Satellite Classifications of Atlantic Tropical and Subtropical Cyclones: A Review of Eight Years of Classifications at Miami

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ABSTRACT

Estimates of the locations and maximum sustained wind speeds of all tropical and subtropical cyclones in the North Atlantic Ocean, the Caribbean Sea and the Gulf of Mexico have been made at Miami since 1971 using satellite techniques developed by Timchalk *et al.* (1965), Dvorak (1972) and Hebert and Poteat (1975). The estimates were compared with the National Hurricane Center's "best tracks" data to establish the measure of accuracy achieved. These data are not entirely independent because the best tracks themselves are determined partly from the satellite estimates; however, comparisons were made only during periods when aerial reconnaissance was also available. The average difference between satellite-derived maximum sustained wind speeds and best track maximum sustained wind speeds has consistently been ~7 kt with standard deviation of ~8 kt. The average difference between satellite locations and best track locations has decreased to ~17 n mi with standard deviation of ~14 n mi, which is believed to be an approximate lower limit for the present state of the art and technology. These results and other information are provided for an 8-year period.

1. Introduction and historical background

For the past eight hurricane seasons, the Miami Satellite Field Services Station (SFSS) of the National Environmental Satellite Service (NESS), formerly the Satellite Applications Section (SAS) of the National Weather Service's National Hurricane Center (NHC), has provided "classifications" of all tropical and subtropical cyclones in the North Atlantic Ocean, the Caribbean Sea and the Gulf of Mexico. Classification includes fixing the location of the storm circulation center, estimating the maximum sustained wind speed (MWS), and describing certain characteristics of the storm such as the trend of development, mean motion and indications of probable future change. These classifications, together with information from other sources, are used by the NHC's hurricane specialists to formulate their advisories and warnings. This report reviews the results from classifications over an 8-year period of effort, the progress made and suggests reasonable expectations for the future.

The thrust of our efforts has been to provide the NHC with the best possible classifications from satellite imagery. The importance to the hurricane forecast of well-determined storm circulation centers is treated in two papers by Neumann (1975a,b). The importance of an accurately estimated MWS is obvious and well recognized as an equally significant parameter for hurricane forecasts and warnings. The Miami SFSS meteorologists have up-to-the-half-hour electronic image animation available to aid in locating circulation centers, together with enlargement prints of satellite pictures of the storms.

From the beginning, an effort has been made to evaluate the accuracy of SFSS estimates of storm location and MWS. No absolute measure of accuracy in estimating the location and strength of tropical or subtropical cyclones is possible because there is no absolute "ground truth" i.e., neither the exact location nor the precise wind speed of the storm is known at any given time. However, comparisons have been made each year with the NHC's best tracks and with data contained in individual storm reports in the belief that these data represent the closest available approximation to the truth. These best tracks are determined after the fact from careful post analyses of all pertinent data. They are not entirely independent data since the best tracks themselves are determined partly from the satellite estimates. However, the effect of this dependency was minimized by evaluating satellite classifications only during periods when aerial reconnaissance and other data were also available. For a more detailed discussion of this question see Gaby *et al.* (1975).

2. Evaluations by year

Formal classifications of all tropical and subtropical Atlantic cyclones began at Miami during the 1971 hurricane season, with an SAS staff of two satellite meteorologists. Visible imagery from the

