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NESDIS 18

Tropical Cyclone Center Locations from Enhanced Infrared Satellite Imagery

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U.S. DEPARTMENT OF COMMERCE
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Tropical Cyclone Center Locations from Enhanced Infrared Satellite Imagery

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TROPICAL CYCLONE CENTER LOCATIONS FROM ENHANCED INFRARED SATELLITE IMAGERY

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ABSTRACT. A procedure to locate tropical cyclone centers with Enhanced Infrared (EIR) satellite imagery is presented. Schematic representations of cloud pattern centers are shown along with EIR examples to help the user select the most likely center position for any of six different cloud pattern categories.

Differences between cyclone centers determined by aircraft reconnaissance fixes and those determined by using only EIR images are evaluated. These differences are then compared with the same kind of differences where the centers were operationally assigned by Miami SFSS meteorologists. The Miami SFSS meteorologists used both visible and infrared satellite images, as well as past storm track positions.

Results show that the Miami SFSS procedure made better estimates of center location. For all six cloud pattern categories combined, the average location difference (error) was 26.5 n mi for the EIR procedure compared with 22.1 n mi for the SFSS procedure. Although the average EIR location differences were about 20% larger than the SFSS differences, the EIR center positions are still very useful, especially during nighttime when no visible images are available.

I. INTRODUCTION

Accurate knowledge of the center location of a tropical cyclone is important for tracking and for warning purposes. An accurate initial center location is also a mandatory requirement in forecasting a cyclone's future track and intensity.

Operationally, tropical cyclone locations are determined by various methods. Aircraft reconnaissance (recon) positions are the most accurate and are usually relied upon when a powerful storm threatens coastal areas; however, daily recon flights are costly and impractical when tropical cyclones are located far from land. It is at these times that satellite data are the most cost effective in locating storms.

Accuracies of tropical cyclone location by use of visible-band satellite images was first discussed by Hubert and Timchalk (1964). Sheets and Grieman (1975) evaluated the accuracies of location and intensity of tropical cyclone from ESSA, ATS, and DMSP satellite data.

More recently, Dvorak (1984) developed procedures to classify and locate cyclone centers with the use of Enhanced Infrared (EIR) imagery. A "BD enhancement curve" was used in this EIR procedure. With this curve, the entire range of infrared brightness temperatures is partitioned nonlinearly into nine gray levels in such a way that the greatest sensitivity is obtained at the low temperature end. For complete details, refer to Dvorak (1984). Operational experience with the method has shown effective results (Gaby et al., 1980; Shewchuck et al., 1980).

The main purpose of this study was to evaluate the accuracy of locating tropical cyclone centers when only EIR images are used. A secondary purpose was to then compare the EIR center location accuracy with that of the operational procedure.

Satellite storm positions are operationally assigned by the Satellite Field Services Station (SFSS) meteorologists, who use all available satellite information. The SFSS procedure includes the use of visible imagery as well as a time sequence of images (animation) and the knowledge of past locations (track) and intensities.

Factors affecting the accuracy of center location include: (1) degree of storm cloud organization, (2) image grid placement, (3) satellite image type and resolution, (4) satellite viewing angle, (5) navigational errors of recon aircraft locations, and (6) subjectivity in the interpretation of cloud pattern organization.

II. DATA

Satellite data used in this study were obtained from operational files for the period 1977 through 1982 maintained by the Miami Satellite Field Services Station (SFSS). Reconnaissance fix positions were obtained from the National Hurricane Center files. The EIR data used in this study consisted of 215 images (8 km resolution) of 21 hurricanes and six tropical storms. In the EIR procedure, only images whose times were within 1.5 hours of the aircraft recon fix time were used. It should be noted that no adjustments were made to the EIR positions because of time differences. This factor alone could account for locations differences as large as 15 n mi for a storm whose movement speed was 10 knots.

