National Transportation Safety Board
Office of Aviation Safety
Washington, D.C. 20594-2000
May 30, 2001

ADDENDUM 2 TO METEOROLOGY FACTUAL REPORT

DCA99MA060

A. ACCIDENT

Location:	Little Rock, Arkansas
Date:	June 1, 1999
Time:	2351 Central Daylight Time (0451Z June 2, 1999)
Aircraft:	American Airlines Flight 1420, McDonald-Douglas MD-82, N215AA

A. METEOROLOGICAL GROUP

Chairman:	Donald E. Eick Weather Group Chairman Meteorologist, Operational Factors Division National Transportation Safety Board Washington, D.C. 20592-2000
Members:	John F. Robinson Warning Coordination Meteorologist National Weather Service North Little Rock, AR
	Neal R. Vines Air Carrier Inspector - Operations Federal Aviation Administration Little Rock, AR

Warren Qualley
Manager of Weather Services
American Airlines
Ft. Worth, TX

Timothy H. Miner
National Safety Committee - Aviation Weather
Allied Pilots Association

William R. Slye
Air Traffic Control Specialist
National Air Traffic Controller Association
Little Rock Adams Field, Little Rock, AR

C. SUMMARY

On June 1, 1999, at 2351 Central Daylight Time (CDT), a McDonnell Douglas MD-82, N215AA, operated by American Airlines as flight 1420, regularly scheduled passenger service from Dallas, Texas, overran the end of runway 4R and collided with the approach light stanchion at the Little Rock National Airport, in Little Rock, Arkansas. The captain and 10 passengers sustained fatal injuries; the remaining 134 passengers and crewmembers sustained various injuries. Shortly before the accident, the weather conditions at the airport were reported as: wind from 180 degrees at 9 knots, visibility 7 miles with thunderstorms, few clouds at 7,000 feet in cumulonimbus clouds, ceiling broken at 10,000 feet; temperature 77 degrees F, dew point 73 degrees F, altimeter 29.86 inches of mercury. Remarks; Automated Surface Observation System (ASOS) observation, thunderstorm began at 23 minutes after the hour, frequent lightning in-clouds and cloud-to-cloud, located from the west through the northwest, thunderstorms west through northwest moving northeast. The airplane was being operated in accordance with 14 CFR 121, and an instrument flight rules (IFR) flight plan had been filed.

D. ADDENDUM

The following data is added for clarification, reference and to support existing data in the Factual Report.

Attachment 62 is the answer on the beam height was calculated in the Massachusetts Institute of Technology – Lincoln Laboratory Weather Project Memorandum Number 95PM Wx-0065 "A Meteorological Analysis of the Aircraft Accident at Adams Field, Little Rock, AR, Involving American Airlines Flight 1420".

Attachment 63 is the program used to determine the Weather Surveillance Radar-1988 Doppler (WSR-88D) beam height calculations used in section 3.0.1. of the Meteorological Factual Report.

Attachment 64 contains supporting communications for section 3.0.3, "Reflectivity". The attachment includes the correspondence to the NWS, the existing National Weather Service (NWS) Weather Service Operations Manual (WSOM) Chapter D-25, reflectivity intensities and the amended chart. Also included is Advisory Circular AC 00-45E, "Aviation Weather Services" page 7-2, that defines the NWS intensity levels 1-6.

Attachment 65 is a series of WSR-88D images from 0422Z through 0452Z with the position of American Airlines Flight 1420 depicted at the time of the scan was completed over the flight track. The color scale used is the current NWS WSR-88D scale displayed on their website (http://weather.noaa.gov/radar/national.html).

Attachment 66 is the Automated Surface Observing System (ASOS) 1-minute high-resolution data on visibility extinction coefficient values and the derived statute mile visibility values as determined by the NWS. Extinction coefficient is a measure of the special rate of extinction or attenuation of any transmitted light, in this case, visible light. The one-minute mean of the extinction coefficient, combined with the day-night photometer and present weather value are used in the algorithm for determining visibility. This 1-minute visibility is marked in red on the time plot. The 10-minute harmonic mean of the ASOS visibility is labeled in yellow on the time plot. Details of the algorithm and the terms used are also included for reference.

Attachment 67 is the ASOS 5-minute altimeter readings based on the high-resolution data. The Little Rock Approach Controller transmitted the altimeter setting of 29.86 inches of mercury at 0427:11Z. The value at the time of the accident was 29.94 inches of mercury or .08 inches higher than what was issued.

Attachment 68 contains the Weather Services International (WSI) weather radar mosaics based on all the WSR-88D radars in the region. The radar mosaics are provided at 10-minute intervals from 0430Z through 0510Z. The yellow parallelogram is the Severe Weather Forecast Alert or severe thunderstorm weather watch that was current at the time.

Attachment 69 contains the American Airlines Flight Manual sections 6.0, 7.0, and 8.0, topics dealing with thunderstorms, windshear, and microbursts. Also included is the American Airlines DC-9 Operating Manual section 13 dealing with environmental factors, specifically windshear avoidance.

Attachment 70 is the Federal Aviation Administration (FAA) Advisory Circular AC 00-24B on Thunderstorms, and excerpts of the Aeronautical Information Manual sections 7-1-26 and 7-1-27 on thunderstorms. These two publications are standard training and guidance material on thunderstorms.

[redacted]

[redacted] 5/30/01

Donald E. Eick
NTSB Meteorologist

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LINCOLN LABORATORY
244 WOOD STREET
LEXINGTON, MASSACHUSETTS 02173-9108

Area Code 781
981-7950

29 May 2001

95C-0359

This serves as explanation of a statement contained within MIT-Lincoln Laboratory Wx Project Memorandum No. 95PM Wx-0065, dated January 7, 2000 and entitled "A Meteorological Analysis of the Aircraft Accident at Adams Field, Little Rock, AR, Involving American Airlines Flight 1420." The statement, on page 4, reads:

> "Near-surface is used here because the lowest scan of the radar actually shows the reflectivity at approximately 130 meters (425 feet) above ground level (AGL)."

<u>Elevation of the centroid of a 0.5° beam from KLZK over runway 4R at LIT Adams Field</u>

Location of KLZK (from Radar Operations Center/NOAA/DOC):
34° 50' 11" North / 92° 15' 43" West

Location of Runway 4R (from FAA Airport Diagram of Adams Field):
34° 43' 16" North / 92° 13' 5" West

Physical distance between these points:
13.43 km (7.25 nm)

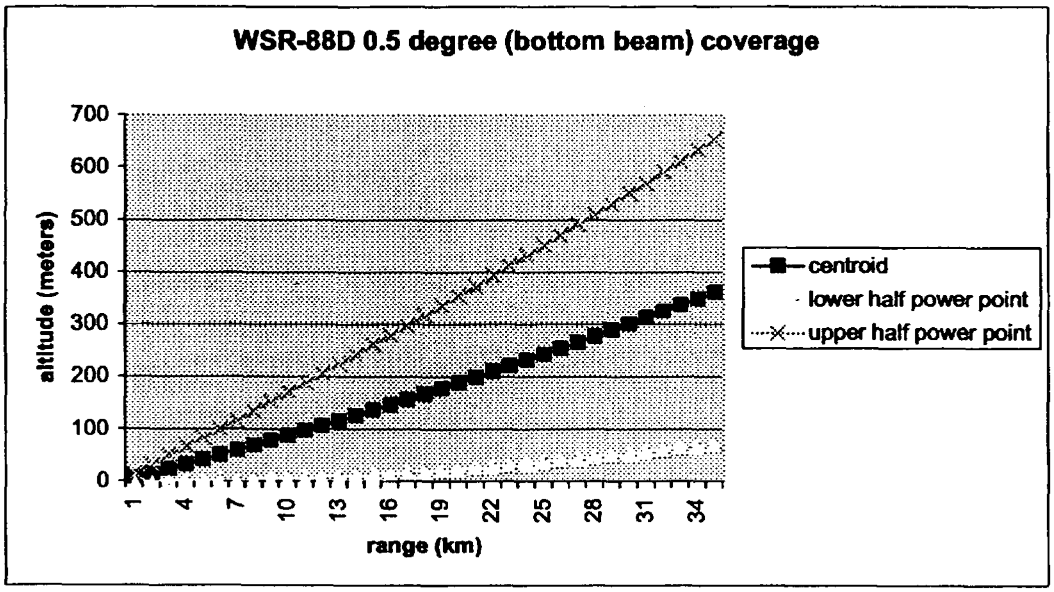
Using the center of a 0.5° beam,
tan 0.5 = (x) / 13.43 km
x = 117.20 m (384.5 ft)

The figure below shows the centroid of the beam (at the given range) at a height of just over 100 m, as demonstrated by the above equation. This is similar to the 130 m (425 ft) I used in my report. WATADS software reports the altitude at the threshold to 4R as 500 ft (rounded to the nearest 100'), also similar to my 425 ft result. The figure also shows the vertical column over which measurements are taken for a given range with a 0.5° beam. However, in this case, ~~the~~ centroid was used.

Taking into account the elevation of both the runway threshold (260 ft) and the NEXRAD (633.6 ft incl. tower height), the centroid of a radar beam at 0.0° is 373.6 ft above the runway. Adding to that the height of the 0.5° beam (384.5 ft), the result is 758 ft from runway 4R threshold to the center of a 0.5° beam directly overhead. If the bottom of the beam coverage is used, the altitude domain over which the precipitation

Attachment 62

measurements covered would extend as low as 373.6 ft. So the minimum altitude coverage over the threshold to runway 4R, taking into account the lower portion of the beam and elevation differences, would be similar to the value quoted in the report.



```
C       PROGRAM RADARHGT
C       Salottolo AS-30
C       REFERENCE FMH NO. 7 PART B PAGE 4
C       COMPUTES THE HEIGHT OF CENTER OF RADAR BEAM
C       GIVEN THE ELEVATION MSL OF ANTENNA SLANT RANGE
C       TO TARGET NMI AND ELEVATION OF ANTENNA IN DEGREES
C       INPUT R SLANT RANGE IN NMI
        TYPE 10
        ACCEPT 20,R
C       INPUT ALPHA ANTENNA ELEVATION IN DEGREES
        TYPE 30
        ACCEPT 20,ALPHA
C       INPUT E ELEVATION OF ANTENNA IN FEET
        TYPE 31
        ACCEPT 20,E
        TYPE 100
        ACCEPT 20,BW
100     FORMAT(' ENTER BEAM WIDTH DEGREES ' $ )
C       CALCULATE R**2*(COS ALPHA )**2/9168.66
        A = R**2
        B =( COS(ALPHA*.0174532))**2
        C = 9168.66
C       CALCULATE R*SIN (ALPHA)
        D = R*SIN(ALPHA*.0174532)
C       COMPUTE THE CENTER BEAM HEIGHT
        H =( A*B/C) + D
        H = H *6076.115
        H = H + E
C       OUTPUT H
        TYPE 40,H
        BW = BW*.0174532
        BW = BW/2
        WB = R*TAN(BW)
        WB = WB * 6076.2
        WB = WB*2
        Z = WB/2
        X = H+Z
        Y = H-Z
        TYPE 101,WB,X,Y
101     FORMAT(' BEAM WIDTH FEET ', F12.2 , ' TOP OF BEAM FT MSL '
 , F12.2 /
        1 ' BOTTOM OF BEAM FT MSL ' , F12.2 )
10      FORMAT(' ENTER SLANT RANGE TO TARGET NMI ' $)
20      FORMAT(F8.2)
30      FORMAT(' ENTER ELEVATION ANGLE DEGREES ' $)
31      FORMAT(' ENTER HEIGHT OF ANTENNA FEET MSL '$)
40      FORMAT(' CENTER OF BEAM FEET MSL ' ,F12.2)
        STOP
```


Attachment 63 -

Eick Donald

From: Salottolo.Greg
Sent: Thursday, May 10, 2001 7:23 AM
To: Eick Donald
Subject: FW: D-25 VIP/DBZ Table

VIP_DBZ_.doc   ATT83736.txt

Don:

Here is the correspondence regarding VIP/dBZ Table.

-----Original Message-----
From: Robert Kuessner [redacted]
Sent: Tuesday, February 15, 2000 9:07 AM
To: Dorothy Haldeman; Michael Szkil
[redacted]
Subject: D-25 VIP/DBZ Table

Dorothy, Mike: This is followup to an earlier E-mail I received from Greg Salottolo of the NTSB which questioned the rainfall rates as noted in Appendix C of the current WSOM Chapter D-25, as compared to what is depicted in FMH #11 Part B, page 5-6, equation 5-16. The rainfall rates versus dBZ values do not agree - this was confirmed in subsequent conversations with Bob Elvander, OM2.

Based on a conversation I had with Mike Szkil, it is my understanding the WSOM Chapter D-25 will be revised in the near future. I would recommend that this would be a good opportunity to also amend the table in Appendix C, to make it agree with the info in FMH #11.

Thanks - Bob K.

______________________ Forward Header ______________________
Subject: D-25 VIP/DBZ Table
Author: Salott[redacted] at EXTERNAL
Date: 2/15/00 7:07 AM

Good Morning Bob:

FYI: This is a corrected Table relating Rainfall Rates to dBZ values (Z-R relationship ..
Z = 300*R1.4).**

<<VIP_DBZ_Conversion_tbl.doc>>

Greg ...

Attachment 64

VIP/DBZ Conversion Table

NWS VIP … National Weather Service Video Integrator and Processor Level.
WSR-88D LVL … WSR-88D Doppler Weather Radar Level.
PREC MODE dBZ … Precipitation Mode dBZ.
RAINFALL .. Rainfall in inches per hour.