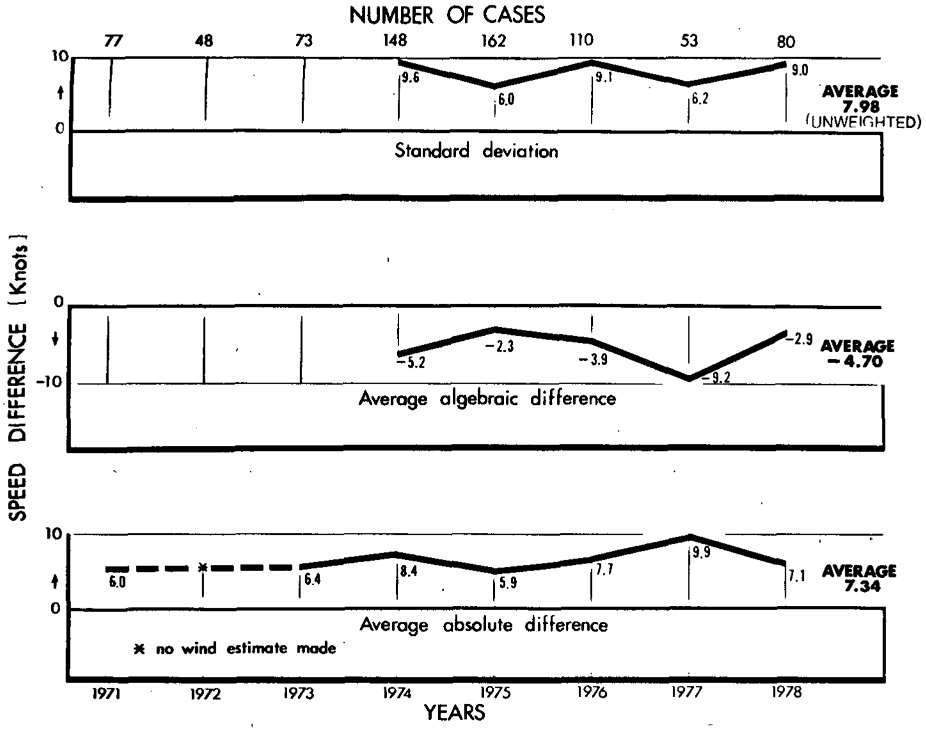

FIG. 1. Miami SFSS tropical and subtropical cyclone maximum sustained wind speed "accuracy" based on average difference between satellite estimates and NHC best tracks (NHC value minus SFSS value).

geostationary Advanced Technology Satellite No. 3 (ATS-3) and from the Automatic Picture Transmission (APT) polar-orbiting satellite ESSA-8 were used to provide two classifications per day in support of NHC operations. During the 1971 season the technique developed by Timchalk *et al.* (1965) was used most of the time with occasional use of the newly developed technique of Dvorak (unpublished at that time). As expected, the ATS-3 pictures proved superior for this purpose. Results were much better for systems with well-defined circulation centers than for systems which had no obvious centers of circulation. Interestingly, the average difference in MWS was ~6 kt, based on 77 cases, a figure that has varied only slightly over the years (see Fig. 1). The average difference in location was about 36 n mi, based on 96 cases.[1]

In 1972 classifications were made using the Dvorak (1972) technique exclusively. The new technique proved superior, especially for the weaker systems, and added considerable objectivity to the work. All but two classifications were made from ATS-3 visible images. The remaining two were made from ESSA-8 APT imagery. The season provided only 48 cases. These gave an average location difference of 33 n mi with standard deviation of 17 n mi. In 1972, storm intensity was given in terms of minimum central pressure, rather than MWS, showing an average minimum pressure difference of 3.8 mb with standard deviation of 2.7 mb. There was an increase in staff of one meteorologist late in the season as the NESS formed the Miami SFSS and the former SAS was dissolved.[2]

In 1973 classifications were again made using the Dvorak (1973) technique with minor local improvements. Almost all classifications were made from ATS-3 visible imagery. The average location difference was 25.8 n mi with standard deviation of 19.2 n mi, based on 87 cases. Storm intensity was again given in terms of minimum central pressure (average pressure difference of 4.7 mb with standard deviation of 3.8 mb) and MWS. The average absolute wind speed difference was 6.4 kt based on 73 cases.[3]

The 1974 season marked a turning point in our operation with the launch of the geostationary Synchronous Meteorological Satellite No. 1 (SMS-1),

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[1] Details are contained in a report by D. C. Gaby—Performance evaluations for the 1971 hurricane season. Unpublished Internal Memo. SAS, NHC, Miami, November 1971.

[2] Details are contained in a report by D. C. Gaby—Performance evaluations for the 1972 hurricane season. Presented at the NOAA/NWS Hurricane Warning Service Evaluation Conference, Miami, November 1972.

[3] Details are contained in a report by D. C. Gaby—Miami SFSS tropical cyclone classifications for the Atlantic Ocean for 1973. Presented at the Interdepartmental Hurricane Warning Conference, Miami, January 1974.

prototype of the new Geostationary Operational Environmental Satellite (GOES) series. Additionally, our staff increased to provide 24 hours per day coverage. Most classifications were made with the SMS-1 satellite which was located above the equator at 45°W longitude for the GATE experiment. A few were made while SMS-1 was moving westward late in the hurricane season, and for storms over the extreme western Caribbean Sea or the Gulf of Mexico a few were made using ATS-3 pictures. Visible spectrum (0.55–0.70 μm) pictures with 4 km resolution were used during daylight and 8 km resolution infrared (10.5–12.6 μm) pictures were used at night. The average location difference was 18.4 n mi with standard deviation of 15.5 n mi, based on 313 cases. The average absolute MWS difference was 8.4 kt, and the average algebraic MWS difference was −5.2 kt with standard deviation of 9.6 kt, based on 148 cases. Details are given in Gaby *et al.* (1975).

