NOTES AND CORRESPONDENCE

Accuracy of TIROS Hurricane Location

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1. Introduction

An important use of the TIROS data to meteorologists is in the location of hurricanes, typhoons and tropical storms. The current data reduction procedures at the readout stations as well as characteristics of the TIROS system introduce a certain amount of location error. The forecaster and mariner can use these data most effectively if they know the probable error of location. For that reason, statistics for three hurricane-typhoon seasons are presented here.

2. Data used

Sixty-seven eye locations were taken from the operational TIROS nephanalyses transmitted from the Command and Data Acquisition (CDA) stations. Some nephanalyses showed storm position by latitude and longitude digits as well as by the vortex symbol. Numerical values were used where available, otherwise the center of the vortex symbol was read from the nephanalysis map.

Satellite fixes were used in this study only when there were independent location data, mainly aircraft reconnaissance. In a few cases the reconnaissance fix and the satellite fix were nearly simultaneous but in most cases the positions were interpolated between two bracketing reconnaissance fixes.

Aircraft storm fixes are not precise. Navigation uncertainty, method of determining the eye-center, irregular asymmetric and changing eyes all can contribute to reconnaissance error. Large errors are frequently evident when a "best track" is deduced after the fact by meteorologists at hurricane centers, but the storm fixes available to the operational forecaster may include significant error. The average is probably less than a typical eye diameter, so for the purpose here, no attempt is made to evaluate the aircraft data.

The deviations of TIROS storm fixes discussed here are, in every case, deviations from the operational reconnaissance fixes. All cases were used where both a TIROS and an independent fix were made. Table 1 lists storm names, dates and TIROS numbers. A greater number of cases could have been included by using the post-season "best track" analysis, but this would have biased results in favor of satellite accuracy. Bias would arise because the post-season analysis is made by considering satellite fixes together with all other data. In some cases (especially in areas remote from reconnaissance bases) the only data available were from TIROS.

Bias *could* also have been introduced if the CDA analyst used any independent meteorological data to aid in the picture analysis. No such bias has been introduced however. Some hurricane bulletins as well as other routine data are available to the CDA stations, but this information has never been used in picture rectification and nephanalysis.

Frequency of location-deviations by 5 n mi class intervals is shown in Fig. 1. Fig. 2, the cumulative per cent frequency vs. distance, summarizes the distribution of Fig. 1. The actual frequencies are plotted and a smooth curve fit to these data by eye. The median and fourth quartile indicated, apply to the smoothed curve. The median deviation for all cases is 50 n mi and 75 per cent of the errors are less than 75 n mi.

The median error for TIROS III fixes is 85 n mi while the median for the fixes of TIROS V, VI, and VII combined is 45 n mi. This indicates the errors made with TIROS III data were greater, for reasons discussed below.

The errors have been examined for possible association with angle of view, direction bias, etc., but no such association was detected, suggesting that the errors were produced by a variety of causes and the combination produces a random distribution of error.