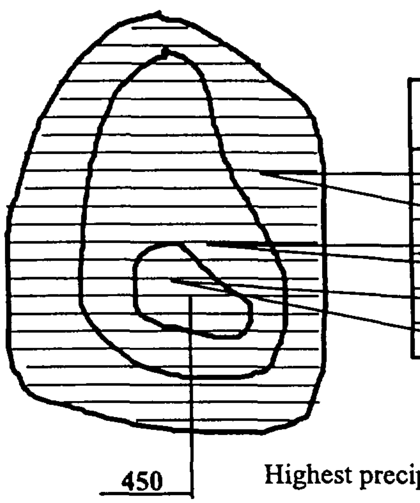
NWS VIP	WSR-88D LVL	PREC MODE DBZ	RAINFALL
0	0 1 2	<5 5 to 9 10 to 14	
1 Very Light	3 4 5	15 to 19 20 to 24 25 to 29	.01 in/hr .02 in/hr .04 in/hr
2 Light to Moderate	6 7	30 to 34 35 to 39	.09 in/hr .21 in/hr
3 Strong	8	40 to 44	.48 in/hr
4 Very Strong	9	45 to 49	1.10 in/hr
5 Intense	10	50 to 54	2.49 in/hr
6 Extreme	11 12 13 14 15	55 to 59 60 to 64 65 to 69 70 to 74 GTE 75	>5.67 in/hr

CORRECTED TABLE TO APPEAR IN NWS
WSOM D-25

INTENSITY

The intensity is obtained from the amount of energy returned to the radar from the target and is indicated on the chart by contours. Six precipitation intensity levels are reduced into three contour intervals as indicated in Table 7-2. In Figure 7-1, over central Montana is an area of precipitation depicted by one contour. The intensity of the precipitation area would be light to possibly moderate. Whether there is moderate precipitation in the area cannot be determined. However, what can be said is that the maximum intensity is definitely below heavy. When determining intensity levels from this chart, it is recommended that the maximum possible intensity be used. To determine the actual maximum intensity level, the SD for that time period should be examined. It should also be noted that intensity is coded for frozen precipitation (i.e., snow or snow showers). This is due to the fact that the WSR-88D is much more powerful and sensitive than previous radars. Finally, it is very important to remember that the intensity trend is no longer coded on the radar summary chart.

Table 7-2 Precipitation Intensities



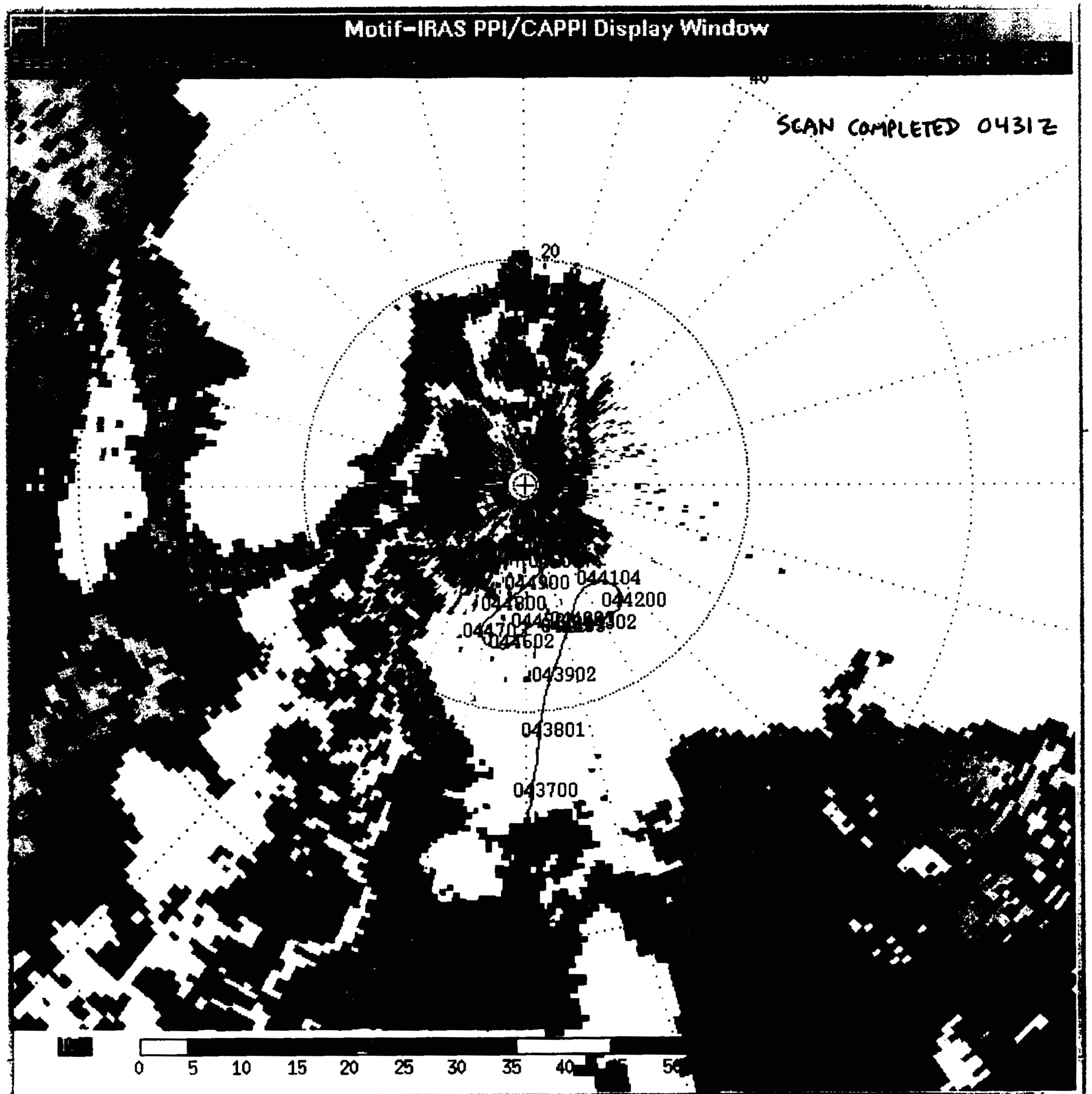
Digit	Precipitation Intensity	Rainfall Rate in./hr. Stratiform	Rainfall Rate in./hr. Convective
1	Light	Less than 0.1	Less than 0.2
2	Moderate	0.1-0.5	0.2-1.1
3	Heavy	0.5-1.0	1.1-2.2
4	Very heavy	1.0-2.0	2.2-4.5
5	Intense	2.0-5.0	4.5-7.1
6	Extreme	More than 5.0	More than 7.1

Highest precipitation top in area in hundreds of feet MSL (45,000 feet MSL).

ECHO CONFIGURATION AND COVERAGE

The configuration is the arrangement of echoes. There are three designated arrangements: a LINE of echoes, an AREA of echoes, and an isolated CELL. (See Radar Weather Reports in Section 3 for definitions of the three configurations.)

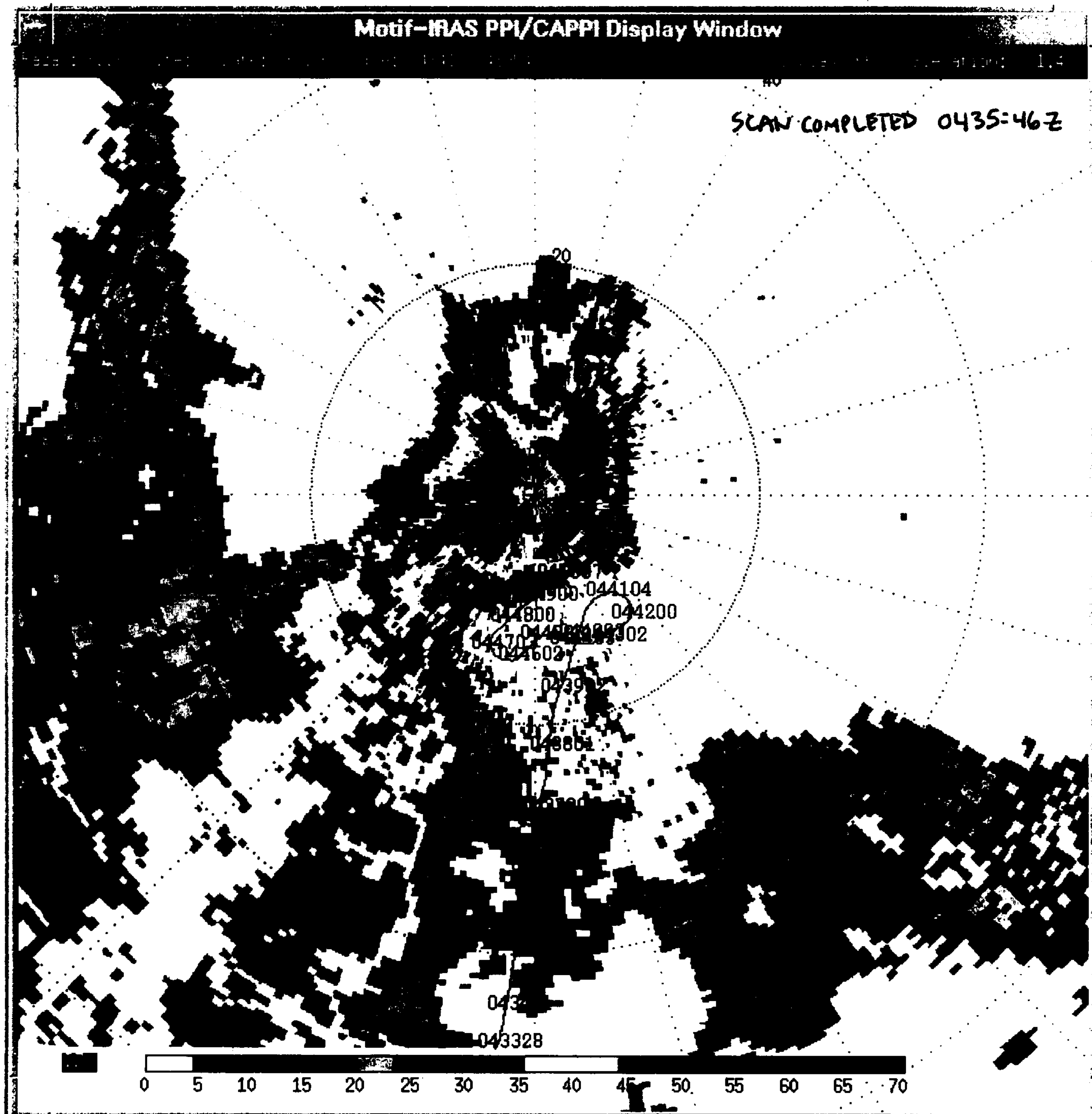
Coverage is simply the area covered by echoes. All the hatched area inside the contours on the chart is considered to be covered by echoes. When the echoes are reported as a LINE, a line will be drawn through them on the chart. Where there is 8/10 coverage or more, the line is labeled as solid (SLD) at both ends. In the absence of this label, it can be assumed that there is less than 8/10 coverage. For example, in Figure 7-1, there is a solid line of thunderstorms with intense to extreme rain showers over central Georgia.