The 1975 season saw several significant improvements in our operational techniques and a more complete evaluation of performance was made (Gaby *et al.*, 1976). Among improvements were the following:

1) The GOES-East satellite was located permanently at 75°W longitude and 2 km resolution visible imagery was used, for the first time, in making daytime classifications.

2) The Hebert-Poteat (1975) technique for the classification of subtropical cyclones was used successfully, especially with Hurricane Doris which evolved smoothly from a subtropical to a tropical cyclone.[4]

3) Two studies by Pike (1974a,b) allowed relaxing the developmental constraints imposed by the Dvorak (1973) technique for better operational application of the MWS estimates at the NHC.

4) Pike also provided a nomogram for correcting the apparent position of a cyclone as viewed obliquely from geostationary altitude above 75°W.[5]

An evaluation of the classifications for 1975 showed an average location difference of 16.5 n mi with standard deviation of 11.2 n m, based on 115 cases. The average absolute MWS difference was 5.9 kt and the average algebraic MWS difference was −2.3 kt with standard deviation of 6.0 kt, based on 162 cases. An updated version of the Dvorak technique was available (Dvorak, 1975). Comparisons among the four meteorologists doing the bulk of the classifications showed no significant differences between individuals, indicating that the Dvorak technique provides objective, consistently reliable results even when used by meteorologists with widely differing experience levels. The Miami SFSS meteorologists have always used a confidence factor in estimating both tropical cyclone location and intensity.[6] Statistical evaluations showed that the higher confidence factors were indeed associated with the more accurate estimates.[7] The time of imagery was shown to have some influence on the estimates of location and MWS. Somewhat better results were obtained using the high-resolution visible imagery during daylight hours. In 1975 we approached a plateau in our ability to estimate the location and intensity of tropical cyclones given the present state of the art and technology.

An evaluation of performance during the 1976 season gave results similar to those for 1975. Details are contained in Gaby *et al.* (1977). The average location difference was 17.0 n mi with standard deviation of 14.3 n mi, based on 115 cases. Significantly better results were obtained for storms of hurricane intensity or greater. The average absolute MWS difference was 7.7 kt, and the average algebraic MWS difference was −3.9 kt with standard deviation of 9.1 kt, based on 110 cases. Less constrained rates of weakening after a study by Lushine (1977) were used routinely. Comparisons were again made among the meteorologists doing the bulk of the classifications and no significant difference was found between individuals. Confidence factors were again found to be well-correlated with the quality of the estimates provided. High-resolution visible imagery again made possible better estimates of location by day, but no significant difference in wind speed estimates was found as a function of time of day.

No evaluation of performance for the 1977 hurricane season has been published although some of the results were presented at the 32nd Interdepartmental Hurricane Warnings Conference of January 1978. Also, no evaluation of performance for the 1978 season has been formally presented. Appendices A and B contain the statistical results of our evaluations of performance for 1977 and 1978, respectively.

For 1977 the average location difference was 16.1 n

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[4] An improved version of the Hebert-Poteat technique is unpublished but available from the senior author at the NHC.

[5] During Hurricane Eloise the location correction at landfall was ~5 n mi in northwest Florida; even higher values could have been expected farther west on the Gulf coast or at higher latitudes in the Atlantic.

[6] Confidence factors 1, 3, and 5, for location, refer to well-defined eye with certain picture registration, well-defined circulation center with certain picture registration, and poorly defined circulation center with certain picture registration, respectively. Confidence factors 2, 4 and 6 are similar and refer to uncertain picture registration; however, these occur so seldom that they were not evaluated. Confidence factors 1, 2 and 3, for intensity, refer to the meteorologist being completely certain as to current intensity number used, tempted to vary up or down by ½ T or ST number, or might vary up or down by 1 T or ST number, or more, respectively.

[7] There is probably some feedback into the system as the result of the hurricane specialist drawing his best track more closely to satellite location estimates of higher confidence.

TABLE 1. Comparisons of Miami 1978 SFSS classification T numbers as made from visible and enhanced infrared images for the same times (±30 min).