Of the 215 EIR image data set, nine (4%) of the images were omitted from data set because they did not fit any of the six cloud categories. Six of these nine cases were of a weakening storm in the Gulf of Mexico in which aircraft reconnaissance found circulations centers but the EIR pictures showed no organization in the cloud pattern. No particular distinction was noted in the remaining three cases. Thus the total number of EIR cases was reduced to 206. The data set for the second procedure consisted of 153 cases in which the cyclone centers had been determined operationally by the Miami SFSS meteorologists.

III. PROCEDURE

The procedure for collecting and analyzing the data for this study consisted of three steps. The first was to locate the Cloud System Center (CSC) for each tropical cyclone on each of the EIR satellite images. The second step was to plot the Recon Centers (RC) on each of the pictures. It should be noted that the recon centers were already marked on some of the EIR pictures before the CSC was determined. These marked centers might have introduced an unintentional bias in the center placement even though every effort was made to follow the center placement rules objectively. The third step was to prepare polar coordinate scatter diagrams showing the CSC positions relative to the RC positions for each of the six CSC categories. Examples of the six CSC categories are shown in Figure 2.

To locate the CSC, a stepwise diagnosis was made to locate the center according to the decision tree shown in Figure 1. The decision tree is based upon the procedures that are used in the Dvorak method (1984) to locate storm centers and to determine tropical cyclone intensity. The decision tree shows that there are six typical cloud pattern categories. Schematic depictions along with EIR image examples for each of the categories are shown in Figure 2(a-f).

Polar coordinate diagrams were prepared to examine the differences between the satellite and recon center positions. Circles whose centers represent the recon positions were drawn with radii of 15, 30, 45, and 60 n mi respectively. CSC positions were then plotted relative to the recon positions. This was done separately for each of the six cloud pattern categories. In addition, tables of cumulative frequency and average location differences were prepared.

IV. RESULTS

Available aircraft recon fixes and EIR images provided a data set of 215 cases. Figure 3a shows the EIR positions. There were no strong azimuthal biases in any of the six categories; but it is easily seen that the smallest differences in location are associated with the "Eye" category, whereas the largest differences are with the "Curved Cloud Features" category.

Figure 3b shows the Miami SFSS positions for 153 cases. As in the EIR cases, Figure 3b shows that the "Eye" category locations are in much better agreement with the recon locations than in the categories whose centers are poorly defined by the cloud features.

These findings indicate that the magnitude of the differences (errors) in locating satellite tropical cyclone centers is clearly a function of the degree of cloud pattern organization and intensity of the storm. The findings are consistent with those of Hubert and Timchalk (1964), Sheets and Grieman (1975), Shewchuck and Weir (1980), and Gaby et al., (1980).

To allow further evaluation of the accuracies of center location of the two different procedures, Tables 1 and 2 were prepared. These tables show the cumulative frequency (Cases) and percentage cumulative frequency (CF) distributions of the center differences (n mi) from the recon positions for each of the six CSC categories.

In all but the first two categories, the EIR center locations showed larger departures from the recon locations. For both procedures, the 100% CF level was reached in the <30 n mi and <45 n mi class intervals for the "Eye" and "Low Cloud Center" categories respectively. In the remaining, less organized cloud pattern categories, the EIR procedure showed much larger center location differences than did the SFSS procedure.

The last columns of Tables 1 and 2 show the average differences for each category separately and for all categories combined. The average differences were calculated by using the upper distance limit of each class interval. It is seen that the average accuracy of the EIR procedure was as good as the SFSS procedure in the "Eye" category, but it was much worse in the "Central Cold Cover" and "Curved Features" categories. The "Eye" category for both procedures showed average accuracies of better than 16.3 n mi, whereas for the "Curved Cloud Features" category, the SFSS procedure showed an average location difference of better than 30.0 n mi compared with the EIR value of better than 49.7 n mi.

For all categories combined, the SFSS procedure showed an average location difference of 22.1 n mi compared with the EIR procedure difference of 26.5 n mi.

V. SUMMARY

The decision tree presented in Figure 1 allows the user to locate the center of a tropical cyclone with infrared pictures taken at night. The six cloud pattern categories used in determining the cyclone centers accommodated all but 4% of the 215 cases examined.

