DOPPLER RADAR DETECTION CAPABILITIES AT MONTGOMERY ALABAMA, 1982–1988

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ABSTRACT

A selected set of significant weather events was documented at Montgomery, Alabama for a seven year period. Analysis of the documented data set revealed pertinent information regarding the detection capabilities of Doppler radar. Types of weather events, ability to interpret the events, event lead times, and event detection ranges are presented. Conclusions show that significant weather events can be detected within the range limitation characteristics of Doppler radar.

1. INTRODUCTION

The WSR 74–C Doppler add-on was installed at the National Weather Service Office (WSO) in Montgomery (MGM), AL in the spring of 1982. Since that time several modifications to the original Doppler package have taken place (Pettit and Johnson, 1983; Part 1). The most significant modifications were the installation of a 3.66 meter antenna which narrowed the radar beam to 1.02 degrees and an automated unfolding technique (Pettit and Johnson, 1983; Part 2) to remove ambigious velocities. Analysis of data over seven years of operation has revealed some important information about the use of Doppler radar in detection of severe weather (Pettit, 1989). The use of Doppler radar for severe weather identification at Montgomery and some of the radar's limiting characteristics are discussed in this paper.

2. RADAR CHARACTERISTICS

Operating characteristics of the WSR 74–C are given in Table 1. The effective range was determined after considering the following: Pulse Repetition Frequency (PRF), maximum unambigious velocity, radar beam width/height, and data processing methods. Detailed Doppler processing methods were described by Doviak and Zrnic (1984). Considering these characteristics the effective Doppler range of the MGM radar was determined to be approximately 136 km. The range limitation and other limiting factors will be discussed in greater detail in the analysis section of this paper.

Table 1. WSR 74C Characteristics with Doppler

Wavelength	5.4 Centimeters	
Peak Power	250 Kilowatts	
Pulse Length		
1. Intensity	2.0 Microseconds	
2. Doppler	0.5 Microseconds	
Minimum Detectable Signal	−107 Dbm	
Antenna		
1. Diameter	3.66 Meters	
2. Beam-width	1.05 Degrees	
PRF	Maximum Range	
1. 250 PRF	600 km/322 n mi	
2. 704 PRF	213 km/115 n mi	
3. 880 PRF	170 km/ 92 n mi	
4. 1100 PRF	136 km/ 73 n mi	
PRF	Effective Range[1]	
1. 250 PRF	230 km/125 n mi	
2. 704/880 PRF	170 km/ 92 n mi	
3. 800/1100 PRF	136 km/ 73 n mi	
Doppler Display Resolution		
(Monitors)	Pixel Size	Expanded
1. 64 km	.250 km	.125 km
2. 128 km	.500 km	.250 km
3. 192 km	1 km	.500 km

[1]The effective range of the Montgomery Doppler was determined to be the maximum range at which unambiguous velocity data could be obtained. Two 360 degree sweeps of data at two different PRFs are required to obtain unfolded velocity data.

3. ANALYSIS OF DATA

Data were taken from documentation logs recorded at Montgomery during the seven year period, 1982–1989. Data for these logs was derived by visual interpretation of velocity and intensity data archived on one half inch video (VHS) color tapes. The data set consisted of 144 events. The data events were given a yes (Y) classification according to the limits described in a–f.

a. Airport Wind Advisory (AWA): Recorded winds at Maxwell Air Force Base (MXF) or WSO, MGM were within 2.2 m sec^{-1} of the predicted advisory wind.
b. Mesocyclone (MESO): Wind damage or hail 3/4 inch in diameter or greater or wind recorded at 25.9 m sec^{-1} or greater.
c. Wind Gusts (including microbursts): Same criteria as in b.
d. Other Wind Shears: Same criteria as in b.
e. Hooks, etc.: same criteria as in b. (Includes Bounded Weak Echo Region, Line Echo Wave Patterns)
f. Tornadic Vortex Signature (TVS): Confirmed tornado.

Event statistics are given in Table 2.

Table 2. Airport Wind Advisory Events.