STORM	T-numbers equal	T-numbers ≠ but < 1/3 different	T-numbers differ by 1/2	T-numbers differ by > 1/2	Number of Comparisons
AMELIA	1	0	2	0	3
BESS	1	0	3	0	4
CORA	2	1	2	1	6
DEBRA	3	1	1	0	5
ELLA	8	0	3	1	12
FLOSSIE	11	4	2	0	17
GRETA	2	4	0	0	6
HOPE	4	0	1	0	5
IRMA	2	1	1	0	4
JULIET	3	2	0	0	5
KENDRA	0	0	5	2	7
WEAK SYSTEMS	10	11	6	1	28
TOTALS	47	24	26	5	102
PERCENTAGES	46.1	23.5	25.5	4.9	- - -
CUMULATIVE PERCENTAGES	46.1	69.6	95.1	100.0	- - -

mi with standard deviation of 15.1 n mi, based on 85 cases. Significantly better storm locations were obtained during daylight hours (1830 GMT) using high-resolution visible imagery than during nighttime hours (0630 GMT) using only infrared imagery.[8] Higher confidence values related to better storm locations. The average absolute MWS difference was 9.9 kt, and the average algebraic MWS difference was −9.2 kt with standard deviation of 6.2 kt, based on 53 cases. In 1977 a new technique for estimating storm intensity from enhanced infrared (EIR) satellite imagery (Dvorak, unpublished at that time) was used experimentally. No significant difference in the accuracy of the MWS estimates was shown as a function of time of day. Higher confidence values related to better wind speed estimates.

In 1978 the location difference was 16.9 n mi with standard deviation of 17.1 n mi, based on 167 cases. Significantly better storm locations were obtained during daylight hours using high-resolution visible imagery than during nighttime hours using only infrared imagery. The higher confidence values related to better storm locations. The average absolute MWS difference was 7.1 kt, and the average algebraic MWS difference was −2.9 kt with standard deviation of 9.0 kt, based on 80 cases. In 1978 the technique for estimating storms from EIR imagery was used on a full-time basis.[9] No significant difference in the accuracy of the MWS estimates was shown as a function of time of day.

Table 1 shows a comparison of Dvorak T numbers for 1978 storms using both visible (VIS) and enhanced infrared (EIR) imagery received at Miami. Whenever possible, classifications were made using both types of imagery. Note that 46% of the classifications made with both VIS and EIR imagery at the same time gave exactly the same T number (MWS), and that 95% were no more than ½ T number different. Thus, the classifications were nearly equally accurate whether by day or by night. This equally good performance regardless of the time of day is attributed to the improved objectivity of the latest Dvorak technique.

3. Summary of eight years of classifications

There are a number of factors known to limit location accuracy, both for individual fixes and as compared with the smoothed best tracks. An accepted rule for the limit to which any feature may be located in an image constructed from a sequence of scan lines is approximately three times the "resolution" or width of the scan line. This resolution is degraded with increased distance from the satellite subpoint. Thus using 8 km resolution (at nadir) infrared images permits a location accuracy for individual fixes of about 24–30 km (16–18 n mi), and using 2 km resolution (at nadir) visible images permits a location accuracy for individual fixes of ~6–8 km (4–5 n mi) across the Atlantic hurricane belt. At very high latitudes the accuracy would be less. The quality of available geographic grids is also a factor, but these are becoming accurate to within 1–2 scan line widths. How well the storm circulation center is defined by the cloud pattern is a factor, with poorly defined systems being more difficult to locate, especially with only infrared imagery at night. Finally, comparisons of individual fixes with a smoothed best track often include an inherent lower limit of accuracy because of the small-scale oscillations of the eye or storm circulation center within the larger envelope of the storm circulation. A rather pronounced trochoidal motion of the eye has been observed in a number of storms and has been documented by radar in Hurricanes Carla 1961 (Anonymous, 1961) (see Fig. 2) and Dora 1964 (Anonymous, 1964). It was first observed in 24 hours per day satellite observations with Tropical Storm Alma

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[8] These 1830 and 0630 GMT location estimates were always by daylight or during the night, respectively, regardless of storm location. A similar statement is not always true for the 1230 and 0030 GMT location estimates because the storms may be in daylight or darkness depending upon their longitude. For example, storms in far western longitudes are typically in darkness at 1230 GMT but well illuminated at 0030 GMT, while the opposite is true for storms in far eastern longitudes.

[9] This improved version of Dvorak's technique, "Tropical cyclone classification procedures using visible and enhanced infrared satellite imagery," is unpublished.