The SFSS procedure, which used time sequences of both visible and infrared satellite pictures along with the knowledge of the past locations and intensities, performed better than the EIR procedure which used only enhanced infrared pictures. For either procedure, the location errors were larger for the less organized cloud pattern centers that are typically associated with weaker storms.

The accuracy of the EIR procedure was as good as the SFSS procedure in the "Eye" and "Low Cloud Center" categories, but it was much worse in the "Central Cold Cover" and "Curved Cloud Features" categories.

When all categories were combined, the EIR procedure location differences (errors) were about 20% larger than those of the SFSS procedure.

Even with the 20% larger location errors, the EIR images alone are valuable because they provide useful estimates of cyclone center locations at night when no visible spectrum imagery is available.

VI. ACKNOWLEDGEMENTS

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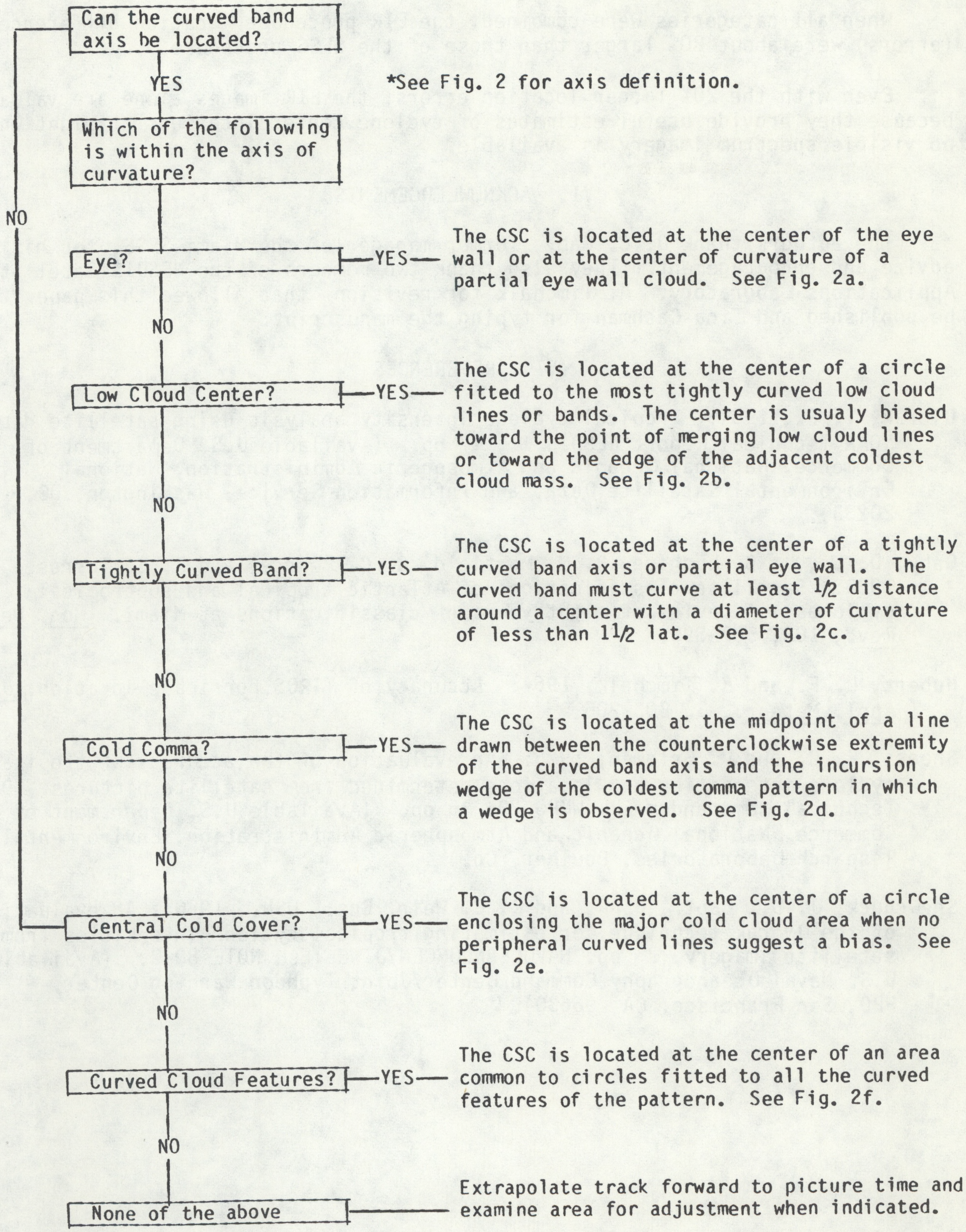