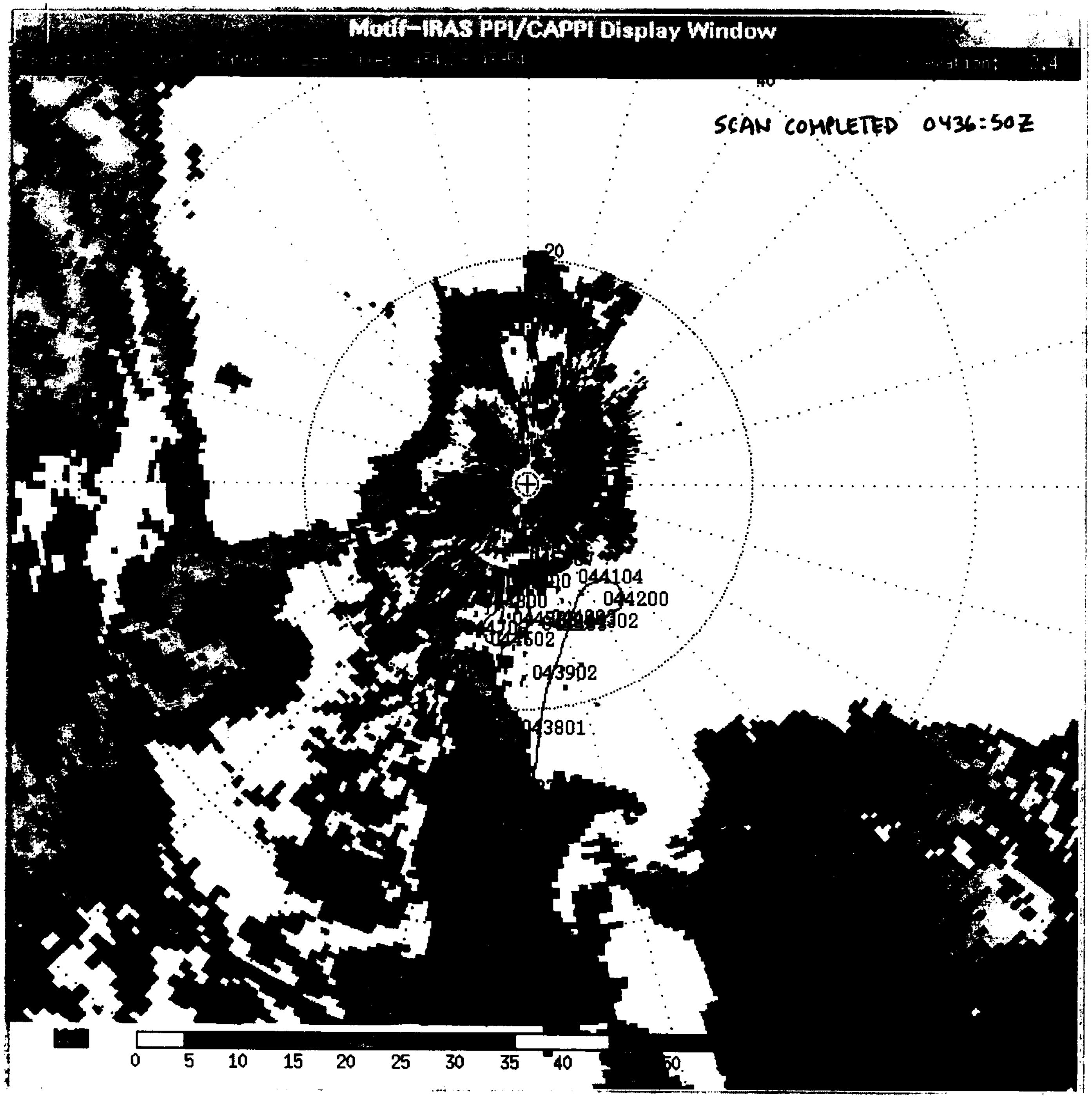
Flight 1420

Attachment Series 65

65A

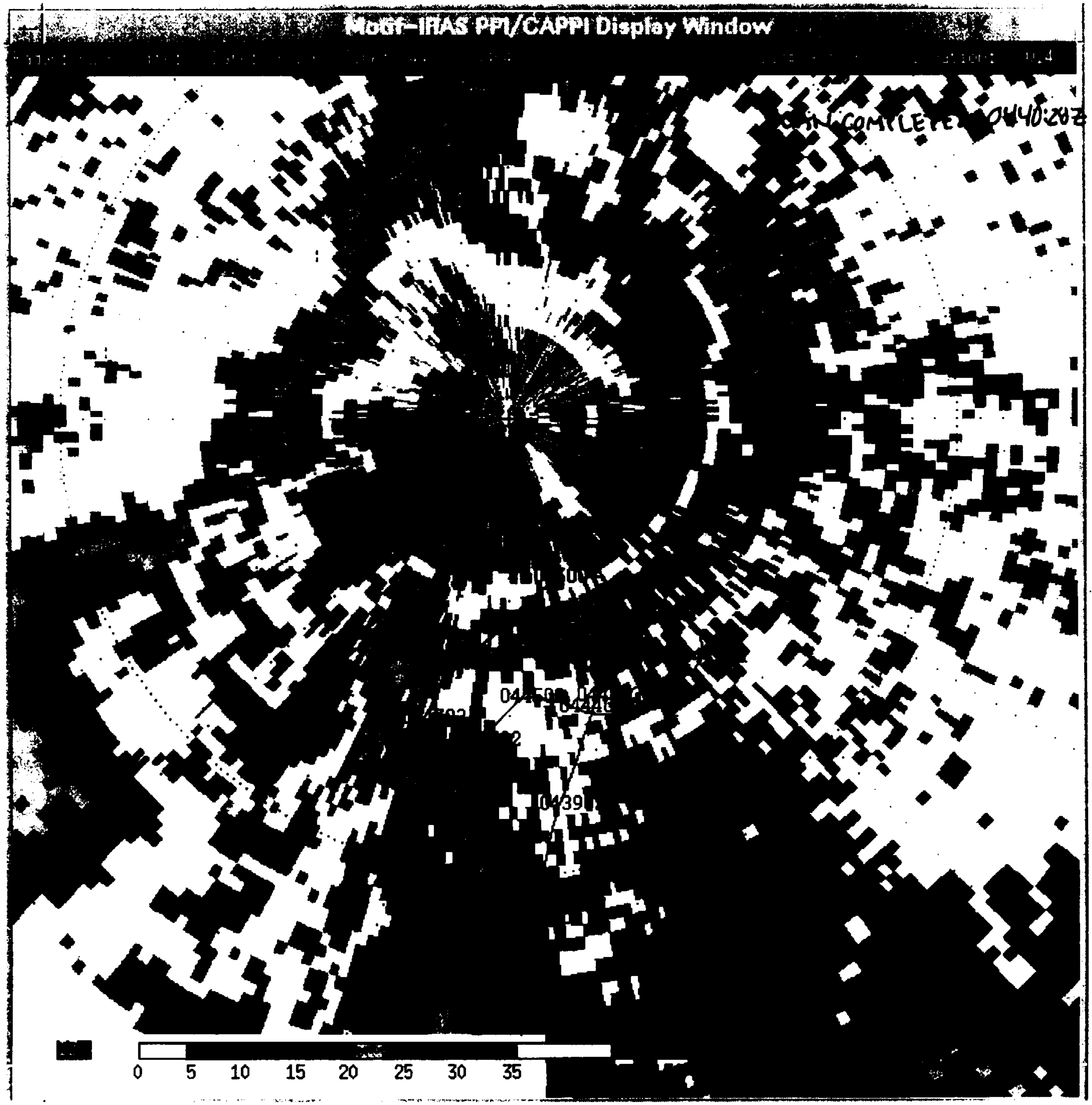

Motif-IRAS PPI/CAPPI Display Window
SCAN COMPLETED 0435:46Z
20
40
044104
044200
044800
044602
043328
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70

65B

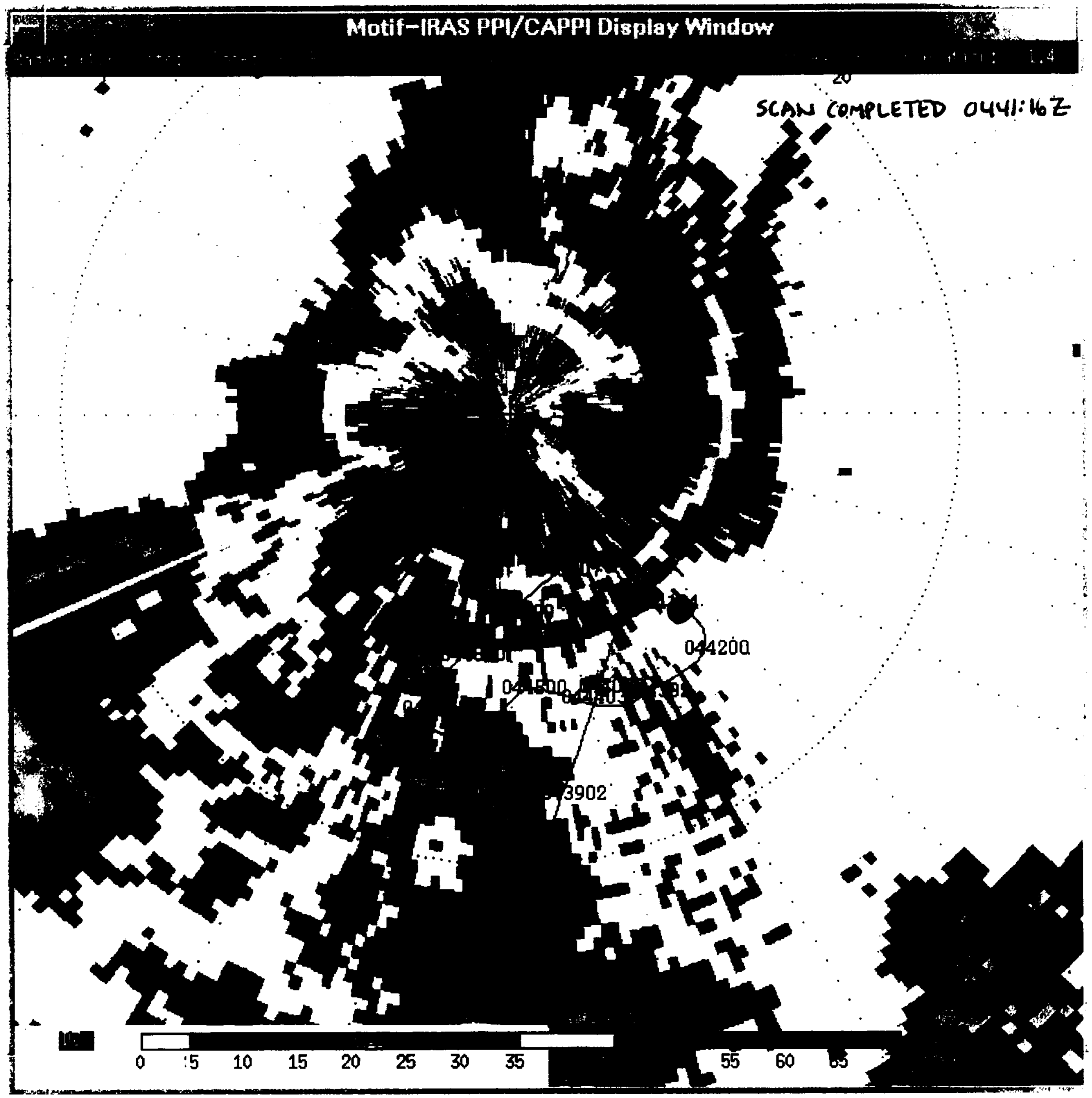


Modif-IRAS PPI/CAPPI Display Window
SCAN COMPLETED 0436:50Z
20
40
044104
044200
043902
043801
0
5
10
15
20
25
30
35
40
50

65C


Mobil-IRAS PPI/CAPPI Display Window
0440:20Z
0439
0 5 10 15 20 25 30 35

6FD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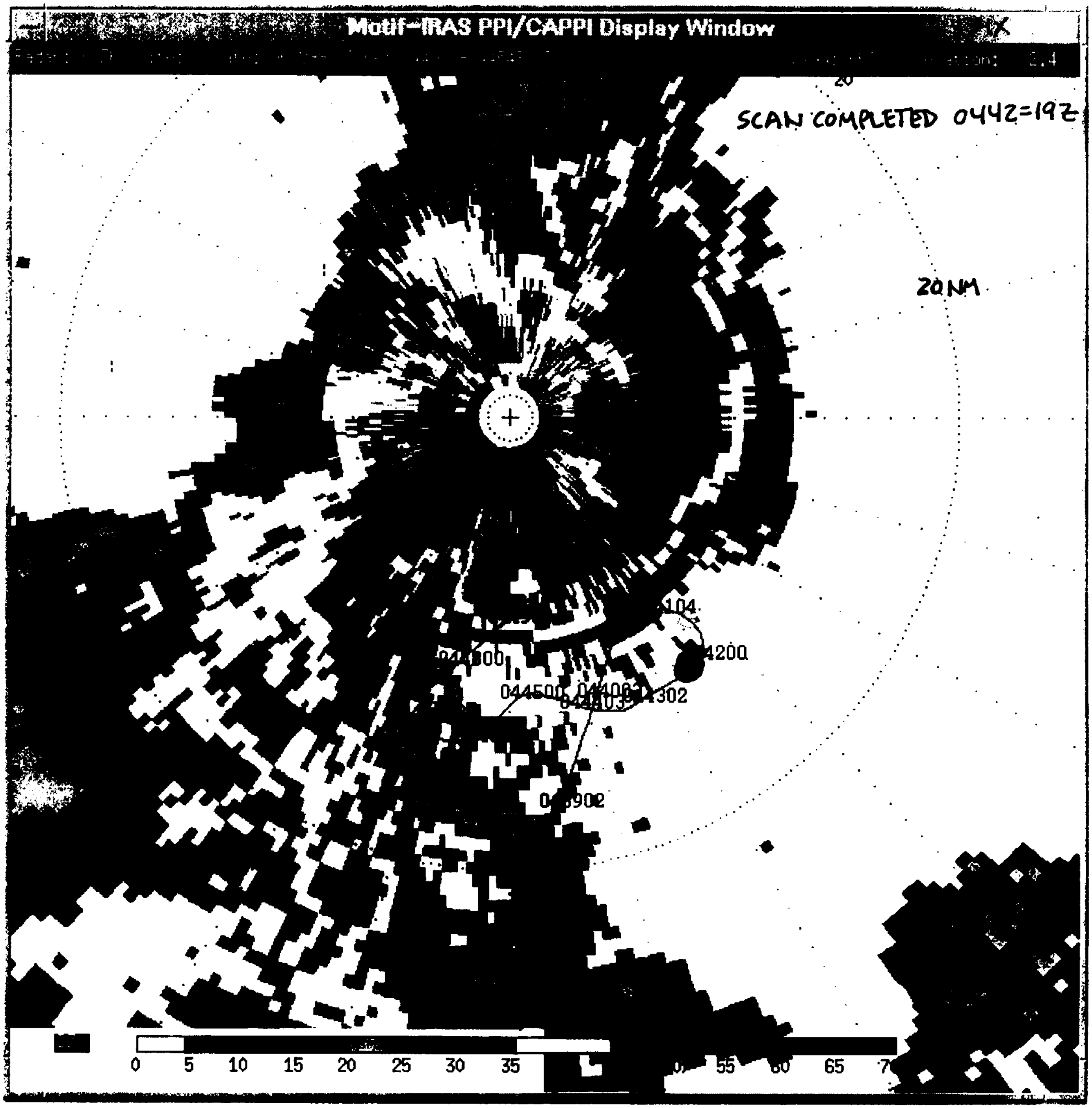
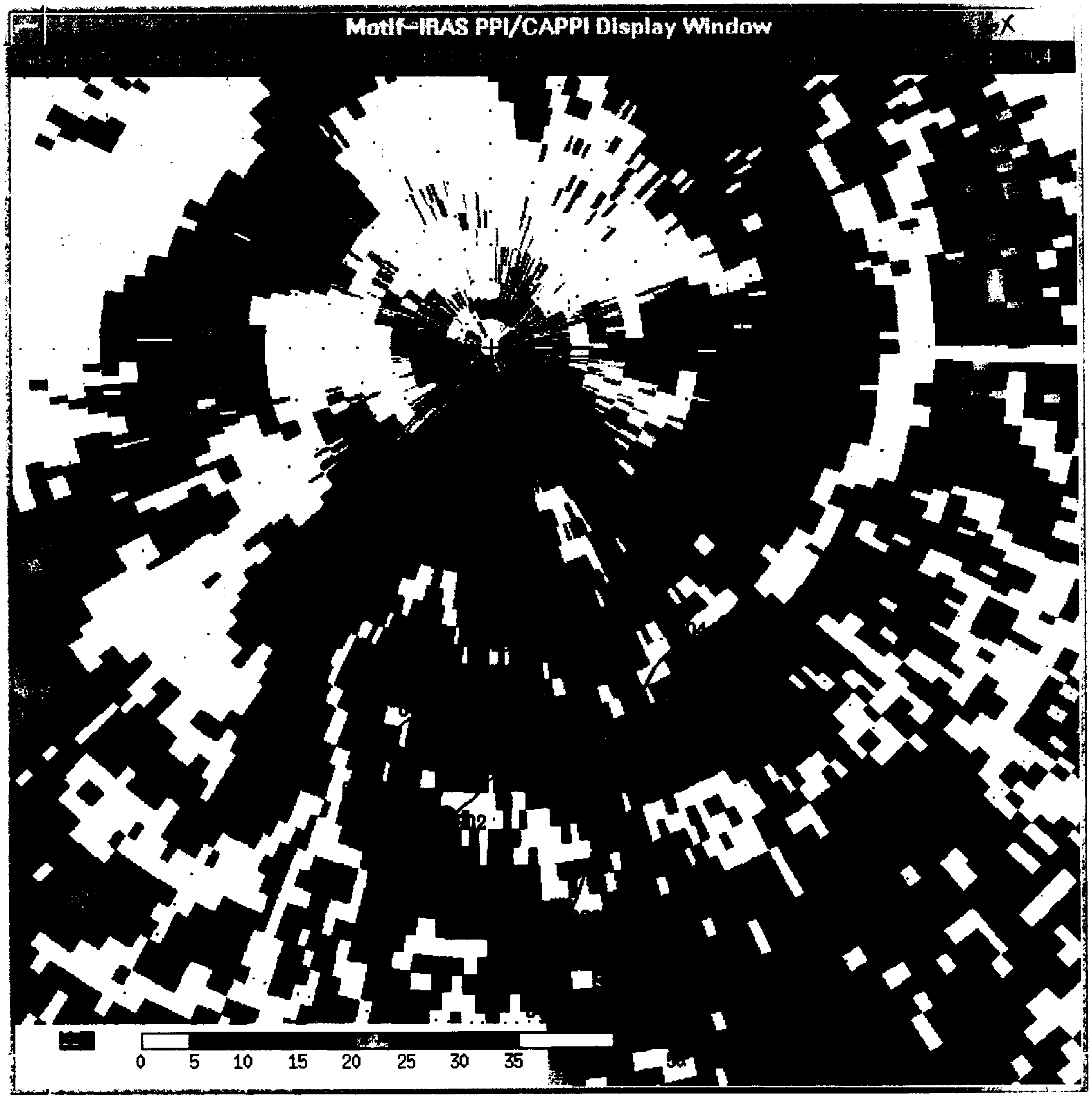
SCAN COMPLETED 0441:16Z
044200
3902
0 5 10 15 20 25 30 35 55 60 65