Meso	TVS	Gusts	Other Shears	Hooks, Etc.	AWA	Total
36	5	33	29	17	24	144
29	5	27	17	9	12	Y Events
7	0	6	12	8	12	N Events
50 min	37 min	88 min	60 min	25 min	88 min	Y Max. Lead Time
16 min	19 min	21 min	22 min	13 min	29 min	Y Avg. Lead Time
200 km	80 km	140 km	112 km	120 km	185 km	Y Max. Range
60 km	46 km	66 km	80 km	63 km	51 km	Y Avg. Range

Avg. Range All Y Events = 63 km

a. Airport Wind Advisory (AWA)

AWA's are issued at MGM when surface wind gusts equal to or greater than 17.9 m sec^{-1} are expected in the vicinity of local airports (MGM and MXF). The forecasting success for AWA's using Doppler radar depends heavily upon the forecast lead times. As the forecast lead time decreases, the chance of advisory verification increases. The predominant reason for this is that at greater Doppler ranges, the radar beam is higher above ground, and the displayed winds will be at the level of the boundary layer winds or higher. In order for increases in lead times some method must be used which will indicate the amount of de-coupling in the boundary layer winds (Badner, 1979), otherwise the predicted wind may be significantly higher than what is actually recorded at the surface forecast point later in time. The angle of the Doppler winds in relation to the radar antenna direction is another factor. Since displayed winds are relative winds (relative to the direction the radar antenna is pointing), any winds moving at angles across the radar beam will be less than the absolute winds. Displayed winds will be zero when this angle becomes 90 degrees (normal to antenna direction).

Of the 24 AWA's documented there were 12 Y events and 12 No (N) events (Table 2). Wind gusts usually occurred with the N events but speeds were less than the verification criteria. Average lead times for the Y events were closely related to the range/height relationship discussed earlier. Issuance of advisories for winds at shorter ranges (lower radar beam height) produced better verifications but shorter lead times. The maximum range of 185 km and the maximum lead time of 88 min were associated with a well defined intense squall line which moved through south central Alabama on December 12, 1987. Figure 1 shows the relationship of radar beam height with range.