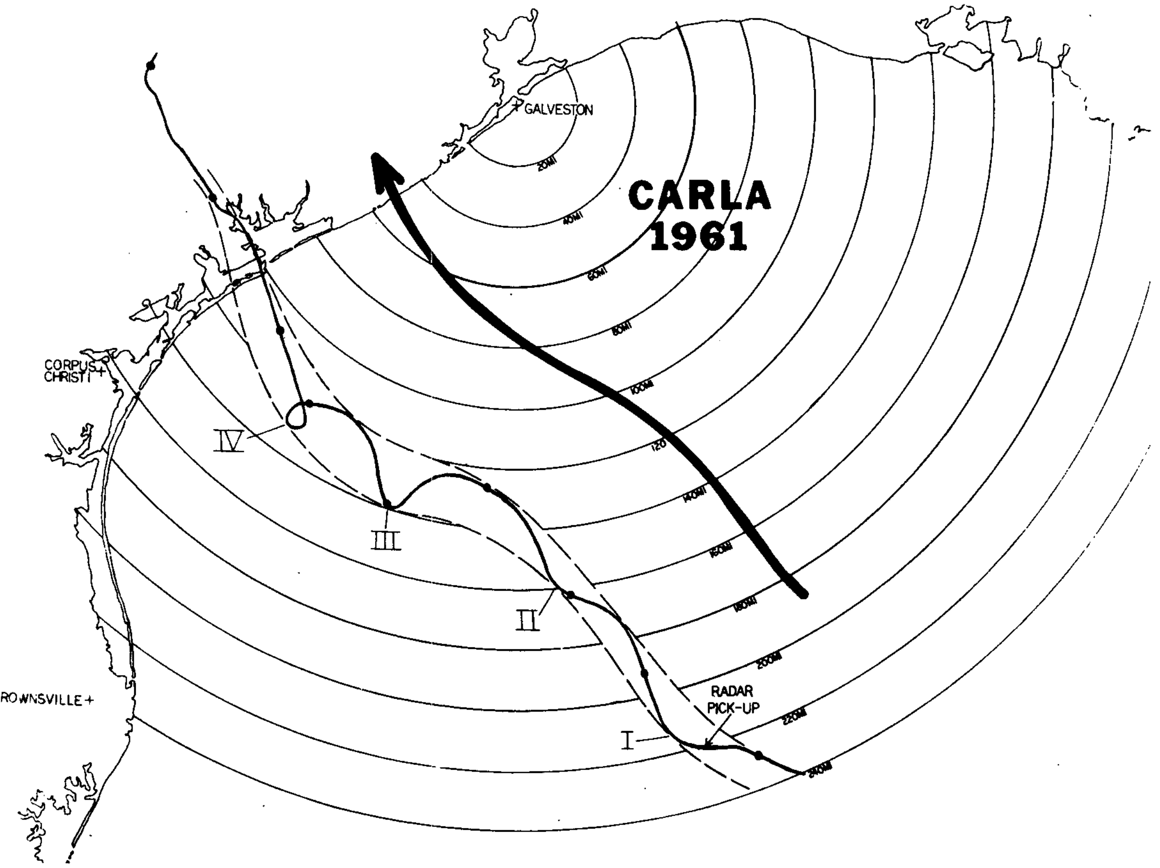

FIG. 2. The track of the eye of Hurricane Carla 1961 as observed by coastal radars. (Adapted from Weatherwise, October 1961.) The heavy line simulates a smoothed track displaced from the detailed eye track for clarity.

1974. Lawrence and Mayfield (1977) determined such a trochoidal path for the eye of Hurricane Belle 1976. Our experience and consideration of the above factors indicate that we are not likely to achieve a better average overall location accuracy than ~13–15 n mi compared to the smoothed best tracks with the present state of the art and technology. This is illustrated in Fig. 3. For the past several years *we have shown an average location difference (compared to the best tracks) of 16–17 n mi, which is very close to the best that might be expected. Comparisons of daytime fixes using high-resolution visible imagery to nighttime fixes using low-resolution (8 km at nadir) infrared imagery have shown that the daytime fixes are an average 6–10 n mi more accurate than those at night.* An improvement in the resolution of the IR imagery from geostationary satellites to 2 km should provide an improvement in location accuracy on average of ~3–5 n mi. Hopefully, such an improvement will be achieved at least in part with the series of geostationary satellites to be launched in the late 1980's.

Fig. 1 shows our ability to estimate accurately the MWS in tropical or subtropical cyclones. One may note a rather consistent performance over the years. *The average algebraic difference in maximum sustained wind speed compared to the NHC's best tracks has been about −5 kt and has never exceeded 10 kt in any year.* Although there has been little significant difference from year to year in the average accuracy of the MWS estimates, there has been a real and significant improvement in the objectivity with which the classifications are made and a considerable improvement in our ability to estimate accurately the MWS at night. Indeed, most Miami satellite meteorologists now prefer the Dvorak technique for the intensity estimates of tropical cyclones from EIR imagery even during the daylight hours when high-resolution visible imagery is also available. From an operational point of view, it is significant that those hurricane advisories issued in early morning and therefore based in part on IR imagery will have the benefit of satellite MWS estimates just as accurate as by day. *We believe it is also significant for operations that our ability to estimate accurately the MWS is appreciably better for storms of at least hurricane*