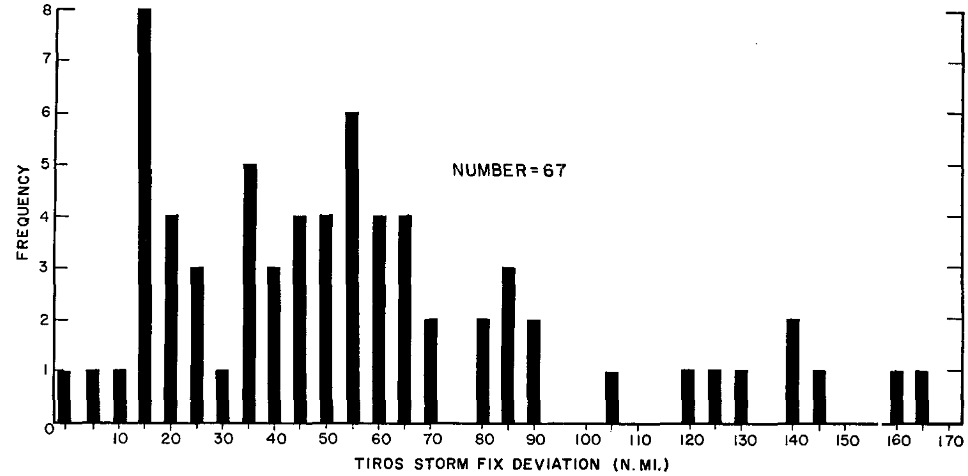

FIG. 1. Frequency of location deviations by 5 n mi class intervals.

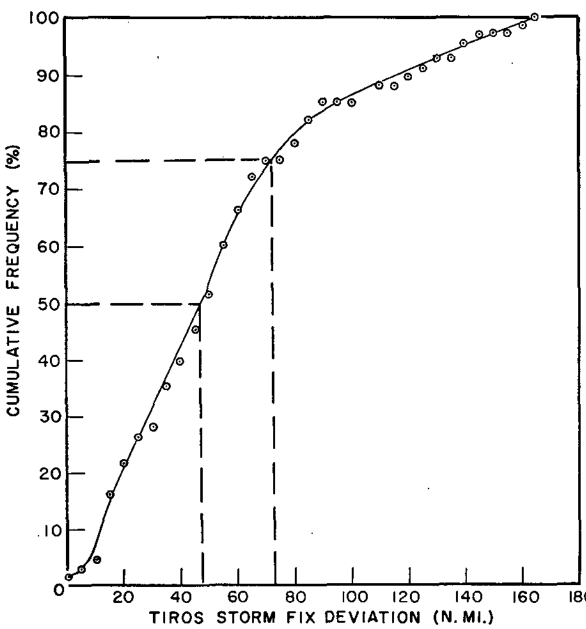

FIG. 2. Cumulative per cent frequency vs. distance of location deviations.

TABLE 1. Hurricanes and typhoons used for location deviation study

Storm	Dates	TIROS	No. fixes	Range of position deviation (n mi) Min	Max
	1961				
Anna	20 July to 23 July	III	4	30	160
Carla	10 Sept. to 11 Sept.	III	2	20	85
Debbie	11 Sept.	III	1	130	
Esther	14 Sept. to 21 Sept.	III	5	45	140
	1962				
Joan	8 July	V	1	105	
Opel	4 Aug.	V	1	15	
Patsy	6 Aug.	V	1	165	
Ruth	14 Aug. to 18 Aug.	V	3	0	80
Sarah	15 Aug. to 22 Aug.	V	6	15	55
Thelma	21 Aug. to 25 Aug.	V	4	10	55
Vera	25 Aug.	V	1	145	
Wanda	30 Aug. to 1 Sept.	V	2	15	80
Amy	29 Aug. to 4 Sept.	V	5	15	90
Jean*	6 Nov. to 9 Nov.	V	2	20	60
Karen*	9 Nov. to 16 Nov.	V	3	15	65
Alma	27 Aug. to 29 Aug.	V	3	25	65
Daisy*	29 Sept. to 6 Oct.	V	5	5	50
Jean*	8 Nov.	VI	1	55	
Karen*	9 Nov. to 14 Nov.	VI	4	15	120
Lucy	28 Nov.	VI	1	35	
Daisy*	1 Oct. to 4 Oct.	VI	3	50	140
	1963				
Arlene*	3 Aug. to 10 Aug.	VI	4	35	55
Arlene*	3 Aug. to 8 Aug.	VII	2	50	125
Beulah	22 Aug. to 27 Aug.	VII	3	20	85

* Storms pictured by more than one satellite.

3. Discussion of source of errors

Satellite hurricane fixes can be in error due to the following effects. Most of them probably exist to a certain extent in all rectification.