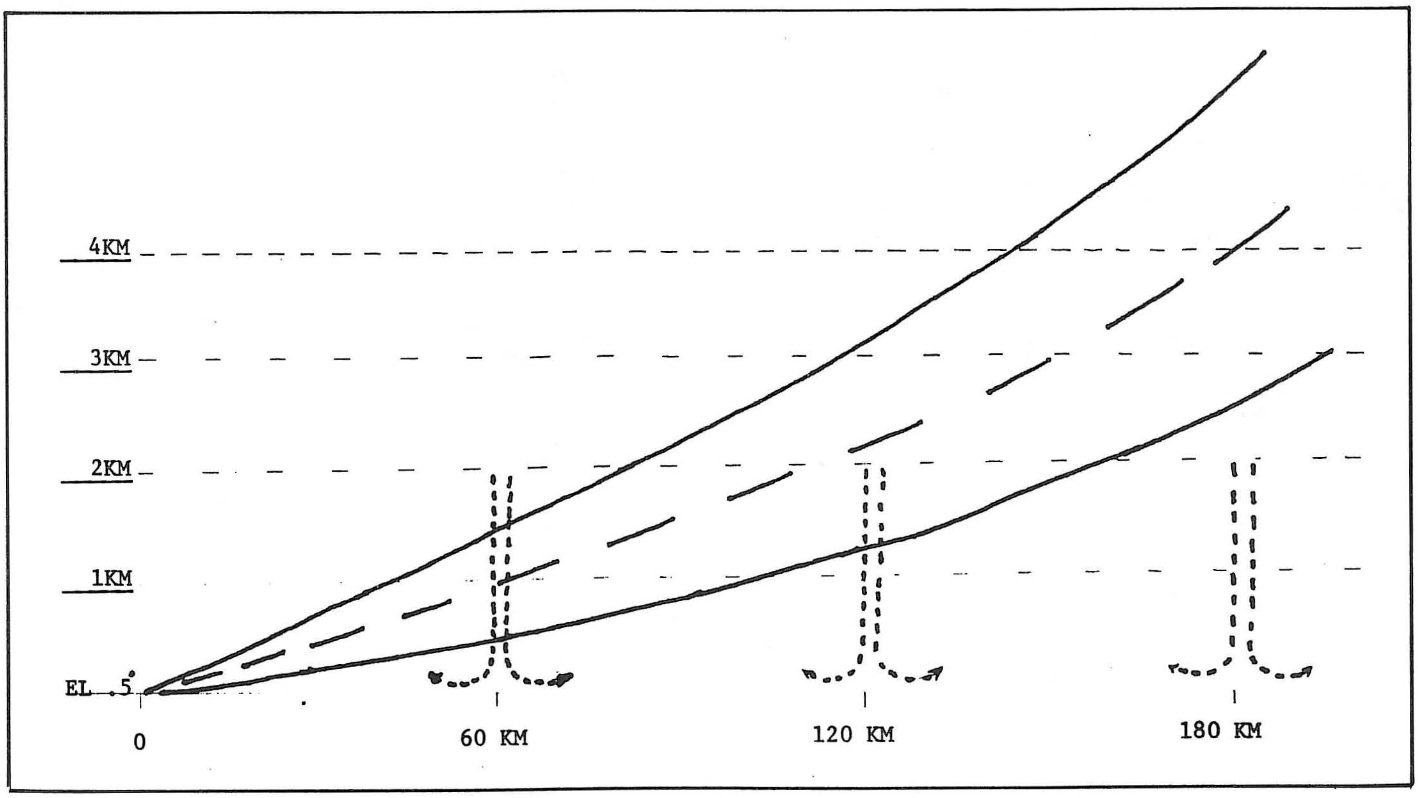

Fig. 1. Relationship of 1 degree radar beam-width with respect to height above ground and range. Dashed vertical lines represent sinking precipitation or air diverging near the surface. As range increases the divergence pattern lowers below the radar sampling volume. Divergence signatures will also become weaker as range increases due to increases in the sampling volume. Winds at 1 km altitude or at longer ranges may not be representative of surface winds when de-coupling of the boundary layer winds takes place.

b. Mesocyclone (MESO)

The number of Y event mesocyclones agrees with findings of other researchers. Well defined mesocyclones usually produce some form of severe weather (Burgess and Donaldson, 1979). Since mesocyclones form in the mid levels of thunderstorms, the range factor tends to be less limiting except at ranges where the beam height above ground increases to above 10 km and the sampling volume becomes larger. Other limiting factors are the diameter of the mesocyclone core, skewing of the mesocyclone in relation to the antenna direction, vertical depth of the mesocyclone core, and time continuity of the mesocyclone rotation (Donaldson, 1970). Donaldson (1970) found that one-half the radar beam-width is likely to set the minimum size for recognition of rotational couplets. Simply put, this means that in order to "see" the towards and away velocity couplets, the radii of the couplets must be greater than the radar one-half beam-width at a given range. Examples of mesocyclone and TVS core radii in relationship to beam spreading with range are given in Figure 2.

Burgess (1976) described the typical core radii of southern plains mesocyclones to be approximately 2.5 to 3 km. For a maxi tornado such as the Binger, Oklahoma tornado of 1981 Brown et. al. (1982) found the mesocyclone core radius to be 4 km with a TVS core radius of 1 km. Using the findings of Burgess and Brown, typical cores as described by them can

