118	10 109	95 96	12 101	135 88	
	87 -11	116 19	88 -30	97 -12	87 -9	98 -3	88 0	
CLIP	445 106	217 116	473 126	196 104	145 177	134 91	135 88	580 123
	126 20	118 2	128 2	124 20	118 -59	127 36	125 37	123 0

36-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	CSUM	EGRR	GFDN	JGSM	JTYM	CLIP
JTWC	375 145							
	145 0							
NGPS	154 141	183 157						
	160 19	157 0						
CSUM	346 144	152 157	413 177					
	176 32	170 13	177 0					
EGRR	0 0	5 105	0 0	5 116				
	0 0	116 11	0 0	116 0				
GFDN	119 140	0 0	119 160	0 0	125 173			
	175 35	0 0	122 -38	0 0	173 0			
JGSM	112 129	91 130	116 163	0 0	6 111	120 119		
	118 -11	114 -16	120 -43	0 0	105 -6	119 0		
JTYM	110 133	7 99	110 159	0 0	81 123	11 128	114 110	
	109 -24	140 41	111 -48	0 0	105 -18	119 -9	110 0	
CLIP	375 145	182 157	413 177	5 116	125 173	119 120	114 110	518 183
	186 41	173 16	188 11	95 -21	177 4	186 66	188 78	183 0

Table 3-5 1999 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	CSUM	EGRR	GFDN	JGSM	JTYM	CLIP								
JTWC	307	176														
	176	0														
NGPS	120	169	146	186												
	182	13	186	0												
CSUM	281	175	119	185	351	220										
	217	42	212	27	220	0										
EGRR	114	159	93	154	124	209	155	150								
	136	-23	139	-15	146	-63	150	0								
GFDN	99	168	0	0	99	202	2	95	105	214						
	218	50	0	0	153	-49	134	39	214	0						
JGSM	101	155	77	151	103	197	80	138	6	120	108	155				
	152	-3	142	-9	154	-43	157	19	115	-5	155	0				
JTYM	96	166	5	98	95	202	7	123	70	156	9	127	98	138		
	138	-28	134	36	139	-63	177	54	136	-20	139	12	138	0		
CLIP	307	176	145	186	351	220	138	142	105	214	106	155	98	138	454	244
	249	73	232	46	249	29	237	95	244	30	243	88	254	116	244	0

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC	NGPS	CSUM	EGRR	GFDN	JGSM	JTYM	CLIP								
JTWC	197	234														
	234	0														
NGPS	70	234	92	271												
	250	16	271	0												
CSUM	176	236	70	244	237	301										
	293	57	281	37	301	0										
EGRR	74	228	57	214	80	290	103	196								
	187	-41	202	-12	202	-88	196	0								
GFDN	61	204	0	0	62	287	1	97	66	237						
	226	22	0	0	237	-50	23	-74	237	0						
JGSM	61	213	48	212	66	253	51	193	3	174	69	203				
	200	-13	199	-13	199	-54	199	6	182	8	203	0				
JTYM	59	205	2	247	62	275	3	122	43	235	5	152	63	187		
	183	-22	270	23	188	-87	293	171	185	-50	190	38	187	0		
CLIP	197	234	91	269	237	301	91	201	66	237	68	201	63	187	331	363
	358	124	352	83	353	52	321	120	357	120	320	119	323	136	363	0

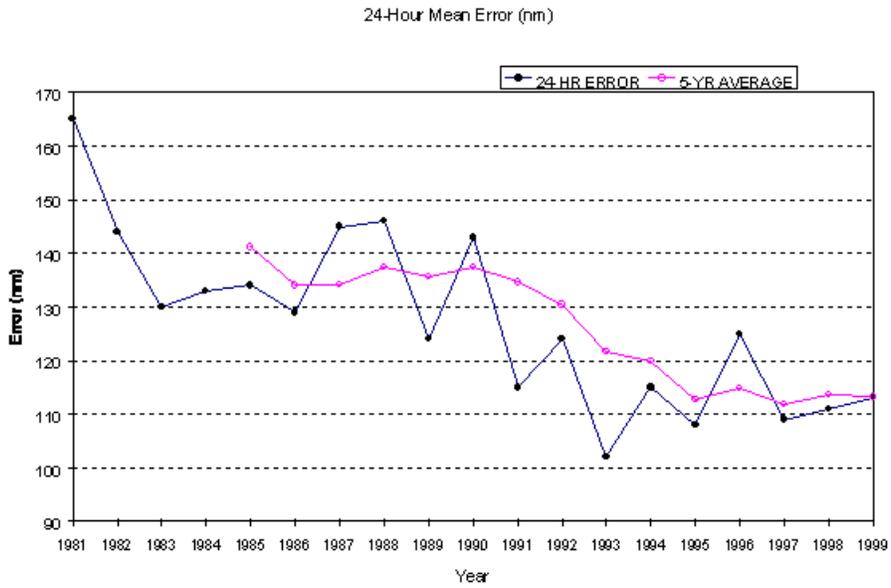


Figure 3-4a. Mean track forecast error (nm) and 5-year running mean for 24 hours for Southern Hemisphere (Africa to 180 degrees) tropical cyclones from 1981-1999.