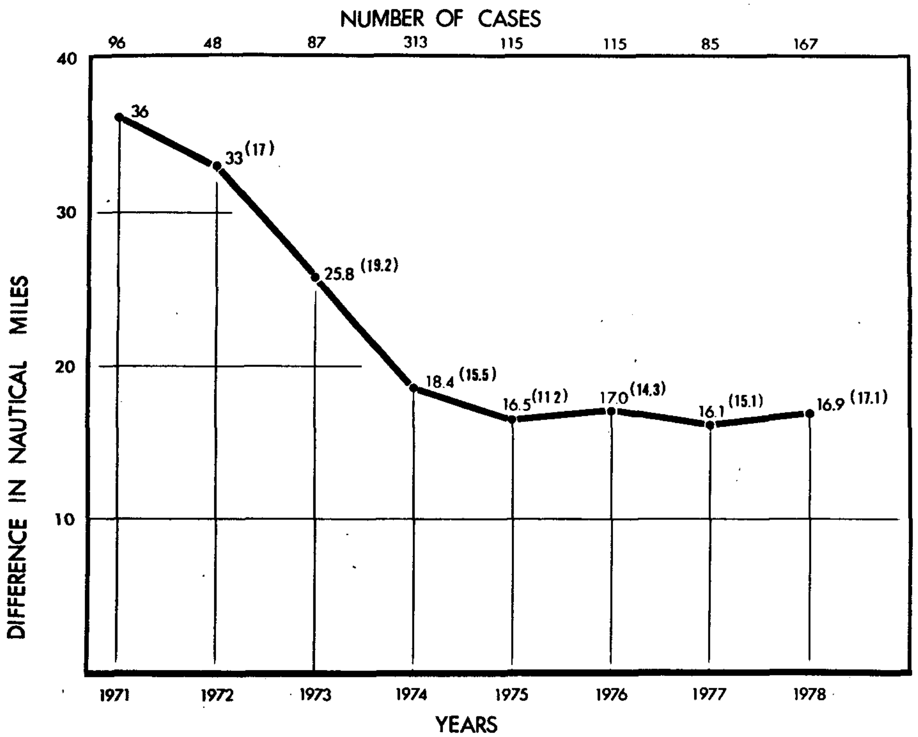

FIG. 3. Miami SFSS tropical and subtropical cyclone location "accuracy" based on average difference between satellite fixes and NHC best tracks. Figures in parentheses are standard deviation (none for 1971).

intensity (65 kt), i.e., for those storms potentially most damaging (Gaby *et al.*, 1977).

4. Conclusions

An ability to locate tropical or subtropical cyclones with an overall average accuracy of ~17 n mi as compared to the NHC's smoothed best tracks has been demonstrated. Little overall improvement should be expected in the near future. Some improvement may be expected with the higher resolution infrared imagery planned for the geostationary satellites in the late 1980's.

An ability to estimate the maximum sustained wind speed in tropical or subtropical cyclones with an average accuracy of <10 kt has been demonstrated. This is probably close to the best that may be expected considering the natural variability of these storms. Continued improvement may be expected in the objectivity of the techniques used and these techniques may even be partially automated in time.

Acknowledgments. Many of the classifications considered in this report, especially during the early years, were made by Kenneth O. Poteat, now retired. Others were made by Arthur C. Pike and Donald C. Cochran, now with the NESS Satellite Field Services Station, Honolulu, Hawaii. A few were made by Paul M. Duernberger, NOAA Corps Officer, on temporary duty assignment. We thank Charles J. Neumann, Chief, Research and Development, NHC, and John R. Hope and Paul J. Hebert, hurricane specialists, NHC, for their reviews of the initial draft and many valuable suggestions. Our thanks go also to Teresa Barker for typing the manuscript and tables.

APPENDIX A

Statistical Summary of 1977 Performance Evaluations

TABLE 2. Miami 1977 SFSS satellite vortex locations compared with NHC best tracks (for periods with aerial reconnaissance only); minimum central pressure below 1000 mb, Current Intensity (CI) number 2.0 or higher, or Subtropical (ST) number 1.5 or higher.

STORM	AVERAGE DIFFERENCE (n.mi.)	STANDARD DEVIATION (n.mi.)	RANGE OF DIFFERENCE (n.mi.)	NUMBER OF CASES
ANITA	12.0	14.4	0-55	31
BABE	23.8	16.8	5-51	9
CLARA	17.4	16.6	3-62	24
DOROTHY	23.6	21.1	0-60	12
EVELYN	9.0	3.8	5-15	9
FRIEDA *	11.1	2.5	8-14	6
ALL STORMS	16.1	15.1	0-62	85

* Did not reach T2.0 or ≤ 1000 mb (not included in all storms).