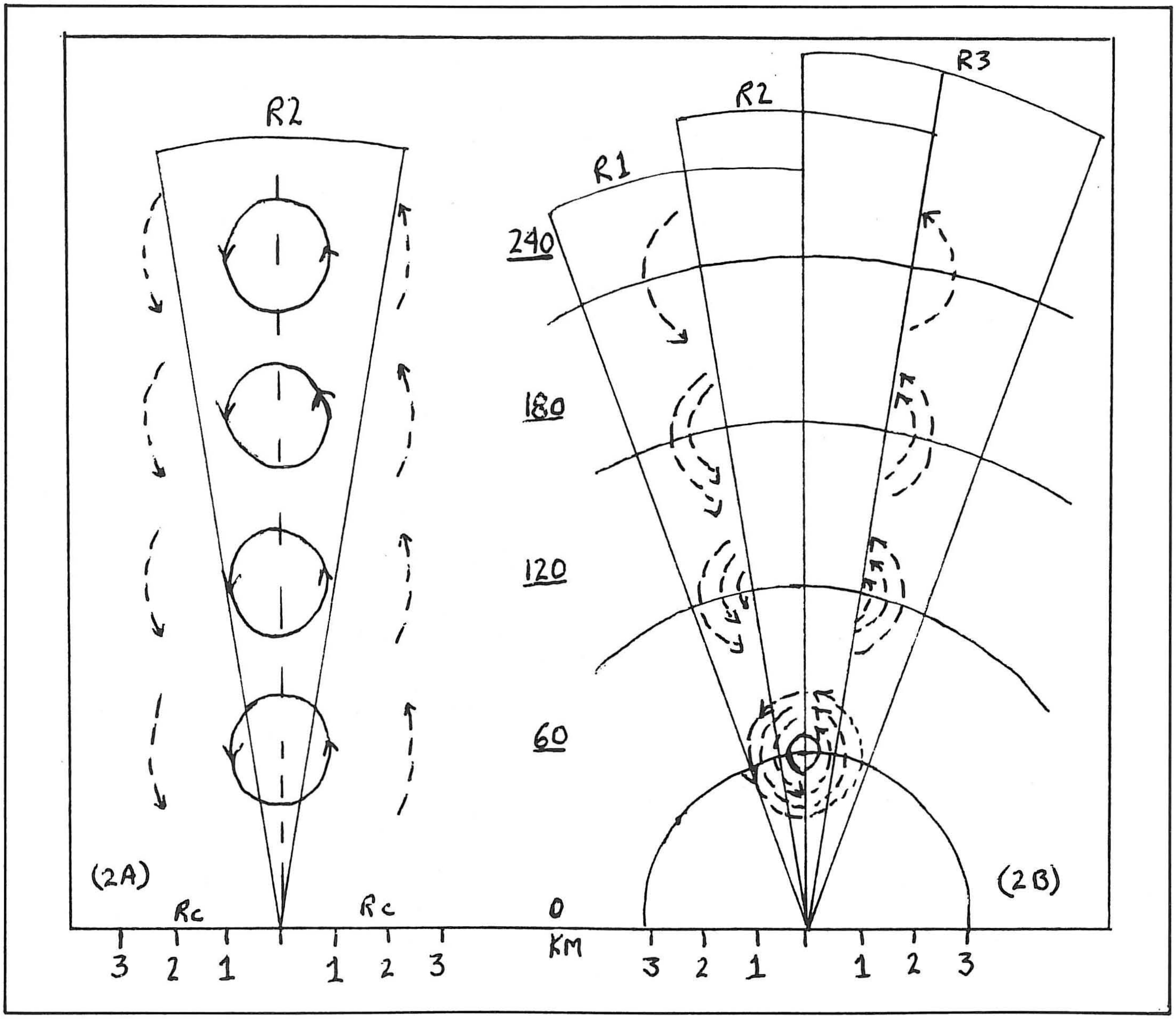

Fig. 2. Rc are core radii as described by Burgess (1976) and Brown (1978). Solid Rc are TVS and dashed are Mesocyclone. R1, R2, and R3 are 1 degree radar radials. Note that at ranges of 120 km or > TVS core radii become equal to or less than the radar 1/2 beam-width. At this point and beyond only the predominant speed/directional component of the TVS will be displayed due to processing methods. A decrease in core radii (Rc) by a factor of 1/2 will decrease the detection ranges proportionately (2A). As range increases to 120 km or > sampling volume increases, mesocyclone resolution (dashed) decreases, couplet velocities diminish, and TVS disappears (2B). Along the center line of R2, velocities tend to cancel each other and will be either, weaker or zero. The width of the cancellation effect along and near the center line of R2 increases as range increases.

be detected at ranges approximate to the example in 2A. As the core radii decrease to values equal to or less than one-half beam-width the ability to detect the velocity couplets diminishes as range increases.

