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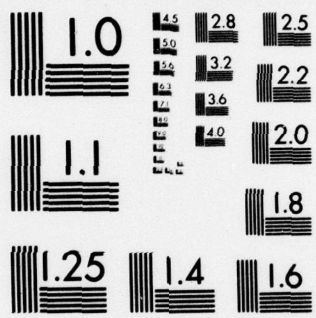
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MODIFIED TWENTY-FOUR HOUR EXTRAPOLATION AS A FORECAST TECHNIQUE FOR THE MOVEMENT OF TROPICAL CYCLONES

by

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APRIL 1976

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ABSTRACT

The Joint Typhoon Warning Center, Guam (JTWC) uses several objective techniques for forecasting the movement of tropical cyclones. Twelve-hour extrapolation (XTRP) and the TYFN75 analog program are the most successful of these techniques. The input parameters for both techniques include the past 12-hr storm position. It is felt that a subjective 24-hr extrapolation technique (XT24) based on reconnaissance positions is more realistic: (1) these data are real-time whereas the warning positions are extrapolated from the reconnaissance positions and (2) a 24-hr period tends to smooth out erratic short-term movements in the storm track. An operational evaluation of XT24 was conducted during the 1975 typhoon season. These results and recommendations for future use are discussed.

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Tables

1. INTRODUCTION

The official Joint Typhoon Warning Center (JTWC) warning is the culmination of a complex series of events which begins with the obtaining of a reconnaissance position (fix). To be suitable for warning purposes, a fix must be obtained 2 to 3½ hr prior to the scheduled warning time. Fixes obtained earlier are essentially too old for the warning time while fixes obtained later do not permit sufficient time for preparation of the warning. Once a warning fix has been obtained and plotted, the warning position is determined by extrapolation. For example, a fix obtained at 0930Z is the basis for extrapolation to 1200Z using the current storm speed for movement. The computerized objective forecast techniques are then run, and from these forecasts a preliminary forecast track is derived out to 72 hr. This track is evaluated subjectively for consistency and compatability with climatology and the current synoptic situation and modified as necessary.

At the present time, 12-hr extrapolation (XTRP) is the best objective technique for forecasting the 24- and 48-hr movement of tropical cyclones. XTRP uses the past 12-hr preliminary best track position and the current warning position as end points. The past 12-hr preliminary best track position is defined as that position best fitting all reconnaissance and supporting data available. The current warning position is determined by extrapolation as described above. A straight line is then drawn through these two points and becomes the forecast track. The speed of movement of the past 12-hr period is used as the forecast speed out to 48-hr.

The next most successful objective technique is the TYFN75 analog program (Jarrell and Wagoner, 1973). This program searches history data tapes for those tropical cyclones with characteristics similar to the current storm. Twenty-one acceptance parameters are considered, with the most critical being the present position and the past 12-hr location and movement of the storm.

During everyday operational application, it was observed that use of the past 12-hr preliminary best track position would frequently result in a "windshield wiper" effect for a series of warnings. This effect is the result of short term trends (based on consecutive fix positions) which indicate that significant changes in the direciton of movement are possible warranted in the forecast storm track. Colon's (1953) investigation of 24-hr persistence (to forecast the direction of movement only) in the Atlantic showed that its probability of success for at least the first 24-hr forecast was quite high in the more southerly latitudes of the Caribbean Sea and the eastern Atlantic. Riehl and Sanborn (1958) in a compilation of the three-day mean tracks for hurricanes, found that for storms in low latitudes, the general tendency is to preserve the initial direction of motion. Based on these observations, a subjective technique employing 24-hr extrapolation (XT24) was evaluated.