TABLE 3. Comparisons of Miami 1977 SFSS satellite vortex location differences (compared to NHC best tracks) as a function of time of imagery. Note: time 0630 GMT represents infrared imagery, and time 1830 GMT represents visible imagery. Times 0030 or 1230 GMT may represent either infrared or visible imagery, depending on storm longitude.

PICTURE TIME (GMT) *	AVERAGE DIFFERENCE (n.mi.)	STANDARD DEVIATION (n.mi.)	RANGE OF DIFFERENCE (n.mi.)	NUMBER OF CASES
0030	20.0	18.6	2-62	22
0630	18.3	17.4	0-55	19
1230	18.2	19.6	0-60	17
1830	10.9	8.4	2-37	20

* Picture times as shown or ± 30 minutes.

TABLE 4. Comparisons of Miami 1977 SFSS confidence factors with satellite vortex location differences (compared to NHC best tracks). Low confidence factor numbers mean higher confidence.

CONFIDENCE FACTOR	AVERAGE DIFFERENCES (n.mi.)	STANDARD DEVIATION (n.mi.)	RANGE OF DIFFERENCE (n.mi.)	NUMBER OF CASES
1	5.0	1.8	2-8	10
3	13.5	11.9	0-60	47
5	28.2	19.8	0-62	23

TABLE 5. Miami 1977 SFSS estimated maximum sustained wind speeds minus NHC best track data. Comparisons are for periods with aerial reconnaissance only; minimum central pressure below 1000 mb, CI number 2.0 or higher, ST number 1.5 or higher. Standard deviations are based on algebraic average difference.

STORM	AVERAGE ABSOLUTE DIFFERENCE (knots)	AVERAGE ALGEBRAIC DIFFERENCE (knots)	STANDARD DEVIATION (knots)	RANGE OF DIFFERENCE (knots)	NUMBER OF CASES
ANITA	10.8	-10.8	7.1	-22 to 0	21
BABE	2.7	- 0.3	4.9	-10 to +5	7
CLARA	9.2	- 9.2	6.6	-20 to 0	13
DOROTHY	17.9	-17.9	4.5	-25 to -10	8
EVELYN	4.0	+ 0.5	6.2	- 6 to +9	4
FRIEDA *	1.3	- 1.3	2.2	- 5 to 0	6
ALL STORMS	9.9	- 9.2	6.2	-25 to +9	53

* Did not reach T2.0 or $\leq$ 1000 mb (not included in all storms).

TABLE 6. Comparison of Miami 1977 SFSS maximum sustained wind speed estimate differences (relative to NHC best tracks) as a function of time of imagery.

PICTURE TIME (GMT) *	AVERAGE ABSOLUTE DIFFERENCE (knots)	AVERAGE ALGEBRAIC DIFFERENCE (knots)	STANDARD DEVIATION (knots)	RANGE OF DIFFERENCE (knots)	NUMBER OF CASES
0030	8.7	-8.1	9.1	-20 to +4	13
0630	11.3	-9.8	9.0	-25 to +9	12
1230	8.8	-8.8	7.4	-20 to 0	10
1830	9.5	-8.5	9.0	-20 to +5	11

* Picture times as shown or ± 30 minutes.

TABLE 7. Comparisons of Miami 1977 SFSS confidence factors with satellite maximum sustained wind speed differences (compared to NHC best tracks). Lower confidence factor numbers mean higher confidence.

CONFIDENCE NUMBER	AVERAGE ABSOLUTE DIFFERENCE (knots)	AVERAGE ALGEBRAIC DIFFERENCE (knots)	STANDARD DEVIATION (knots)	RANGE OF DIFFERENCE (knots)	NUMBER OF CASES
1	8.6	- 7.4	5.0	-22 to +9	22
2	10.8	-10.5	5.9	-25 to +4	31
3	-	-	-	- - -	0

APPENDIX B

Statistical Summary of 1978 Performance Evaluations

TABLE 8. Miami 1978 SFSS satellite vortex locations compared with NHC best tracks (for periods with aerial reconnaissance only); minimum central pressure below 1000 mb, CI number 2.0 or higher or ST number 1.5 or higher.

STORM	AVERAGE DIFFERENCE (n.mi.)	STANDARD DEVIATION (n.mi.)	RANGE OF DIFFERENCE (n.mi.)	NUMBER OF CASES
AMELIA	44.3	- - -	- - -	1
BESS	13.4	8.4	3 to 33	12
CORA	19.8	13.5	6 to 53	14
DEBRA	12.6	4.0	9 to 18	4
ELLA	11.8	8.9	0 to 41	43
FLOSSIE	32.3	33.5	0 to 113	18
GRETA	14.4	15.0	0 to 59	53
HOPE	23.1	0.4	0	2
IRMA *	10.3	6.5	0 to 22	9
JULIET	14.0	11.1	3 to 38	8
KENDRA	23.3	18.0	5 to 51	12
ALL STORMS	16.9	17.1	0 to 113	167

* No aerial reconnaissance available (not included in all storms).