Figure 1. The decision tree for determining which cloud pattern type to use in the analysis.

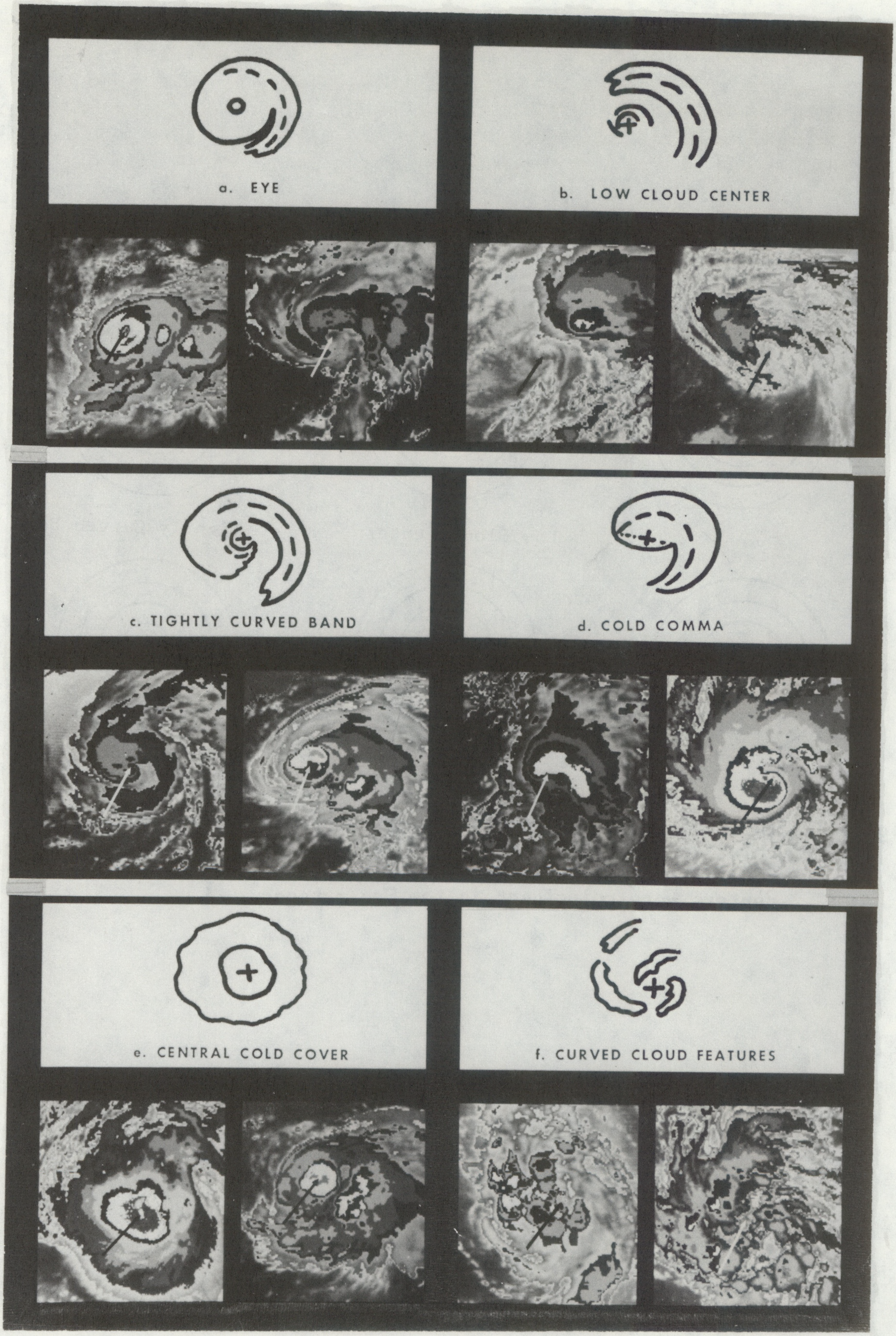

Figure 2. Examples of the six cloud pattern types used for determining tropical cyclone centers. The heavy dashed lines (a-d) represent the curved band axis.