Typical core radii for mesocyclones and TVS's have not been thoroughly documented for the southeast United States, however, thunderstorms in this area are not entirely typical of southern plains thunderstorms, especially in size, and core radii are probably less than those described by Burgess and Brown. A study to verify core radii using the MGM data is planned for the future.

In addition, Burgess and Donaldson (1979) found that some smaller and more rapidly developing tornadoes are not accompanied by parent circulations which can be detected by current Doppler techniques. They also found that warning lead times and ease of mesocyclone recognition are roughly proportional to tornado size and intensity. These findings are in close agreement with Wakimoto and Wilson (1989) which suggests that the maximum range for detection of non-supercell tornadoes will be approximately 45 km. Warning statistics at MGM tend to agree with these findings (Pettit, 1989).

According to Schaefer et. al. (1975), out of a total of 22,840 tornadoes that occurred in the U.S. between 1950 and 1983, 84% of the tornadoes were classified as F0, F1, and F2. Only .2 % were classified as F5. While one must be very careful about making assumptions, it is not unreasonable to suspect from the findings of this author and others that a large number of the smaller tornadoes which are very common to many areas of the U.S. and have small core radii, will go undetected by present Doppler radar techniques.

Results at Montgomery tend to agree with many of the previously mentioned findings about detection of mesocyclones and TVS's. Those mesocyclones that were readily identified produced damage or large hail in 29 out of 36 cases (84%). Tornadoes were confirmed with 11 of the mesocyclones. There were 5 documented TVS events, all producing tornadoes. Detection ranges were directly related to the size of the mesocyclone and TVS core radii and detection ranges were limited to about 60 km average (Table 2). Burgess (1976) noted similar results with 37 mesocyclones where 95% produced some form of surface damage and the average detection range of the 37 mesocyclones was approximately 80 km.

c. Wind Gusts

Wind gusts and microbursts were combined because many microburst divergence signatures were beyond the detection range of the Doppler radar. Divergence signatures associated with microbursts were noted in only 6 cases with only 1 failing to verify. The small number of documented microbursts can be attributed to a number of factors such as the short life span of the event, the lower atmospheric level where they occur, the fact that the diverging air may lack precipitation or other particles, and the failure of personnel to document the events correctly as microbursts.

During FLOWS the duration of microbursts were between 1 to 10 min and during JAWS and NIMROD there were only 4 microbursts with durations greater than 7 min (Wolfson, et al., 1985). Wilson (1984) discovered that microbursts decrease rapidly from roughly 200 m to 1,000 m in altitude and accurate measurements of divergence in the lowest 1 km are essential. From these findings and the example in Figure 1, it is evident that in order to see the classic divergent wind pattern with Doppler radar, the radar beam height must be about 1 km or less and the time window for detection will generally be 10 min or less. With standard atmospheric refraction index and .5 degree antenna elevation the radar beam is 1 km altitude at 60 km range.

d. Other Wind Shears

From Table 2, other wind shears consisted of those documented events that were not classified as MESO, TVS or GUSTS. There were 29 other wind shears documented and many more that were not documented over the period of data. The easiest shears to interpret were those associated with squall lines and fronts where significant change in directional and speed components of the wind occurred. Predicting the surface wind at a point later in time, however, presented some of the same problems associated with the AWA's. Shearing of the wind is a frequent meteorological event and most thunderstorms have considerable shearing in and around them. Distinguishing what is significant and what is not can be rather difficult for one viewing the Doppler velocity displays. This is evident from Table 2 which shows that 41% of the 29 documented cases were N events.

e. Hooks, Etc.

This category included hook echoes, line echo wave patterns, bounded weak echo regions, and upper level divergence taken from Doppler and intensity modes of the radar. The category was included to show that many hook echoes are "bogus" owing to the characteristics of the radar and operator interpretations. Of the 17 events listed in Table 2 only 9 events were classified as Y events. Mesocyclones were noted in 7 of the cases and 1 event indicated very strong upper level divergence. Personnel at Montgomery were able to confirm tornadoes or funnel clouds in only 3 of the 17 documented events. The data clearly show, however, that Doppler radar will enhance the ability of the operator to correctly interpret data from the radar.