65E

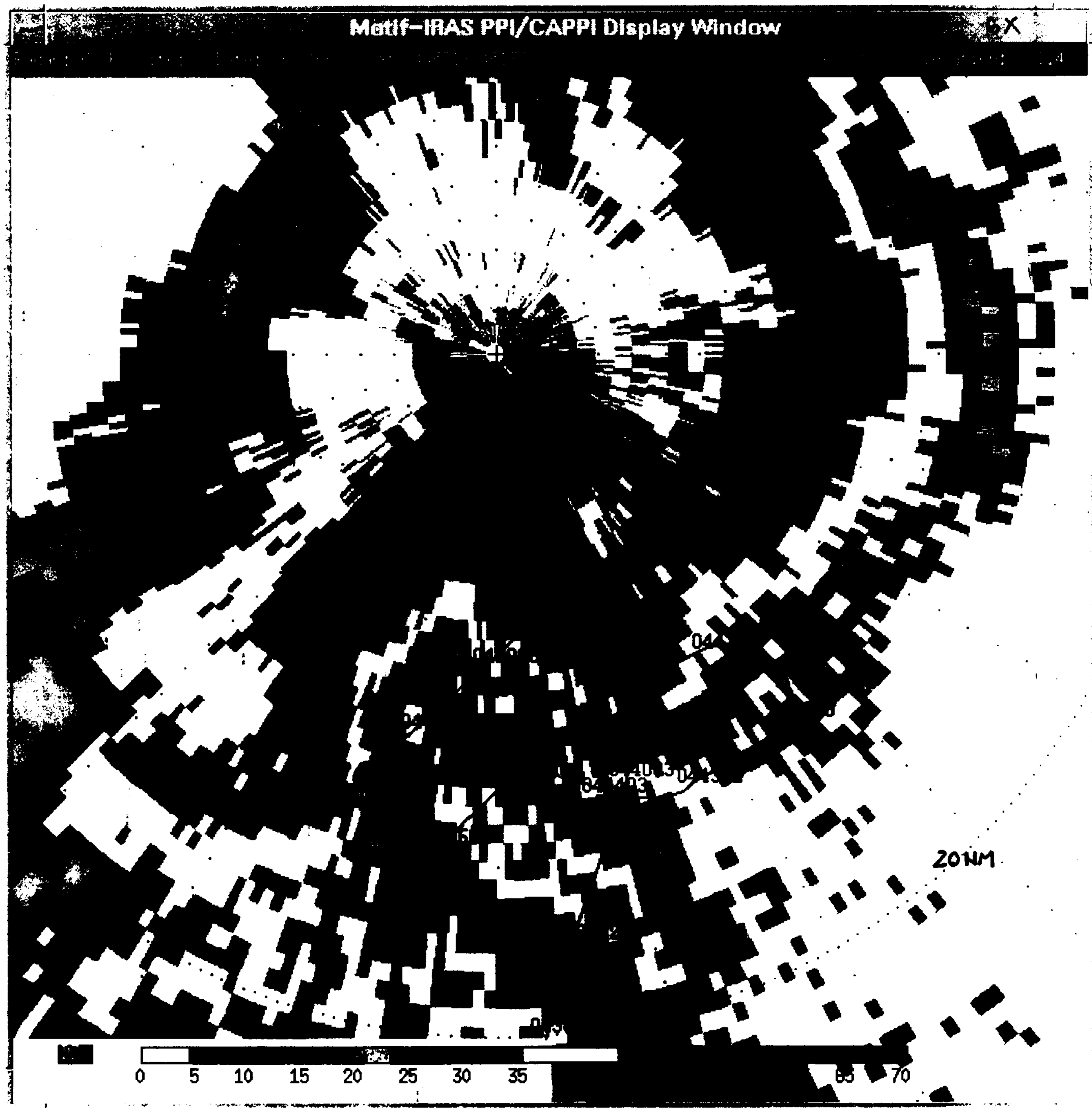

Motif-IRAS PPI/CAPPI Display Window
SCAN COMPLETED 0442=19Z
20NM
20
104
4200
044500
4302
0 5 10 15 20 25 30 35
55 60 65

65F



SCAN COMPLETED AT 0446:14Z

6E G



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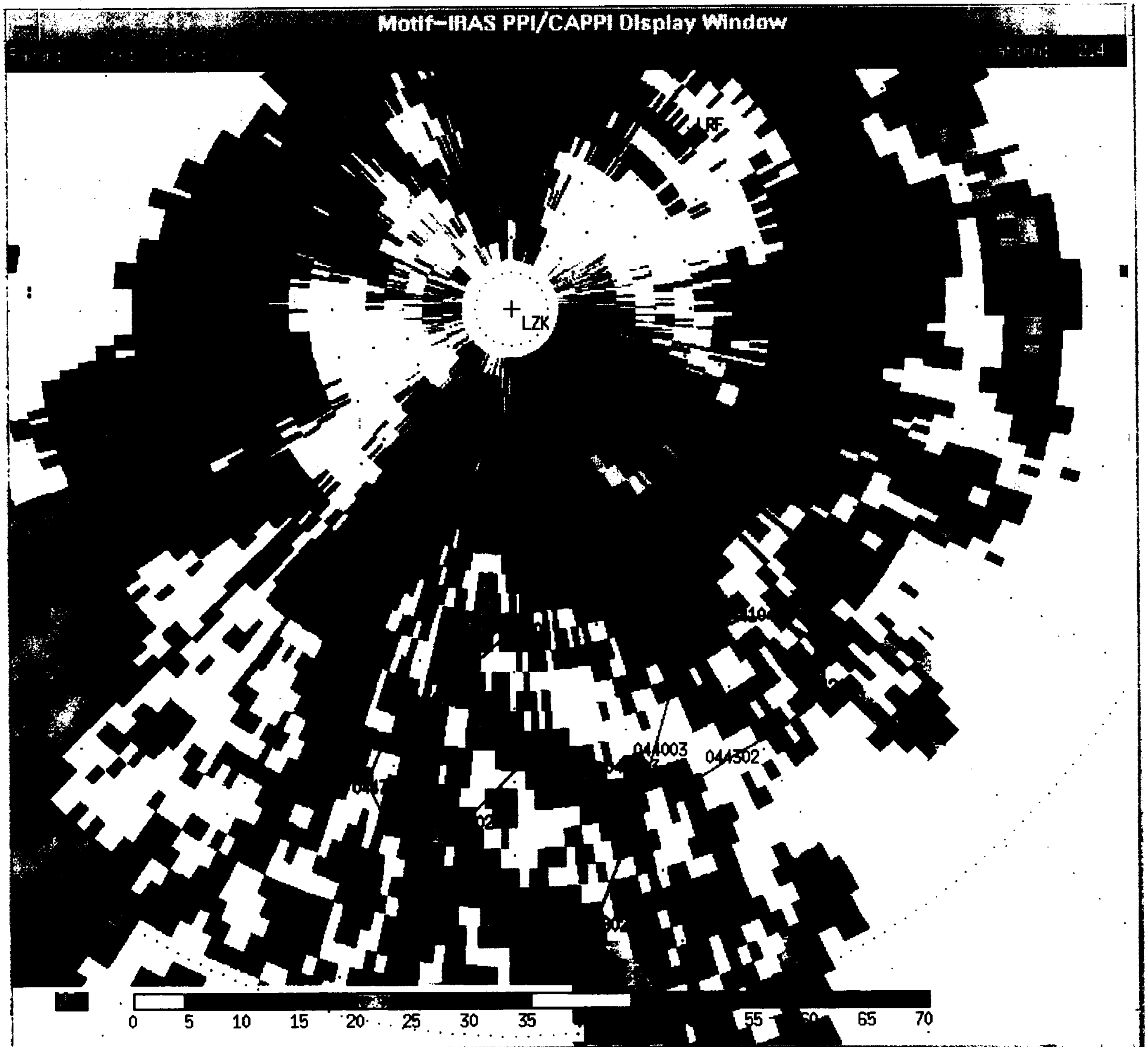
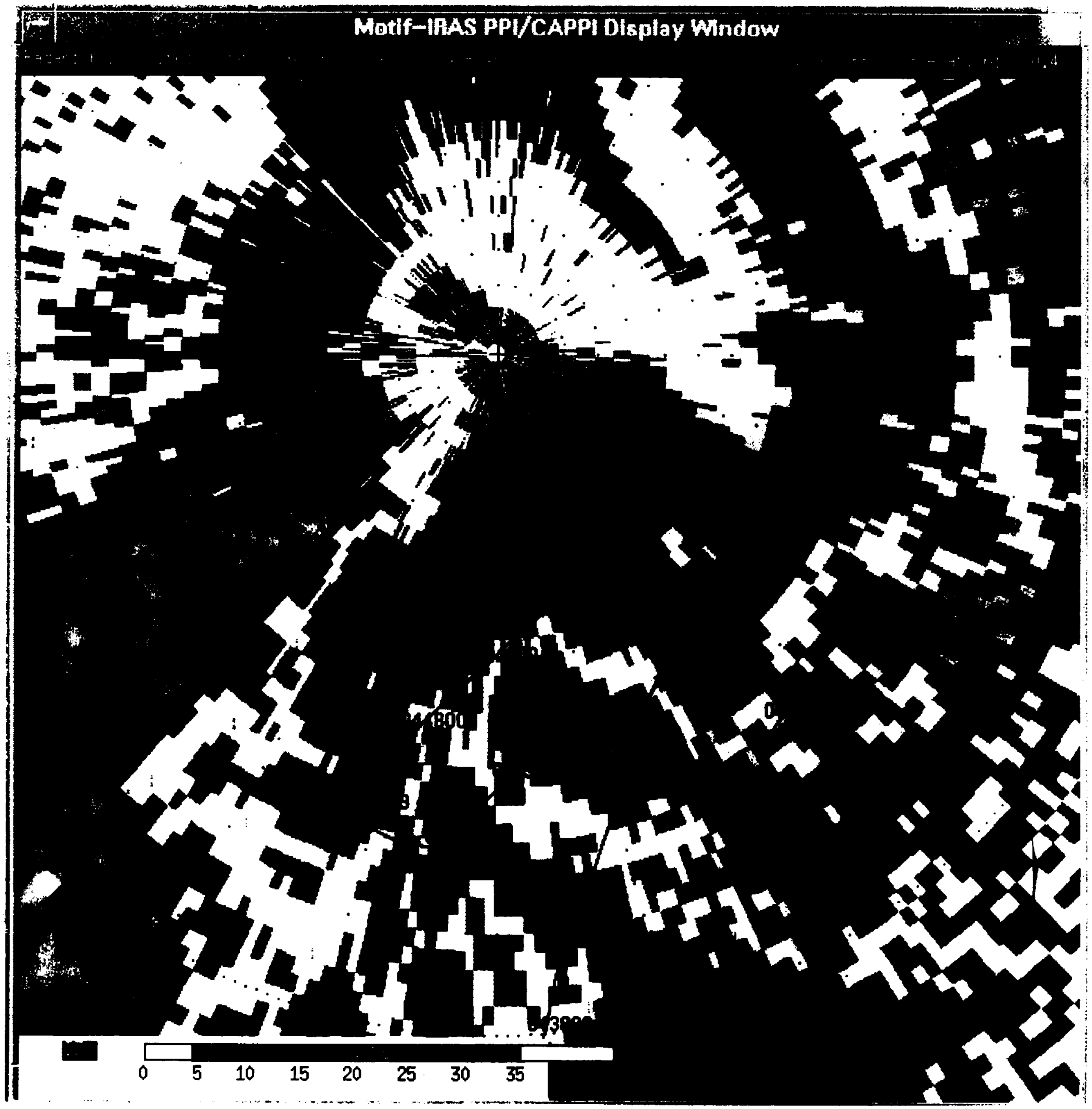