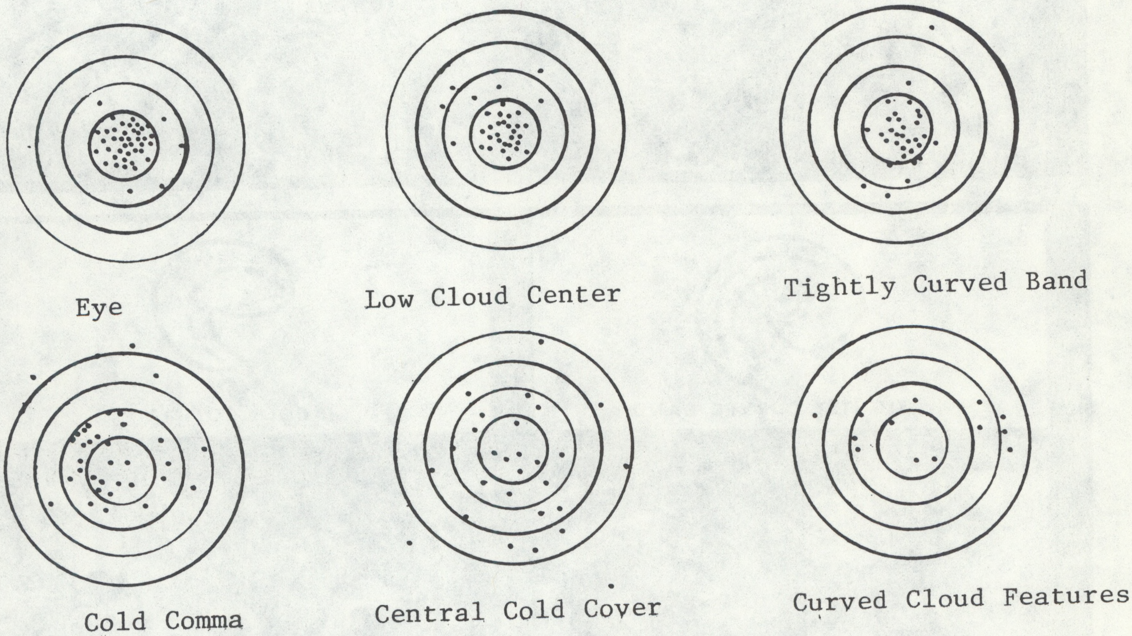

Figure 3a. The position of 215 storm centers determined from EIR pictures relative to recon centers. Radii of circles are 15, 30, 45, and 60 n mi respectively. Not shown are 13 cases in which the two centers were coincident in the Eye category.