2. METHOD

Fifteen typhoons from 1974 and two from 1973 were utilized in an initial after-the-fact evaluation of XT24. The latest available fix position (upon which the JTWC warning was based), and that reconnaissance position 24-hr ago ±6 hr were used as the end points for linear extrapolation out to 72-hr. The speeds of the official JTWC forecast were used for movement. It should be noted that for storms which JTWC was forecasting to recurve, the official JTWC speed for the 24-hr forecast was also used for the 48- and 72-hr forecast. This was done to eliminate the inconsistency of using speeds of movement of 5 to 10 kt (2.6 to 5.1 m sec^{-1}) as a storm slows down prior to recurvature and then speeds up 20 to 35 kt (12.9 to 18.0 m sec^{-1}) after recurvature. These speeds were used in lieu of the past 24-hr speed (persistence) for several reasons. Storms moving faster or slower than climatology do not usually maintain these speeds for 48 to 72 hr. Persistence also cannot take into account such factors as terrain influences (storms crossing the Philippines, for example, exhibit a dramatic increase in speed), rate of development, and the position and amplitude of middle and upper tropospheric features. The JTWC speeds are determined subjectively after an evaluation of all available data.

The reconnaissance positions are used as end points in lieu of the warnings positions for several reasons. First, they are based on real-time data while the current warning position is simply extrapolated from what is considered the best reconnaissance position, thereby introducing additional error. During the period 1969-1974, the average warning position error was 19 nm for all typhoons in the JTWC area of responsibility. Furthermore, at the time any warning is being prepared, it is not possible to know the absolute warning position accuracy; this can only be determined by detailed post-season analysis. Additionally, as mentioned previously, tropical cyclones often behave quite erratically over a 12-hr period and it is difficult to ignore short-term trends which indicate that a radical change in the forecast track is possibly warranted. Thus, the 24-hr reconnaissance position is used in an attempt to smooth out short-term trends. It is also significant that although JTWC heavily considers the 500 mb prognosis for tropical cyclone steering, it has been observed that once a storm becomes well-organized (and in the absence of a well-defined ridge or trough), its circulation can effectively mask the steering flow over a considerable area. It then becomes difficult to separate the basic steering current from the circulation surrouding the storm. In the western Pacific, this is primarily true below 20N where the steering flow is generally easterly at 10-20 kt (5.1 - 10.3 m sec^{-1}). Above 20N, strong westerlies dominate with short-wave troughs and an occasional long-wave trough moving off mainland China. Here, a tropical cyclone may more realistically be considered a point vortex embedded in a broad-scale flow patter of 30 kt (15.4 m sec^{-1}) or greater.

Due to the nature of this self-steering concept, and for the reasons outlined above, it was felt that XT24 should be an improvement over XTRP and a valuable input to the official JTWC forecast. Since aircraft reconnaissance provides the most accurate and reliable fix data (Table 1), XT24 was based in order of preference as follows: (1) aircraft fixes; (2) land radar; (3) satellite eye fixes; and (4) satellite fixes other than eye fixes.

Table 1. Forecast position error (nm) for various categories of reconnaissance platforms (1973 and 1974 composite data). The number of cases is shown in parentheses (Harrison, 1975).

a. All Forecasts (Tropical Depressions, Tropical Storms, and Typhoons.

PLATFORM	FORECAST INTERVAL		
	WARNING	24-HR	48-HR
Aircraft	18 (466)	111 (410)	207 (261)
DMSP Satellite	25 (358)	119 (248)	226 (126)
Radar	17 (61)	125 (36)	228 (22)
Other	43 (93)	151 (43)	---

b. Forecasts for Typhoons (when maximum winds were 35 kt or greater).

PLATFORM	FORECAST INTERVAL		
	WARNING	24-HR	48-HR
Aircraft	16 (323)	106 (299)	200 (229)
DMSP Satellite	20 (205)	103 (162)	228 (111)
Radar	15 (39)	115 (26)	210 (20)
Other	36 (29)	122 (11)	---