4. CONCLUSIONS

The data from Table 2 agree with many earlier scientific findings about Doppler radar. The data illustrates the ability to detect and interpret a variety of events and shows some of the limitations for detecting those events. The average detection range of 63 km for all Y events indicates that the detection range of Doppler radar will be rather limited and contingent upon: the characteristics of a given radar, the type of meteorological event, the life cycle of the event, the physical size of the event, the skill of the operator, and in the case of automation, the completeness and accuracy of the computer algorithms.

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REFERENCES

Badner, J., 1979: Low Level Wind Shear: A Critical Review. *NOAA Tech. Memo. NWS FCST-23,* 50–52.

Brown, R. A., L. R. Lemon and D. W. Burgess, 1978: Tornado Detection by Pulsed Doppler Radar. *Mon. Wea. Rev., 106,* 29–38.

Burgess, D. W., 1976: Single Doppler Radar Vortex Recognition: Part 1, Mesocyclone Signatures. *Preprints, 17th Conf. on Radar Meteor. (Seattle),* 97–103.

Donaldson, R. J., Jr., 1970: Vortex Signature Recognition by a Doppler Radar. *J. Appl. Meteor., 9,* 661–670.

Doviak, R. J. and D. S. Zrnic, 1984: *Doppler Radar and Weather Observations.* Academic Press, Orlando, 91–119.

D. W. Burgess and R. J. Donaldson, 1979: Contrasting Tornadic Storm Types. *Preprints, 11th Conf. on Severe Local Storms, Boston,* 189–192.

Pettit, P. E. and W. N. Johnson, 1983: Operational Evaluation of 5CM Doppler Radar—Two Contributions, *NOAA Tech. Memo NWS SR-110,* 21pp.

Pettit, P. E. 1989: Doppler Radar Observations at Montgomery, AL, 1982–1988. *Nat. Wea. Dig., Vol. 14, No. 3,* 16–19.

Schaefer, J. T., D. L. Kelly and R. F. Abbey, 1985: A Minimum Assumption Tornado Hazard Probability Model, *NOAA Tech. Memo. NWS NSSDC-8,* 30 pp.

Wakimoto, R. M. and J. W. Wilson, 1989: Non-supercell Tornadoes. *Mon. Wea. Rev.,* 117, 1113–1140.