SCAN COMPLETED AT 0448:07Z

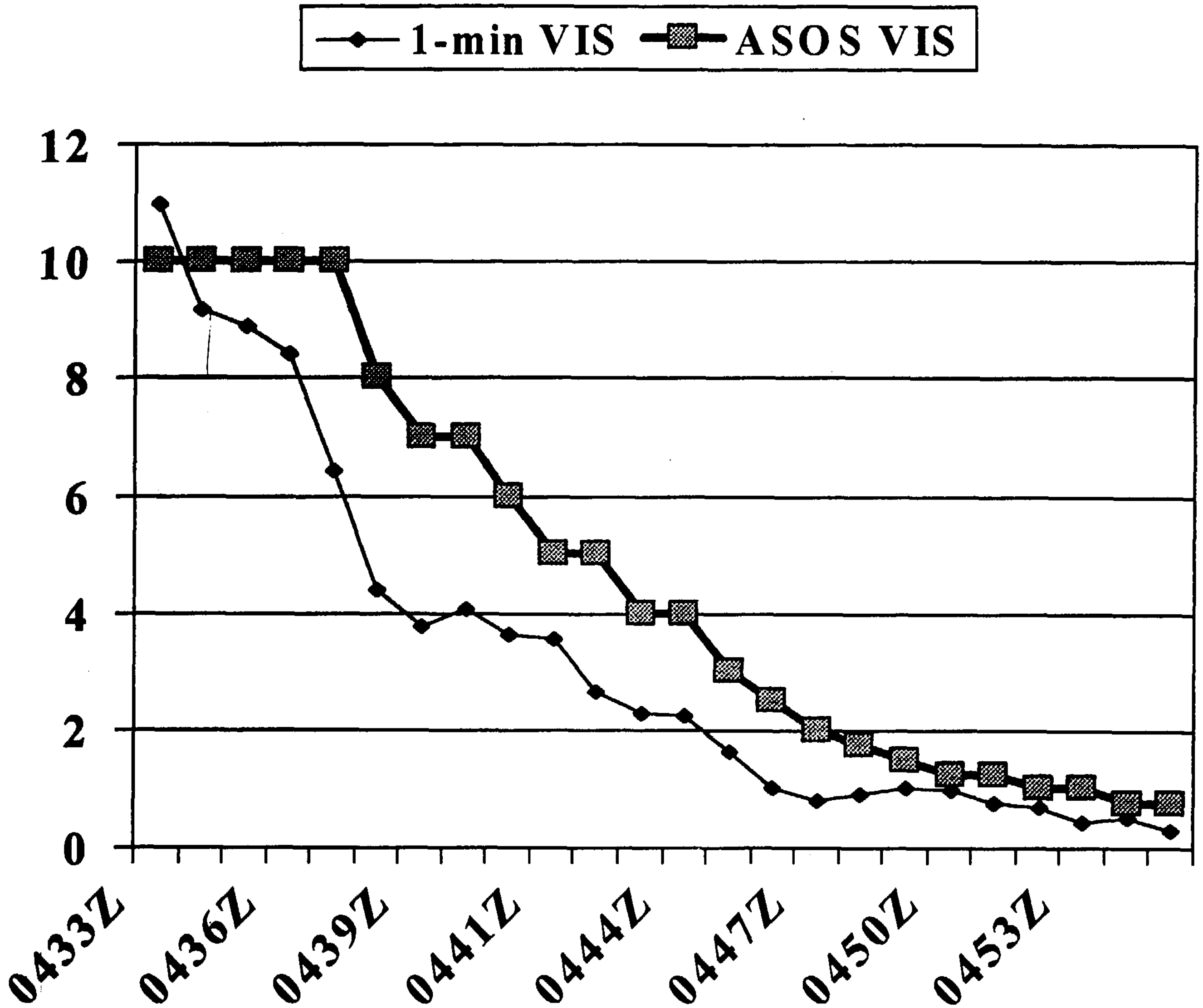
I



SCAN COMPLETED AT 0451:59Z

65J

ASOS High Resolution Data

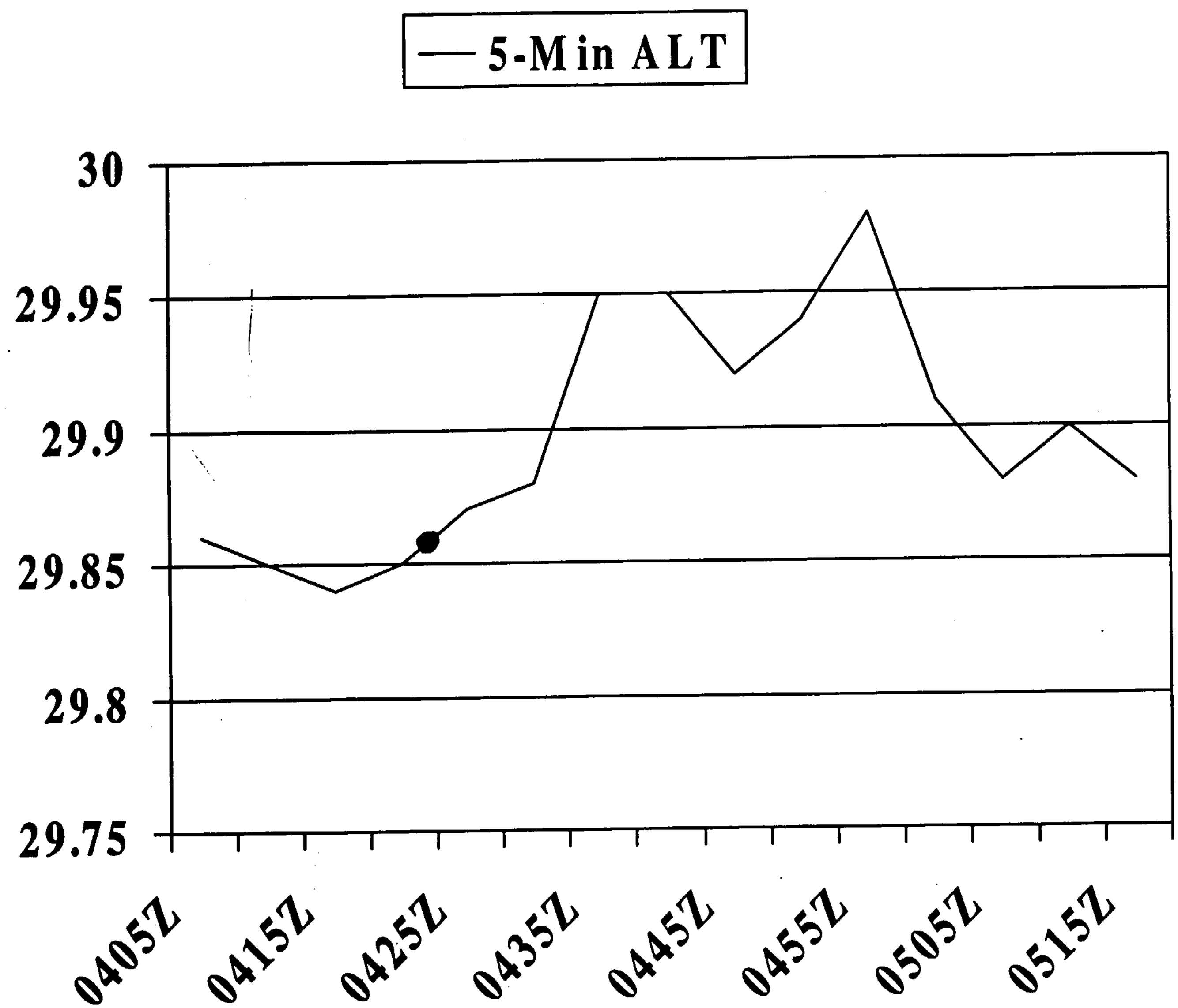


Attachment 66

Time (UTC)	Extinction Coefficients	1-Minute Visibility (Statute Miles)	ASOS Algorithm Reported Visibility (Statute Miles)	Comments / Edit Actions
0415:23	0.148 N	10.00	-	First data point in data set.
0416:23	0.145 N	10.00	-	
0417:23	0.147 N	10.00	-	
0418:23	0.141 N	10.00	-	
0419:23	0.139 N	10.00	-	
0420:23	0.141 N	10.00	-	
0421:23	0.150 N	10.00	-	
0422:23	0.149 N	10.00	10	Algorithm output from data set available. At 22:22:20 LST (04:22:20Z) observer edits the visibility from 10SM to 7SM.
0423:23	0.145 N	10.00	10	
0424:23	0.145 N	10.00	10	
0425:23	0.143 N	11.00	10	
0426:23	0.144 N	11.00	10	
0427:23	0.151 N	11.00	10	
0428:23	0.148 N	11.00	10	
0429:23	0.150 N	11.00	10	
0430:23	0.177 N	11.00	10	
0431:23	0.158 N	11.00	10	
0432:23	0.145 N	11.00	10	
0433:23	0.163 N	11.00	10	
0434:23	0.235 N	9.19	10	
0435:23	0.246 N	8.87	10	
0436:23	0.298 N	8.40	10	
0437:23	0.420 N	6.40	10	
0438:23	0.671 N	4.39	8	
0439:23	0.807 N	3.78	7	
0440:23	0.741 N	4.05	7	
0441:23	0.855 N	3.61	6	

Time (UTC)	Extinction Coefficients	1-Minute Visibility (Statute Miles)	ASOS Algorithm Reported Visibility (Statute Miles)	Comments / Edit Actions
0442:23	0.867 N	3.56	5	
0443:23	1.239 N	2.65	5	
0444:23	1.475 N	2.30	4	
0445:23	1.530 N	2.23	4	
0446:23	2.244 N	1.62	3	
0447:23	3.818 N	1.03	2 1/2	
0448:23	5.112 N	0.80	2	
0449:23	4.550 N	0.89	1 3/4	At 22:49:32 LST (04:49:32Z) the observer resets the visibility to automated mode. Visibility changed from the edited 7SM to 1 3/4SM.
0450:23	3.887 N	1.01	1 1/2	Mishap at 0450Z / 2250 LST
0451:23	4.089 N	0.97	1 1/4	
0452:23	5.367 N	0.77	1 1/4	
0453:23	6.044 N	0.69	1	
0454:23	10.050 N	0.45	1	
0455:23	8.715 N	0.51	3/4	
0456:23	16.470 N	0.29	3/4	
0457:23	15.100 N	0.32	1/2	
0458:23	12.490 N	0.37	1/2	
0459:23	7.903 N	0.55	1/2	
0500:23	4.045 N	0.98	1/2	

5-Minute Altimeter Data



Attachment 67

AmericanAirlines®

February 2, 2001

Mr. Don Eick
National Transportation Safety Board
490 L'Enfant Plaza East, SW, Room 5332
Washington, D.C. 20594-2000

Dear Don:

Enclosed please find the radar images you requested. Please note the times of the images, starting with 0430Z 2 June 1999, then every 10 minutes through 0510Z, 2 June 1999. These are the 5-minute WSI product, available at the meteorologists' work positions, but not the dispatchers' desks. Also, please remember that the images are displayed in our WSI system approximately five to ten minutes after their time stamp. For example, the 0430Z image would arrive and be displayed at about 0435-0440Z.

Please let me know if you have any other questions.

Sincerely,

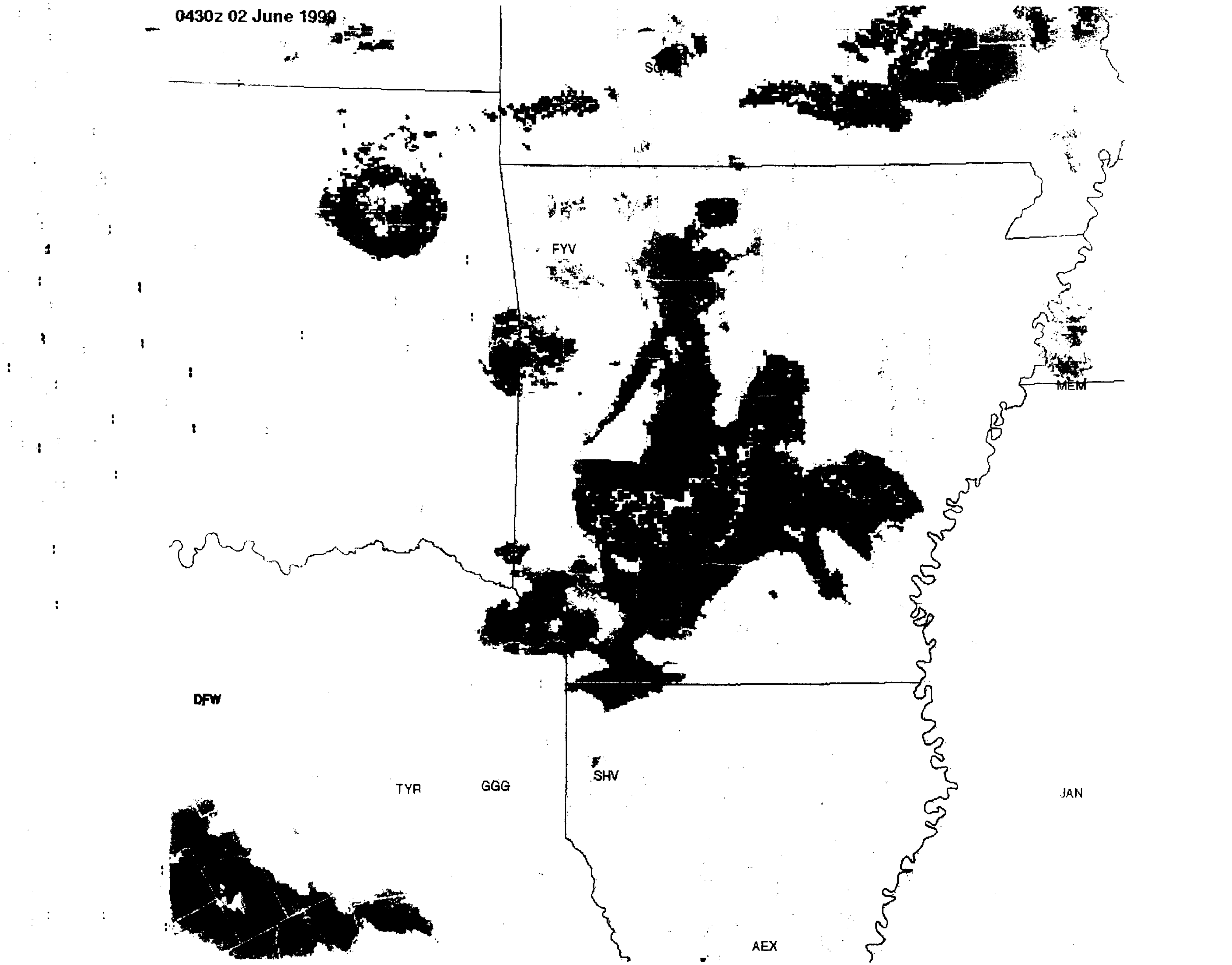
[redacted]