From the results in Table 2, several general conclusions were drawn. Note in Table 2 and subsequent tables, that "X-AXIS" refers to the techniques listed horizontally, while "Y-AXIS" refers to those listed vertically. The example in Table 2 compares XTRP to XT24. In 326 cases available for comparison, the average 24-hr vector error for XTRP was 116 nm, while that for XT24 was 117 nm. The difference in accuracy between these two techniques was 1 nm. For all typhoons, XT24 compared favorable with JTWC and XTRP. When those tropical cyclones moving east, northeast, etc. and/or above 20N were eliminated from the verification, XT24 was a marked improvement over JTWC at 72-hr and XTRP at 48-hr (Table 3). Of course, it should be remembered that westward moving tropical cyclones below 20N may recurve, loop, or otherwise behave quite erratically. It should also be noted that in the absence of a steering flow to cause recurvature above 20N, XT24, may still be applicable.

Based on the positive results from this evaluation, XT24 was used operationally during the 1975 typhoon season with one modification. Due to the increased time span of 24-hr between end points, it was felt that the 24-hr ±6 hr reconnaissance position could be replaced by the past 24-hr preliminary best track position. This extended period permits sufficient time to evaluate additional data and establish an accurate position.

3. RESULTS

The forecast verification data for the 1975 typhoon season are presented in Table 4. Twenty-four hour extrapolation is verified against TYFN75 (only those analogs moving generally westward), XTRP, and HPAC which is the average of climatology and 12-hr persistence. XTRP was slightly more accurate for

Table 2. Objective forecast techniques for 17 typhoons from 1973 and 1974.

24-HOUR

	JTWC		XTRP		XT24	
JTWC	344	107				
	107	0				
XTRP	327	107	327	116		
	116	9	116	0		
XT24	343	107	326	116	343	117
	117	10	117	1	117	0

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

48-HOUR

	JTWC		XTRP		XT24	
JTWC	259	207				
	207	0				
XTRP	248	204	248	215		
	215	11	215	0		
XT24	259	207	248	215	259	220
	220	13	217	2	220	0

72-HOUR

	JTWC		XT24	
JTWC	176	327		
	327	0		
XT24	176	327	176	326
	326	-1	326	0

JTWC - Official JTWC Subjective Forecast
XTRP - 12-Hr Extrapolation
XT24 - Modified 24-Hr Extrapolation

Table 3. Objective forecast techniques for selected typhoons from 1973 and 1974.

24-HOUR

	JTWC		XTRP		XT24	
JTWC	215	103				
	103	0				
XTRP	208	104	208	114		
	114	11	114	0		
XT24	215	103	208	114	215	105
	105	2	105	-9	105	0

48-HOUR

	JTWC		XTRP		XT24	
JTWC	171	199				
	199	0				
XTRP	166	199	166	207		
	207	8	207	0		
XT24	171	199	166	207	171	186
	186	-14	186	-21	186	0

72-HOUR

	JTWC		XT24	
JTWC	121	331		
	331	0		
XT24	121	331	121	256
	256	-75	256	0

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

JTWC - Official JTWC Subjective Forecast
XTRP - 12-Hr Extrapolation
XT24 - Modified 24-Hr Extrapolation

Table 4. Objective forecast techniques for 13 typhoons from 1975.

24-HOUR ERRORS

	JTWC		XTRP		HPAC		TYFC		TYFS		TYFR		MH70		MH50		XT24	
JTWC	221	130																
	130	0																
XTRP	205	130	205	142														
	142	12	142	0														
HPAC	183	128	182	138	183	135												
	135	7	135	-3	135	0												
TYFC	59	121	57	145	53	121	59	134										
	134	13	134	-11	132	11	134	0										
TYFS	195	127	184	135	165	130	54	137	195	144								
	144	18	144	10	140	11	136	-1	144	0								
TYFR	204	130	193	141	177	136	59	134	190	144	204	144						
	144	14	143	2	140	5	146	12	144	0	144	0						
MH70	144	133	143	148	126	137	37	101	128	149	137	142	144	159				
	159	26	159	12	145	8	141	40	148	-1	154	12	159	0				
MH50	138	133	136	148	119	137	37	102	122	151	131	143	137	160	138	144		
	144	11	143	-5	134	-3	115	13	137	-13	143	0	143	-17	144	0		
XT24	177	130	173	140	169	136	50	134	158	144	169	139	121	146	114	137	177	149
	149	19	149	9	150	14	131	-3	141	-4	151	12	144	-2	145	8	149	0