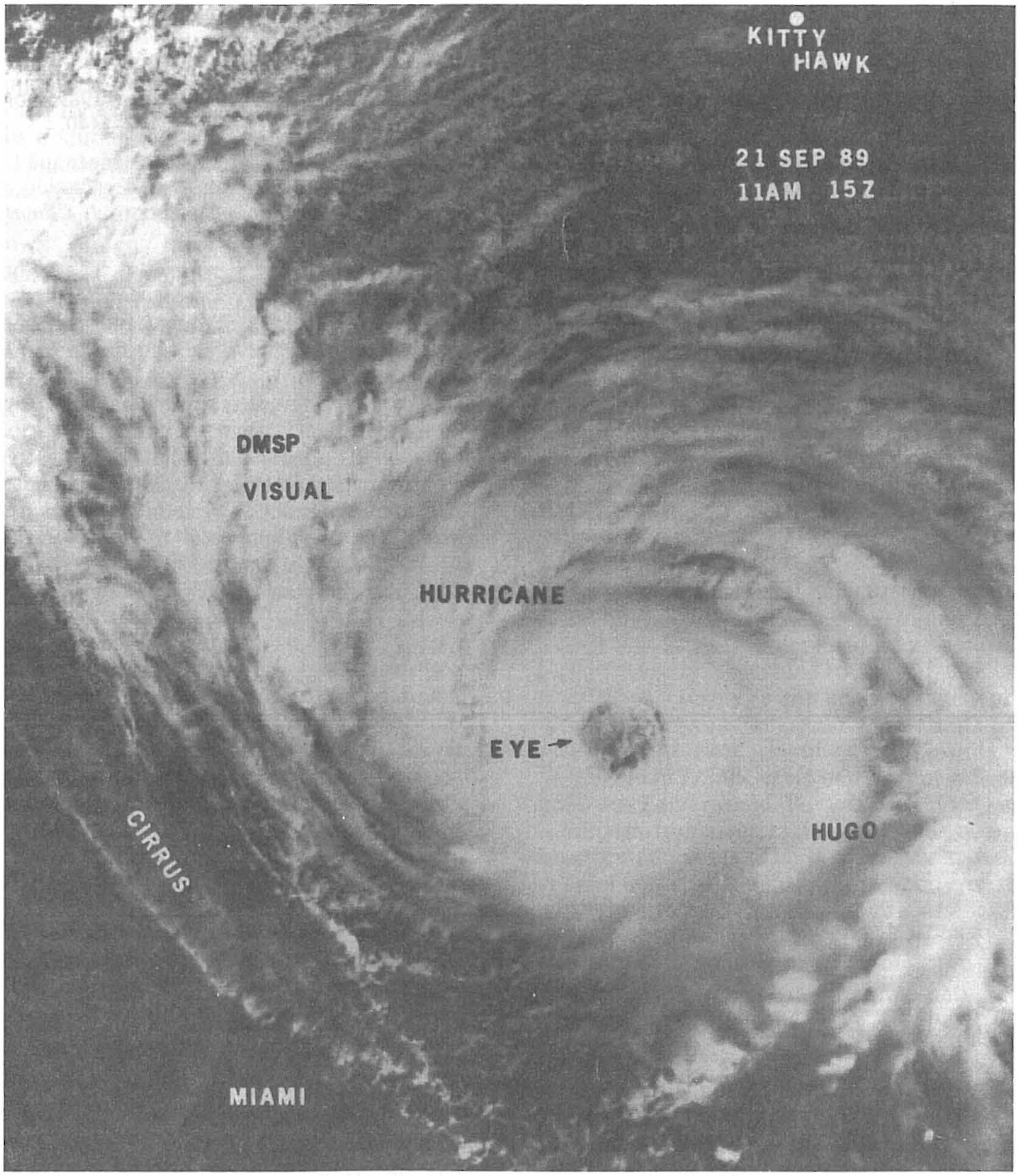
Wilson, J. W., R. Roberts, C. Kessinger and J. McCarthy, 1984: Microburst Wind Structure and Evaluation of Doppler Radar for Airport Wind Shear Detection, *J. Climate Appl. Meteor.,* 23, 898–915

Wolfson, M. W., J. T. DiStefano and T. Fujita, 1985: Low Altitude Wind Shear Characteristics in Memphis, TN Area. *Preprints, 14th Conf. on Severe Local Storms. (Indianapolis),* 323–327.

SCRIPT-SLIDE PROGRAM 1-90

WINDS OF THE WORLD AS SEEN IN WEATHER SATELLITE IMAGERY

The training module recently prepared by NESDIS, entitled "Winds of the World-As Seen in Satellite Imagery," is now available as NWA publication 1-90. This learning module is designed to show how surface and near surface winds may be revealed by satellite imagery. The groups of satellite imagery wind indicators studied are: convective phenomena; flow over and around mountains and islands; sunglint; fog; and dust and smoke. This Script-Slide Training Module contains 79 slides and a comprehensive text. The cost of $70.00 for NWA members and $84.00 for non-members includes shipping and handling; overseas orders are sent by air and require an additional $5. To order program send money order or check in American funds to: NWA Publications, 4400 Stamp Road, Room 404, Temple Hills, MD 20748.



Hurricane Hugo slammed into the South Carolina coast with 135 mph winds and torrential rain on the night of September 21, 1989. Many people were killed, more than two hundred thousand were evacuated, and damages in North Carolina and South Carolina were estimated to be in excess of 6 billion dollars. This DMSP visual image taken at 1500 UTC 21 September 1989 shows Hurricane Hugo approaching the South Carolina coast. Hugo's huge eye was over 50 km (30 mi) in diameter and winds reached 135 mph. Provided by Hank Brandli.