TABLE 9. Comparisons of Miami 1978 SFSS satellite vortex location differences (compared to NHC best tracks) as a function of time of imagery. Note: time 0630 GMT represents infrared imagery, and time 1830 GMT represents visible imagery. Times 0030 or 1230 GMT may represent either infrared or visible imagery, depending on storm longitude.

PICTURE TIME (GMT) *	AVERAGE DIFFERENCE (n.mi.)	STANDARD DEVIATION (n.mi.)	RANGE OF DIFFERENCE (n.mi.)	NUMBER OF CASES
0030	17.1	13.7	0 to 46	38
0630	24.8	31.4	0 to 113	24
1230	18.9	16.5	2 to 54	31
1830	14.6	12.7	0 to 50	45

* Picture time as shown or ± 30 minutes.

TABLE 10. Comparisons of Miami 1978 SFSS confidence factors with satellite vortex location differences (compared to NHC best tracks). Low confidence factor numbers mean higher confidence.

CONFIDENCE FACTOR	AVERAGE DIFFERENCE (n.mi.)	STANDARD DEVIATION (n.mi.)	RANGE OF DIFFERENCE (n.mi.)	NUMBER OF CASES
1	7.8	6.7	0 to 29	49
3	12.3	11.0	2 to 59	49
5	27.9	20.8	0 to 113	65

TABLE 11. Miami 1978 SFSS estimated maximum sustained wind speeds minus NHC best track data. Comparisons are for periods with aerial reconnaissance only; minimum central pressure below 1000 mb, CI number 2.0 or higher, ST number 1.5 or higher. Standard deviations are based on algebraic average difference.

STORM	AVERAGE ABSOLUTE DIFFERENCE (knots)	AVERAGE ALGEBRAIC DIFFERENCE (knots)	STANDARD DEVIATION (knots)	RANGE OF DIFFERENCE (knots)	NUMBER OF CASES
AMELIA	14.0	-14.0	- - -	- - -	1
BESS	5.7	- 5.7	3.3	-10 to 0	6
CORA	2.0	+ 0.3	3.2	- 5 to +6	8
DEBRA	8.0	- 8.0	2.8	-10 to -6	2
ELLA	10.4	- 5.2	11.0	-18 to +19	18
FLOSSIE	0.6	+ 0.6	1.7	0 to +5	9
GRETA	9.0	+ 0.1	11.4	-20 to +23	24
HOPE	0.0	0.0	- - -	- - -	1
IRMA *	3.0	- 3.0	4.5	-10 to 0	5
JULIET	9.8	- 9.8	3.3	-12 to -5	4
KENDRA	6.0	- 5.4	5.7	-15 yo +2	7
ALL STORMS	7.1	-2.9	9.0	-20 to +23	80

* No aerial reconnaissance available (not included in all storms).

TABLE 12. Comparison of Miami 1978 SFSS maximum sustained wind speed estimate differences (relative to NHC best tracks) as a function of time of imagery.

PICTURE TIME (GMT) *	AVERAGE ABSOLUTE DIFFERENCE (knots)	AVERAGE ALGEBRAIC DIFFERENCE (knots)	STANDARD DEVIATION knots)	RANGE OF DIFFERENCE (knots)	NUMBER OF CASES
0030	8.2	- 2.4	10.8	-20 to +23	18
0630	7.3	- 4.9	8.57	-20 to +10	13
1230	6.8	- 5.4	7.3	-18 to +10	16
1830	6.7	- 3.0	8.4	-18 to +15	23

* Picture times as shown or ± 30 minutes.

TABLE 13. Comparisons of Miami 1978 SFSS confidence factors with satellite maximum sustained speed differences (compared to NHC best tracks). Lower confidence factor numbers mean higher confidence.

CONFIDENCE NUMBERS	AVERAGE ABSOLUTE DIFFERENCE (knots)	AVERAGE ALGEBRAIC DIFFERENCE (knots)	STANDARD DEVIATION (knots)	RANGE OF DIFFERENCE (knots)	NUMBER CASES
1	7.4	- 1.1	9.9	-18 to +19	27
2	6.7	- 3.7	8.5	-20 to +23	52
3	10.0	-10.0	- - -	- - - -	1

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