48-HOUR ERRORS

	JTWC		XTRP		HPAC		TYFC		TYFS		TYFR		MH70		MH50		XT24	
JTWC	165	288																
	288	0																
XTRP	153	279	153	321														
	321	32	321	0														
HPAC	133	280	132	288	133	251												
	251	-30	252	-37	251	0												
TYFC	49	300	47	369	41	249	49	341										
	341	41	341	-28	289	41	341	0										
TYFS	153	285	144	318	125	243	48	344	154	358								
	359	74	-61	42	338	94	442	98	358	0								
TYFR	157	289	148	319	129	250	49	341	153	358	158	300						
	300	11	298	-21	274	24	358	16	298	-59	300	0						
MH70	98	291	97	343	81	249	26	341	91	377	95	299	98	357				
	357	66	360	18	299	50	521	180	354	-23	354	55	357	0				
MH50	96	292	94	344	78	249	26	347	89	381	93	302	95	358	96	356		
	356	64	358	14	276	27	443	96	357	-24	358	56	355	-3	356	0		
XT24	129	277	126	290	121	250	39	276	122	331	126	275	80	298	77	281	129	273
	273	-5	272	-19	274	24	230	-46	265	-66	271	-4	273	-25	271	-11	273	0

72-HOUR ERRORS

	JTWC	TYFC	TYFS	TYFR	MH70	MH50	XT24
JTWC	113 441 441 0						
TYFC	34 472 520 48	35 520 520 0					
TYFS	108 444 545 101	35 520 588 69	110 538 538 0				
TYFR	108 444 440 -4	35 520 572 52	110 538 444 -94	111 445 445 0			
MH70	57 432 504 72	15 511 664 153	57 529 508 -21	58 454 504 50	59 498 498 0		
MH50	58 435 485 50	17 520 531 11	58 534 497 -37	59 462 495 33	58 497 484 -13	60 488 488 0	
XT24	82 438 394 -44	26 519 332 -187	82 536 392 -144	82 421 392 -29	46 486 356 -130	45 439 352 -87	83 393 393 0

the 24-hr forecast, while XT24 was more accurate out to 48- and 72-hr. Suprisingly, XT24 was more accurate than the JTWC official forecast and all of the objective forecast techniques for the 72-hr forecast. This appears to be partially due to the fact that even though tropical cyclones rarely move in a straight line, their erratic behavior when averaged over a period of 72-hr and in the absence of a significant upper-level steering flow (e.g., to cause recurvature) can often be approximated by a straight line (e.g., by the use of XT24). This is similar to the finding of Riehl and Sanborn (1958) which was discussed earlier.

4. SUMMARY

Most significantly, this study has demonstrated that persistence (and climatology) can be important inputs to the official JTWC forecast out to 72-hr. In addition, a longer time period of 24-hr permits the smoothing out of short-term trends which may be misleading indications of a storm's future movement. XT24 illustrates considerable skill as a forecast technique for the movement of tropical cyclones beyond 24-hr. It gives a relatively real-time estimate of where a storm is moving since real-time data is used as input to the forecast. This is an advantage over TYFN75 which, while utilizing real-time data as an input, is still relying on climatology for its forecast. Due to the relatively small sample size, it is recommended that the evaluation of XT24 continue during the 1976 typhoon season.

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The Joint Typhoon Warning Center, Guam (JTWC) uses several objective techniques for forecasting the movement of tropical cyclones. Twelve-hour extrapolation (XTRP) and the TYFN75 analog program are the most successful of these techniques. The input parameters for both techniques include the past 12-hr storm position. It is felt that a subjective 24-hr extrapolation technique (XT24) based on reconnaissance positions is more → next page

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