Warren L. Qualley
Manager Weather Services

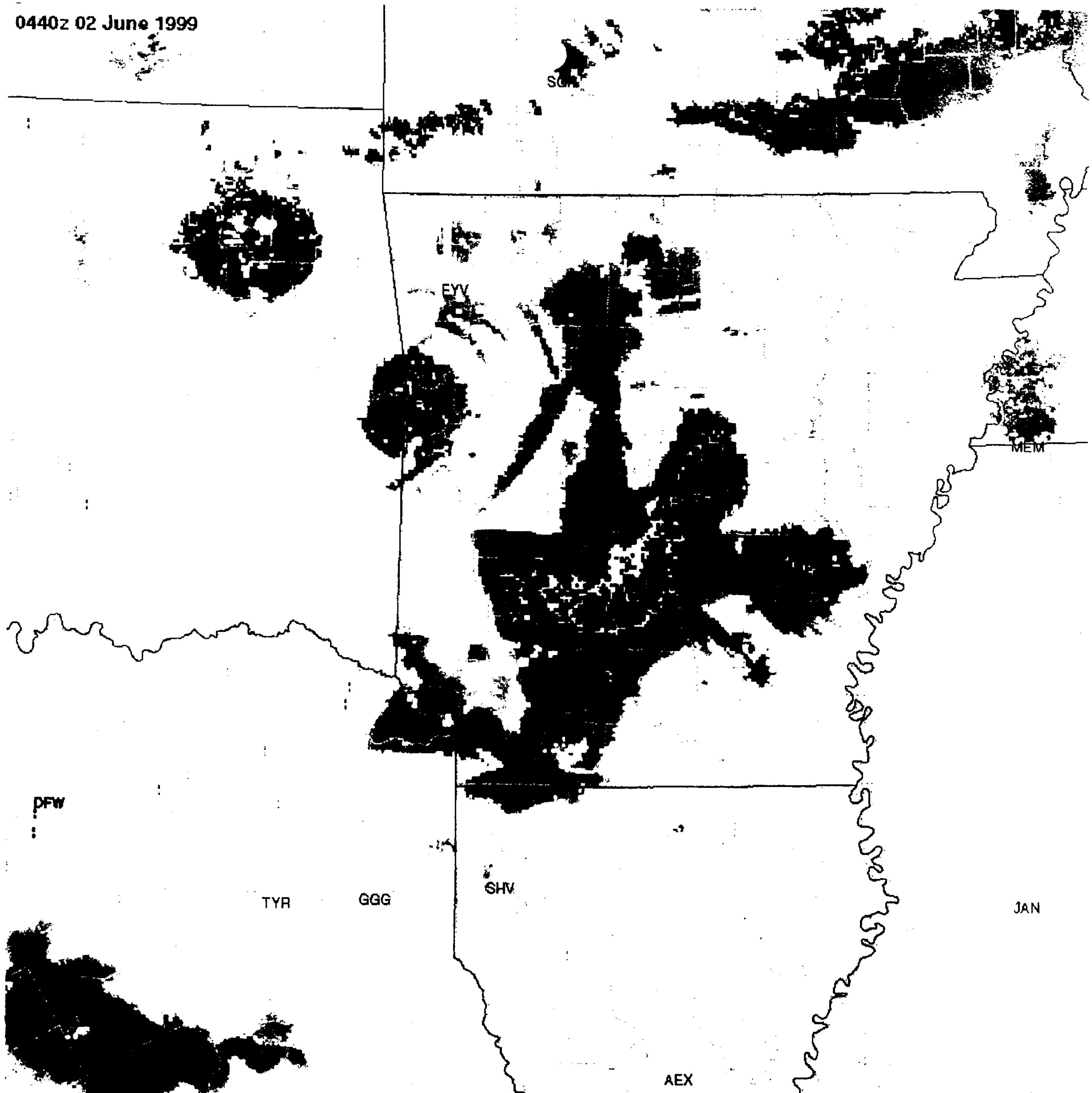
enclosures

Attachment 6B

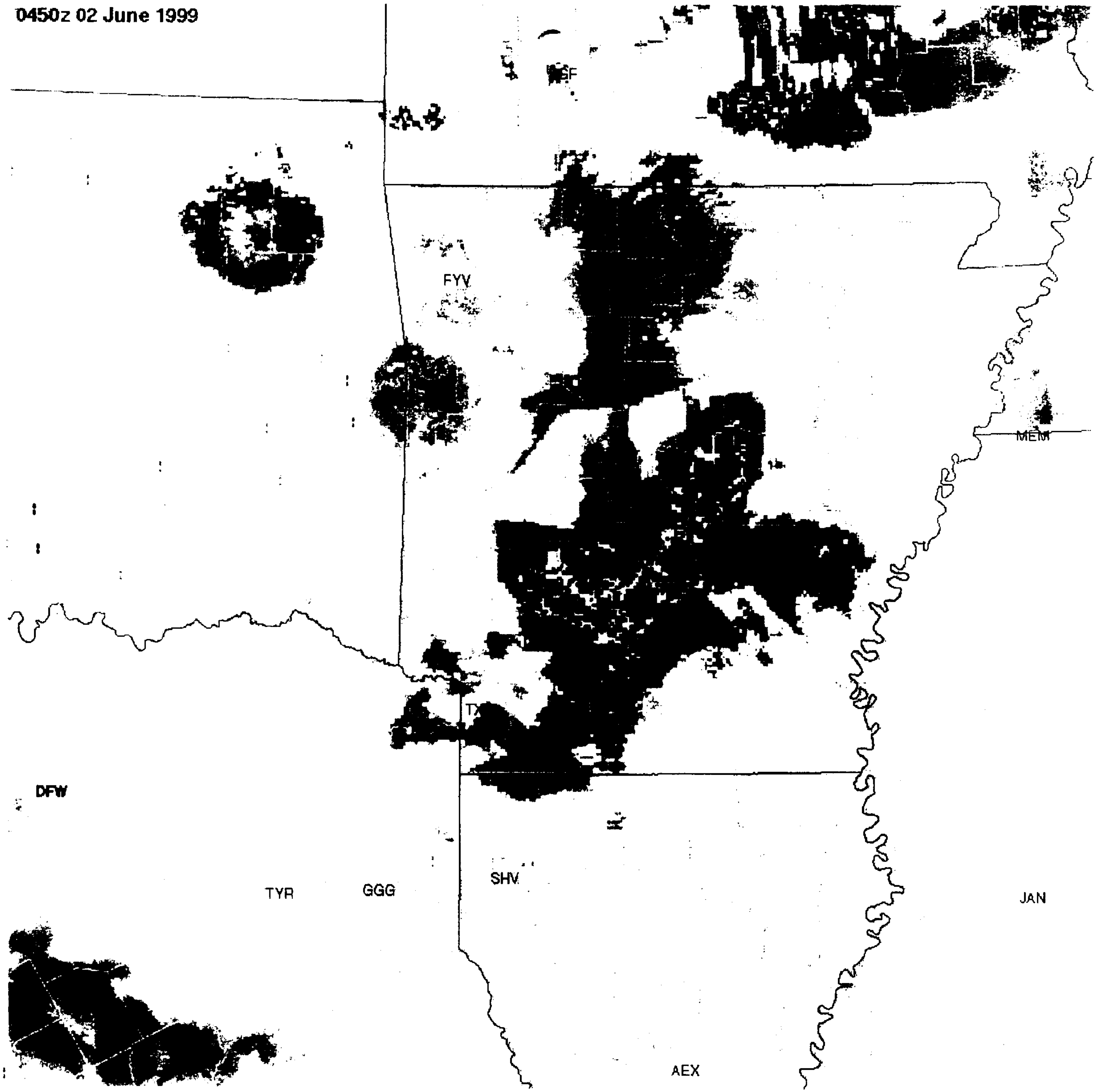
SYSTEM OPERATIONS CONTROL, P.O. BOX 619617, MD 867-GSWFA, DFW AIRPORT, TEXAS 75261-9617

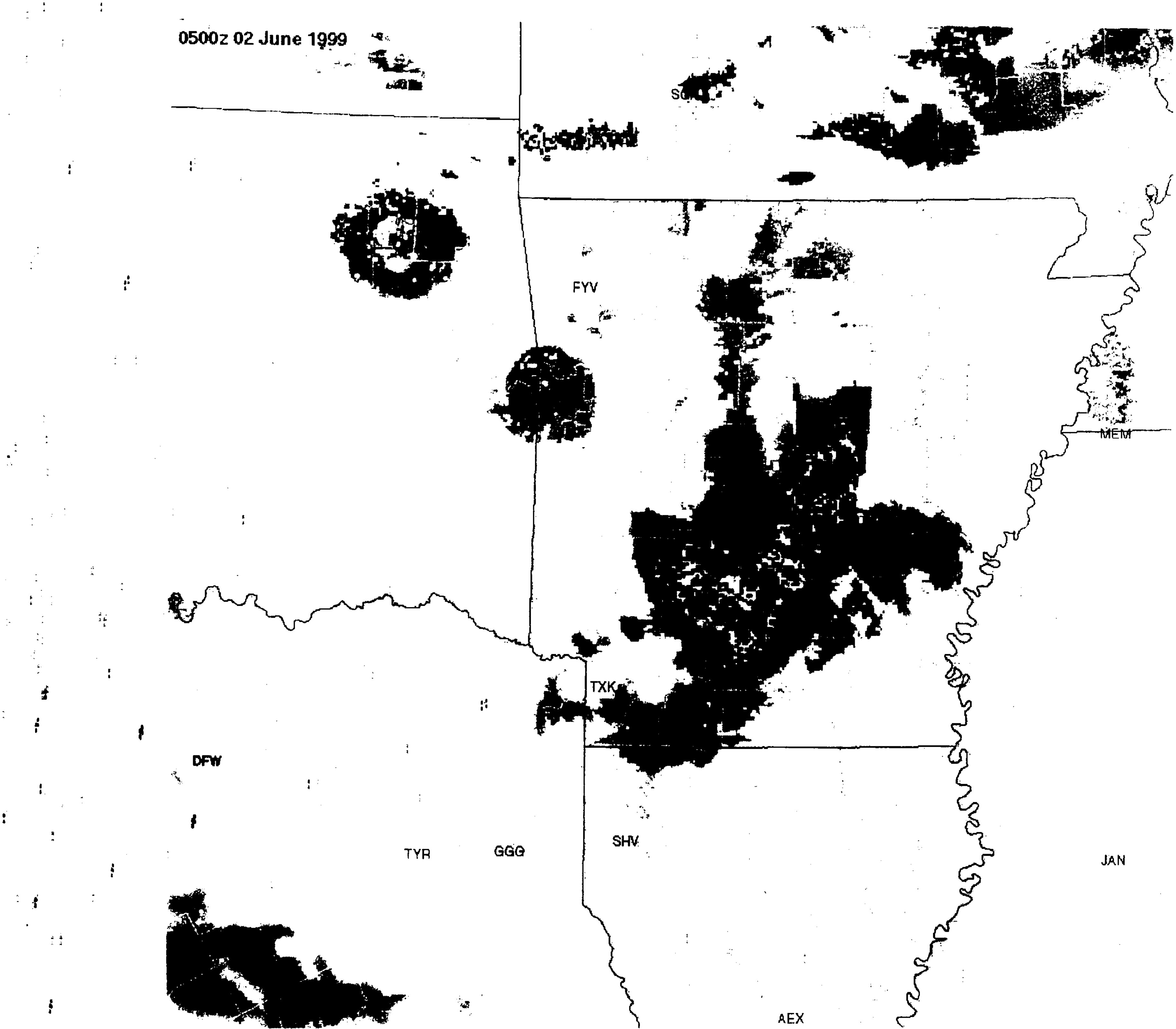

0430z 02 June 1999
SGF
FYV
MEM
DFW
TYR
GGG
SHV
JAN
AEX

0440z 02 June 1999



0450z 02 June 1999




0500z 02 June 1999
SGF
FYV
MEM
TXK
DFW
TYR
GGG
SHV
JAN
AEX

6. Thunderstorms

6.1 General

A. Do not enter or depart terminal areas when such areas are blanketed by thunderstorms except where known thunderstorm-free routes exist and are followed. Airborne radar and all available weather reports will be used to make this determination.

B. When thunderstorm activity is anticipated, the Dispatcher and Captain will, after a thorough review of the weather reports and forecasts, plan a flight so as to avoid broken or solid thunderstorm areas or permit their circumnavigation with airborne and ground radar.

C. Aircraft will not be dispatched or flown when current or forecast weather reports indicate thunderstorms in the area or along the route unless the airborne weather radar equipment is in satisfactory operating condition, or the storms in the area are widely scattered and reports indicate that the tops may be circumnavigated visually.

D. In the event of radar failure, the responsibility and authority rests with the Captain to determine that a thunderstorm area can be navigated with safety and reasonable comfort to passengers.

6.2 Tornado Identification

Tornado Identification is much less reliable but it is known that certain major tornadoes produce an echo arranged like the figure six. Other tornadoes will leave no characteristic echo for identification.

Attachment 69

7. WINDSHEAR

7.1 General

A. Because unexpected changes in wind speed and direction can be hazardous to aircraft at low altitudes on approach to and departing from airports, it is essential that all such encounters be reported by the most expeditious means to the Tower, AA Operations and the Dispatch Office. These reports will provide a means to immediately relay the windshear condition to other arriving or departing aircraft, and/or consider alternate operations to other aircraft.

1. Reports should be given in a clear, concise and understandable manner. Do not report windshear in positive or negative terminology. Examples of proper concise reporting might be:
   a) "Abrupt loss of 20 knots encountered at 400 feet."
   b) "Gradual gain of 25 knots between 700 and 400 feet followed by loss of 40 knots between 400 feet and surface."
   c) "Abrupt windshear at 300 feet, max thrust required."
   d) Dispatchers will notify other flights, whenever pilots report conditions described above.

7.2 LLWAS - Low Level Windshear Alert Systems

A. An array of between 6 and 24 wind sensors that alerts the control tower when a windshear between sensors greater than a predetermined level has been exceeded. Wind readouts are displayed to the tower controller and an advisory will be transmitted to the pilots of arriving and departing aircraft as long as the windshear condition persists. The following terminology will be used by the controller: "American (flight #) wind two one zero at one two, north boundary wind three four zero at three zero."

B. These wind reports are advisory only. The reported surface winds, as presently obtained from the centerfield instrumentation, are controlling for our Flight Operations.

C. Airports that have a LLWAS installed are indicated by a note on the Flight Manual Part II airport diagram page.

7.3 Low Level Windshear Advisories

If the statement "Low Level Windshear Advisories are in effect," is broadcast on the ATIS or issued by ATC, there has been a report of windshear within the past 20 minutes from either:

- a pilot report
- a TDWR (Terminal Doppler Weather Radar) report, or
- the airport LLWAS

The pilot can ask ATC for more detailed information which would identify the runway or airport boundary where the alert was reported from and/or the reported airport boundary winds.