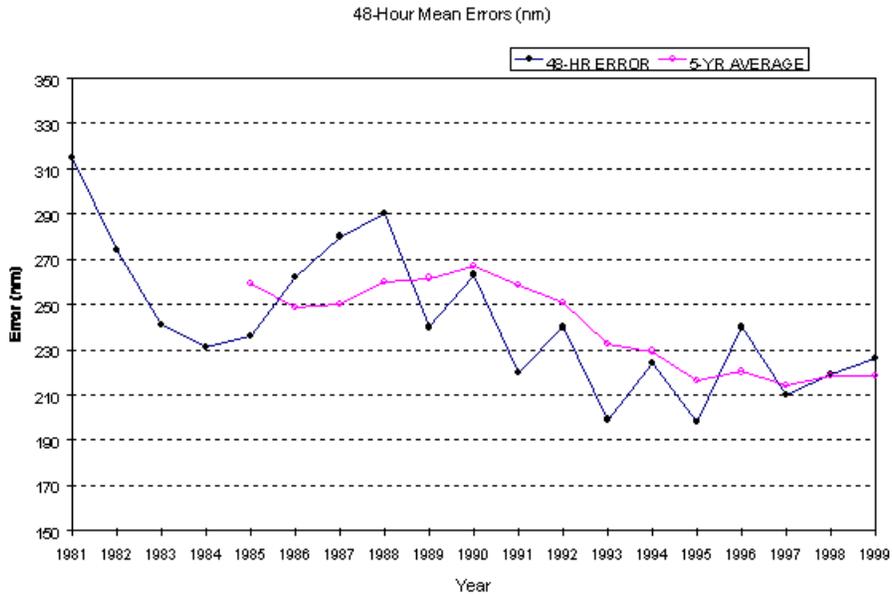


Figure 3-4b. Mean track forecast error (nm) and 5-year running mean for 48 hours for Southern Hemisphere (Africa to 180 degrees) tropical cyclones from 1981-1999.

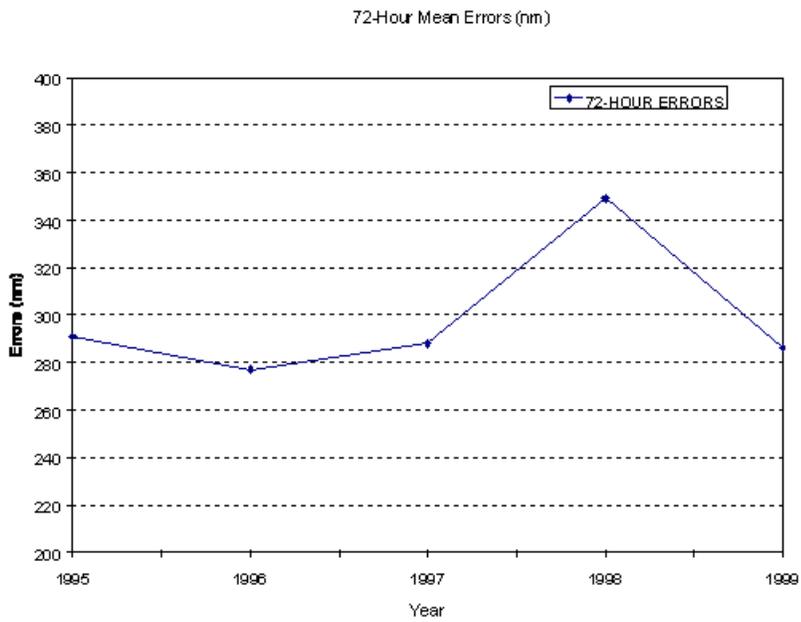


Figure 3-4c. Mean track forecast error (nm) at 72 hours for Southern Hemisphere (Africa to 180 degrees) tropical cyclones from 1995-1999.