1) Satellite-camera *attitude error*.
2) *Time* of picture taking *error*.
3) *Asymmetrical*, changing *distortions* in the camera-television system.
4) *Poorly marked or no eye* appearing on the photograph.
5) *Projection error* introduced because method of rectifying pictures assumes that all cloud patterns are at sea level.

A recent practice at the CDA stations is to estimate the eye fix accuracy for the storm in addition to the accuracy that applies to the over-all nephanalysis. The analyst does this by considering the error sources for the particular part of the picture showing the storm. If for example the storm were at a high oblique angle toward the horizon and he could not identify the eye, he would probably show $\pm 2°$ or more for the uncertainty. Only in cases where nearby identified terrain aided in the rectification would he estimate accuracy better than $\pm 1°$.

Error Sources 1 and 2. The *attitude error* and the picture taking *time error* probably are random, perhaps the order of ± 20 miles. Whenever a landmark appears any place in the picture-taking sequence the attitude and time errors become obvious and adjustments are then made for all pictures taken on that pass, thus minimizing the error due to these causes. Due to the fact that each picture-taking sequence covers approximately 55° of arc of the earth's surface, most sequences picture some landmark. Six fixes used here were made on passes with no landmarks. The deviations in this small sample ranged from 15 to 130 n mi with a median of 90 n mi, compared to a median for all fixes of 50 n mi. The sample of six with such wide scatter cannot yield any reliable result, but the suggestion is that accuracy may suffer if no landmarks are pictured.

Error Source 3. The geographical grids computed for picture rectification incorporate the foreshortening due to the oblique viewing angle and the symmetrical lens distortion in the system. Distortions that are not included in the rectification scheme are those due to asymmetrical lens distortion, stretching or compression of the picture due to maladjustment of the ground equipment, etc. Some of these distortions are evident when terrain and/or the horizon is visible in the picture. In those cases an attempt is made to fit the geographical grid to minimize the error by distributing the misfit equally between the identifiable features. It is likely that this source of error is responsible for a large part of the total deviations observed. In general it was expected that picture distortion would produce more serious location errors when the storm lay far from the satellite subpoint, but no such tendency could be detected. The angle to the storm center, measured from the local vertical, was plotted against magnitude of error. The result was a wide dispersion with no suggestion of correlation.

Error Source 4. The cloud shield over storms is frequently not symmetrically distributed about the eye. For that reason if the eye is not visible, errors are introduced because estimates of its location must be made. Especially with TIROS III this was a problem because the ability of that system to discriminate shades of gray at high brightness was poor. Consequently the geometric center of the cloud shield was sometimes used as the eye location. In many cases however, spiral cloud bands could be seen extending into the overcast cloud shield. The apparent converging point is a better eye position than the geometric center of the cloud shield. The vidicon saturation at high brightness was corrected after TIROS III so most of the eyes have been photographed by later satellites.

Even when a dark spot is visible in the storm cloud shield, there is the possibility that it is not precisely the eye identified by the aircraft fix. The view from above may see a shadowed cloud wall or the break in a cirrus overcast which is not centered over the eye.

Error Source 5. The rectification procedure assumes all cloud patterns are at sea level. The error thus induced is smaller than the ones already discussed however, and can be disregarded. If the storm is viewed at an angle 45° away from the vertical, a cirrus cloud shield at 50,000 ft (approximately 8 n mi altitude) would produce an error due to this assumption of only 8 n mi. The data were examined for this tendency but none was detected.

4. Conclusions

1) Forecasters, mariners and other recipients of operational storm fixes from TIROS should regard their location to have a probable error significantly less than 60 n mi, unless nephanalysis carries a notation that the storm fix error may be greater than $\pm 1°$. Where the accuracy estimate is "$\pm 1°$", the error is probably closer to 30 to 40 miles although it will deviate from the aircraft fixes, on the average, 50 n mi.

2) The deviations in the 67 cases studied here appear to be randomly distributed in regard to angle of view, location, etc., with no indication that any one error source is dominant.