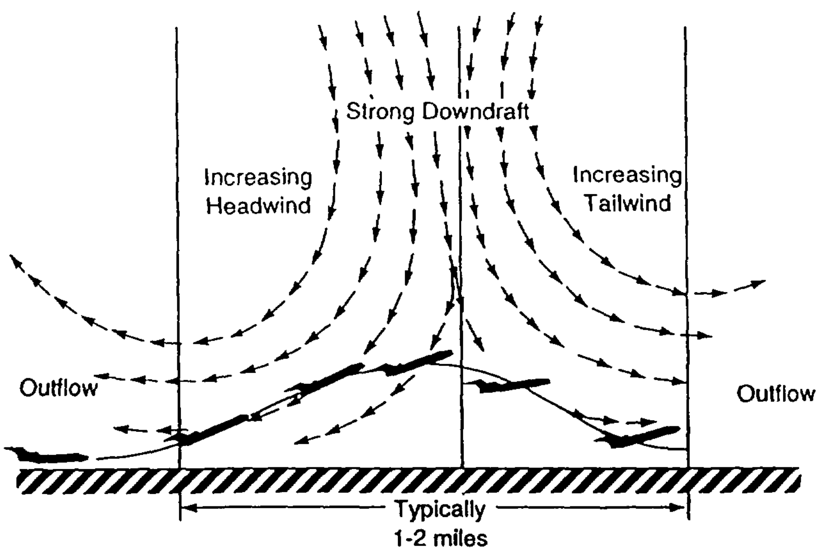
8. MICROBURSTS

8.1 General

A. A microburst is created when air aloft is cooled through the evaporation of falling precipitation increasing the density of the air relative to its surroundings. This "heavier" air begins to descend, increasing speed until reaching the ground where it spreads out it all directions. This commonly occurs in heavy rain (wet microburst) but may be present where all of the precipitation has evaporated prior to reaching the ground as in virga (dry microburst).

B. The downdrafts are typically less than one mile in diameter and can be as strong as 6000 feet per minute. Approximately 1000 to 3000 feet above the ground, the down draft begins to change to a horizontal flow which, at the surface, can be as high as 45 knots in each direction. An aircraft crossing the center of a microburst could therefore encounter up to a 90 knot windshear. Upon entering the microburst, an aircraft would experience increasing headwinds with a corresponding increase in energy. An aircraft near the ground on approach would decrease engine power in order to maintain glidepath. Then, upon crossing the center of the microburst, the aircraft would enter the area of increasing tailwind with a corresponding decrease of performance. A pilot unaware of the phenomenon would experience rapidly decreasing airspeed near the ground at a low power setting.

C. Microbursts seldom last more than 15 minutes. When microburst activity starts, multiple microbursts in the same general area are not uncommon and should be expected. Due to their small size and short duration, detection with conventional instrumentation is difficult. This should improve with the introduction of the TDWR (Terminal Doppler Weather Radar). Until then, the best means of detection is through PIREPs, visual cues (dusts, surface rain patterns, virga, etc.) and recognition of atmospheric conditions conducive to their development such as localized heavy rain shaft, light surface winds outside of the rain area, high temperature and low dew point (approximately 30°) Fahrenheit temperature/dew point spread.



Windshear

Avoidance

General

Avoid areas of known severe windshear. PIREPS of windshear in excess of 20 knots or 500 fpm climb or descent below 1000 feet AFL are a good indication of such areas. Consider the time elapsed since the report and the change in reported or observed (radar or visual) weather. Microbursts in particular can create severe windshear conditions, but these conditions develop, change, and dissipate rapidly.

The most dangerous form of windshear is a convective microburst. Some have been documented with wind changes in excess of 200 knots. Because microbursts intensify for several minutes after they first impact the ground the severity may be up to twice that which is initially reported.

Search for clues which may indicate the presence of severe windshear. Severe windshear has been encountered under the following conditions:

- Thunderstorm and convective clouds
- Rain and snow showers
- Frontal systems
- Low altitude jet streams
- Strong or gusty surface winds

Takeoff

When positive indications of severe windshear exist, delay takeoff until conditions improve. When conditions are such that moderate windshear may be encountered, even though not reported, the following precautions are recommended:

- Use maximum thrust instead of standard thrust for takeoff.
- Use the longest suitable runway.
- Do not use any pitch mode of the flight director for takeoff.
- Maximize available margins between V_R and stick shaker through runway selection, flap selection, and delayed rotation. The delayed rotation speed must not exceed either: (1) the runway weight limit V_R speed or (2) a 20 knot increase. For example, if the actual gross weight is 140,000 pounds and the runway limit is 150,000 pounds, mentally remember to rotate at the V_R speed which corresponds to the runway limit of 150,000 pounds.

Landing

When positive indications of severe windshear exist, avoid the areas by:

- Diverting around the areas.
- On approach, initiate a go-around and / or hold until conditions improve.

When conditions are such that moderate windshear may be encountered, even though not reported, the following precautions are recommended:

- Select the minimum landing flap position consistent with the field length, (e.g., Flaps 28 instead of Flaps 40, if runway length and conditions permit).
- Add an appropriate airspeed correction (correction applied in the same manner as gusts) up to a maximum of 20 knots.
- Select longest runway available that avoids areas of suspected windshear.
- Use the autopilot and autothrottle for the approach to provide more monitoring and recognition time.
- To avoid large thrust and / or trim changes in response to sudden airspeed increases (headwind shear), manually restrain the Throttles from being driven back to idle. Be prepared to execute the escape maneuver if the airspeed increase is followed by a sudden decrease, and flight path control becomes marginal.

Microburst Identification

Dry Microbursts

- PIREPS

CAUTION

Actual windshear may be up to twice as severe as PIREP.

- LLWAS - Detects microbursts within two and one-half miles of the airport.
- VIRGA - Weak precipitation areas that do not reach the surface.
- TURBULENCE - Moderate or greater turbulence may be associated with the outflow from a microburst.
- VISUAL CUES - Blowing dust, rings of dust, dust devils, or other tornado-like features, and other evidence of strong local outflow near the surface.
- AIRBORNE WEATHER RADAR - Indications of weak (green) cells with bases from 5000 to 15,000 feet AGL which indicate weak precipitation, usually virga. In addition, areas of red (doppler turbulence) surrounding weak precipitation may indicate microburst windshear conditions in their formative stages aloft.
- WINDSHEAR FORECAST - Potential for convection; mid-level moisture, very dry surface condition; 30° - 50° temperature / dew point spread.

Wet Thunderstorm Microbursts

- PIREPS

CAUTION

Actual windshear may be up to twice as severe as PIREP.

- LLWAS - Detects microbursts within two and one-half miles of the airport.
- THUNDERSTORMS - In addition to the well known hazards of thunderstorms, and estimated one percent of thunderstorms contain embedded microbursts.
- TURBULENCE - Moderate or greater turbulence may be associated with the outflow from a microburst.
- VISUAL CUES - Heavy rain, lightning, blowing dust, rings of dust, dust devils, or other tornado-like features, and other evidence of strong local outflow near the surface.

CAUTION

Visual clues may be obscured by low visibilities in wet thunderstorm microburst situations.

- AIRBORNE WEATHER RADAR - Indications of weak (green) cells with bases from 5000 to 15,000 feet AGL which indicate weak precipitation, usually virga. In addition, areas of red (doppler turbulence) surrounding weak precipitation may indicate microburst windshear conditions in their formative stages aloft.
- THUNDERSTORM FORECAST - Although no techniques currently exist to forecast wet microbursts, crews should consider the thunderstorm forecasts contained in the terminal forecasts and severe weather advisories as a possible indication of the presence of wet microbursts.

Recognition

As a guideline, marginal flight path control may be indicated by uncontrolled changes from normal, steady state, flight conditions in excess of the following:

- 15 knots indicated airspeed
- 500 fpm vertical speed
- Five degrees pitch attitude
- One dot displacement from the glide slope
- 10° heading variation from nominal
- Pronounced roll
- Illumination of Red WINDSHR Light (decreasing performance) or Amber WINDSHR Light (increasing performance).

NOTE

Illumination of Red WINDSHR Light requires use of full power. However, if escape initiated because an Amber WINDSHR Light illuminates, and no other significant indication of windshear exists, consider using go-around power instead of full power.

Windshear Procedures

For Windshear procedures, refer to WARN 4 – Windshear / Microburst During Takeoff Roll *or* WARN 5 – Windshear / Microburst Escape Procedure.

AC 00-24B - THUNDERSTORMS

Department of Transportation
Federal Aviation Administration

1/2/83

Initiated by: AFO-260

1. **PURPOSE.** This advisory circular describes the hazards of thunderstorms to aviation and offers guidance to help prevent accidents caused by thunderstorms.

2. **CANCELLATION.** Advisory Circular 00-24A, dated June 23, 1978, is canceled.

3. **RELATED READING.** Advisory Circulars 00-6A, Aviation Weather, 00-45B, Aviation Weather Services, 00-50A, Low Level Windshear *{This AC has been canceled - Ed.}*.

4. **GENERAL.** We all know what a thunderstorm looks like. Much has been written about the mechanics and life cycles of thunderstorms. They have been studied for many years; and while much has been learned, the studies continue because much is not known. Knowledge and weather radar have modified our attitudes toward thunderstorms, but one rule continues to be true - any storm recognizable as a thunderstorm should be considered hazardous until measurements have shown it to be safe. That means safe for you and your aircraft. Almost any thunderstorm can spell disaster for the wrong combination of aircraft and pilot.

5. **HAZARDS.** A thunderstorm packs just about every weather hazard known to aviation into one vicious bundle. Although the hazards occur in numerous combinations, let us look at the most hazardous combination of thunderstorms, the squall line, then we will examine the hazards individually.

a. Squall Lines. A squall line is a narrow band of active thunderstorms. Often it develops on or ahead of a cold front in moist, unstable air, but it may develop in unstable air far from any front. The line may be too long to detour easily and too wide and severe to penetrate. It often contains steady-state thunderstorms and presents the single most intense weather hazard to aircraft. It usually forms rapidly, generally reaching maximum intensity during the late afternoon and the first few hours of darkness.

b. Tornadoes.

(1) The most violent thunderstorms draw air into their cloud bases with great vigor. If the incoming air has any initial rotating motion, it often forms an extremely concentrated vortex from the surface well into the cloud. Meteorologists have estimated that wind in such a vortex can exceed 200 knots; pressure inside the vortex is quite low. The strong winds gather dust and debris and the low pressure

Attachment 70

generates a funnel shaped cloud extending downward from the cumulonimbus base. If the cloud does not reach the surface, it is a "funnel cloud"; if it touches a land surface, it is a "tornado."

(2) Tornadoes occur with both isolated and squall line thunderstorms. Reports for forecasts of tornadoes indicate that atmospheric conditions are favorable for violent turbulence. An aircraft entering a tornado vortex is almost certain to suffer structural damage. Since the vortex extends well into the cloud, any pilot inadvertently caught on instruments in a severe thunderstorm could encounter a hidden vortex.

(3) Families of tornadoes have been observed as appendages of the main cloud extending several miles outward from the area of lightning and precipitation. Thus, any cloud connected to a severe thunderstorm carries a threat of violence.

c. Turbulence.

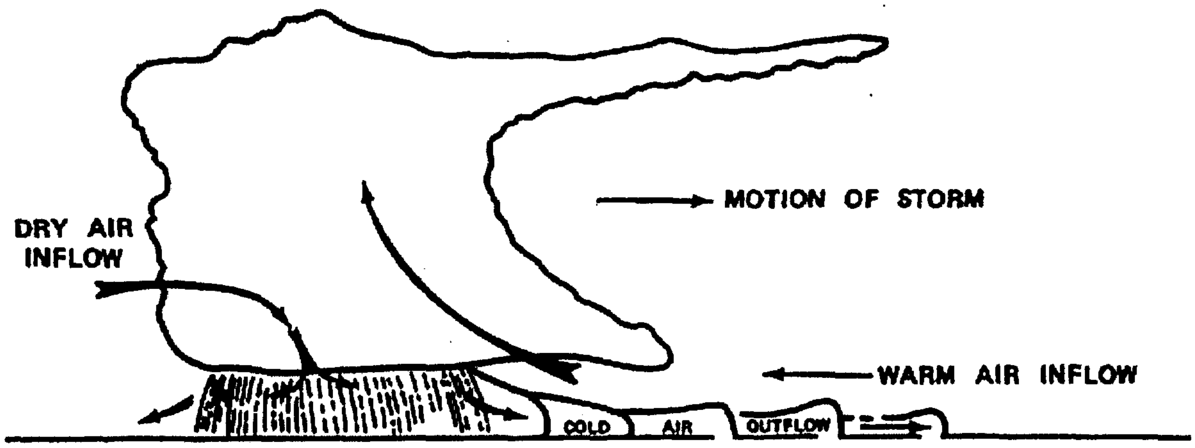
(1) Potentially hazardous turbulence is present in all thunderstorms, and a severe thunderstorm can destroy an aircraft. Strongest turbulence within the cloud occurs with shear between updrafts and downdrafts. Outside the cloud, shear turbulence has been encountered several thousand feet above and 20 miles laterally from a severe storm. A low level turbulent area is the shear zone associated with the gust front. Often, a "roll cloud" on the leading edge of a storm marks the top of the eddies in this shear and it signifies an extremely turbulent zone. Gust fronts often move far ahead (up to 15 miles) of associated precipitation. The gust front causes a rapid and sometimes drastic change in surface wind ahead of an approaching storm. Advisory Circular 00-50A, "Low Level Windshear," explains in greater detail the hazards associated with gust fronts. Figure 1 shows a schematic cross section of a thunderstorm with areas outside the cloud where turbulence may be encountered.

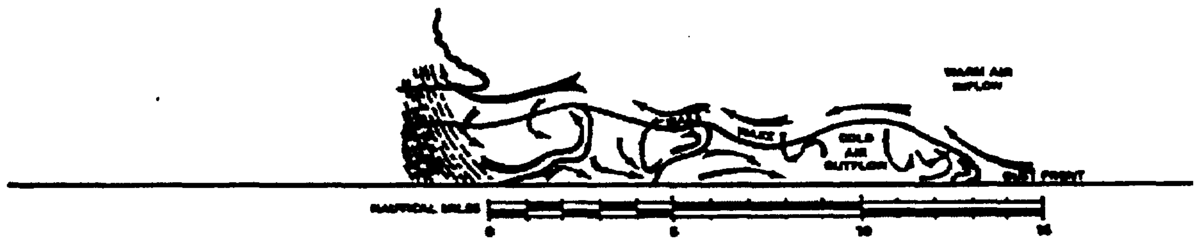
(2) It is almost impossible to hold a constant altitude in a thunderstorm, and maneuvering in an attempt to do so produces greatly increased stress on the aircraft. It is understandable that the speed of the aircraft determines the rate of turbulence encounters. Stresses are least if the aircraft is held in a constant attitude and allowed to "ride the waves." To date, we have no sure way to pick "soft spots" in a thunderstorm.

d. Icing.

(1) Updrafts in a thunderstorm support abundant liquid water with relatively large droplet sizes; and when carried above the freezing level, the water becomes supercooled. When temperature in the upward current cools to about -15 °C, much of the remaining water vapor sublimates as ice crystals; and above this level, at lower temperatures, the amount of supercooled water decreases.