Table 3-6 1999 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES								
12-HOUR MEAN FORECAST ERROR (NM)								
	JTWC		NGPS		GFDN		CLIP	
JTWC	47	39						
	39	0						
NGPS	24	37	32	74				
	71	34	74	0				
GFDN	15	28	0	0	24	69		
	55	27	0	0	69	0		
CLIP	47	39	28	75	22	68	71	46
	36	-3	36	-39	32	-36	46	0

Table 3-6 1999 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		EGRR		GFDN		CLIP	
JTWC	41	79								
	79	0								
NGPS	23	78	29	130						
	131	53	130	0						
EGRR	0	0	0	0	2	63				
	0	0	0	0	63	0				
GFDN	13	64	0	0	0	0	21	143		
	85	21	0	0	0	0	143	0		
CLIP	41	79	26	130	0	0	19	138	65	91
	75	-4	70	-60	0	0	68	-70	91	0

36-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		GFDN		CLIP	
JTWC	31	121						
	121	0						
NGPS	17	117	25	165				
	155	38	165	0				
GFDN	11	108	0	0	15	185		
	132	24	0	0	185	0		
CLIP	31	121	23	169	14	183	58	141
	117	-4	117	-52	101	-82	141	0

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		EGRR		GFDN		CLIP	
JTWC	22	184								
	184	0								
NGPS	12	176	21	205						
	164	-12	205	0						
EGRR	0	0	0	0	2	63				
	0	0	0	0	63	0				
GFDN	7	172	0	0	0	0	13	295		
	186	14	0	0	0	0	295	0		
CLIP	22	184	20	205	0	0	12	278	51	193
	176	-8	166	-39	0	0	148	-130	193	0

Table 3-6 1999 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		EGRR		GFDN		CLIP	
JTWC	10	374								
	374	0								
NGPS	4	384	13	253						
	258	-126	253	0						
EGRR	0	0	0	0	2	87				
	0	0	0	0	87	0				
GFDN	5	342	0	0	0	0	8	408		
	269	-73	0	0	0	0	408	0		
CLIP	10	374	13	253	0	0	7	362	35	302
	342	-32	234	-19	0	0	292	-70	302	0

Table 3-7 1999 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES

12-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		EGRR		GFDN		CLIP		HPAC	
JTWC	343	61										
	61	0										
NGPS	104	61	181	74								
	79	18	74	0								
EGRR	3	27	1	50	4	110						
	128	101	143	93	110	0						
GFDN	101	55	4	84	0	0	161	69				
	54	-1	66	-18	0	0	69	0				
CLIP	340	61	134	76	3	128	131	62	495	127		
	79	18	103	27	24	-104	81	19	127	0		
HPAC	340	61	133	76	3	128	131	62	493	120	493	75
	72	11	73	-3	52	-76	64	2	75	-45	75	0

Table 3-7 1999 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		EGRR		GFDN		CLIP		HPAC	
JTWC	322	113										
	113	0										
NGPS	100	115	172	119								
	126	11	119	0								
EGRR	63	107	49	115	114	110						
	106	-1	95	-20	110	0						
GFDN	98	107	4	120	5	109	154	109				
	99	-8	125	5	132	23	109	0				
CLIP	320	112	128	123	86	105	128	102	470	180		
	133	21	147	24	123	18	130	28	180	0		
HPAC	320	112	128	123	86	105	128	102	469	175	469	137
	134	22	136	13	133	28	124	22	137	-38	137	0

36-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		EGRR		GFDN		CLIP		HPAC	
JTWC	284	171										
	171	0										
NGPS	85	181	150	160								
	171	-10	160	0								
EGRR	3	117	1	72	4	170						
	179	62	200	128	170	0						
GFDN	93	168	4	183	0	0	145	161				
	152	-16	196	13	0	0	161	0				
CLIP	283	170	111	166	3	179	122	155	441	250		
	206	36	203	37	149	-30	204	49	250	0		
HPAC	280	166	110	165	3	179	122	155	438	248	438	205
	196	30	208	43	162	-17	192	37	205	-43	205	0

Table 3-7 1999 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		EGRR		GFDN		CLIP		HPAC	
JTWC	245	226										
	226	0										
NGPS	61	248	124	198								
	204	-44	198	0								
EGRR	47	187	34	180	98	234						
	187	0	158	-22	234	0						
GFDN	78	220	3	167	4	192	134	211				
	209	-11	265	98	276	84	211	0				
CLIP	245	226	90	202	73	177	115	206	407	316		
	274	48	267	65	263	86	270	64	316	0		
HPAC	243	223	90	202	72	176	115	206	405	315	405	272
	264	41	283	81	256	80	264	58	272	-43	272	0

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		EGRR		GFDN		CLIP		HPAC	
JTWC	59	286										
	286	0										
NGPS	15	333	88	248								
	272	-61	248	0								
EGRR	11	261	26	259	79	261						
	180	-81	278	19	261	0						
GFDN	13	304	2	76	1	73	96	303				
	240	-64	366	290	382	309	303	0				
CLIP	59	286	65	262	57	242	87	301	329	435		
	432	146	378	116	385	143	392	91	435	0		
HPAC	59	286	65	262	56	235	86	303	327	436	327	393
	385	99	390	128	355	120	379	76	393	-43	393	0