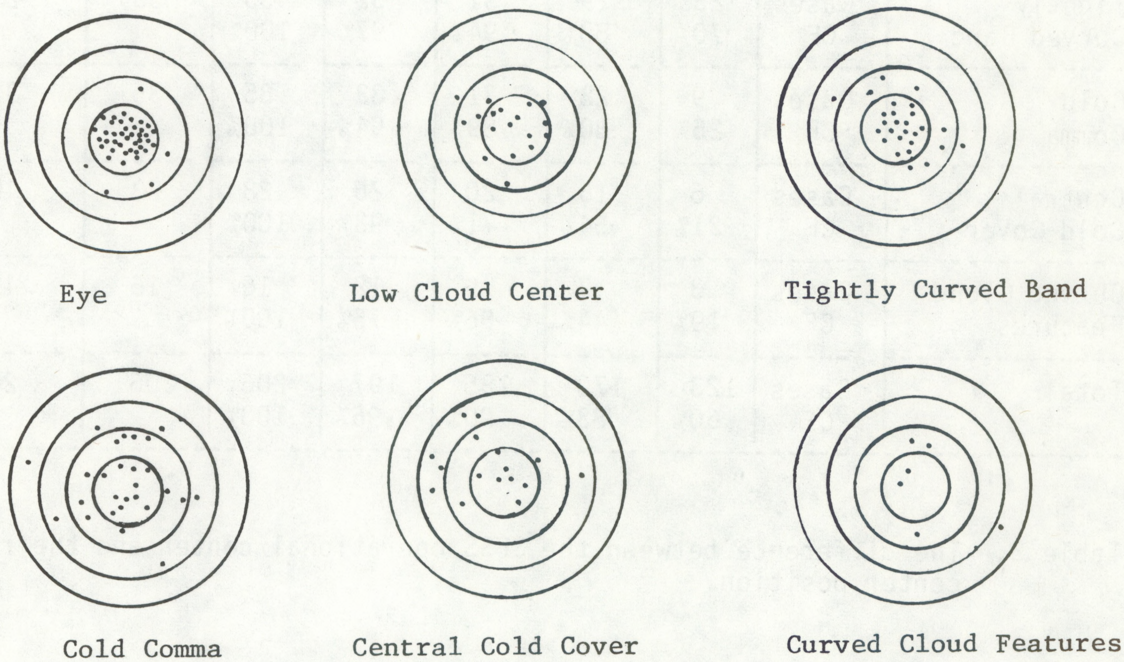

Figure 3b. The position of 153 (SFSS) operationally determined centers relative to recon centers. Radii of circles are 15, 30, 45, and 60 n mi respectively. Not shown are 13 cases in which the two centers were coincident in the Eye category.

TABLE 1. The difference between the EIR center position and the recon center position.

Pattern		<15 n mi	<30 n mi	<45 n mi	<60 n mi	<90 n mi	Cases	Ave Diff. n mi
Eye	Cases	55	60				60	16.3
	CF	92%	100%					
Low Cloud Center	Cases	27	31	34			34	19.4
	CF	79%	91%	100%				
Tightly Curved Band	Cases	23	29	31	32	33	33	23.2
	CF	70%	88%	94%	97%	100%		
Cold Comma	Cases	9	28	31	33	35	35	32.6
	CF	26%	80%	89%	94%	100%		
Central Cold Cover	Cases	6	15	20	26	28	28	40.2
	CF	21%	54%	71%	93%	100%		
Curved Cloud Features	Cases	3	7	9	12	16	16	49.7
	CF	19%	44%	56%	75%	100%		
Total	Cases	123	170	185	197	206	206	26.5
	CF	60%	83%	90%	96%	100%		

Table 2. The difference between the SFSS operational center and the recon center position.

Pattern		<15 n mi	<30 n mi	<45 n mi	<60 n mi	<90 n mi	Cases	Ave Diff. n mi
Eye	Cases	53	58				58	16.3
	CF	91%	100%					
Low Cloud Center	Cases	12	17	18			18	20.8
	CF	67%	94%	100%				
Tightly Curved Band	Cases	18	25	27			27	21.1
	CF	67%	93%	100%				
Cold Comma	Cases	11	21	26	27	28	28	30.0
	CF	39%	75%	93%	96%	100%		
Central Cold Cover	Cases	7	10	16			16	29.1
	CF	44%	63%	100%				
Curved Cloud Features	Cases	2	5	5	6		6	30.0
	CF	33%	83%	83%	100%			
Total	Cases	103	136	150	152	153	153	22.1
	CF	67%	89%	98%	99%	100%		

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