(2) Supercooled water freezes on impact with an aircraft. Clear icing can occur at any altitude above the freezing level; but at high levels, icing from smaller droplets may be rime or mixed rime and clear. The abundance of large, supercooled water droplets makes clear icing very rapid between 0 °C and -15 °C and encounters can be frequent in a cluster of cells. Thunderstorm icing can be extremely hazardous.





e. **Hail.**

(1) Hail competes with turbulence as the greatest thunderstorm hazard to aircraft. Supercooled drops above the freezing level begin to freeze. Once a drop has frozen, other drops latch on and freeze to it, so the hailstone grows - sometimes into a huge iceball. Large hail occurs with severe thunderstorm with strong updrafts that have built to great heights. Eventually, the hailstones fall, possibly some distance from the storm core. Hail may be encountered in clear air several miles from dark thunderstorm clouds.

(2) As hailstones fall through air whose temperature is above 0 °C, they begin to melt and precipitation may reach the ground as either hail or rain. Rain at the surface does not mean the absence of hail aloft. You should anticipate possible hail with any thunderstorm, especially beneath the anvil of a large cumulonimbus. Hailstones larger than one-half inch in diameter can significantly damage an aircraft in a few seconds.

f. Low Ceiling and Visibility. Generally, visibility is near zero within a thunderstorm cloud. Ceiling and visibility also may be restricted in precipitation and dust between the cloud base and the ground. The restrictions create the same problem as all ceiling and visibility restrictions; but the hazards are increased many fold when associated with the other thunderstorm hazards of turbulence, hail, and lightning which make precision instrument flying virtually impossible.

g. Effect on Altimeters. Pressure usually falls rapidly with the approach of a thunderstorm, then rises sharply with the onset of the first gust and arrival of the cold downdraft and heavy rain showers, falling back to normal as the storm moves on. This cycle of pressure change may occur in 15 minutes. If the pilot does not receive a corrected altimeter setting, the altimeter may be more than 100 feet in error.

h. Lightning. A lightning strike can puncture the skin of an aircraft and can damage communications and electronic navigational equipment. Lightning has been suspected of igniting fuel vapors causing explosion; however, serious accidents due to lightning strikes are extremely rare. Nearby lightning can blind the pilot rendering him momentarily unable to navigate either by instrument or by visual reference. Nearby lightning can also induce permanent errors in the magnetic compass. Lightning discharges, even distant ones, can disrupt radio communications on low and medium frequencies. Though lightning intensity and frequency have no simple relationship to other storm parameters, severe storms, as a rule, have a high frequency of lightning.

i. Engine Water Ingestion.

(1) Turbine engines have a limit on the amount of water they can ingest. Updrafts are present in many thunderstorms, particularly those in the developing stages. If the updraft velocity in the thunderstorm approaches or exceeds the terminal velocity of the falling raindrops, very high concentrations of water may occur. It is possible that these concentrations can be in excess of the quantity of water turbine engines are designed to ingest. Therefore, severe thunderstorms may contain areas of high water concentration which could result in flameout and/or structural failure of one or more engines.

(2) At the present time, there is no known operational procedure that can completely eliminate the possibility of engine damage/flameout during massive water ingestion. Although the exact mechanism of these water induced engine stalls has not been determined, it is felt that thrust changes may have an adverse effect on engine stall margins in the presence of massive water ingestion.

(3) Avoidance of severe storm systems is the only measure assured to be effective in preventing exposure to this type of multiple engine damage/flameout. During an unavoidable encounter with severe storms with extreme precipitation, the best known recommendation is to follow the severe turbulence penetration procedure contained in the approved airplane flight manual with special emphasis on avoiding thrust changes unless excessive airspeed variations occur.

6. WEATHER RADAR.

a. Weather radar detects droplets of precipitation size. Strength of the radar return (echo) depends on drop size and number. The greater the number of drops, the stronger is the echo; and the larger the drops, the stronger is the echo. Drop size determines echo intensity to a much greater extent than does drop number. Hailstones usually are covered with a film of water and, therefore, act as huge water droplets giving the strongest of all echoes.

b. Numerous methods have been used in an attempt to categorize the intensity of a thunderstorm. To standardize thunderstorm language between weather radar operators and pilots, the use of Video Integrator Processor (VIP) levels is being promoted.

c. The National Weather Service (NWS) radar observer is able to objectively determine storm intensity levels with VIP equipment. These radar echo intensity levels are on a scale of one to six. If the maximum VIP Levels are 1 "weak" and 2 "moderate," then light to moderate turbulence is possible with lightning. VIP Level 3 is "strong" and severe turbulence is possible with lightning. VIP Level 4 is "very strong" and severe turbulence is likely with lightning. VIP Level 5 is "intense" with severe turbulence, lightning, hail likely, and organized surface wind gusts. VIP Level 6 is "extreme" with severe turbulence, lightning, large hail, extensive surface wind gusts, and turbulence.

d. Thunderstorms build and dissipate rapidly. Therefore, do not attempt to plan a course between echoes. The best use of ground radar information is to isolate general areas and coverage of echoes. You must avoid individual storms from inflight observations either by visual sighting or by airborne radar. It is better to avoid the whole thunderstorm area than to detour around individual storms unless they are scattered.

e. Airborne weather avoidance radar is, as its name implies, for avoiding severe weather - not for penetrating it. Whether to fly into an area of radar echoes depends on echo intensity, spacing between the echoes, and the capabilities of you and your aircraft. Remember that weather radar detects only precipitation drops; it does not detect turbulence. Therefore, the radar scope provides no assurance of avoiding turbulence. The radar scope also does not provide assurance of avoiding instrument weather from clouds and fog. Your scope may be clear between intense echoes; this clear area does not necessarily man you can fly between the storms and maintain visual sighting of them.

f. Remember that while hail always gives a radar echo, it may fall several miles from the nearest visible cloud and hazardous turbulence may extend to as much as 20 miles from the echo edge. Avoid intense or extreme level echoes by at least 20 miles; that is, such echoes should be separated by at least 40 miles before you fly between them. With weaker echoes you can reduce the distance by which you avoid them.

7. DO'S AND DON'TS OF THUNDERSTORM FLYING.

a. Above all, remember this: never regard any thunderstorm lightly, even when radar observers report the echoes are of light intensity. Avoiding thunderstorms is the best policy. Following are some do's and don'ts of thunderstorm avoidance:

(1) Don't land or take off in the face of an approaching thunderstorm. A sudden gust front of low level turbulence could cause loss of control.

(2) Don't attempt to fly under a thunderstorm even if you can see through to the other side. Turbulence and windshear under the storm could be disastrous.
(3) Don't fly without airborne radar into a cloud mass containing scattered embedded thunderstorms. Scattered thunderstorms not embedded usually can be visually circumnavigated.
(4) Don't trust the visual appearance to be a reliable indicator of the turbulence inside a thunderstorm.
(5) Do avoid by at least 20 miles any thunderstorm identified as severe or giving an intense radar echo. This is especially true under the anvil of a large cumulonimbus.
(6) Do circumnavigate the entire area if the area has 6/10 thunderstorm coverage.
(7) Do remember that vivid and frequent lightning indicates the probability of a severe thunderstorm.
(8) Do regard as extremely hazardous any thunderstorm with tops 35,000 feet or higher whether the top is visually sighted or determined by radar.

b. If you cannot avoid penetrating a thunderstorm, following are some do's BEFORE entering the storm:
(1) Tighten your safety belt, put on your shoulder harness if you have one, and secure all loose objects.
(2) Plan and hold your course to take you through the storm in a minimum time.
(3) To avoid the most critical icing, establish a penetration altitude below the freezing level or above the level of -15 °C.
(4) Verify that pitot heat is on and turn on carburetor heat or jet engine anti-ice. Icing can be rapid at any altitude and cause almost instantaneous power failure and/or loss of airspeed indication.
(5) Establish power settings for turbulence penetration airspeed recommended in your aircraft manual.
(6) Turn up cockpit lights to highest intensity to lessen temporary blindness from lightning.
(7) If using automatic pilot, disengage altitude hold mode and speed hold mode. The automatic altitude and speed controls will increase maneuvers of the aircraft thus increasing structural stress.
(8) If using airborne radar, tilt the antenna up and down occasionally. This will permit you to detect other thunderstorm activity at altitudes other than the one being flown.

c. Following are some do's and don'ts DURING the thunderstorm penetration:
(1) Do keep your eyes on your instruments. Looking outside the cockpit can increase danger of temporary blindness from lightning.
(2) Don't change power settings; maintain settings for the recommended turbulence penetration airspeed.
(3) Do maintain constant attitude; let the aircraft "ride the waves." Maneuvers in trying to maintain constant altitude increase stress on the aircraft.
(4) Don't turn back once you are in the thunderstorm. A straight course through the storm most likely will get you out of the hazards most quickly. In addition, turning

maneuvers increase stress on the aircraft.

[redacted]

WILLIAM T. BRENNAN
Acting Director of Flight Operations

7-1-26. THUNDERSTORMS

a. Turbulence, hail, rain, snow, lightning, sustained updrafts and downdrafts, icing conditions - all are present in thunderstorms. While there is some evidence that maximum turbulence exists at the middle level of a thunderstorm, recent studies show little variation of turbulence intensity with altitude.

b. There is no useful correlation between the external visual appearance of thunderstorms and the severity or amount of turbulence or hail within them. The visible thunderstorm cloud is only a portion of a turbulent system whose updrafts and downdrafts often extend far beyond the visible storm cloud. Severe turbulence can be expected up to 20 miles from severe thunderstorms. This distance decreases to about 10 miles in less severe storms.

c. Weather radar, airborne or ground based, will normally reflect the areas of moderate to heavy precipitation (radar does not detect turbulence). The frequency and severity of turbulence generally increases with the radar reflectivity which is closely associated with the areas of highest liquid water content of the storm. NO FLIGHT PATH THROUGH AN AREA OF STRONG OR VERY STRONG RADAR ECHOES SEPARATED BY 20-30 MILES OR LESS MAY BE CONSIDERED FREE OF SEVERE TURBULENCE.

d. Turbulence beneath a thunderstorm should not be minimized. This is especially true when the relative humidity is low in any layer between the surface and 15,000 feet. Then the lower altitudes may be characterized by strong out flowing winds and severe turbulence.

e. The probability of lightning strikes occurring to aircraft is greatest when operating at altitudes where temperatures are between minus 5 degrees Celsius and plus 5 degrees Celsius. Lightning can strike aircraft flying in the clear in the vicinity of a thunderstorm.

f. METAR reports do not include a descriptor for severe thunderstorms. However, by understanding severe thunderstorm criteria, i.e., 50 knot winds or 3/4 inch hail, the information is available in the report to know that one is occurring.

g. NWS radar systems are able to objectively determine radar weather echo intensity levels by use of Video Integrator Processor (VIP) equipment. These thunderstorm intensity levels are on a scale of one to six.

REFERENCE -
PILOT/CONTROLLER GLOSSARY, RADAR WEATHER ECHO INTENSITY LEVELS.

EXAMPLE -

[1] Alert provided by an ATC facility to an aircraft: (aircraft identification) level five intense weather echo between ten o'clock and two o'clock, one zero miles, moving east at two zero knots, tops Flight Level three nine zero.

[2] Alert provided by an AFSS/FSS: (aircraft identification) level five intense weather echo, two zero miles west of Atlanta V-O-R, two five miles wide, moving east at two zero knots, tops Flight Level three nine zero.

{New-2000-4 Redesignated February 24, 2000. Was 7-1-27.}

7-1-27. THUNDERSTORM FLYING

a. Above all, remember this: never regard any thunderstorm "lightly" even when radar observers report the echoes are of light intensity. Avoiding thunderstorms is the best policy. Following are some Do's and Don'ts of thunderstorm avoidance:

1. Don't land or takeoff in the face of an approaching thunderstorm. A sudden gust front of low level turbulence could cause loss of control.

2. Don't attempt to fly under a thunderstorm even if you can see through to the other side. Turbulence and wind shear under the storm could be disastrous.

3. Don't fly without airborne radar into a cloud mass containing scattered embedded thunderstorms. Scattered thunderstorms not embedded usually can be visually circumnavigated.

4. Don't trust the visual appearance to be a reliable indicator of the turbulence inside a thunderstorm.

5. Do avoid by at least 20 miles any thunderstorm identified as severe or giving an intense radar echo. This is especially true under the anvil of a large cumulonimbus.

6. Do clear the top of a known or suspected severe thunderstorm by at least 1,000 feet altitude for each 10 knots of wind speed at the cloud top. This should exceed the altitude capability of most aircraft.

7. Do circumnavigate the entire area if the area has 6/10 thunderstorm coverage.

8. Do remember that vivid and frequent lightning indicates the probability of a strong thunderstorm.

9. Do regard as extremely hazardous any thunderstorm with tops 35,000 feet or higher whether the top is visually sighted or determined by radar.

b. If you cannot avoid penetrating a thunderstorm, following are some Do's before entering the storm:

1. Tighten your safety belt, put on your shoulder harness if you have one and secure all loose objects.

2. Plan and hold your course to take you through the storm in a minimum time.

3. To avoid the most critical icing, establish a penetration altitude below the freezing level or above the level of minus 15 degrees Celsius.

4. Verify that pitot heat is on and turn on carburetor heat or jet engine anti-ice. Icing can be rapid at any altitude and cause almost instantaneous power failure and/or loss of airspeed indication.

5. Establish power settings for turbulence penetration airspeed recommended in your aircraft manual.

6. Turn up cockpit lights to highest intensity to lessen temporary blindness from lightning.

7. If using automatic pilot, disengage altitude hold mode and speed hold mode. The automatic altitude and speed controls will increase maneuvers of the aircraft thus increasing structural stress.

8. If using airborne radar, tilt the antenna up and down occasionally. This will permit you to detect other thunderstorm activity at altitudes other than the one being flown.

c. Following are some Do's and Don'ts during the thunderstorm penetration:

1. Do keep your eyes on your instruments. Looking outside the cockpit can increase danger of temporary blindness from lightning.

2. Don't change power settings; maintain settings for the recommended turbulence penetration airspeed.

3. Do maintain constant attitude; let the aircraft "ride the waves." Maneuvers in trying to maintain constant altitude increase stress on the aircraft.

4. Don't turn back once you are in the thunderstorm. A straight course through the storm most likely will get you out of the hazards most quickly. In addition, turning maneuvers increase stress on the aircraft.

{New-2000-4 Redesignated February 24, 2000. Was 7-1-27.}